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Office of Solid Waste and Emergency Response
Office of Superfund Remediation and
Technology Innovation

Optimization Review
Black Butte Mine Superfund Site

Lane County, Oregon

OPTIMIZATION REVIEW

BLACK BUTTE MINE SUPERFUND SITE
LANE COUNTY, OREGON

Report of the Optimization Review
Site Visit Conducted at the Black Butte Mine Superfund Site on
January 10, 2012

July 13, 2012

EXECUTIVE SUMMARY

The purpose of this optimization review was to evaluate site conditions and identify optimal approaches for conducting a remedial investigation (RI) of the Black Butte Mine (BBM) Superfund Site. The review was conducted using U.S. Environmental Protection Agency (EPA) optimization review methods.

This document focuses on the fate and transport of mercury and other trace metals at and downstream of the BBM Superfund Site as a means to focus and streamline the sequence of RI activities. It is expected that this report may form the basis for additional systematic project planning among the optimization review team, project technical team, and stakeholders to develop, review, and finalize RI-specific work planning and implementation documents.

EPA's Office of Solid Waste and Emergency Response (OSWER) and the Office of Superfund Remediation and Technology Innovation (OSRTI) define optimization as follows:

> *"Efforts at any phase of the removal or remedial response to identify and implement actions that improve the action's effectiveness and cost-efficiency. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply some other approach to identify opportunities for greater efficiency and effectiveness. Contractors, states, tribes, the public, and PRPs are also encouraged to put forth opportunities for the Agency to consider."*

Optimization reviews include a "systematic site review," whereby the site as a whole is often considered. However, optimization can focus on a specific aspect of a given cleanup phase (or a particular operable unit [OU]), with other phases and site areas considered to the degree that they affect the focus of the optimization effort. For optimization reviews conducted before a Record of Decision (ROD) is issued, the focus is on developing the conceptual site model (CSM) by leveraging existing data and exploring potentially applicable sampling and analysis tools and strategies that facilitate a comprehensive systematic planning process.

The recommendations in this report are intended to help the site team identify opportunities for an optimized RI approach. Where noted in this report, further analysis of a recommendation may be needed before the recommendation can be implemented. The recommendations are based on an independent evaluation and represent the opinions of the optimization review team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the Region and other site stakeholders. While the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans (QAPP).

Site-Specific Background

The BBM Superfund Site (the site) is located in Lane County, Oregon, approximately 35 miles southeast of Eugene and approximately 10 miles upstream from the Cottage Grove Reservoir (CGR) (Figure 1).

Mercury mining and processing operations were active at the site from the late 1890s to the late 1960s. The site has been identified as a significant contributor of mercury to sediment and fish tissue in CGR. EPA Region 10 (Region 10) entered the site on the National Priorities List (NPL) in 2010.

Located on the north face of Black Butte, the mine area is drained by Dennis Creek, Garoutte Creek, and Furnace Creek, which border the north, west, and south sides of the site (see Figure 2). Both Dennis Creek and Furnace Creek are tributaries to Garoutte Creek which, after joining Big River to form the Coastal Fork Willamette (CFW) River, flows to the CGR approximately 10 miles downstream. The principal site features include collapsed and open mine adits, the Main Tailings Pile located adjacent to Dennis Creek, the Old Ore Furnace Area, the New Furnace Area, and the Furnace Creek Tailings Area (Ecology and Environment 2006) (Figure 2).

The CGR was constructed in 1942 as a U.S. Army Corps of Engineers (USACE) flood-control reservoir. Reservoir levels are decreased annually between the end of September and November. The low pool level is maintained until early February, when management practice requires that water levels begin increasing to the maximum pool level, which is attained in mid-May. At full pool, the reservoir area is 1,158 acres; at low pool, the water area is reduced to approximately 25 percent of the maximum acreage.

The site was identified as a potential source for mercury contamination in CGR by the Mercury Working Group of the Oregon Department of Environmental Quality (ODEQ) Water Quality Division during an evaluation of Oregon's lakes. This evaluation focused on the analysis of mercury in fish tissue samples collected in 1993 and 1994. In 1994, the site was referred to ODEQ's Site Assessment Section (SAS) staff for review. The SAS recommended further site investigation as a medium priority (ODEQ 1996). Pursuant to a cooperative agreement with EPA Region 10, ODEQ conducted a preliminary assessment (PA) of the site (ODEQ 1996). EPA Region 10 completed a site inspection in 1998 and removal assessment investigation in 2006. EPA Region 10 conducted a removal action (RA) at the site in 2007 (EPA Region 10 2008). The RA consisted of soil and tailings characterization, excavation, relocation of mine wastes that exceeded site-specific criteria, and placement of mine wastes that exceeded site-specific screening criteria in a repository constructed on site.

In 2009, EPA Region 10 completed a Hazard Ranking System (HRS) evaluation for the site (Ecology and Environment 2009). Results of the overland flow/flood component of the evaluation were sufficient to qualify the site for inclusion on the NPL. Other pathways (groundwater, groundwater to surface water, and soil) were excluded from the HRS evaluation because their effect on the overall ranking score was negligible. As a result of the HRS evaluation, the BBM Site was added to the NPL on March 4, 2010.

Currently, the EPA (with ODEQ participation) is in the planning stages for a RI for the BBM Site. The optimization review documented in this report was conducted to ensure that the RI work plan addresses all of the potentially significant sources of mercury contamination observed in surface water, sediments, and biota immediately downstream of the BBM Site and farther downstream within the CGR. A factor that was important in deciding to optimize the RI planning process for the site is the large size of the affected area, which includes the actual mine site, downstream rivers, and the CGR. In addition, the complex fate and transport mechanisms involving transformations between various mercury compounds over the 10-mile transport distance also contributed to the need for this optimization review. The seasonal variation of CGR water levels for flood control adds additional complexity. The main goal of this review was to lay the foundation for the design of an RI that effectively and efficiently characterizes the nature and extent and evaluates risks to human health and ecological receptors for all major sources of mercury contamination occurring at the BBM Site and in the downstream surface water features, including the CGR.

Summary of Methods

The methods used in the optimization review included:

- A site visit by the optimization review team, conducted on January 10, 2012,
- Literature reviews to examine previously constructed conceptual site models (CSMs) for mercury sourcing and transport,
- Construction of a revised CSM that considers all potential ongoing sources of mercury contamination, including those associated with the BBM Site and other sources that could be associated with historical sediments in the CGR, and
- Construction of a sampling strategy with decision logic aimed at testing the hypotheses inherent in the revised CSM.

Summary of Conceptual Site Model

For the purpose of this optimization review, the project technical team is employing the CSM project life cycle concept further described in the EPA document "Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model" (EPA 2011), available at www.epa.gov/tio/download/remed/csm-life-cycle-fact-sheet-final.pdf.

This preliminary CSM and limited existing data indicate that the Furnace Creek Tailings Area may be an important source of contemporary loading of mercury and potentially other metals to downstream surface water features, including CGR. It is important to note that more than a century of BBM mercury inputs have historically loaded downstream surface water, including the CFW River and subsequently the CGR through its 60-year existence. Based on CGR sediment coring results, Curtis (2003) reports that sediment mercury concentrations were up to three times greater in the early 1970s relative to more recently measured concentrations. As a result, historical mercury loading likely exceeded contemporary loading by several orders of magnitude. The CSM recognizes, therefore, that significant mercury concentrations may exist in CGR as a result of historical loading.

The preliminary CSM further hypothesizes that an important source for contemporary loading from the BBM Site to downstream surface water features is suspended particles with elevated concentrations of mercury (and other metals). This suspended particulate mercury is generated by mechanical erosion of BBM Site tailings from the Furnace Creek Tailings Area and, potentially, the Main Tailings Pile. Some particulate mercury may also be converted to a dissolved form in surface water transport. At the BBM Site, much of the mercury contained within these suspended particles may exist in a less bio-available form (mercuric sulfide [HgS]), which may be converted to more soluble forms during transport or after deposition. Mercury enters the CGR in both particulate and dissolved phases. Some of the dissolved mercury is converted to methylmercury (MeHg) by bacteria inhabiting anoxic environments (the sediments and potentially the anoxic portion of the water column). Over time, some of the particulate mercury that settles in the sediments may be converted to dissolved mercury and become available for methylation. Once methylated, mercury can bioaccumulate in the food chain resulting in unacceptably elevated concentrations in sport fish.

Summary of Findings

The summary below lists findings identified by the optimization review team as significant to optimizing the RI approach. Findings are presented first for the BBM Site and vicinity, followed by the findings for CGR.

Key findings related to the BBM Site and vicinity include:

- Consistent with the preliminary CSM focus on Furnace Creek, very steep terrain and evidence of active tailings erosion and mobilization were observed adjacent to Furnace Creek during the site visit. Site data indicate tailings from the Furnace Creek Tailings Area contain more elevated mercury concentrations than the tailings from other portions of the site and that the mercury in the Furnace Creek tailings is typically in a more bio-available form (Ecology and Environment 2006).

- A post-RA surface water loading assessment (Thoms 2008) suggests that the transport of suspended solids containing mercury appears to be the primary mode of mercury transport from the site. Based on one sampling campaign during non-storm conditions, the assessment estimates that Furnace Creek could contribute between 50 to 75 percent of the mercury load in the CFW River. Re-calculation of this value by the optimization review team suggests a lower contribution (26 to 59 percent); however, it still represents a potentially significant source.

- Although the tailings thickness exceeds 10 feet over much of the site, direct evaluation of potential impacts from the tailings leachate on groundwater quality is likely infeasible because of the site's fractured bedrock geology and the occurrence of the water table within the bedrock.

- As a result of historical airborne deposition of elemental mercury during mining and ore processing operations, the surrounding hillsides and the non-mine portions of Black Butte may serve as significant sources of mercury loading to surface water. Curtis (2004) determined that from 44 to 87 percent of mercury in off-site hillside soil was complexed with organic matter. Mercury complexed with organic matter is more readily converted to methylmercury.

