

FINAL TREATABILITY STUDY WORKPLAN
MONTANA POLE AND TREATING PLANT SITE – PHASE 5
BUTTE, MONTANA

Prepared for:

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DEQ Contract No. 407026
Task Order No. 30



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March 30, 2009

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ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms per liter
amsl	Above mean seal level
ARAR	Applicable or relevant and appropriate requirements
ARCO	Atlantic Richfield Company
CDM	Camp Dresser and McKee
COC	Chain of custody
DEQ	Montana Department of Environmental Quality
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
Fe(II)	Ferrous iron
FS	Feasibility study
FSP	Field sampling plan
ft	Foot or feet
GAC	Granular Activated Carbon
GWRTAC	Ground-Water Remediation Technologies Analysis Center
HASP	Health and safety plan
ISCO	In situ chemical oxidation
KBr	Potassium bromide
LNAPL	light non-aqueous phase liquid
LTU	Land treatment unit
MBMG	Montana Bureau of Mines and Geology
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MDHES	Montana Department of Health and Environmental Services
MnO ₂	Manganese dioxide
MPTP	Montana Pole and Treating Plant
NCRT	Near Creek Recovery Trench
NHRT	Near Highway Recovery Trench
PAH	Polycyclic aromatic hydrocarbons
PCP	Pentachlorophenol
ppb	Parts per billion
ppm	Parts per million
RAO	Remedial action objective
REAC	Response Engineering Analytical Contract
RI/FS	Remedial investigation and feasibility study
ROD	Record of decision
ROST	Rapid Optical Screening Tool
RU	Remediation unit
SAP	Sampling and analysis plan
SSP	Soil staging and pretreatment piles
TarGOST	Tar-specific Green Optical Screening Tool
TCDD	Tetrachlorodibenzodioxin
TEF	Toxicity Equivalence Factor
WTP	Water treatment plant

1.0 PROJECT DESCRIPTION

As part of the Phase 5 Remedial Action at the Montana Pole and Treating Plant (MPTP), in situ treatment options are being considered to address contamination remaining beneath the Interstate 15/90 overpass and in areas of elevated pentachlorophenol (PCP) concentrations in groundwater at the MPTP. This work plan describes proposed studies to collect site-specific data to assist in evaluating the suitability and possible design of in situ treatment remedies.

At MPTP, a dissolved PCP groundwater plume is currently contained by a system of two groundwater recovery trenches and treated at an onsite water treatment plant (WTP). PCP concentrations in captured groundwater are asymptotically approaching a level above the remedial goal, suggesting that the pump and treat system at the site must operate for many years or decades before PCP concentrations would attenuate to a concentration below the remedial goal (Tetra Tech Inc. [Tetra Tech] 2008a). Areas of residual soil contamination, including areas beneath the Interstate 15/90 overpass, may be acting as a source zone, slowly releasing PCP over time and preventing the pump and treat system from achieving remedial action objectives (RAO) within a reasonable timeframe. The purpose of conducting a Phase 5 Remedial Action is to address source-area contamination and areas of elevated PCP in groundwater to reduce the overall timeframe required to meet RAOs in groundwater.

1.1 SITE HISTORY

The MPTP, located in Butte, Montana, operated as a wood treating facility from 1946 to 1984 (U.S. Environmental Protection Agency [EPA] and Montana Department of Environmental Quality [DEQ] 1993) (see Figure 1 – Site Location Map). During most of this period, a solution of about 5 percent PCP, mixed with petroleum carrier oil similar to diesel, was used to preserve poles, posts, and bridge timbers. The PCP solution was applied to wood products in butt vats and pressure cylinders (retorts). Creosote was used as a wood preservative for a brief period in 1969.

In March 1983, a citizen filed a complaint concerning oil seeping into Silver Bow Creek near the MPTP. The Montana Department of Health and Environmental Services (MDHES), now the DEQ, investigated the complaint and discovered an oil seep on the south side of Silver Bow Creek directly downgradient of the MPTP. Further investigation of the site revealed oil-saturated soils adjacent to the creek and on MPTP property. Subsequent sampling confirmed the presence of PCP, polycyclic aromatic hydrocarbons (PAH), and dioxins/furans in site soils and oil samples. In July 1985, the U.S. Environmental Protection Agency (EPA) Emergency Response Branch began a removal action on the site to minimize impacts to

Silver Bow Creek and to stabilize the site. The MPTP was included on the National Priority List for Superfund sites on July 22, 1987 (*Code of Federal Regulations*, Vol. 52, 140, pg. 17623).

In October 1989, EPA granted MDHES the initial enforcement funding to conduct potentially responsible party noticing and administrative order negotiations and issuance. In April 1990, MDHES signed an administrative order on consent with the Atlantic Richfield Company (ARCO) under which ARCO agreed to conduct a remedial investigation and feasibility study (RI/FS) at the site. Following MDHES and EPA approval of the RI/FS work plan, ARCO began the RI/FS in June 1990.

In June 1992, the EPA proposed an additional removal action to control and recover the light nonaqueous phase liquid (LNAPL) (floating oils) identified during the remedial investigation. The water treatment facility went into operation January 22, 1993, at which time a system previously installed by EPA Emergency Response in 1985 was shut down.

1.2 REMEDIAL ACTION OBJECTIVES FOR GROUNDWATER

At the Montana Pole site, the groundwater RAOs include: (1) containing the LNAPL and dissolved groundwater contaminant plumes from further migration; (2) limiting releases of LNAPL and dissolved phase contaminated groundwater to Silver Bow Creek sufficiently for attaining applicable standards for surface water (Table 2); (3) attaining all applicable or relevant and appropriate requirements (ARAR); (4) implementing institutional and engineering controls to prevent access to or further impacts on contaminated groundwater at the site; and (5) remediating the groundwater.

Cleanup levels for site groundwater are shown on Table 1. The groundwater cleanup levels are based on maximum contaminant levels (MCL) and non-zero maximum contaminant level goals (MCLG) established by the Safe Drinking Water Act, or-risk based levels developed in the absence of MCLs and MCLGs. Attainment of these cleanup levels at groundwater points of compliance will be protective of human health and the environment and will ensure that uncontaminated aquifers and adjacent surface waters are protected for potential beneficial uses.

**TABLE 1
GROUNDWATER CLEANUP LEVELS**

CONTAMINANT	CLEANUP LEVEL (µg/L)
Pentachlorophenol	1.0
Benzo(a)pyrene	0.2
Benzo(a)anthracene	1.0
Benzo(b)fluoranthene	0.2
Benzo(k)fluoranthene	1.0
Chrysene	1.0
Dibenzo(a,h)anthracene	0.2
Indeno(1,2,3-CD)perylene	1.0
Benzo (g,h,i)perylene	1.0
Total D PAHs	360
Dioxin TCDD toxicity equivalence factor (TEF)	3.0×10^{-5}
2,4,6-Trichlorophenol	6.5
2-Chlorophenol	45
2,4,-Dichlorophenol	27
2,3,5,6-Tetrachlorophenol	267

Cleanup levels for Silver Bow Creek are shown on Table 2. These levels are based on MCLs, MCLGs, and the Montana Water Quality Act I-Classification standard.

**TABLE 2
SURFACE WATER CLEANUP LEVELS**

CONTAMINANT	CLEANUP LEVEL (µg/L)
Pentachlorophenol	1.0
Benzo(a)pyrene	0.2
Benzo(a)anthracene	1.0
Benzo(b)fluoranthene	0.2
Benzo(k)fluoranthene	1.0
Chrysene	1.0
Dibenzo(a,h)anthracene	0.2
Indeno(1,2,3-CD)perylene	1.0
Benzo (g,h,i)perylene	1.0
Total D PAHs	360
Dioxin TCDD (TEF)	1.0×10^{-5}
2,4,6-Trichlorophenol	6.5
2-Chlorophenol	45
2,4,-Dichlorophenol	27
2,3,5,6-Tetrachlorophenol	267

Cleanup levels for treated water discharges to Silver Bow Creek are shown on Table 3. These levels are based on MCLs, MCLGs, and the Montana Water Quality Act I-Classification standard.