- Historical data indicate the presence of potential mercury impacts in surface water sediments from the site downstream to CGR. The contribution of historical mercury present in surface water sediments versus the flux of new fined-grained material with elevated mercury from BBM is not well understood.

- The pH of the groundwater discharging to two of the mine adits visited during the site visit was in the neutral range, suggesting the general absence of acid mine drainage impacts at the site.

Key findings that relate to CGR include:

- Deposition of atmospheric mercury attributable to various industrial and mining sources (such as coal-fired power plants) world-wide (also referred to as the global mercury pool) likely contributes a small but unknown fraction of the total dissolved mercury burden of the CGR. Given that one of the sources of mercury to CGR is deposition from the global mercury pool, mercury reductions in fish tissue may be limited to some baseline level that reflects this ongoing source.

- Methyl mercury generation generally requires the presence of three constituents: dissolved mercury, microbial labile organic carbon, and sulfate. Uncertainties exist regarding the factors that control the availability of these constituents and subsequently the methylation process. The seasonal changes of the water level in the reservoir may result in the cycling of sulfide to sulfate, thus perpetuating the availability of sulfate and potentially the methylation process.

- Sediment cores from CGR indicate that elevated mercury concentrations are present in older, legacy sediments. Exposure of these sediments to surface water erosion during the yearly low water level period may be an important ongoing source of mercury to the reservoir.

- Review of the available total mercury, dissolved mercury, and fish tissue mercury concentration data for CGR suggests that even if only a small fraction of the total mercury is present in dissolved phase, sufficient mercury methylation will occur to result in elevated mercury in fish tissue. Based on existing data, calculations by the project team indicate that the percentage of total mercury that is methylated in CGR water is only 6 percent. In sediments, the percentage is only 0.1 percent. These low levels are apparently sufficient to support methylation.

Summary of Recommendations

Recommendations for the BBM Site portion of the RI include:

- To improve the understanding of dominant sources of total mercury, dissolved mercury, and methylmercury release from the BBM Site, quarterly surface water sampling under storm and non-storm conditions is recommended along with the collection of concurrent sediment and groundwater samples. Discharge measurements of the site streams should accompany the sampling to support the determination of mercury loading estimates.

- Site data regarding the assessment of potential impacts of tailings leachate on site groundwater quality consist only of a limited number of laboratory-based leaching procedure samples; the procedure had a high detection limit (above 440 nanograms per liter [ng/L]). The majority of the analytical results for these samples were below this detection limit. However, since the typical mercury background concentration is less than 200 ng/L, the potential impacts of the tailings on groundwater are unknown. The collection of vadose zone groundwater samples from the site tailings areas is necessary, but may be not be readily accomplished because the water table at the site occurs in fractured bedrock. Therefore, the optimization review team recommends other groundwater data could be used. If the presence of a historical tailings disposal area on the Garoutte Creek floodplain can be verified, the optimization review team recommends that groundwater samples be collected from the saturated sediments (if any exist) beneath the tailings. In addition, the potential presence of groundwater under saturated conditions in tailings adjacent to Dennis and Furnace Creeks should be evaluated. If groundwater is determined to exist in these tailings, this groundwater should also be sampled.

- If BBM environmental media and Furnace Creek tailings in particular are not found to be major contributors to mercury and trace metal contamination in Garoutte Creek, it is recommended that the project team consider increased sediment sampling in Garoutte Creek and sediment sampling in the CFW River to assess the significance of these potential sources for downstream loading of total mercury, dissolved mercury, and methylmercury.

- It is recommended that a Demonstration of Method Applicability (DMA) analysis be conducted for X-ray fluorescence (XRF) and Lumex field-based metals analysis. Results of this analysis can be used to assess confidence in RA characterization results and to assess the utility of field-based methods for metals analyses during the RI. The DMA could include site soil and hillside sampling and generate preliminary data to optimize sampling for the RI's human health and ecological risk assessments.

Recommendations for the CGR RI include:

- Development of the data necessary to understand the source of methylmercury in CGR fish tissue requires investigation of the major sources of mercury mass influx to the reservoir (in addition to the current contribution from BBM) and of the factors controlling the availability of the rate-limiting constituents (dissolved mercury, labile organic carbon, and sulfate). In light of technical, administrative, funding, and schedule challenges, it may prove beneficial for Region10 to consider conducting activities at BBM and CGR as separate OUs.

- A major objective to consider for the CGR RI is establishing baseline data for (1) fish tissue mercury concentration levels in the CGR and (2) the influx rate of mercury (total, dissolved, and methylated) to the reservoir. This baseline data can be used to assess the effects of any mitigation efforts at the BBM Site or in the CGR.

- It is recommended that various CGR environmental media be sampled to enable a preliminary assessment of the factors controlling methylmercury generation. Sampling may include the collection of quarterly or semiannual surface water, sediment, and sediment pore water. Specific objectives of this sampling would include (1) confirming the existence of sulfate cycling in the high pool sediments and (2) assessing the significance of internal loading through the erosion and mobilization of elevated mercury concentration legacy sediments during low pool conditions.

NOTICE

Work described herein was performed by Tetra Tech EMI for the U.S. Environmental Protection Agency (EPA). Work conducted by Tetra Tech EM Inc., including preparation of this report, was performed under Work Assignment 2-58 of EPA contract EP-W-07-078. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization practices from remedial investigation to site completion implemented by the United States Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI). The project contacts are as follows:

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LIST OF ACRONYMS

BMP	Best management practice
CFW	Coastal Fork of the Willamette
CGR	Cottage Grove Reservoir
CSM	Conceptual site model
DMA	Demonstration of methods applicability
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DPT	Direct-push technology
EMMA	End Member Mixing Analysis
DU	Decision unit
EPA	United States Environmental Protection Agency
FS	Feasibility study
GIS	Geographic information system
Hg	Mercury
HgP	Suspended (particulate-bound) phase mercury
HgR	Reactive mercury
HgT	Total mercury
HRS	Hazard Ranking System
ICS	Incremental composite sampling
kg/yr	Kilograms per year
LASAR	Laboratory Analytical Storage and Retrieval
MeHg	Methylmercury
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
ng	Nanogram
ng/L	Nanograms per liter
NGVD	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
ODEQ	Oregon Department of Environmental Quality
ORD	Office of Research and Development
ORP	Oxidation-reduction potential
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
OU	Operable unit
PA	Preliminary assessment
P&T	Pump and treat
PEL	Probable effects level

PRG	Preliminary Remediation Goal
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
RA	Remedial Action
RI	Remedial investigation
ROD	Record of Decision
RSE	Remediation System Evaluation
SAS	Site Assessment Section
SC	Specific conductance
SPLP	Synthetic Precipitation Leaching Procedure
SLV	Screening level value
SPP	Systematic project planning
SQuiRTs	Screening Quick Reference Tables
SSE	Selective sequential extraction
TAL	Target analyte list
TEL	Threshold effects level
TMDL	Total Maximum Daily Load
TOC	Total organic carbon
TSS	Total suspended solids
UCL	Upper confidence limit
UNEP	United Nations Environmental Programme
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
XRF	X-Ray fluorescence

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1.0 INTRODUCTION

1.1 PURPOSE

The Black Butte Mine (BBM) Superfund Site is located in Lane County, Oregon, approximately 35 miles southeast of Eugene and 10 miles upstream from the Cottage Grove Reservoir (CGR). Mercury mining and processing operations were active at the site from the late 1890s to the late 1960s. The site has been identified as a significant contributor of mercury to sediment and fish tissue in CGR (Park and Curtis 1997). Region 10 included the site on the National Priorities List (NPL) in 2010.

The purpose of this optimization review was to evaluate site conditions and identify optimal approaches for conducting a remedial investigation (RI) of the BBM Site. The U.S. Environmental Protection Agency's (EPA's) emphasis on the optimization of site investigation projects such as Black Butte is rooted in an on-going program of evaluating operating remedies at Fund-lead sites. During fiscal years 2000 and 2001, independent Remediation System Evaluations (RSEs) were conducted at 20 operating pump and treat (P&T) sites (those sites with P&T systems funded and managed under Superfund by the EPA, other federal agencies, and by the states). In light of the opportunities for system optimization that arose from those RSEs, the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) has incorporated RSEs into a larger post-construction complete strategy for Fund-lead remedies as documented in Office of Solid Waste and Emergency Response (OSWER) Directive No. 9283.1-25, *Action Plan for Ground Water Remedy Optimization*. Concurrently, the EPA developed and applied the Triad Approach and related best management practices (BMPs) to optimize site characterization strategies, methods and technologies. The Triad Approach and related BMPs include the increased use of conceptual site models (CSMs) as the basis to identify project data gaps and focus on addressing data gaps when developing site characterization objectives and work plans. The EPA has expanded the reach of optimization to encompass reviews of projects at the investigation stage (such as for the BBM Site).

EPA OSWER and OSRTI define optimization as follows:

> *"Efforts at any phase of the removal or remedial response to identify and implement actions that improve the action's effectiveness and cost-efficiency. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply some other approach to identify opportunities for greater efficiency and effectiveness. Contractors, states, tribes, the public, and PRPs are also encouraged to put forth opportunities for the Agency to consider."*

Optimization reviews include a "systematic site review," whereby the site as a whole is often considered. However, optimization can focus on a specific aspect of a given cleanup phase (or a particular operable unit [OU]), with other phases and site areas considered to the degree that they affect the focus of the optimization effort. For optimization reviews conducted before a Record of Decision (ROD) is issued, the focus is on developing the conceptual site model (CSM) by leveraging existing data and exploring potentially applicable sampling and analysis tools and strategies that facilitate a comprehensive systematic planning process.

A strong interest in sustainability has also developed in the private sector and within federal, state, and municipal governments. Consistent with this interest, OSRTI has developed a methodology (EPA 2012) for environmental footprint evaluation (www.cluin.org/greenremediation/methodology/index.cfm), and now routinely considers green remediation and environmental footprint reduction during optimization reviews.

For a site in the investigation stage, the optimization review process includes reviewing site documents, potentially visiting the site for 1 day, and compiling a report that includes recommendations for design and execution of a comprehensive, efficient, and cost-effective investigation strategy.

The recommendations in this report are intended to help the site team identify opportunities for an optimized RI approach. Where noted in this report, further analysis of a recommendation may be needed before the recommendation can be implemented. The recommendations are based on an independent evaluation and represent the opinions of the optimization review team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the Region and other site stakeholders. While the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans (QAPP).

The national optimization strategy includes a system for tracking consideration and implementation of optimization recommendations and includes a provision for follow-up technical assistance from the optimization team as mutually agreed on by the site management team and EPA OSRTI.

The optimization review and site technical teams participated in a site visit and early systematic planning from January 9 to 11, 2012. This optimization review report provides findings and recommendations resulting from review of site documentation and data in conjunction with the site visit and systematic planning efforts. Suggestions provided for sample numbers, collection and analytical methods, locations, and other parameters may be adjusted to meet project specific schedule, budget, and logistical considerations.

This document addresses the fate and transport of mercury and other trace metals at the BBM Site and the CGR as a means to focus and streamline the sequence of RI activities. It is recognized that sampling for metals (including mercury) and other parameters may be necessary to assess total risk and that sampling to assess exposure routes and areas for human and ecological risk assessment are integral components of any RI. Where appropriate and timely, suggestions address these considerations; however, it is expected that this report will form the basis for additional systematic planning among the optimization review team, project technical team, and stakeholders to develop, review, and finalize RI specific work planning and implementation documents.

1.2 REVIEW TEAM COMPOSITION

The optimization review team consisted of the following individuals:

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Steve Dyment	EPA OSRTI	703-603-9903	dyment.stephen@epa.gov
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1.3 DOCUMENTS REVIEWED

Key documents that provided the significant basis for the formulation of preliminary CSM components include:

- *Preliminary Assessment of Black Butte Mine* (Anderson 1996): This document states the theory that tailings pile erosion and particulate transport in surface water are the primary mode for off-site mercury migration.
- *Mercury Distribution in Sediments and Bioaccumulation by Fish in Two Oregon Reservoirs: Point Source and Nonpoint Source Impacted Streams* (Park and Curtis 1997): This document compares mercury loading in CGR with the neighboring Dorena Reservoir, a watershed where there are no known mercury mines. The results of the comparison suggest that the BBM site is a significant point source of mercury contamination to CGR.
- *Black Butte Mine Site Inspection Report* (Ecology and Environment 1998): This report documents the first comprehensive environmental investigation of the site. Soil, tailings, sediments, surface water, and groundwater samples were collected and analyzed via conventional laboratory methods for mercury and selected target analyte list (TAL) metals. Elevated (relative to background) concentrations of mercury and sporadic elevated concentrations of some trace metals were measured in soil, tailings, and sediments. Mercury was not detected above a detection level of 200 nanograms per liter (ng/L) in any of the groundwater or surface water samples, or in a sample collected from one of the BBM adits; however, these samples exceeded background concentrations for some trace metals (antimony, chromium III, cobalt, copper, manganese, and nickel exceeded background groundwater level concentrations).
- *Final Report – Reconnaissance Soil Sampling at the Black Butte Mine* (Curtis 2004): This document describes an investigation to characterize mercury concentrations and speciation in soils at the site and off-site on adjacent hillsides and ridge tops. Maximum off-site concentrations are less than the Region 9 Preliminary Remediation Goal (PRG) of 23 milligrams per kilogram (mg/kg). Selective sequential extraction (SSE) analyses of the off-site samples indicated that less than 20 percent of the mercury was present in relatively insoluble mercuric sulfide forms and 44 to 87 percent of the mercury was complexed with organic matter which is more readily converted to methylmercury.
- *Mercury Levels and Relationships in Water, Sediment, and Fish Tissue in the Willamette Basin, Oregon* (Hope and Rubin, 2205): Sampling of surface water mercury concentrations in the CFW River are discussed. Seasonal sampling upstream of the CGR shows that on average, 56 percent of the total mercury (HgT) load was transported in the dissolved phase.
- *Black Butte Mine, Removal Assessment Report* (Ecology and Environment 2006): The investigation documented in this report was conducted to generate a comprehensive site data set to support a removal action (RA) to eliminate significant mercury releases from the site. This investigation included X-ray fluorescence (XRF) and Lumex field-based analyses of mercury and arsenic in soil, tailings, and sediment samples and conventional laboratory analysis of a subset of these samples. In addition, synthetic precipitation leaching procedure (SPLP), methylmercury, and SSE analyses were performed for a subset of these samples. Results indicate that the mercury present in these materials generally occurs in insoluble forms that are not readily methylated.
- *Final Removal Action Report for Black Butte Mine, Cottage Grove, Oregon* (EPA 2008): This report documents the 2007 RA, which consisted of the characterization of soils and tailings and regrading, excavation, and on-site disposal of soils and tailings that exceeded site-specific screening criteria. Excavated tailings that exceeded site-specific screening criteria were placed in an on-site repository. Characterization sampling along Furnace Creek revealed the presence of an extensive volume of tailings with mercury concentrations that exceeded the RA-defined action

level for tailings adjacent to surface water. The Furnace Creek tailings were left in place as a result of funding restrictions.

- *Mercury Loading Assessment Results, Black Butte Mine* (Thoms 2008): This post-RA surface water loading assessment suggests that the transport of suspended solids (fine silt and clay size particles) containing mercury persists as the primary mode of mercury transport to the Coastal Fork Willamette (CFW) River and CGR. Based on one sampling campaign during baseflow conditions, the assessment estimates that Furnace Creek could contribute between 50 and 75 percent of the mercury load in the CFW River. Re-calculation of this value by the optimization review team suggests the contribution may be lower (26 to 59 percent); however, Furnace Creek still represents a potentially significant source.

A complete list of information sources reviewed for the site is provided in Section 7.0. In addition, historical aerial photographs, topographic maps, and geographic information system (GIS) shapefiles were obtained and evaluated during this review.

1.4 QUALITY ASSURANCE

This optimization review uses existing environmental data to interpret the CSM, evaluate principal study questions, identify data gaps, and support systematic planning to make recommendations for streamlined sequencing, sampling, and analytical strategies. The quality of the existing data was evaluated by the optimization review team before the data were used for these purposes. The evaluation for data quality includes a brief review of how the data were collected and managed (where practical, the site QAPP is considered), the consistency of the data with other site data, and the intended use of the data in the optimization review. Data that were of suspect quality were either not used as part of the optimization review or were used with the quality concerns noted. Where appropriate, this report provides recommendations to improve data quality.

The key data source documents reviewed for this evaluation include Ecology and Environment (1998), Curtis (2003), Curtis (2004), Ecology and Environment (2006), EPA (2008), and Thoms (2008). The data from Ecology and Environment (1998 and 2006) and the Lumex mercury data from EPA (2008) were subjected to validation in accordance with EPA (1990) and EPA (2004) guidance. The investigation documented in Thoms (2008) included the collection of quality assurance /quality control (QA/QC) samples of surface water and sediment. The data for this investigation, however, were not validated. Information regarding validation of the data reported in Curtis (2003) and Curtis (2004) is unavailable in these documents. Data quality issues regarding the Curtis (2004) data, however, were anecdotally conveyed by the Oregon Department of Environmental Quality (ODEQ) to the project team. These issues included sample extraction and analyses at separate laboratories and the lack of associated documentation.

Thoms (2008) reports mercury concentration results of total mercury in surface water for a field sample (25.6 micrograms per liter (µg/L)) and a field duplicate (14.1 µg/L) collected in Furnace Creek downstream from the Furnace Creek Tailings Area. Both samples exceed the total mercury measured in other surface water samples collected during that investigation by more than 3 orders of magnitude. The elevated result for both the field sample and its duplicate suggests that the two samples most likely reflect the variability inherent in a grab sample.

Qualitative interpretation of these data indicates that the mercury level in Furnace Creek is inordinately elevated relative to the levels in other surface water features in the BBM vicinity. The elevated Furnace Creek total mercury concentrations are consistent with the close proximity of the stream to the old furnace-derived tailings which, as discussed in the next section, contain elevated, more leachable forms of mercury relative to other tailings at the site.

1.5 PERSONS CONTACTED

The optimization review team met with stakeholders on January 9 through 11, 2012, at the ODEQ offices in Eugene, Oregon. In addition to the optimization review team, the following persons were present for the stakeholders meeting and include members of the project technical team:

Name	Affiliation	Email Address
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On January 10, 2012, the individuals listed above (with the exception of Kay Morrison) and the optimization review team toured the site.

2.0 SITE BACKGROUND

2.1 LOCATION AND PRINCIPAL SITE FEATURES

BBM is located in Lane County Oregon in the CFW River Basin, approximately 10 miles upstream from the CGR (see Figure 1). Located on the north face of Black Butte, the mine area is drained by Dennis Creek, Garoutte Creek, and Furnace Creek which border the north, west, and south sides of the site (see Figure 2). Both Dennis Creek and Furnace Creek are tributaries to Garoutte Creek which, after it joins the CFW River, flows to the CGR. Principal site features include collapsed and open mine adits (entrances), the Main Tailings Pile located adjacent to Dennis Creek, the Old Ore Furnace Area, the New Furnace Area, and the Furnace Creek Tailings Area (Ecology and Environment 2006) (see Figure 2).

The CGR was constructed in 1942 as a U.S. Army Corps of Engineers (USACE) flood-control reservoir. The reservoir, which was created by constructing a dam on the CFW River, receives drainage from a watershed with an area of approximately 99 square miles. Reservoir levels are decreased annually between the end of September and November. The levels are decreased from the maximum pool level of 791 feet, National Geodetic Vertical Datum of 1929 (NGVD) until the low pool level of 750 feet, NGVD is attained. The low pool level is maintained until early February, when management practice requires that water levels begin increasing to the maximum pool level, which is attained in mid-May. At full pool, the reservoir area is 1,158 acres; at low pool, the water area is reduced to approximately 25 percent of this size.

2.2 SITE HISTORY

This section describes (1) historic land use and operations conducted at the site and (2) the chronology of enforcement and remedial activities.