TABLE 3
DISCHARGE TO SURFACE WATER CLEANUP LEVELS

CONTAMINANT	CLEANUP LEVEL (µg/L)
Pentachlorophenol	1.0
Benzo(a)pyrene	0.2
Benzo(a)anthracene	1.0
Benzo(b)fluoranthene	0.2
Benzo(k)fluoranthene	1.0
Chrysene	1.0
Dibenzo(a,h)anthracene	0.2
Indeno(1,2,3-CD)perylene	1.0
Benzo (g,h,i)perylene	1.0
Total D PAHs	360
Dioxin TCDD (TEF)	1.0×10^{-5}
2,4,6-Trichlorophenol	6.5
2-Chlorophenol	45
2,4,-Dichlorophenol	27
2,3,5,6-Tetrachlorophenol	267
Arsenic	48
Cadmium	1.1
Chromium	11
Copper	12
Lead	3.2
Zinc	110

1.3 REMEDY IMPLEMENTATION STATUS

Implementation of the MPTP cleanup is occurring in a number of phases. The primary remedy components completed during Phase 1 of the remedial action (May 1996 to November 1997) consisted of constructing the land treatment unit (LTU) and 13 soil staging and pretreatment piles (SSP), building an addition to the WTP, constructing two contaminated groundwater recovery trenches, and excavating the northside contaminated soils (Camp Dresser and McKee [CDM] 1996). The Phase 1 construction activities are summarized in the *Phase 1 Construction Report* dated August 2001.

Phase 2 of the remedial action (March 1999 to May 1999) consisted of removal and disposal of hazardous and non-hazardous waste debris remaining on site (CDM 1998). Phase 2 remedial actions are summarized in the *Remedial Action Report, Montana Pole and Treatment Plant Site Phase 2 –Debris Removal* dated September 26, 2000.

Phase 3 of the remedial action (October 1999 to December 2000) consisted of excavating the southside contaminated soils, offloading Phase 1 treated soils from the LTU, placing approximately 132,000 cubic yards of contaminated soil on the LTU, installing the north and south in situ treatment systems, and relocating sewer and potable water lines (CDM 1999). The in situ treatment system was operated through November 2002, when a pump required extensive repair. While the pump was out for repairs, analytical data from samples subsequently collected from Silver Bow Creek—a record of decision (ROD)-defined point of compliance—showed significant decrease in PCP concentrations. Since that time, PCP concentrations in surface water samples from Silver Bow Creek have generally remained below the ROD cleanup standard. For this reason, the in situ system has not been reactivated.

Phase 4 of this project is a continuation of Phase 3 activities, and includes off-loading the LTU as surface soil lifts are remediated below action limits set for the site. Phase 4 began in April 2001 with offload of approximately 27,000 cubic yards of treated soils from the LTU, and placement of these treated soils onsite. To date, more than 200,000 cubic yards of contaminated soils has been excavated from the site, and approximately 150,000 cubic yards of these soils has been treated on the LTU and backfilled; an additional 24,000 cubic yards of SSP soils has been treated and backfilled.

Phase 5 will address the contaminated soils beneath Interstate 15/90 that divides the site. This work plan is part of Phase 5 activities at the site.

Phase 6 will consist of removal and disposal of the soil treatment facilities on the south side of the site, and final revegetation of all disturbed areas.

2.0 SITE DESCRIPTION

This section discusses the natural and physical characteristics of the Site.

2.1 GEOLOGY AND HYDROLOGY

The feasibility study (FS) report for the MPTP site indicates that soils within the MPTP site consist of thin, gravel-textured to thick, fine-grained alluvial soils. Along Silver Bow Creek, soils reportedly consist of a mixture of natural alluvial-derived soils and varying thicknesses of organic-rich peat; however, past mining activities have altered soils in the immediate vicinity of the Silver Bow Creek channel. These altered soils reportedly contain mining-related wastes that are generally fine-grained, sandy textured materials with higher metals and sulfide concentrations than the natural soils in the vicinity of the site (ARCO 1993). Note that soil in most areas of the site was disturbed during remedial excavations conducted during Phases 1 and 3 of the remedial action.

The FS report indicates that two lithologic zones and two water-bearing zones (aquifers) have been identified beneath the MPTP site. The FS report describes these water-bearing zones as follows (ARCO 1993).

Alluvial deposits consisting of upper and lower interbedded sands, sand and gravels, clays, and silts vary in thickness from 11 feet (ft) in the southwest, to 35 ft in the northern portion of the site (near Silver bow Creek), to over 47 ft on the eastern portion of the site. The occurrence of clay lenses encountered during drilling corresponds to low spots of the weathered bedrock surface, such that the topography of these clays resembles the weathered bedrock topography. The water table is approximately 5 to 10 ft below ground surface.

Weathered Bedrock Deposits are described as an orangish-brown to whitish-gray grus; a friable medium to fine gravel sized, angular quartz and feldspar with abundant micas and a trace of hornblende in a slightly kaolinitic matrix. The topography of the weathered bedrock surface varies significantly throughout the site. A local bedrock high is in the southwestern portion of the site, near Greenwood Avenue, indicating intrusion by the Boulder Batholith. The uppermost aquifer encountered at the site is composed of the Quaternary age alluvial valley fill sediments. Groundwater is present at the site under unconfined conditions, with depth to water measurements ranging from approximately 5 to 20 ft.

Groundwater elevation data collected during the RI from wells monitoring the alluvial aquifer system indicate that the direction of groundwater flow is generally towards the northwest. Monitoring wells

penetrating the alluvial aquifer zone indicate a range in water levels from elevations of approximately 5,439 to 5,426 ft above mean sea level (amsl) (ARCO 1993). March 2008 monitoring data indicate a range in water levels from elevations of approximately 5,441 to 5,429 ft amsl.

The FS report reveals that contours of the potentiometric surface in the southeastern portion of the site show a hydraulic gradient of approximately 0.003 ft/ft, while within the northwestern portion of the site this is approximately 0.007 ft/ft. The average hydraulic gradient across the entire site is approximately 0.005 ft/ft. More recent groundwater contour maps and monitoring data indicate a groundwater flow direction of north to northwest, and suggest that a hydraulic gradient of 0.009 ft/ft is appropriate for the site. A gradient of 0.009 ft/ft is very high, but is plausible due to the depression caused by the Near Highway Recovery Trench (NHRT) pumping.

During the RI, horizontal hydraulic conductivities for the site reportedly ranged from 0.11 to 119 ft/day; average horizontal hydraulic conductivity for the alluvial aquifer was calculated as 16 ft/day. A pumping test was performed for EPA under the Response Engineering Analytical Contract (REAC) in October 1992, north of the highway where the horizontal hydraulic conductivity was estimated at 171 feet/day (EPA 1993). A groundwater model was constructed under the REAC with a hydraulic conductivity of 171 ft/day north of the highway and 315 ft/day south of the highway. These conductivities are similar to those currently used by the Montana Bureau of Mines and Geology (MBMG) in modeling: 200 ft/day north of the highway and 300 ft/day south of the highway. The effective porosity is estimated as 20 percent based upon an average total soil porosity of 32 percent (ARCO 1993).

At the time of the RI/FS investigations, the average groundwater velocity across the site was estimated as 0.3 ft/day, the average groundwater velocity north of the interstate was estimated as 0.48 ft/day, and the average groundwater velocity south of the interstate was estimated as 0.18 ft/day. Assuming a distance of 1,200 ft from the site of the plant process area to Silver Bow Creek, the corresponding groundwater flow travel time across the site was estimated to be approximately 10 years (ARCO 1993). Since that time, contaminated soils have been excavated and treated, in situ cells have been installed in groundwater, and treated soils have been backfilled onsite. These activities changed the natural conditions noted at the site at the time of the RI/FS investigations. A bromide tracer test was performed in January 2002; the bromide took 19 days to reach the NHRT from PZ-05-02 (a distance of 650 feet), resulting in an estimated groundwater velocity of 34 ft/day. The higher estimate of 34 ft/day is not surprising considering the bromide was injected into an infiltration cell, and approximately 60% of the path to the NHRT is through the south infiltration galleries where a 2-foot gravel layer below the static

water level could conduct bromide faster than could natural aquifer materials. MBMG modeling using site monitoring data gives an average groundwater velocity value of 7 ft/day by invoking Darcy's Law:

$$v = \frac{Q}{A} = K \cdot i$$

Where, v is the Darcy velocity, K is the hydraulic conductivity, and i is the hydraulic gradient. Specifying that $i = 0.009$ from PZ-05-02 to the NHRT using a 2008 static water level contour map, $v = 315 \cdot 0.009 = 3$ ft/day south of the highway. Using this groundwater velocity number and ARCO's 1993 estimate of 1,200 feet from the site of the plant process area to Silver Bow Creek revises the corresponding groundwater flow travel time across the site to approximately one year.

2.2 WATER TREATMENT PLANT

The groundwater treatment system at the site consists of two groundwater recovery trenches which supply contaminated water to an onsite WTP. Water from both trenches is routed through an oil-water separator to remove any recovered product and then through the carbon filtration system to remove dissolved PCP. After carbon treatment, the water is discharged to Silver Bow Creek. Between 1993 and 2007, the WTP treated approximately 1.87 billion gallons of contaminated water and removed approximately 1,920 kilograms of dissolved PCP from the groundwater (in addition to PCP removed through oil recovery operations). More than 60,000 gallons of free product has also been recovered and disposed of since this date. As specified in the ROD, groundwater recovery and treatment systems will continue to operate until ROD cleanup levels for groundwater are met for the site.

Because groundwater elevations have been lower than the bottom of the product recovery culvert of the NHRT, a belt skimmer has been used at Manhole 2 to recover LNAPL product from the surface of the groundwater. In 2007, approximately 4 gallons of LNAPL product was recovered from Manhole 2 using the belt skimmer, as opposed to 461 gallons of LNAPL product recovered from the same location in 2006. A very modest increase in oil on the surface of the oil-water separator was noted during November and December 2007, but no significant oil was recovered from the NHRT recovery point at Manhole 2, as was the case in spring 2006. Under very similar conditions of groundwater rise in 2006, hundreds of gallons of free oil flowed into the manhole in a short time period and was recovered, while during 2007 and 2008, only "gallons" of oil was recovered from the manhole, with essentially the same physical conditions in the trench. Only the well at the extreme east end of the NHRT had measurable thicknesses of oil for several months. None of the monitoring wells outside of the trench has had any free oil since

the low water period of early winter 2007. Previously, measurable free oil had been present in these wells.

2.3 SITE CONSTRAINTS LIMITING POTENTIAL REMEDIAL ALTERNATIVES

Several physical features at MPTP may limit the potential applicability and feasibility of remedial alternatives. Structures at MPTP limit access to the subsurface, including the Interstate 15/90 overpass, a railroad line along the north portion of the site and a spur that extends beneath the Interstate on the eastern portion of the site, the WTP, the NHRT and the Near Creek Recovery Trench (NCRT), LTU located south of the Interstate, and underground utilities. The inaccessible area beneath the Interstate 15/90 overpass encompasses an area of approximately 300 by 500 feet. A site diagram is presented as Figure 2.

In addition to the physical limitations at the site, the selected remedial alternative must be compatible with the current groundwater capture and treatment system. This includes compatibility with the Granular Activated Carbon (GAC) treatment units and hydraulic compatibility with the NHRT and NCRT.

2.4 NATURE AND EXTENT OF CONTAMINATION

This section summarizes the nature and extent of contamination at the MPTP site.

2.4.1 Groundwater Contamination

Groundwater sampling is performed on a regular basis at the MPTP site. Groundwater samples were collected and analyzed for PCP from a total of 89 monitoring wells during 2007 and 2008. The results of groundwater sampling conducted in 2007 are reported in *Final 2007 Annual Sampling and Monitoring Report for the Montana Pole and Treating Plant Site* (Tetra Tech 2008c). Dissolved PCP concentration contour maps using groundwater data from samples collected in 2007 and 2008 are presented in Figures 3 and 4, respectively. Groundwater monitoring results have indicated generally decreasing concentrations through time, although elevated concentrations can occur due to seasonal water level changes.

Groundwater samples collected during 2007 and 2008 indicated that the extent of the dissolved PCP groundwater plume exceeding the RAO cleanup goal of 1 microgram per liter ($\mu\text{g/L}$) extends from near the retention pond on the south side of Interstate 15/90 in a generally northwest direction beneath the Interstate 15/90 overpass and toward Silver Bow Creek. Areas of (elevated) PCP concentrations greater than 200 $\mu\text{g/L}$ were encountered south of the Interstate in the area of infiltration wells INF-13, -14, and -

15, and north of the Interstate in an area extending northwest from monitoring well MW-B-04 (near the north side of the Interstate) toward monitoring well MW-I-01 (located on the north side of the railroad tracks). During 2007, the highest dissolved PCP concentrations were found in wells INF-13 (1,030 to 1,360 µg/L), INF-08 (274 to 747 µg/L), and monitoring well MW-I-01 (57.7 to 2,590 µg/L).

Groundwater samples collected during 2007 exhibited detectable concentrations of dioxins in wells INF-04, INF-05, MW-E-01, and GW-12. Groundwater samples collected during 2007 did not exhibit detectable concentrations of carcinogenic PAHs, resulting in calculated Group B2 PAH toxicity equivalents below the cleanup standard. Therefore, the primary contaminant of concern at the site and the main focus of this treatability study is PCP, both in LNAPL and dissolved phases.

PCP is a fully chlorinated phenol (an aromatic ring compound with one hydroxyl group). PCP is a weak organic acid and can therefore, in aqueous solutions, be found as either organic PCP or as a phenoxide ion. Once PCP dissolves in water, its adsorptive behavior begins to control its fate. As aqueous solubility decreases, the adsorption increases. Because PCP is a weak acid, its solubility in water depends strongly on pH. Groundwater pH is generally in the neutral range at the Site, rendering PCP more mobile in groundwater than the other contaminants of concern.

The LNAPL plume consists of PCP dissolved in petroleum carrier oil that was used for wood treatment processes. The petroleum carrier oil is reportedly similar to diesel fuel and was purchased from local refineries (CDM 2001).

LNAPLs exist as a separate, immiscible phase when in contact with water and/or air. Upon release to the environment, LNAPL migrates downward under the force of gravity. As the LNAPL moves through the unsaturated zone, a portion of the LNAPL is retained as globules among soil particles due to capillary forces. If sufficient LNAPL is present, the LNAPL can continue to migrate downward until it encounters the surface of the water table. Once LNAPL reaches the water table, the LNAPL moves laterally as a free-phase layer on top of the water table. Constituents of LNAPL can partition (be physically transported) into other phases in contact with the LNAPL, including water, soil, and air.

LNAPL that has become entrapped within pore spaces due to capillary forces is described as residual LNAPL. The LNAPL residual saturation is defined as the smallest saturation of remaining LNAPL in the formation against which applied hydraulic recovery is not possible due to capillary forces that hold the LNAPL in pore spaces of the formation. Residual LNAPL is not recoverable using hydraulic recovery techniques such as pump and treat, and represents a potential source for continued groundwater contamination via partitioning of contaminants into groundwater.