2.2.1 HISTORICAL LAND USE AND OPERATIONS

Before it was developed as a mercury mine, the site was undeveloped forest land. The mercury deposit of concern at the site occurs primarily as cinnabar, a mercuric sulfide mineral. Elemental mercury was produced on the site by heating crushed ore in a furnace where the elemental mercury was volatilized and subsequently condensed and collected for bottling.

BBM was initially developed by S.P. Garoutte in 1890 with installation of a Scott-Hutner furnace to process 40 tons/day of mercury ore. The Quicksilver Mining Company took ownership of the property in 1897 and expanded the mine operation and furnace capacity. BBM ceased operations in 1909 because of declining mercury prices. A New York-based company (identity unknown) resumed mercury production in 1916 with a redesigned Scott furnace. However, production was again suspended in 1919 because of falling mercury prices. With installation of at least one rotary furnace during the period from 1927 to 1942, a new operator (Quicksilver Syndicate) increased mercury ore processing to 150 tons/day. Some reprocessing of tailings from earlier operations also occurred during this time. Declining mercury prices again resulted in mine closure in 1943. In 1956 and 1957, the mine was leased by Mercury & Chemicals Corporation of New York. Information regarding ownership and production is unavailable in the years from 1957 to the final abandonment of the mine in the late 1960s (Region 10 2008). The site was purchased by Land and Timber Company in 1990 and is currently used for timber production and wildlife habitat.

During its peak operating years, BBM was the second largest mercury mine in Oregon. From 1900 to 1957, a total of 16,904 flasks of elemental mercury were produced at the mine (one flask equals 76 pounds) (Region 10 2008).

2.2.2 CHRONOLOGY OF ENFORCEMENT AND REMEDIAL ACTIVITIES

No enforcement actions were identified from the documents reviewed.

With regard to remedial activities, the site was identified as a potential source for mercury contamination in CGR by the Mercury Working Group of the ODEQ Water Quality Division during an evaluation of Oregon's lakes. This evaluation was focused on the analysis of mercury in fish tissue samples collected in 1993 and 1994. In 1994, the site was referred to ODEQ's Site Assessment Section (SAS) staff for review. The SAS recommended further site investigation as a medium priority (ODEQ 1996). Pursuant to a cooperative agreement with EPA Region 10, ODEQ conducted a preliminary assessment (PA) of the site (ODEQ 1996). Region 10 completed site inspections in 1998 and removal assessment investigations in 2006. An RA was conducted at the site by Region 10 in 2007 (Region 10 2008), which consisted of soil and tailings characterization, excavation, and relocation of mine wastes that exceeded site-specific action levels; mine wastes that exceeded site-specific action levels were placed in a repository constructed on site.

In 2009, Region 10 completed a Hazard Ranking System (HRS) evaluation for the site (Ecology and Environment 2009). Results of the overland flow/flood component of the evaluation were sufficient to qualify the site for inclusion on the NPL. Other pathways (groundwater, groundwater to surface water, and soil) were excluded from the HRS evaluation because their effect on the overall ranking score was negligible. As a result of the HRS evaluation, BBM was added to the NPL on March 4, 2010.

2.3 POTENTIAL HUMAN AND ECOLOGICAL RECEPTORS

Ecological hazards resulting from elevated mercury relate to the capability of the mercury to chemically transition to its methylated form. Once present in the environment, methylmercury accumulates in fish and other predators through their consumption of organisms lower in the food chain. Similarly, human health exposure risks may be posed by the ingestion of fish, water fowl, or plants containing methylmercury or the ingestion of mercury in surface water and groundwater.

The RI is expected to evaluate human health and ecological risks associated with a variety of media potentially contaminated from BBM. The optimization review team considered the CSM in development of the preliminary pathway receptor network diagram provided in Figure 3. The primary media and receptors at the site include:

- Groundwater: potential contaminated discharge to surface water, human consumption of supply well water;
- Soil: contact/ingestion by casual trespassers or forest workers. Ecological receptors include plant uptake and birds and mammals that may ingest or contact soil;
- Surface water: fish, waterfowl contamination; human consumption;
- Sediment: fish, waterfowl contamination; human consumption; and
- Air: potential ground surface-to-air flux of elemental mercury.

2.4 EXISTING DATA AND INFORMATION

This section presents information available from existing site documents. Interpretations included in this section were generally extracted from the cited documents. Particular attention was paid to CSM elements and conclusions that may warrant consideration during the RI/feasibility study (FS). Existing data are summarized sequentially for the BBM Site and CGR.

2.4.1 BBM SITE EXISTING DATA

The following sections present the existing data for the BBM Site. The sections describe sources of contamination at the BBM Site, the geology and hydrogeology of the site, and existing analytical characterization data for soil, groundwater, surface water, and sediment.

2.4.1.1 BBM SITE SOURCES OF CONTAMINATION

Known sources of contamination at the site are the tailings contained in the Main Tailings Pile and the Furnace Creek Tailings Area (Figure 2). Available data suggest that mercury is not readily mobilized to groundwater (Ecology and Environment 2006). Analytical results for samples collected from water draining from mine adits were non-detect for mercury. The detection level associated with these analyses, however, were relatively elevated (1,400 nanogram/liter [ng/L]) compared with the Garoutte Creek background concentration of less than 0.5 ng/L). In addition, although synthetic leaching testing results obtained from the tailings indicate a low propensity of the tailings to leach mercury, the testing was conducted at an elevated detection level (440 ng/L) compared to the background mercury concentration in groundwater (less than 200 ng/L) (Ecology and Environment 2006). As a result, the limited available data show only that the tailings do not leach mercury to groundwater at elevated concentration levels in excess of 3 times background values. Based on the available information, the relative proportions of dissolved and suspended load mercury transport from the site are not known; however, limited seasonal sampling from the CFW River upstream of the CGR suggests that suspended and dissolved mercury are roughly equal contributors to the total mercury load. Since mercury is a dynamic contaminant, the relative proportions of dissolved mercury and suspended mercury being exported from the mine site may differ from what is being measured downstream and may vary in response to stormflow conditions. Dissolved and suspended mercury samples collected from the CGR indicate that, during low pool periods, the suspended concentration is actually higher than CFW River values, suggesting the importance of particle entrainment as exposed sediments are eroded during low pool conditions (as shown in Figure 4). During high pool conditions in the summer, mercury associated with suspended load sediments is transported from the BBM and deposited in CGR.

2.4.1.2 BBM SITE GEOLOGY AND HYDROGEOLOGY

The following sections summarize site geology and hydrogeology and the environmental sampling results from previous investigations. To evaluate the sampling results, measured constituent concentrations in soil, tailings, sediment, surface water, and groundwater are compared with relevant screening levels. Table 1 provides a combined listing of the screening levels referenced in this report.

The site is located on a steep hillside underlain by thin soils directly underlain by bedrock. Accumulations of recent alluvium occur in Garoutte Creek Valley, located at the foot of Black Butte. Bedrock consists of hydrothermally altered andesitic lavas, silicic ash tuff, and volcanic breccias. Locally, these deposits have been intruded by basalt and andesite. The bedrock is faulted and fractured. Black Butte fault is exposed on the summit of Black Butte; the mercury ore deposit is believed to have formed along this fault (Derkey 1973).

The principal aquifer units in the vicinity of the site include (1) the bedrock aquifer, which occurs in the fractured bedrock units underlying the hillside, and (2) the overlying floodplain aquifer, which occurs in alluvium, where present, in the Dennis Creek, Furnace, and Garoutte Creek valleys. The two aquifers are likely hydraulically connected, with the water table likely occurring in Garoutte Creek floodplain sediments at the foot of Black Butte and in the shallow bedrock underlying the mine site (Anderson 1996).

2.4.1.3 BBM Site Soil Contamination

The materials present at ground surface at the site include native soils, waste rock or overburden, and processed mine tailings. Only small amounts of waste rock or overburden exist on the site because most of the mining occurred underground and within the ore-bearing materials. Previous characterization results for native soil and waste/rock tailings are discussed in the following sections.

2.4.1.3.1 Native Soil

Mercury concentrations in native soil have been characterized on hillsides in the general vicinity of the site (Curtis 2004) and on site at the New Furnace Area (Ecology and Environment 1998). Samples collected near the tops of surrounding ridges facing the mine and analyzed via a fixed-based laboratory contained up to 8 mg/kg total mercury. SSE conducted on these samples indicated that less than 20 percent of this mercury was found in the relatively insoluble mercury sulfide form and 44 to 87 percent of the mercury was complexed with organic matter; the latter is more labile (Curtis 2004). Soil samples collected from the New Furnace Area had elevated concentrations of mercury, arsenic and other metals including chromium, copper, nickel, and vanadium (Ecology and Environment 1998). During the RA, soils from the New Furnace Area were excavated, consolidated, and placed in an on-site capped repository (EPA 2008).

2.4.1.3.2 Waste Rock/Tailings

Waste rock/tailings at the site are classified into two groups: those produced from the older furnaces (referred to collectively as the Old Furnace), which operated prior to introduction of the New Furnace in 1927; and those produced as a result of the New Furnace operations. New Furnace tailings were derived from ore processed in the rotary kiln furnace operated at the site from 1927 to 1942. The New Furnace extracted a greater fraction of mercury from ore compared to the Old Furnace. As a result, New Furnace tailings contain lower levels of mercury that are potentially leachable (Ecology and Environment 2006).

New Furnace tailings were disposed in the Main Tailings Pile. Old Furnace tailings were disposed in and along Furnace Creek, referred to as the Furnace Creek Tailings Area. Samples collected from the two locations were subjected to various analyses; results are discussed below.