2.4.2 Soil and LNAPL Contamination

Some areas at the MPTP site were inaccessible to remedial excavation during previous response actions. Inaccessible areas included areas beneath the Interstate 15/90 overpass and beneath the water treatment building. Soil sampling was conducted in 2003 by CDM to identify the extent of LNAPL and soil contamination beneath the Interstate 15/90 overpass. Findings of this investigation are presented in *Butte Area Structures Interstate 15/90 Bridge Replacement Environmental and Geotechnical Data Report* (CDM 2004). Soil borings were advanced along both sides of the Interstate and along the median. Field observations of the soil cores identified residual LNAPL that occurred within a “smear zone.” This smear zone is interpreted as the result of fluctuating (over time) LNAPL deposits within soil pore spaces at the water table. This smear zone was identified in borings advanced near the west bridge of the Interstate 15/90 overpass in an area inaccessible to soil excavation. This inaccessible area encompasses an area of approximately 300 by 500 ft. Interpreted smear zone thicknesses ranged from 3.0 to 11.2 ft, and the elevation smear zone generally was located between elevations of 5,436 and 5,425 ft amsl. In comparison, the recent (2007 and 2008) static water levels for wells MW-A-04, MW-D-95, and AW-02—located within the median of the west bridge—ranged from approximately 5,428 to 5,430 ft amsl. Approximate elevation of the site before construction of the overpass ramps was 5,440 ft amsl.

A review of the boring logs indicates a fairly heterogeneous soil description consisting of silty sand and silty clay: some silt and clay lenses are in the top elevation of the smear zone; the smear zone becomes more homogeneous sand toward its bottom elevation (see boring logs in Appendix B).

3.0 PRE-SCREENING OF SOURCE AREA TREATMENT TECHNOLOGIES

This section further identifies and screens remediation technologies that may be used to address source areas contaminants and areas of elevated PCP in groundwater at MPTP.

Eight in situ treatment technologies for soil were evaluated in the 1993 FS (ARCO 1993). Technologies eliminated from further consideration in the 1993 FS included vitrification, radio frequency heating, stabilization/solidification, vacuum extraction, and steam extraction. Vitrification and in situ stabilization/solidification were eliminated because they had not proven effective for most organic wastes.

Radio frequency heating was eliminated because the technology was in developmental stage and would be difficult and costly to implement. Vacuum extraction was eliminated because the chemicals of concern at the site are not easily extracted via vapor extraction due to their relatively low volatility. Steam stripping was eliminated due to the difficulty of maintaining a controlled steam front within heterogeneous soils (ARCO 1993). A combination of two technologies, in situ bioremediation and in situ soil flushing, was retained as the appropriate remedy for the site because this remedy appeared to provide the best balance of satisfying the selection criteria.

In October 2008, Tetra Tech conducted a literature review to further evaluate in situ treatment technologies. Based on this literature review, three in situ treatment technologies were retained for further evaluation: (1) in situ chemical oxidation, (2) in situ soil flushing, and (3) in situ bioremediation (Tetra Tech 2008b). In preparation of this Treatability Study Work Plan, Tetra Tech conducted additional literature review of these three technologies.

3.1 IN SITU BIOREMEDIATION

In situ bioremediation involves addition of amendments to the subsurface to enhance naturally occurring biological processes that degrade contaminants. In situ bioremediation techniques were selected as a remedy in the ROD to be employed with other remedial techniques for treatment of the contaminated aquifer and contaminated soils not recovered by previous excavation activities. Although in situ bioremediation can destroy PCP, this is not typically suitable for treatment in source and residual source areas because of the limited rate at which non-aqueous phase contaminants dissolve into the aqueous phase—decreasing the effectiveness of biological agents to degrade these contaminants. In addition, high concentrations of PCP likely inhibit the growth of biological agents. Although this work plan does not propose to evaluate in situ bioremediation techniques for purposes of addressing LNAPL source areas, the use of an in situ bioremediation technique may be effective at treating well-defined areas of elevated PCP concentrations in the dissolved groundwater plume. The following describes two pathways of

biodegradation, aerobic and anaerobic biodegradation, that have been observed to degrade PCP. Both aerobic and anaerobic conditions exist at MPTP.

3.1.1 Aerobic In Situ bioremediation

PCP can be aerobically biodegraded by serving as an electron donor (food source) for bacteria. In aerobic degradation, the phenol ring of PCP is cleaved, producing intermediates that can ultimately biologically degrade to carbon dioxide, water, and chloride. Use of this technology generally involves addition of oxygen and nutrients into the aquifer to increase biological activity. For aerobic oxidation to occur, a dissolved oxygen concentration in the groundwater of at least 2 milligrams per liter (mg/L) is typically required (MacEwen, Scott, and others 2001). Increasing the oxygen and, if necessary, the nutrient content of the aquifer can be achieved in several ways: (1) extracted groundwater can be enriched with oxygen and nutrients, and reinjected into the aquifer; (2) air injection wells can be installed to bubble air through the saturated zone thereby dissolving oxygen into the groundwater; or (3) a material that releases oxygen, such as the proprietary Oxygen Release Compound[®], can be introduced into the subsurface through temporary or permanent injection wells.

3.1.2 Anaerobic In Situ bioremediation

Implementation of enhanced anaerobic degradation requires injection of materials into the groundwater that would stimulate anaerobic microbial activity. The addition of an organic substrate or a hydrogen releasing compound to an aquifer has the potential to stimulate microbial growth and development, creating an anaerobic environment in which the anaerobic degradation of PCP may be enhanced. Microbial use of the carbon source or hydrogen drives reductive chlorination of PCP (that is, PCP is used as an electron acceptor). Dissolved oxygen levels below 0.5 mg/L are reportedly necessary for anaerobic degradation of PCP to occur (MacEwen, Scott, and others 2001). Materials that have been used as a carbon source to promote anaerobic degradation include molasses, cooking/vegetable oil, and the proprietary Hydrogen Release Compound[®]. In addition, inorganic nutrients (nitrogen and/or phosphorus) and trace vitamins and minerals are added to support anaerobic microbial activity. This technology involves injecting these materials into the aquifer through either temporary or permanent injection wells.

3.2 IN SITU CHEMICAL OXIDATION

In situ chemical oxidation (ISCO) involves delivery of a reagent into the subsurface capable of chemically oxidizing contaminants. Oxidation destroys the contaminants by converting them to innocuous compounds. The effectiveness of ISCO is governed by site-specific conditions including site

stratigraphy, hydrogeological conditions, and the geochemical characteristics of the soil matrix and groundwater. In addition, the persistence of the oxidant in the subsurface is an important factor to consider when evaluating the suitability of a reagent. These factors affect the ability to distribute oxidant throughout the treatment zone, the retention time of contaminants within the treatment zones, and the oxidant demand of natural constituents readily oxidized along with the contaminants. Because the oxidizing reagents must directly contact the contaminants to destroy them, ability to distribute the oxidizing reagent throughout the treatment zone is crucial.

Oxidizing reagents that can destroy phenols such as PCP reportedly include: permanganate, Fenton's Reagent, persulfate, activated persulfate, ozone, and ozone/peroxone (EPA 2006). Information provided by DEQ indicated that the following reagents have been used or were being considered for use at other wood treating sites with PCP contamination:

- Activated sodium persulfate
- Modified Fenton's reagent
- Cool-Ox[®], a proprietary calcium peroxide-based reagent
- Klozur[®]-CR, a proprietary sodium persulfate and peroxygen-based reagent.

Tetra Tech conducted additional literature review to evaluate the potential effectiveness of each of the above reagents for use at MPTP. Based on this screening, modified Fenton's Reagent, a calcium peroxide-based reagent, was retained. Table 5 summarizes findings of the literature review and provides the basis for retaining or screening out ISCO reagents.