Main Tailings Pile. Mercury concentrations in the Main Tailings Pile were generally less than 100 mg/kg (Thoms 2008). Results from SPLP analysis of three tailings samples from the Main Tailings Pile and New Furnace Area were non-detect to low concentration (ranging from 0.00149 to less than 0.002 milligrams per liter [mg/L] compared with the Oregon Leachate Reference Concentration of 0.2 mg/L), suggesting that the dissolution of mercury from these materials is not a significant contributor to groundwater and surface water (Ecology and Environment 2006). The noted detection levels (2,000 and 1,490 ng/L) are elevated, however, relative to the observed background mercury concentrations in Garoutte Creek (below 0.5 ng/L); the tailings may, therefore, still leach mercury at lower but significant levels. The SPLP mimics leaching caused by contact of the tailings with precipitation. Methylmercury analytical results for the tailing pile equaled the ODEQ Level II soil screening level value (SLV) for plants of 0.0002 mg/kg (Ecology and Environment 2006). SSE analyses indicated that mercury in the tailings generally exists as relatively insoluble elemental mercury and mercuric sulfide species (Ecology and Environment 2006) and, thus, exhibits a low potential for leaching.

Samples were analyzed for selected trace metals (Ecology and Environment 1998). All samples exceeded the Region 9 PRG for arsenic (0.39 mg/kg); subsequent field-based XRF analysis confirmed elevated arsenic concentrations.

Furnace Creek Tailings Area. Mercury concentrations in the Furnace Creek Tailings Area range from approximately 400 to 2,000 mg/kg as determined via XRF (EPA 2008). Although SPLP analysis results for three waste rock tailings samples from the Old Furnace Area were non-detect for mercury, the detection level for the analyses was elevated (440 ng/L) (Ecology and Environment 2006). As a result, the available data show only that the tailings may not leach mercury to groundwater at significantly elevated concentrations (higher than 440 ng/L); the tailings may act as a source of mercury to groundwater and surface water. Two Old Furnace Area tailings samples were analyzed for methylmercury; both exceeded the screening level (0.0002 mg/kg) with the maximum concentration exceeding by a factor of 6 (Ecology and Environment 2006). Results of SSE analysis indicate that the mercury species present in this area have a higher solubility than in the Main Tailings Pile and an increased potential to form methylmercury (Ecology and Environment 2006).

Samples analyzed for arsenic showed elevated concentrations (47 to 131 mg/kg) (Ecology and Environment 2006). To date, these tailings have not been analyzed for metals other than mercury and arsenic.

2.4.1.4 BBM SITE GROUNDWATER CONTAMINATION

Historical groundwater sampling at the site is limited to 11 locations, including an on-site spring, an on-site well, a former mine adit, seven off-site wells, and an off-site spring (Ecology and Environment 1998). All analyses were performed with a detection level of 200 ng/L. Mercury was not detected in any of the 11 samples, including the sample from the mine adit. Later sampling from a BBM adit confirmed a below detection level result for mercury (Ecology and Environment 2006) (but the detection limit for the later analysis was higher [1,400 ng/L]).

Analytical results for groundwater samples also exhibited elevated concentrations of one or more of the following metals: arsenic, chromium, copper, lead, nickel, and selenium relative to a background well (Ecology and Environment 1998).

2.4.1.5 BBM SITE SURFACE WATER CONTAMINATION

Furnace Creek and Dennis Creek surface water samples (analyzed for total metals) collected downstream from the site exhibited elevated levels of mercury (based on fixed-based laboratory results). Samples collected during the post-RA sampling event showed that the downstream concentration exceeded background by a factor of 570 for Furnace Creek and by a factor of 1.9 for Dennis Creek. In the immediate vicinity of the site, downstream concentrations in Garoutte Creek were greater than background (Thoms 2008). The Garoutte Creek background total mercury concentration (0.5 ng/L) was measured in a sample collected upstream from BBM (Thoms 2008). Mercury concentrations in all downstream samples from Furnace Creek (current and historical) exceed the National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuiRT) threshold effects level (TEL) and probable effects level (PEL) benchmark screening levels (see Table 1). Concentrations in samples collected from Dennis Creek and Garoutte Creek were less than the SQuiRT TEL (Ecology and Environment 2006). Samples from Dennis Creek and Garoutte Creek collected downstream from the site were also analyzed for metals other than mercury (Ecology and Environment 1998) and concentrations generally exceeded background. Analytical results for samples collected from Dennis Creek exceeded benchmark screening levels for antimony, chromium, copper, lead, and nickel. Samples collected from Garoutte Creek exceeded benchmark screening levels for lead and nickel and are similar in magnitude to concentrations detected in samples collected from Dennis Creek.

2.4.1.6 BBM SITE SEDIMENTS

The following discussion of sediment characterization results summarizes the sediment quality as characterized by fixed-base laboratory analysis.

Sediments samples collected from Furnace Creek and Dennis Creek downstream from the site consistently exhibit elevated levels of mercury. Samples collected during the post-RA sampling event showed that the downstream concentration exceeded background by a factor of 79 for Furnace Creek and by a factor of 10 for Dennis Creek. In the immediate vicinity of the site, downstream sediment concentrations in Garoutte Creek were elevated relative to background (Thoms 2008). In general, concentrations in all three creeks exceed the NOAA SQuiRT TEL and PEL benchmark screening levels. A Furnace Creek sediment sample collected downstream from the Old Furnace Area exhibited an elevated methylmercury concentration (0.0127 J mg/kg), which is two orders of magnitude higher than the ODEQ Level II soil screening level for plants (0.0002 mg/kg) (Ecology and Environment 2006). The methylmercury concentration for a Garoutte Creek sediment sample collected downstream from the confluence of Dennis Creek and Garoutte Creek was less than the ODEQ Level II soil screening level. SSE analysis results for the above noted Furnace Creek and Garoutte Creek sediment samples indicated that the majority of the mercury exists in relatively insoluble forms that are not readily methylated (converted to methylmercury) (Ecology and Environment 2006).

Concentrations of metals other than mercury in downstream sediment samples are similar to background levels. Arsenic, chromium, copper, nickel, and zinc exceeded benchmark screening levels in both upstream and downstream samples (Ecology and Environment 1998).

2.4.2 CGR EXISTING DATA

Contamination sources and the existing analytical characterization data for the CGR are discussed in the following sections. Primary investigations used to develop the sections below include Curtis and Allen-Gil (1994), Curtis and Park (1996), and Curtis (2003). The sampled media include sediment, surface water, and fish tissue.

2.4.2.1 CGR CONTAMINATION SOURCES

Total mercury is sourced to CGR as suspended load (particulate mercury [HgP], meaning mercury associated with suspended sediment particles) and as dissolved load, including dissolved inorganic and organic (methylated) species. Elevated mercury in the tissue of the fish that inhabit CGR may originate from several sources, both internal and external to the reservoir. To bioaccumulate, mercury must be present as methylmercury which is formed through the life processes of bacteria. Given appropriately reducing conditions and sufficient supplies of dissolved mercury, sulfate, and labile organic carbon, the bacteria convert dissolved inorganic mercury into methylmercury. In addition, methylmercury, under certain conditions, may revert back to dissolved inorganic species through a process called demethylation.

2.4.2.1.1 EXTERNAL SOURCES

The primary external sources of mercury to CGR include suspended and dissolved mercury from BBM and the Garoutte Creek watershed at large, suspended and dissolved mercury from the CGR watershed at large, and deposition of atmospheric mercury attributable to various industrial and mining sources (such as coal-fired power plants) world-wide (also referred to as the global mercury pool).

BBM and the Garoutte Creek Watershed. The contributions from the BBM Site and the Garoutte Creek Watershed at large will be assessed in the BBM portion of the RI. CGR receives drainage from a watershed with an area of approximately 99 square miles. By comparison, the area of the Garoutte Creek Watershed, is approximately 17 square miles, or approximately 20 percent of the parent CGR Watershed. As noted previously, Thoms (2008) estimated that the Furnace Creek (a tributary to Garoutte Creek) contributes up to 50 to 75 percent of the mercury load in the CFW River. Re-calculation of this value by the project team suggests the contribution may be lower (26 to 59 percent); however, it still represents a potentially significant source. If actual loading approaches the upper end of the loading estimates, the 20 percent of the CGR Watershed drained by Garoutte Creek contributes a disproportionately large fraction of the total mercury load to the CGR.

CGR Watershed at Large. CGR is situated within the Black Butte-Elkhead Mercury District (Thoms 2008) and, as such, some amount of mercury is naturally released to the environment through weathering of mineralized bedrock and soil. Park and Curtis (1997) indicate that, for the Dorena Reservoir located approximately 10 miles northeast of CGR but also within the mercury-mineralized district, mercury levels in sediments and fish tissue were elevated, but were approximately 2/3 lower than the levels observed in CGR.

Global Mercury Pool. Natural sources of mercury include volcanoes, geothermal activity, wildfires, and the weathering of rocks and soils. As a result of global industrialization, anthropogenic sources have increased the atmospheric mercury load. A 2005 global inventory of mercury emissions (United Nations Environmental Programme [UNEP] 2008) estimates that anthropogenic loading is in the same range as the loading from natural sources (1,930 compared with 1,600 metric tons per year). UNEP estimates that atmospheric gaseous elemental mercury concentrations globally range from 1.1 to 4 nanograms per cubic meter (ng/m^3).

2.4.2.1.2 INTERNAL SOURCES

Internal sources of mercury to the CGR contribute mercury to the water column and sediments within the reservoir. A potentially significant internal source is CFW River erosion and mobilization of historical, mercury-contaminated sediments during low pool conditions. Evidence for this internal loading source derives from analysis of mercury in sediment cores from the CGR and observed conditions during the site visit.

Three sediment cores have been collected from CGR, one in 1995 and two in 2002 (Curtis 2003). All cores were collected from the deepest portion of the reservoir and did not penetrate the full thickness of sediment. Based on lead isotope and cesium analysis, a mean sedimentation rate of 0.37 inch/year is estimated for CGR. Mercury concentrations were measured in the three cores in approximately 4.0-inch intervals. The results indicate that, with the exception of a spike in approximately 1998, mercury concentrations in the sediments deposited over the period from 1980 through 2002 were relatively stable (ranging from 0.5 to 1.0 mg/kg), suggesting that mercury input has remained relatively constant. The maximum mercury concentrations (2.0 to 3.5 mg/kg) in the cores were measured in sediments deposited in the early 1970s.