**TABLE 5
SUMMARY OF ISCO TECHNOLOGY SCREENING**

ISCO Reagent	Description of Method	Advantages	Limitations	Screening Result
Fenton's Reagent / Hydrogen Peroxide	Solution of hydrogen peroxide with Ferrous Iron (Fe(II)) in acid solution are injected.	Produces strong hydroxyl radical.	Oxidants are short-lived in the subsurface, limiting distribution. May not be cost effective compared to Modified Fenton Reagents that do not involve injection of Fe(II). Metals could be mobilized due to lowering pH. May damage underground utilities. Transport of Fe(II) in subsurface can be problematic.	Not retained based on short life of reagent in subsurface.
Ozone	Ozone gas is generated onsite with ozone generating units and is sparged into the subsurface.	Strong oxidant. Does not leave a residual other than O ₂ . Because the reagent is a gas, may be more effective at addressing contamination in the unsaturated zone than liquid-delivered reagents.	Fugitive ozone emissions may present a health and safety concern, especially if ozone would be injected beneath structures.	Not retained based on concern with fugitive emissions.
Permanganate	Delivered to subsurface as an aqueous solution of either potassium permanganate or sodium permanganate.	Use is well demonstrated. Long-term persistence of Manganese dioxide (MnO ₂) in the subsurface promotes good distribution of the oxidant.	MnO ₂ (s), a reaction byproduct, may accumulate and may cause reduction in permeability. Produces a strong purple color in water and may impact secondary drinking water standard for manganese of 0.05 parts per million (ppm).	Not retained based on drinking and surface water quality concerns associated with purple color of manganese ion.
Persulfate/ Activated Persulfate/ Klozur [®] CR by ChemRem	Sodium persulfate solution is most commonly used. Can be activated with heat, Fe(II), or base to form sulfate radical (SO ₄ ⁻), a stronger oxidant.	The persulfate anion is relatively stable and may persist for weeks in the subsurface.	May impact secondary drinking water standard for sulfate of 250 ppm.	Not retained based on concerns regarding the potential for creation of sulfate, since the existing sulfate concentrations in groundwater often already exceed 250 ppm.
Modified Fenton's Reagent (calcium peroxide-based reagent), Cool-Ox [®] by Deep Earth Technologies	Calcium peroxide-based reagent. Relies on naturally occurring iron in the subsurface to activate peroxide. A derivative of traditional Fenton's Reagent chemistry.	Does not rely on injection of Fe(II). Reagent causes a small rise in pH of treated groundwater that may promote partitioning of PCP into the aqueous phase where it is more readily oxidized.	Oxidation may not be as rapid as other reagents.	Retained

3.3 IN SITU SOIL FLUSHING

In situ flushing is the injection or infiltration of a flushing solution into the subsurface above a contaminated zone of soil or groundwater. The flushing solution percolates through the contaminated zone and removes contaminants via solubilization, emulsion formation, or chemical reaction. In situ flushing possibly could serve at the MPTP site to mobilize (or “flush”) LNAPL from unsaturated and smear zones into the saturated zone for subsequent collection via a downgradient groundwater collection system, such as the existing NHRT and NCRT. The specific contaminants in the soil at any particular site determine the type of flushing solution needed in the treatment process. The flushing solution is typically one of two types of fluids: (1) *water only*; or (2) *water plus additives* such as acids (low pH), bases (high pH), or surfactants (like detergents). *Water* is used to treat contaminants that dissolve easily in water. An *acidic solution* is a mixture of water and an acid, such as nitric acid or hydrochloric acid. Acidic solutions are used to remove metals and organic contaminants, such as those typically found in battery recycling or industrial chrome plating processes. For example, zinc contamination—which can result from plating operations—would be treated with an acidic solution. A *basic solution* is a mixture of water and a base, such as sodium hydroxide (ammonia is an example of a base commonly used in households). Basic solutions are used to treat phenols and some metals. A *surfactant* can be a detergent or emulsifier. Emulsifiers help mix substances that normally do not mix such as oil and water. For this reason, surfactant solutions can be effective at removing oily contaminants such as those encountered at MPTP. Researchers also are investigating the use of water plus *organic solvents* as a flushing solution. Organic solvents such as ethanol are used to dissolve certain contaminants that water alone cannot dissolve.

In situ soil flushing works best at sites with soil that has spaces permitting the wash solution to move through it. If the soil has a high percentage of silt or clay, for example, the flushing solution cannot easily move through the soil, so it cannot easily make contact with the contaminants. This limits the overall effectiveness of the soil flushing process. In addition, some flushing fluids contain additives which may themselves create new groundwater contamination if they are not completely removed. There are additional considerations for the use of this technology. For example, the flow of groundwater must be well understood to design the well system for a given site. Also, extensive field investigations may be necessary to define the groundwater flow completely. The makeup and arrangement of subsurface layers must be well understood in order to predict the path of the flushing fluids and contaminants, and to ensure that the contamination does not spread beyond the area from which it can be collected.

At the MPTP site, the flushing fluid could be injected into the subsurface via vertical injection wells

placed near the highway, via horizontal wells constructed beneath the highway, or using the existing in situ system. In addition vertical and/or horizontal injection wells could be installed at the remaining hotspots. As flushing fluids migrate through the contaminant zone, contaminants are mobilized and mix with the flushing fluid and groundwater. This mixture of spent flushing fluid, contaminants, and groundwater is typically captured for treatment and reuse (Ground-Water Remediation Technologies Analysis Center [GWRTAC] 1997). At the MPTP site, the captured flushing fluid possibly could be treated at the WTP and reinjected.

By removing LNAPL, which can act as a continuous source of groundwater contamination, soil flushing programs may shorten the timeframe required to achieve cleanup goals. Because soil flushing systems increase mobilization of contaminants, and because mounding of groundwater may cause lateral dispersion of LNAPL, these systems must be carefully designed to reduce potential of unwanted dispersion of the LNAPL plume. Also, any chemicals used to increase the effectiveness of the flushing process must not adversely impact the ability of the existing groundwater treatment (carbon absorption) to remove contaminants from the collected groundwater. Moreover, if the groundwater collection system is not adequately designed, contaminants mobilized by soil flushing may migrate past the downgradient collection system. Additional field investigations are necessary to determine the makeup and arrangement of subsurface soils to be treated with in situ flushing. Because this technology could shorten the timeframe for meeting RAOs at the MPTP site, and because the technology could be implemented beneath the Interstate and the remaining hotspots, this technology is retained for further evaluation.

3.4 RESULTS

As a result of the literature evaluation in combination with a review of site conditions and years of monitoring data, the following technologies have been retained for further evaluation at the MPTP:

- Modified Fenton's Reagent (calcium peroxide-based reagent) such as Cool-Ox[®] by Deep Earth Technologies
- In Situ Soil Flushing.

Vendor-provided information on Cool-Ox[®] by Deep Earth Technologies is in Appendix C.

4.0 TEST OBJECTIVES AND EXPERIMENTAL DESIGN

The primary objective of the proposed treatability study is to assess the feasibility of reducing PCP and other contaminant concentrations in source and residual source areas using one or more of the pre-screened source area in situ remediation technologies. The effectiveness of most cleanup technologies depends on the ability to thoroughly contact the contaminants with the remediation agent. Therefore, identifying the location of source and residual source areas (i.e., residual LNAPL) is critical for developing an effective remediation strategy. Residual source areas are likely located beneath the Interstate 15/90 overpass where soil could not be excavated during previous removal activities. In addition, review of groundwater data indicates that residual source areas may also be located to the south and north of the interstate. Based on these observations, additional site investigation to identify source and residual source areas is proposed. The following phases are proposed for the treatability study:

- Phase 1 will involve collection of additional site data to identify areas of source and residual source area contamination and to provide additional data for the site conceptual model.
- Phase 2 will involve treatability studies of pre-screened in situ remediation technologies at select site areas.
- Phase 3 will be a continuation of Phase 2 activities if the results of the Phase 2 treatability work are positive.

The study objectives and experimental designs for Phase 1 and Phase 2 of the treatability study are further defined in the following sections using EPA's data quality objectives (DQO) process.

4.1 EXPERIMENTAL DESIGN

This section discusses the experimental design of the proposed supplemental site investigation (Phases 1 and 2). Experimental design of additional treatability studies (Phase 3) will be developed following completion of the Phase 1 and 2 site investigation.

4.1.1 Phase 1: Additional Characterization using ROST/TarGOST

Additional site investigation can provide data that would either verify the site conceptual model or provide information that could be used to update the model. Supplemental site investigation will be conducted to meet the following objectives:

- To the extent possible, confirm previous observations of a smear zone (residual LNAPL) located beneath the Interstate 15/90 overpass. Safety considerations and administrative limitations may prevent sampling in the median of the interstate; therefore, sampling may be conducted within

the site boundary along the north and south berms of the Interstate 15/90 overpass.