Conditions observed during the January 10, 2012, site visit suggest that the historical mercury-contaminated sediments are likely subjected to erosion and mobilization during the low pool conditions. As shown in the photos taken during the site visit stop at the Wilson Creek Boat Ramp (dry at the time of the visit) (Appendix A), the CFW River was observed flowing in a narrow channel floored by bedrock. The channel was incised into lake-bottom sediments that appear to consist predominantly of fine sand, silt, and clay. The sediments appeared to range from 3 to 5 feet thick. Based on observations from the boat ramp, the river appeared to be actively eroding and mobilizing the lake-bottom sediments. Once mobilized, the sediments would be transported by the river to the low pool portion of the reservoir, where they would be deposited. Through the process of erosion, transport, and deposition, any mercury contained in the historical sediments could be converted to dissolved form and subjected to methylation.

2.4.2.2 CGR SEDIMENT

Sediment characterization results from the Curtis and Allen-Gil (1994), Park and Curtis (1997), and Curtis (2003) investigations are summarized below.

Curtis and Allen-Gil (1994) measured mercury concentrations in CGR sediment in September 1989, June 1990, September 1990, and September 1992. The September events correspond to the end of the high pool season, while the June event represents conditions approximately 1 month after the high pool conditions became established. The same two locations were sampled for each event, both located in shallow water: one near the dam, and the other midway between the CRW River entry point to the reservoir and the dam. From the available information in the report, however, it is unclear to which of the sampling points the reported data specifically applied. Notwithstanding this uncertainty, the average concentration for the two locations ranged from a high of 0.53 mg/kg for the September 1989 event to a low of 0.06 mg/kg for the June 1990 event.

In comparing CGR with the neighboring Dorena Reservoir, Park and Curtis (1997) collected six sediment samples along the long axis of the CGR from the CFW River entry point to a point just upstream from the dam. The sampling was performed in March 1994, presumably under low pool conditions. Mercury concentrations ranged from 1.11 mg/kg for the point upstream from the dam to 0.18 mg/kg at a location near Wilson Creek, in the high pool portion of the reservoir. In general, the most elevated concentrations were observed in the three low pool area samples, which increased in concentration toward the dam (0.68, 1.03, and 1.11 mg/kg). The concentration for the CFW River entry point sample (0.83 mg/kg) was in the same range as the three low pool area samples.

In an event that essentially served to resample five of six Park and Curtis (1997) locations, Curtis (2003) collected sediment samples distributed along the long axis of CGR. Sampling was performed between July and September 2002, presumably under high pool conditions. The results confirmed the sampling conducted by Park and Curtis (2003). Specifically, mercury concentrations increased from a low of 0.68 mg/kg at the upstream end of the reservoir in the high pool portion of the reservoir to a high of 3.6 mg/kg in the low pool area.

2.4.2.3 CGR SURFACE WATER

CGR surface water mercury concentrations were evaluated by ODEQ for the Total Maximum Daily Load (TMDL) assessment of the Willamette Basin (ODEQ 2006) and through sampling events conducted in 2002 and 2003. For the Willamette Basin TMDL, ODEQ (2006) estimates that the ambient mercury load supplied by the CGR watershed is 3.13 kilograms per year (kg/yr) and that the average annual water column mercury concentration is 0.92 ng/L.

Based on data available in the ODEQ online Laboratory Analytical Storage and Retrieval (LASAR) database (http://deq12.deq.state.or.us/lasar2), ODEQ measured total suspended solids (TSS), total mercury, and dissolved mercury concentrations in four monitoring events spanning the period from mid-fall 2002 to late spring 2003. Measureable TSS concentrations, ranging from 5.3 to 8.2 mg/L, were observed for the three events corresponding to low pool conditions (October, December, and March). TSS was non-detect for the one high pool condition event in mid-June. The occurrence of measurable TSS concentrations during low pool conditions likely reflects erosion of the lake-bottom sediments exposed during low water level periods. Total mercury concentrations are elevated for the low pool sampling events in comparison to the mid-June event. The average low pool total mercury concentration was 6.5 ng/L compared with 1 ng/L for the mid-June sample. Dissolved mercury concentrations appeared less dependent on pool level. The low pool samples averaged 1.7 ng/L compared with 1 ng/L for the mid-June sample.

2.4.2.4 CGR Fish Tissue

CGR was the first body of water in Oregon to be placed under a public health advisory as a result of elevated mercury concentrations in fish tissue. In 1979, the Lane County Health Department, in consultation with the Oregon Health Division, issued a public health advisory suggesting safe consumption limits for fish caught from the reservoir. CGR fish tissue testing performed by ODEQ in 2003 indicated an average mercury concentration in fish tissue of 0.53 micrograms per gram (µg/g). Mercury levels measured by ODEQ in bass from CGR ranged up to 1.6 µg/g. The Oregon Department of Human Services generally issues mercury advisories for fish from a water body if average tissue concentrations exceed 0.35 µg/g (www.oregon.gov/DHS/news/2004news/2004-0422.shtml).

Curtis and Allen-Gil (1994), Park and Curtis (1997), and Curtis (2003) also provide fish tissue sampling results for CGR. With the exception of one sample, tissue samples from 12 bass bioassays from 1990 and 1992 sampling events conducted by Curtis and Allen-Gil (1994) exceeded the health advisory level (0.35 µg/g). For the 1990 sampling event, concentrations in bass tissue ranged from 0.22 to 1.79 µg/g and averaged 0.86 µg/g. For the 1992 event, concentrations ranged from 0.37 to 0.74 and averaged 0.51 µg/g. From fish samples obtained in June 1993, September 1994, July 1995, and November 1995, Park and Curtis (1997) obtained concentrations in bass tissue ranging from approximately 0.25 to 0.87 µg/g. Results of their investigation indicated that mercury concentrations in bass tissue increase with fish age and that concentrations varied and trended differently for each sampling event. Curtis (2003) measured mercury concentrations in bass tissue in August and September 2002. Concentrations ranged from 0.86 to 1.2 µg/g and averaged 1.1 µg/g. Curtis (2003) also measured mercury concentrations in benthic invertebrate tissue and determined that average mercury concentrations were more than an order of magnitude less than the average observed for bass tissue. These results suggest increased bioaccumulation of mercury associated with a higher position in the food chain of CGR.

3.0 DESCRIPTION OF PLANNED OR EXISTING REMEDIES

An RA was implemented at the BBM Site in 2007 to address the potential for erosion of tailings and associated release of mercury via surface water transport of tailings and soil particles to downstream surface water bodies (EPA 2008). The RA consisted of characterization of soils and tailings. Soils that exceeded site specific action levels were excavated, and placed in an on-site repository (Figure 2).

The RA's principal objectives were to stabilize the Main Tailings Pile slope adjacent to Dennis Creek, stabilize the Old Ore Furnace tailings area near Furnace Creek, and cap site areas with potential to contribute mercury to site surface water and sediments. Near Dennis Creek, the Main Tailings Pile slope was reduced through regrading to minimize tailings spillage into the creek. The tailings generated by this re-grading were either placed in the on-site repository or were used as capping material in other portions of the site, as discussed below.

Three action levels, based on the EPA Region 9 PRG for mercury in residential soil (23 mg/kg, dermal contact), SSE analysis results, and mercury background sediment concentrations (Ecology and Environment 2006) were used in the RA (Table 1). If field mercury analysis (via XRF or Lumex) indicated concentrations at a location exceeded the applicable action level, the area was either capped or the material exhibiting the elevated concentrations was excavated and placed in the on-site repository.

The three action levels included the following:

- The EPA Region 9 PRG value (23 mg/kg) was used for areas where sequential extraction analyses indicated that mercury was present in more soluble forms; the Old Furnace area was evaluated using this action level.
- For areas where the SSE analysis indicated that the mercury was generally present only in the less soluble mercuric sulfide form, an action level of 115 mg/kg was applied; the Main Tailings Pile and the New Furnace Area (SSE indicated that mercury was present in low solubility forms in both areas) were evaluated using this action level.
- An action level of 10 mg/kg (three times site background mercury concentration in sediment) was used for site areas where tailings were susceptible to erosion and particulate transport in surface water. This action level was applied to the Main Tailings Pile in close proximity to Dennis Creek, the Old Ore Furnace Area, and to delineate tailings located in the Furnace Creek Tailings Area.

Because the SPLP results from the Main Tailings Pile suggested the tailings in this pile were not leaching mercury at elevated concentrations in groundwater (above 440 ng/L) and since the SSE results indicated that the mercury in Main Tailings Pile tailings generally occurs in relatively insoluble forms, these tailings were used as "clean" fill in the RA. Main Tailings Pile tailings were, therefore, used to cap the New Furnace Area and Old Ore Furnace Area.

The RA also included an assessment of Furnace Creek; the results indicated the presence of a larger than anticipated volume of tailings that, based on SSE analysis results, contained mercury in more leachable forms. As a result of funding limitations and because the tailings did not present an imminent risk to human health and the environment, however, the tailings located in the Furnace Creek Tailings Area were left in place (EPA 2008). The Furnace Creek Tailings Area may therefore still represent a potentially significant source of mercury contamination to Garoutte Creek, CFW, and CGR

4.0 CONCEPTUAL SITE MODEL

This section discusses the optimization review team's interpretation of historical information, existing characterization, and RA data to explain how historical events and site characteristics have led to current conditions. Section 4.1 provides a summary of the optimization review team's interpretation of the preliminary CSM, and subsequent sections provide additional detail to help support that interpretation. Identified data gaps are discussed in Section 4.4, while findings and recommendations associated with sequencing RI activities are provided in Sections 5 and 6.

Currently, the preliminary CSM includes two key elements, (1) the release and transport of mercury from the BBM Site and (2) the mercury methylation processes in the CGR. These elements are presented in Sections 4.1 and 4.2. It is also recognized that other components of the CSM such as mercury on neighboring slopes and storage/transport/methylation processes within the CFW may be important factors to consider. To the extent possible these CSM elements are included in considerations and recommendations for optimizing RI efforts discussed in Section 4.4 of this report.