- Determine if residual contaminant source areas are significant contributors to elevated groundwater PCP concentrations at the site. Areas on the north (near monitoring wells MW-87-03) and south side of the interstate (near monitoring wells INF-13/14/15, INF-16/17/18, and GW-05) will be investigated to determine if suspected source areas associated with elevated PCP groundwater concentrations are present.
- Conduct a tracer study to confirm assumptions regarding groundwater flow direction and velocity. Information obtained from a bromide tracer test can aid in the evaluation of the ISCO treatability study performance and could be used to develop design parameters for a potential full-scale, in situ remediation system.

The Rapid Optical Screening Tool (ROST) is proposed to meet the supplemental site investigation test objectives. ROST is an innovative assessment tool that can rapidly identify LNAPL in situ. Laser and ultraviolet fluorescence methods can detect petroleum hydrocarbons in situ by detecting fluorescence of those compounds. The ROST provides qualitative profiles of petroleum hydrocarbons with depth. ROST spectrometry utilizes a laser in the tip of a probe that induces petroleum hydrocarbons to fluoresce, this varying with depth. The intensity and duration of the fluorescence are continually recorded. ROST technology is reportedly able to screen several hundred feet of soil in a single day. ROST results can be plotted on a three-dimensional map. Vendor-provided information on Tar-specific Green Optical Screening Tool (TarGOST), a proprietary version of ROST, is in Appendix C.

Additional discussion with the Vendor indicates that a tracer can be injected at the time of the ROST/TarGOST investigations. Information provided by tracer studies will be used to confirm or modify previous assumptions regarding groundwater flow and velocity. In addition, tracer studies can aid in the design of in situ remedial designs by:

- Estimating the expected transverse dispersivity (i.e., the lateral coverage) of injected reagent from the injection point/well
- Estimating the expected transit times of the injected reagent through treatment areas, as well as estimating the expected transit times of the reagent and/or breakdown products of the reagent to receptors such as the WTP or Silver Bow Creek
- Estimating the dilution effects caused by the diffusion of injected reagents with immobile groundwater, thereby providing information useful for determining the appropriate strength of the injected reagent.

A “transport analysis” tracer study is proposed that involves monitoring the migration of injected tracers from the injection point to downgradient locations. Tracer concentration breakthrough curves (concentration versus time) would be developed from observations at downgradient monitoring points.

The downgradient monitoring points would likely include existing groundwater monitoring points. The

proposed tracer for the study is potassium bromide (KBr).

4.1.2 Phase 2: Proof of Principle Demonstration of Cool-Ox

The TarGOST vendor has recently joined forces with the developers of the Cool-Ox ISCO, allowing application of the Cool-Ox reagent at the same time the site TarGOST investigation occurs, thus using “real-time” data to determine correct placement of the ISCO reagent. The Phase 2 ISCO treatability study would occur in the area of monitoring wells INF-13/14/15, believed far enough away from both the WTP and Silver Bow Creek to minimize any unintended negative effects of the ISCO treatment on the WTP or Silver Bow Creek. After injection of the Cool-Ox reagent, sampling would be conducted to estimate the degree of PCP degradation, to identify breakdown products that could be detrimental to the WTP or to Silver Bow Creek, to determine the overall reaction time, and to determine the lateral distance of impact of the Cool-Ox ISCO. Injection of a bromide tracer with the ISCO reagent is proposed to allow for monitoring the movement of the injected solutions/breakdown products, and to monitor for effects of groundwater displacement. If decreases in contaminant concentrations are observed following ISCO reagent injections, the use of a tracer can aid in determining if the observed decreases in contaminant concentrations result from actual contaminant destruction or from displacement of contaminated water by the injected solutions.

4.1.3 Phase 3: Follow-on Treatability Work

If the results of Phases 1 and 2 indicate that the Cool-Ox ISCO can be used at MPTP to effectively treat PCP to the cleanup standard of 1 part per billion (ppb) without negative impact on the existing WTP or on Silver Bow Creek, Phase 3 work would ensue to design further applications in the area beneath the Interstate 15/90 overpass and in the northwest corner of the site.

4.2 DATA QUALITY OBJECTIVES

The DQO process is a series of planning steps designed to ensure that the type, quantity, and quality of environmental data used in decision-making are appropriate for the intended purpose. EPA has issued guidelines to help data users develop site-specific DQOs (EPA 2000). The DQO process is intended to:

- Clarify the study objective
- Define the most appropriate type of data to collect
- Determine the most appropriate conditions from which to collect the data

- Specify acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the design.

The DQO process specifies project decisions, the data quality required to support those decisions, specific data types needed, data collection requirements, and analytical techniques necessary to generate the specified data quality. The process also ensures that the resources required to generate data are justified. The DQO process consists of the following seven steps; the output from each step influences choices that ensue in the process.

- Step 1:** State the problem.
- Step 2:** Identify the decision.
- Step 3:** Identify the inputs to the decision.
- Step 4:** Define the study boundaries.
- Step 5:** Develop a decision rule.
- Step 6:** Specify tolerable limits on decision errors.
- Step 7:** Optimize the design.

A brief discussion of these steps and their application to the pilot test portion of this work plan is provided below.

4.2.1 Step 1: State the Problem

At MPTP, a dissolved PCP groundwater plume is currently contained by a system of two groundwater recovery trenches and treated at an onsite WTP. However, PCP concentrations in captured groundwater are asymptotically approaching a level above the PCP remedial goal of 1 ppb, suggesting that the pump and treat system at the site must operate for many years or decades before PCP concentrations would attenuate to a concentration below the remedial goal. Areas of residual soil contamination, including areas beneath the Interstate 15/90 overpass, as well as localized “hot spots” on the north and south sides of the interstate, may be acting as a source zones, slowly releasing PCP over time and preventing the pump and treat system from achieving RAOs within the reasonable timeframe specified in the 1993 ROD.

4.2.2 Step 2: Identify the Decision

Based on the problem stated in Step 1, the following principal study question was developed:

Principal Study Question: What in-situ remedial technology, if any, should be implemented to address contamination beneath the Interstate 15/90 overpass and other “hot spots” of contamination at the site that are acting as continuous sources of the dissolved groundwater contaminant plume?

Based on this principal study question, the following alternative actions were developed:

Alternative Action (1): Recommend that no in-situ remedial technology be considered and that groundwater contamination continue to be addressed by operation of the WTP

Alternative Action (2): Recommend implementing an in-situ remedial technology that will address contamination beneath the Interstate 15/90 overpass and/or at “hot spots” of contamination that are acting as continuous sources of the dissolved groundwater contaminant plume.

The principal study question and the alternative actions were combined to form the following decision statement:

Decision Statement: Determine whether or not existing data and data collected during the treatability study support implementing an in-situ remedial technology to address contamination beneath the Interstate 15/90 overpass and/or at other “hot spots” of contamination.

4.2.3 Step 3: Identify the Inputs to the Decision

The purpose of this step is to identify the information inputs needed to support the decision statement and to specify which inputs will require environmental measurements. Table 6 presents the data inputs needed and shows the relationship between the data inputs and evaluation criteria and performance goals.

4.2.4 Step 4: Define the Study Boundaries

The purpose of this step is to clarify the site characteristics that the environmental measurements are intended to represent (EPA 2000). This step includes the following activities: (1) specifying the characteristics that define the population of interest, (2) defining the spatial boundary of the decision statement, (3) defining the temporal boundaries of the decision, (4) defining the scale of decision making, and (5) identifying any practical constraints on data collection.

Characteristics That Define the Population of Interest: The population of interest for this treatability study is contaminated media (primarily LNAPL and “hot spots” of residual soil contamination) that acts as a continuous source of the dissolved contaminant groundwater plume. This contaminated media, likely present beneath the Interstate 15/90 overpass and at various “hot spots,” is the primary target of possible future in-situ remedial actions.

Spatial Boundary of the Decision: The site boundaries of the MPTP site would serve as the spatial boundary of the decision statement. Within the site boundary, the site likely would be divided into geographical subsets about which independent decisions can be made.

Temporal Boundaries of the Decision: During Phases 1 and 2 of the treatability study, subsurface

contamination on the north side of the site is not expected to vary significantly over time because no in-situ pilot studies would be conducted during Phase 1. Phase 2 activities involve application of an oxidant to evaluate its effectiveness on the south portion of the site. Changes in subsurface conditions would be monitored during this period.

**TABLE 6
SUMMARY OF DATA INPUT NEEDS**

Evaluation Criteria	Performance Goals of In Situ Remedy	Proposed Performance Level	Treatability Study Data Needed to Estimate Performance	Source of Data
Long-Term Effectiveness and Permanence	Achieve conditions compatible with planned future use of the site and decrease timeframe to meet RAOs.	For the media treated, achieve RAOs specified in the ROD.	Contaminant concentrations following treatment and over time.	Environmental sampling
Reduction of Toxicity, Mobility, or Volume	Reduce effort needed to maintain long-term remedial operations at the site.	Contaminant mass reduced in treatment area to levels where the treated media no longer prevent groundwater from achieving RAOs specified in the ROD.	Contaminant concentrations following treatment. The makeup and arrangement of subsurface layers for placement of injection and extraction galleries to deliver treatment technology.	Environmental sampling
Short-Term Effectiveness	Maintain conditions compatible with the current groundwater collection and treatment system.	At the boundaries of the site, maintain the RAOs specified in the ROD.	Contaminant concentrations and injected material in groundwater entering the WTP; and in treated water, groundwater, and surface water leaving the site.	Environmental sampling
Cost	Reduce long-term costs	Performance level to be determined by stakeholders.	Estimated cost of full-scale remediation	Cost estimate for full-scale remediation, rough (-30%, +50%).
Compliance with ARARs	Comply with ARARs identified in the ROD.	Comply with ARARs identified in the ROD.	Contaminant concentrations of treatment residuals that may impact groundwater quality, especially nitrate and sulfate.	Environmental sampling
Overall Protection of Human Health and the Environment	Achieve RAOs specified in the ROD.	For the media treated, achieve RAOs specified in the ROD.	Contaminant concentrations following treatment.	Environmental sampling

Scale of Decision Making: The site will be divided into areas for the most efficient remediation utilizing selected, in-situ, remedial technology(ies). Independent decisions may result for each of these areas. For example, the various areas may be treated by different remediation processes. These areas will be described as remediation units (RU). The boundaries of the RUs may take into consideration environmental measurements (that may identify the presence of various “hot spots” of contamination), physical constraints that may affect implementability of in-situ remedies (such as Interstate 15/90 overpass and makeup and arrangement of subsurface soils), and financial considerations. The following preliminary RUs are proposed:

Remediation Unit (1): Contaminated media north of Interstate 15/90 (near MW-87-03) acting as a source to the groundwater plume with dissolved contaminant.

Remediation Unit (2): Contaminated media beneath the Interstate 15/90 overpass acting as a source to the groundwater plume with dissolved contaminant.

Remediation Unit (3): Contaminated media south of Interstate 15/90 (near INF-13/14/15) acting as a source to the groundwater plume with dissolved contaminant.

The boundaries of the RUs may be redefined based on data collected during Phases 1 and 2 of the treatability study.

Practical Constraints of Data Collection: Practical constraints of data collected include the physical and administrative access beneath the Interstate 15/90 overpass, and buried utilities including underground piping associated with the WTP and infiltration cells.

4.2.5 Step 5: Develop a Decision Rule

The decision rule states what regulatory response action would be appropriate depending on whether a chosen parameter is greater or less than the action level (EPA 2000).

Decision Rule: If data collected during Phases 1 and 2 of the treatability study indicate that the in situ remedial technology meets each of the specified performance levels, further study or implementation of the in situ remedial technology is recommended. Otherwise, further study or implementation of the in situ remedial technology is not recommended.

4.2.6 Step 6: Specify the Tolerable Limits on the Decision Errors

The purpose of this step is to specify quantitative performance criteria for the decision rule expressed as probability limits on potential errors in decision making (EPA 2000). The probability limits on decision errors specify the level of confidence the site manager desires in conclusions drawn from the site data (EPA 2000). The outputs from this step are the site manager's tolerable decision limits based on a consideration of the consequences of an incorrect decision.

For this treatability study, the performance criteria for the decision cannot be readily expressed as probable limits on potential errors in decision making; therefore the site manager will use professional judgment to weigh the consequences of an incorrect decision.

4.2.7 Step 7: Optimize the Design

A nonprobabilistic sampling (judgmental sampling) approach will be used. Judgmental samples will be used subjectively to provide information about specific areas of the site. Information relating to the contaminant sources and site history will aid in the selection of sampling locations.

5.0 EQUIPMENT AND MATERIALS

Equipment, materials, and reagents that will be used during the field sampling activities will be identified in the Field Sampling Plan (FSP). Equipment, materials, and reagents that will be used during the treatability study will be identified by vendors contracted to conduct the TarGOST and Cool-Ox injection activities. A truck-mounted Geoprobe[®] will likely be used to deploy the TarGOST probe and to conduct the direct injections of Cool-Ox.

6.0 SAMPLING AND ANALYSIS

This section identifies the contents and aids in the preparation of a Sampling and Analysis Plan (SAP). A SAP consists of two parts—the FSP and the Quality Assurance Project Plan. The SAP ensures that samples obtained for characterization and testing are representative, and that the quality of the analytical data generated is known and appropriate. The SAP addresses field sampling, waste characterization, and sampling and analysis of the treated wastes and residuals from the testing apparatus or treatment unit. As described in EPA’s *Guidance for Conducting Treatability Studies under CECRLA* (EPA 1992), the SAP is usually prepared after Work Plan approval. The following sections present the general sampling approach for the source area investigation, the bromide tracer study, and the ISCO treatability study.

6.1 SOURCE AREA INVESTIGATION SAMPLING

A ROST/TarGOST investigation will be conducted to characterize residual contaminant source areas. Sampling locations are proposed along lines that transect the dissolved groundwater plume perpendicular to groundwater flow. Table 7 identifies areas proposed for ROST/TarGOST investigation.

**TABLE 7
PROPOSED ROST/TARGOST INVESTIGATION AREAS**

AREA	RATIONALE FOR INVESTIGATING AREA
Near monitoring well MW 87-03 north of the interstate.	Area exhibits elevated PCP concentrations.
Near monitoring well INF-13/14/15 south of the interstate.	Area exhibits elevated PCP concentrations and is the proposed area for the ISCO treatability study.
Near monitoring well INF-16/17/18 south of the interstate.	Area exhibits elevated PCP concentrations.
Near monitoring well GW-05 south of the interstate.	Area exhibits elevated PCP concentrations and was not previously excavated.
Along the north and south sides of Interstate 15/90 .	Previous environmental borings have identified significant residual LNAPL beneath the interstate at the western approach to the overpass.

Figure 5 identifies the proposed transect lines along which the sampling locations will be placed. Spacing of the TarGOST borings will be based on observations made in the field and will be guided based on soil characteristics and the presence of contamination.

Collection of soil cores for visual observation of LNAPL at 10% of the TarGOST locations is proposed. Direct observation of collected soil cores in the field can indicate the presence of LNAPL in soil. LNAPL can also be detected by shaking a jar containing a soil sample with water to see if a LNAPL

phase is formed. In addition to observation of soil cores for the presence of LNAPL, the soil cores will be evaluated in the field in accordance with the Unified Soil Classification System and field observations recorded as appropriate. The sampling protocol for the source area investigation will be developed in the SAP.

6.2 BROMIDE TRACER STUDY SAMPLING

Tracer investigations will be conducted to confirm or modify previous assumptions regarding groundwater hydraulics. Table 8 identifies areas proposed for tracer investigations and the rationale for the investigations.