The site and CGR CSM elements collectively reflect the current best available understanding of how mercury is released, transported, and converted to methylmercury. The CSM elements include only those processes that are believed to be dominant and controlling for mercury fate and transport. For example, although methylation may be occurring upstream from CGR, the CSM assumes that the dominant methylation processes responsible for elevated mercury in fish tissue occur within the CGR itself. Similarly, although mercury could originate from other sources at the site, such as contributions from groundwater or by overland flow from adjacent hillsides, the Furnace Creek Tailings Area is assumed to be the dominant mercury source. Only the most plausible processes were included in the CSM. Other processes will be evaluated and incorporated into the CSM as necessary through RI sampling and data evaluation. Processes not represented in the CSM will be evaluated in the RI through the data evaluation logic discussed in Section 4.4. Through the data evaluation process, the CSM will evolve and mature from the current preliminary form into the baseline CSM for the site systematic project planning (SPP) efforts.

The elements of the CSM for the site and the CGR are consistent with previous models developed and presented in the site documents reviewed, including:

- The proposal by the U.S. Geological Survey (USGS) to USACE for estimation of the mercury budget for CGR (USGS 2011);
- The ODEQ mercury loading analysis conducted in 2007 (Thoms 2008);
- The ODEQ mercury loading estimate for the Willamette River Basin TMDL Project (Hope 2003)

4.1 CSM COMPONENTS FOR BBM

In an ODEQ preliminary assessment of the BBM Site, Andersen (1996) indicates that surface water is the most significant migration pathway for mercury from the site. He suggests that "surface transport of soil and sediment (from the BBM Site) has resulted in widespread contamination distribution downstream of the mine site in Dennis Creek, the Coast Fork of the Willamette River, and in CGR." In accordance with the information obtained from document review and from discussions with Region 10 and ODEQ personnel, this CSM was been refined as follows:

- The BBM Site, specifically the Furnace Creek Tailings Area, may represent a significant source of mercury contamination to Furnace, Garoutte Creeks, the CFW River, and the CGR. Potentially important site sources of suspended and dissolved mercury contamination include physical erosion of tailings piles and mine soils, surface water transport of the eroded tailings and soil particles, and deposition of the sediments in downstream surface water features. Leaching from existing tailings or dissolution of mercury, originating as suspended mercury, also likely occurs along the transport pathway.

The preliminary CSM is consistent with the results of the surface water and sediment sampling and analysis conducted by Thoms (2008). As discussed in previous sections, based on one sampling event of flow representative of non-storm conditions (Thoms 2008), it was estimated that Furnace Creek could contribute between 50 and 75 percent of the mercury load in the CFW River. Re-calculation of this value by the optimization review team suggests that the contribution may be lower (26 to 59 percent); however, Furnace Creek still represents a potentially significant source. Figure 4 is a schematic illustration of these processes.

A primary motivation for addressing mercury contamination from BBM is to minimize or eliminate the currently existing conditions that led to elevated mercury concentrations in the tissue of the fish that inhabit the CGR and the watershed in general. As discussed further in Section 5.0 (Findings), however, there are significant challenges associated with accurately determining the relative role of the BBM Site in causing the elevated concentrations of mercury in fish tissue.

Key elements of the CSM describing dominant processes responsible for the release and transport of mercury form the BBM Site and supported by site investigation documents include:

- The Furnace Creek Tailings Area is a key source for elevated mercury concentrations in downstream surface water features, including CGR.
- Fine grained, mercury-laden tailings particles are generated from mechanical erosion and are transported via surface water flow into Furnace Creek.
- Mercury in sediments present in Furnace Creek bed may also be remobilized and resuspended during storm flow conditions.
- A portion of the eroded particles contributes to the suspended load in the surface water flows in Furnace Creek, Garoutte Creek, CFW River, and CGR.
- Similar processes in Dennis Creek and historical impacts in Garoutte Creek along with background watershed contributions result in lower contributions of mercury to CFW and CGR; and
- Mercury is delivered to CGR in both dissolved mercury and suspended mercury phases consisting of both inorganic and methylated forms. Geochemical conditions in CGR bottom waters and sediments are favorable for bacteria that can convert dissolved mercury to methylmercury, which is then available for uptake into the food chain. Some of the suspended mercury in the CGR may be converted to dissolved mercury over time.

4.2 CSM COMPONENTS FOR CGR

The CSM element describing the dominant processes responsible for the occurrence of methylmercury in the CGR includes the following components:

- Methylmercury in CGR can originate from internal and external production. Internal methylation is influenced by the seasonal changes in CGR water levels. Existing management practices set the water level at a high point during the spring and summer months and at a low level during the fall and winter.

- The current CSM and limited existing data indicate that the Furnace Creek Tailings Area is likely an important source of contemporary loading of mercury and potentially other metals to downstream surface water features, including CGR. It is important to note that more than a century of inputs have historically loaded the CFW and subsequently the CGR through its 60-year existence. Based on CGR sediment coring results, Curtis (2003) reports that sediment mercury concentrations were up to three times greater in the early 1970s as compared with more recent concentrations. The CSM recognizes, therefore, that significant mercury concentrations exist in CGR as a result of historical loading.
- A potential internal source of mercury to the CGR is CFW River erosion of historical, elevated concentration lake bottom sediments exposed during low pool conditions. The historical sediments thus mobilized are carried via suspended load to the low pool portion of the CGR, where some of the sediment is deposited.
- Mercury methylation occurs primarily in the uppermost sediment layers and the anoxic section of the water column in the reservoir; deeper sediments are effectively isolated from the methylation process.
- Mercury is supplied to the uppermost sediments via transport of suspended tailings and particles in incoming surface water or from the re-erosion of previously deposited sediments exposed during low pool conditions.
- Sedimentation occurs within the low pool portion of CGR during the late fall and winter season and throughout CGR during the high pool conditions (spring and summer season).
- Geochemical conditions at the bottom of CGR are favorable for conversion of the mercury contained in the tailings to methylmercury. The methylmercury levels in CGR sediments are a small percentage of the total inorganic mercury load, indicating that an understanding of the small sub-fraction available for methylation remains an uncertainty in understanding the mercury dynamics in CGR.
- Mercury methylation requires anoxic conditions, the presence of inorganic mercury in a dissolved bioavailable form, a microbial labile organic carbon source, and sulfate. Understanding which of these key variables is controlling methylmercury production in CGR can provide important information necessary to consider reservoir management strategies as a means to control methylation.
- Methylation activity is enhanced in the sediments that are re-submerged after exposure to the atmosphere during low pool conditions. During atmospheric exposure, the sulfide is oxidized to sulfate, allowing the resumption of methylation during high pool conditions.

4.3 IDENTIFICATION OF DATA GAPS

The CSM is the primary tool to identify significant data gaps in the existing site information. Data gaps identified from the site and CGR CSM elements, and considerations for filling those data gaps, are discussed in the following sections.

4.3.1 SITE DATA GAPS

Data gaps associated with the site exist with respect to the occurrence and variation of mercury in creeks near the site and in the downstream surface water features. Data gaps also exist with respect to the capacity of the tailings and mercury-contaminated mine soils to leach dissolved mercury or other metals to groundwater and surface water, to the accuracy and reliability of field-based methods (XRF and Lumex) for measuring metals concentrations in site media, and to the potential presence of soil contamination in the vicinity of the tailings disposal areas. Additional details regarding each of these data gaps follow.

Surface Water Flow and Quality. A significant data gap is the need to gain an understanding of the chemical and physical form of mercury as it is released from the site and the role that stream flow conditions play. To address this data gap, data are needed regarding mercury concentrations (measured by chemical species and form [total versus dissolved]) as well as concentrations for other ancillary water quality parameters in surface water in Dennis Creek, Furnace Creek, and Garoutte Creek. At one station on each stream, sampling should be performed during periods of baseflow as well as periods with storm water runoff (the stormflow hydrograph for a given station and stream). Ideally, this sampling should include up to two baseflow and stormflow events representing the range of annual antecedent moisture and flow conditions. In addition, data are needed at locations up and downstream from the BBM Site to evaluate the seasonal variation of mercury (speciation and form) and ancillary parameter concentrations during both storm and non-storm conditions. Data generated from these events could be used to confirm the results of the 2008 post-RA surface water loading assessment (Thoms 2008) and to verify whether the bulk of the loading occurs during storm flow events.

Tailings Leaching Capacity and Groundwater Quality. Additional data are needed regarding the overall capacity of the site tailings and mine soils to leach mercury and other metals into groundwater and the role, if any, of groundwater in the off-site migration of mercury. Also unknown is the contribution to the site groundwater mercury flux from transient groundwater flow, defined as vadose zone groundwater recharged from a specific precipitation event and in transit to the water table. Data are needed regarding mercury and trace metal concentrations in groundwater beneath/immediately downgradient from the Main Tailings Pile and the Furnace Creek Tailings Area. These data are necessary to evaluate the significance of groundwater as a pathway for off-site mercury migration.

Demonstration of Method Applicability (DMA) for Field-Based Soil Analyses. Additional data are needed regarding the correlation of mercury and metals concentrations measured using field-based methods (XRF and Lumex) and concentrations measured via fixed-based laboratory methods. In accordance with BMPs, a DMA consisting of the collection of samples to be homogenized and split for field-based and fixed-base laboratory analysis from selected site areas (including the Old Ore Furnace Capped Area, New Furnace Capped Area, and adjacent hillsides) and analysis of mercury and metals could be conducted. The results of these paired analyses could be used to establish the correlation between field-based and fixed-based laboratory analyses and assess the general applicability of the field-based methods for RI activities. In addition, a DMA data can provide preliminary information to optimize analytical and sampling strategies to address human health and ecological risk assessment needs. Information on conducting DMAs and establishing relationships for collaborative analytical methods is provided in EPA (2008a), available from the following web address: www.brownfieldstsc.org/pdfs/Demonstrations_of_Methods_Applicability.pdf.