**TABLE 8
PROPOSED TRACER INVESTIGATION STUDIES**

AREA AND METHOD OF TRACER INJECTION	METHOD OF INJECTION	ANTICIPATED DOSE RESPONSE WELLS	RATIONALE FOR TRACER STUDY
Upgradient of GW-05	Directly injected via GeoProbe during TarGOST investigation	GW-05 PZ-S7-01 MW-14 PZ-S4-01 INF-13/14/15	Examine groundwater hydrology near GW-05 where elevated PCP concentrations have been found
Upgradient of INF-13/14/15	Directly injected via GeoProbe during TarGOST investigation	INF-13/14/15 PZ-S3-02 PZ-S5-01 PZ-S6-01 PZ-S4-01 PZ-S2-02 PZ-S1-02 MW-Y-01 MW-X-01 INF-10/11/12 Water Treatment Plan Influent	Examine groundwater hydrology near INF-13/14/15 where elevated PCP concentrations have been found; this also would aid design of the Phase 2 in situ pilot study anticipated near INF-13/14/15
Near MW-87-03	Directly injected via GeoProbe during TarGOST investigation	MW-87-03 MW-1-01 GS-18 HCA-21 MW-H-01 GW-14R-98 MW-L-96	Examine groundwater hydrology near MW-87-03 where elevated PCP concentrations have been found
ISCO treatability study area (likely near INF-13/14/15)	Injected with reagents during ISCO pilot study	<i>To be determined based on actual pilot study location.</i>	Aid in the performance monitoring of the pilot study

Bromide concentrations will be measured at the dose response wells using a field probe with a bromide-ion-specific sensor. The bromide concentration reading will be collected by suspending the probe at the

mid point of the screened interval of the dose response well. Collection of groundwater samples during 10% of the field readings is proposed to validate the bromide concentration data collected by the field probe. The sampling protocol for the bromide tracer study will be described further in the SAP.

6.3 IN SITU CHEMICAL OXIDATION PERFORMANCE MONITORING

Following injection of ISCO reagents at the pilot study area, sampling will be conducted to estimate the degree of PCP degradation, to identify breakdown products that could be detrimental to the WTP or to Silver Bow Creek, to determine the overall reaction time, and to determine the lateral distance of impact of the ISCO reagents. Figure 5 identifies the anticipated area of the ISCO pilot study; however, the actual area will be determined based on information obtained from the Phase 1 TarGOST and bromide tracer investigations. The existing monitoring well network will be used to monitor the performance of the ISCO pilot study. Figure 5 identifies the anticipated performance monitoring wells and the anticipated location of the pilot study in the area of INF-13/14/15. Injection of a bromide tracer with the ISCO reagent is proposed to allow for monitoring the movement of the injected solutions/breakdown products and to monitor for effects of groundwater displacement. The sampling protocol for performance monitoring of the ISCO pilot study will be developed in the SAP.

7.0 DATA MANAGEMENT

Tetra Tech will use documentation protocols in the field to verify that appropriate procedures are followed and to ensure sample integrity. This section describes the use of field logbooks and explains the sample numbering system and chain-of-custody (COC) procedures that will be used during this project.

Logbooks will be used to document field activities. The field logbook is a bound book with hard cover and sequentially numbered pages. It will contain the actual field data or references to other field documents that contain specific descriptions of activities that occurred in the field on any given day. All entries will be signed and dated. The following is a partial list of the types of information that could be recorded:

- Name and title of author, date and time of entry, and physical and environmental conditions
- Name and address of field contact
- Names and titles of field sampling crew
- Purpose of sampling activity
- Type of sample media
- Sample collection methods
- Number and volume of samples taken
- Description of sampling points, and any sampling point adjustments
- Date and time of collection
- Sample identification numbers
- Sample distribution
- References for all maps and photographs of the site
- Records of telephone conversations
- Calibration of equipment used
- Field corrective actions taken.

Field sampling personnel must properly identify all samples collected in the field with an adhesive sample label attached to the sample container. The sample label must contain the site name, field identification number, date, time, and location of sample collection. Sample information will be legibly printed with waterproof ink.

Sample custody will be managed in three parts: (1) sample collection, (2) laboratory analysis, and (3) final evidence files. Final evidence files, including all originals of laboratory reports and purge files, will be maintained in a secure area.

A sample or evidence file is in a person's custody under any of the following circumstances:

- In that person's possession

- In that person's view, after being in that person's possession, then placed by that person in a secured location
- In a designated secured area.

The following sample packaging and shipment procedures will be used to ensure that the samples will arrive at the laboratory with the COC form intact:

- The field team leader will be personally responsible for care and custody of the samples until they are transferred or properly dispatched. As few people as possible will handle samples.
- All containers will be tagged with sample identification numbers and locations.
- Sample labels will be completed for each sample using waterproof ink.

A properly completed COC form will accompany all samples. Sample numbers and locations will be listed on the COC form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the form. This form will document transfer of custody of samples from the sampler to another person, to a mobile laboratory, to the permanent laboratory, or to or from a secured storage area.

Samples will be properly packaged for shipment and dispatched to the appropriate laboratory for analysis with a separate, signed COC enclosed in each sample box or cooler. Shipping containers will be sealed and secured with strapping tape and Tetra Tech custody seals for shipment. The preferred procedure will include use of a custody seal attached to the front right and back left of the container, with each seal crossing from the lid to the body of the container. The custody seals will be covered with clear plastic tape, and the container will be strapped shut with strapping tape in at least two locations.

An original COC record identifying container contents will accompany all deliveries. The sampler will retain a carbon copy of the COC for the project files.

8.0 HEALTH AND SAFETY

A task-specific Health and Safety Plan (HASP) will be prepared by Tetra Tech prior to the start of treatability study activities. The task-specific HASP will conform to requirements of the existing site specific HASP.

9.0 RESIDUALS MANAGEMENT

Residual waste generated onsite will be disposed of as written in the Site Operation and Maintenance Plan. PCP, PAHs, and dioxins/furans are defined as hazardous waste by the Comprehensive Environmental Response, Compensation, and Liability Act (*Code of Federal Regulations*, Section 101(14)). Residual waste generated at offsite locations by contracted third parties shall be managed by those third parties in accordance with federal, state, and local regulations.

10.0 REPORTING

Tetra Tech will prepare the following work plans and reports documenting results of the treatability study:

- Phase 1 Sampling and Analysis Plan
- Phase 1 Subsurface Investigation Report
- Interim Tracer Study Report
- Work Plan for Conducting Phase 2 ISCO/In Situ Flushing Treatability Study
- Final Tracer Study Report
- Draft Phase 1 and Phase 2 Treatability Studies Report
- Final Phase 1 and Phase 2 Treatability Studies Report.

The proposed schedule for completing the above work plans and reports appears in Section 11.

11.0 SCHEDULE

The tentative schedule for the scope of work included in his work plan is as follows:

- Final Treatability Study Work Plan submittal – March 30, 2009
- Draft Sampling and Analysis Plan – April 24, 2009
- Final Sampling and Analysis Plan – May 22, 2009
- Submit request for bids for subsurface investigation – June 2009
- Conduct subsurface investigation field activities – July 2009
- Submit Subsurface Investigation Report – August 2009
- Submit Draft Work Plan for conducting Phase 2 ISCO/in situ flushing study – September 2009
- Submit Final Work Plan for conducting Phase 2 ISCO/in situ flushing study – October 2009
- Submit request for bids for Phase 2 ISCO/in situ flushing study – October 2009
- Begin Phase 2 ISCO/in situ flushing study – November 2009
- Submit Draft Phase 1 and Phase 2 Treatability Studies Report – January 2010
- Submit Final Phase 1 and Phase 2 Treatability Studies Report – April 2010.

A Gantt chart illustrating the above schedule is included as Appendix D.

12.0 MANAGEMENT AND STAFFING

Management and technical personnel will be selected by Montana Department of Environmental Quality.

13.0 BUDGET

Preliminary budgetary cost information for conducting the TarGOST investigation and ISCO injections with Cool-Ox was obtained from vendors. A projected cost estimated for Phase 1 and Phase 2 of the treatability study was developed and is included as Appendix E.

14.0 REFERENCES

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