Furnace Creek Tailings Trace Metal Concentrations. A data gap exists regarding trace metal concentrations in the tailings disposed in the Furnace Creek Tailings Area. These tailings are believed to have been generated as a result of Old Ore Furnace operations. Trace metal concentrations should be measured in samples of tailings from the Old Ore Furnace Area and from the Furnace Creek Tailings Area. An additional data gap exists regarding confirmation of the extent of the Furnace Creek Tailings Area, as does generation of a site tailings data set sufficient to meet requirements for risk assessment.

General Site Soil. A data gap exists regarding trace metal concentrations in soil underlying the Main Tailings Pile, the tailings in the vicinity of the Old Ore Furnace, and the site in general. Mercury and other trace metal concentrations should be measured in site soil samples. In addition, a data gap exists regarding confirmation sampling of the results obtained by Curtis (2004) for methylmercury on hillsides adjacent to

Black Butte. Generation of a site soil data set sufficient to meet requirements for risk assessment is also a data gap.

Sediment. Additional sediment data are needed to establish baseline concentrations for sediments in Garoutte Creek near BBM and to assess the potential for stream sediments to contribute to suspended loading of mercury and other metals in surface water. After baseline conditions in Garoutte Creek have been established, more comprehensive sediment characterization may be necessary to satisfy the data requirements for risk assessment. Similarly, if important for remedial design, the team may consider downstream sediment sampling in Garoutte Creek or CFW River to understand potential sinks and mercury transformation processes as mercury moves to CGR.

4.3.2 CGR DATA GAPS

CGR water levels are seasonally managed for flood control, conservation storage, and water release to downstream areas. Low water levels are maintained in the winter months, while water levels are held at higher levels during the summer. Significant data gaps exist in the understanding of the origin of the elevated total mercury concentrations measured in the tissues of fish inhabiting the CGR. Fundamental to understanding fish tissue concentrations is an accurate characterization of the overall mercury budget for the reservoir. Specifically, the relative importance of internally versus externally generated methylmercury is unknown. In addition, data gaps exist regarding the methylation processes operating internally within the CGR. For example, the data needed to compare the significance of methylation in the low pool sediments with methylation in the wetland areas exposed during low pool but inundated during high pool are unavailable (Figure 4). Uncertainty also exists regarding the time horizon needed to assess the beneficial impact on fish tissue concentrations from any actions taken to reduce the methylmercury flux from sources internal or external to the reservoir.

Given the above data gaps in the existing CGR characterization, several fundamental data gaps may be addressed during the RI. The resulting data will support assessment of the benefits associated with changes in reservoir management practices or future remedial actions at the BBM Site that have the potential to reduce future mercury concentrations in fish tissue.

Total Mercury Concentrations for Range of Trophic Levels. Data are needed regarding how total tissue mercury concentrations vary with food web trophic level. Total mercury concentrations in biota should increase with trophic position. Organisms such as snails or other invertebrates at the lower bound of the food chain should have low total mercury concentrations, while the tissue of predatory fish at the upper bound should have elevated total mercury concentrations. The trophic sampling may potentially support risk assessment needs and is expected to support the identification of appropriate species for continued tissue sampling as a means to evaluate potential reductions of mercury in tissues achieved through source mitigation or reservoir management measures. Where appropriate, fish species identified for trophic level sampling will focus on CGR species potentially supporting recreational or sustenance consumption.

Baseline Total Mercury Concentrations in Upper Trophic Level Fish. In the event that the trophic-level sampling results indicate that mercury concentrations in fish tissues are unrelated to trophic position, baseline total mercury concentrations should be measured in upper level fish. As indicated above, this sampling may potentially support risk assessment and would be intended to provide the basis for determining mercury reductions in fish tissues achieved by potential source mitigation or CGR cleanup measures.

Mercury In-Flow/Out-Flow Budget. To date, a mercury budget has not been established for CGR; however, the USGS is collecting the data needed to establish a mercury budget for CGR (USGS 2011).

This analysis will reflect existing (baseline) conditions for the watershed. If source mitigation measures are implemented at BBM, this sampling can be extended to document any mercury loading reductions achieved.

4.4 IMPLICATIONS FOR REMEDIAL STRATEGY

Suggested RI sampling strategies and associated data evaluation logic developed by the optimization review team are presented in this section. Table 2 summarizes the proposed number of samples, sampling approach, and analytes for each CSM element (the BBM Site and the CGR) and potentially affected environmental medium. A key objective of this optimization review effort is source identification and characterization; the media critical to this objective include surface water, sediment, shallow groundwater, and native soil. Although considered noncritical for source characterization, other media (for example, CFW River surface water) will be critical for the human health and ecologic risk evaluations that will be based on the data collected in the RI. General recommendations are provided in Table 2 for consideration in evaluating these media.

It should be noted that the recommended sampling approaches and numbers of samples provided are preliminary – that is, they should be considered to be a starting point for planning the RI. In addition, qualitative judgments govern each decision point (such as, "elevated" sampling result). The project technical team may determine appropriate quantitative judgments for these decision points. Final sampling design and specification of quantitative decision point parameters will require input from all stakeholders (including Region 10 human health and ecologic risk assessment staff) involved in the RI.

The focus of this optimization review was the identification and sequencing of sampling approaches and associated decision logic to guide future RI efforts at the BBM Site. Data collection approaches and evaluation strategies are also presented for CGR, but with the goal of establishing a baseline data set that can be used to assess the effects of source mitigation or reservoir management measures and that can be used to help assess potential candidate management practices that could improve conditions in the reservoir.

4.4.1 RECOMMENDATIONS FOR RI IMPLEMENTATION AT THE BBM SITE

Sampling to test and confirm the site CSM should include the collection and analysis of:

- Baseflow and storm event surface water samples from the creeks in the immediate vicinity of the site (Dennis, Furnace, and Garoutte).
- Groundwater samples from saturated unconsolidated material underlying on-site tailings (sampling conducted concurrent with the storm event surface water sampling);
- Precipitation (rate and concentration);
- Sediment samples from these creeks;
- Native soils potentially contaminated by site operations; and
- Tailings from the Furnace Creek Tailings Area and the Main Tailings Pile.

Sampling locations, rationale, and data evaluation logic are presented in the following sections for each of these media.

4.4.1.1 SEQUENCING OF CHARACTERIZATION BY MEDIA

The recommended RI characterization sequence consists of three phases as follows:

- Phase 1 includes the initial groundwater characterization and the storm event sampling. These tasks are prerequisites for the seasonal groundwater and sediment sampling and for establishing the appropriate timing for the seasonal storm surface water grab sampling. In addition, the Phase 1 tailings and soil field analyses and associated fixed-base laboratory analysis may also be used for conducting the DMA for XRF and Lumex field analyses methods.

- Phase 2 consists of concurrent seasonal surface water, sediment, and groundwater grab sampling during storm and non-storm stream flow events. Phase 2 would also include baseline soil and tailings sampling and analysis, and the DMA for XRF and Lumex field analysis. These baseline soil samples would be collected from the site soils and adjacent hillsides as well as the tailings from the Furnace Creek Tailings Area. Evaluation of Phase 2 results will guide the design of Phase 3 sampling.

- If the CSM is supported by the sampling from Phase 2, Phase 3 sampling will consist of detailed characterization of the Furnace Creek Tailings Area. If the Phase 2 sampling suggests that a source other than the Furnace Creek Tailings Area is a significant contributor of mercury and other metals contamination to the environment, the focus of the sampling may be adjusted accordingly (for example, to focus on hillside soil).

4.4.1.2 SURFACE WATER CHARACTERIZATION

Surface water characterization is proposed to address the data gaps identified in the existing surface water characterization for the site (see Section 4.4.1). The primary objective of the surface water sampling would be to evaluate the significance of suspended mercury and dissolved mercury transport from BBM to area creeks. The data collected can help quantify annual loading from Dennis and Furnace Creeks to Garoutte Creek, help identify areas of mercury inputs originating on the BBM property, and provide pathway information on mercury transport and transformation to and within these creeks. This sampling and the associated data evaluation may establish the potential existence of other significant mercury sources at, or in the immediate vicinity of, the site. The 2008 surface water mercury loading estimate completed by ODEQ (ODEQ 2008) identified the Furnace Creek Tailings Area as a significant contributor of mercury in the CFW River and potentially CGR. The surface water sampling approach proposed in this section is based in part on the recommendations developed from that study.

4.4.1.2.1 SAMPLING APPROACH

The optimization review team recommends collection of surface water samples from Garoutte Creek, Furnace Creek, and Dennis Creek at the following eight locations (see Figure 5):

- Garoutte Creek (Station 1) – upstream of the confluence with Furnace Creek,
- Garoutte Creek (Station 2) – downstream of the confluence of Furnace Creek in a location upstream of the confluence with Dennis Creek,
- Garoutte Creek (Station 3) – downstream of the confluence of Dennis Creek,
- Garoutte Creek (Station 4) – upstream of where Garoutte Creek and Big River merge to form the CFW River
- Furnace Creek (Station 5) – upstream of the site,
- Furnace Creek (Station 6) – downstream of the Furnace Creek Tailings Area,
- Dennis Creek (Station 7) – upstream of the site, and
- Dennis Creek (Station 8) – downstream of the Main Tailings Pile.

Station 1 will serve as a reference location for water quality upstream from the site. Sampling that occurs quarterly for 1 year is recommended. During each season (quarter), one sampling event occurring during storm flow conditions and one sampling event conducted during normal and low flow conditions is recommended. The proposed eight sampling locations and the eight events (two per quarter for 1 year) will generate 64 annual samples, plus appropriate QC samples.

Samples should be analyzed for total mercury, dissolved mercury, methylmercury (total), methylmercury (dissolved), reactive mercury (total), reactive mercury (dissolved), and target analyte list (TAL) metals (total), as well as total suspended solids (TSS), pH, dissolved organic carbon (DOC), and common ions. This combination of analytes will support the estimation of mercury and trace metal concentrations in dissolved and suspended phases and will provide insight on the speciation of the suspended and dissolved phases. Results of the reactive mercury analysis will indicate the relative proportions of a sample in which the mercury is present in less reactive species (such as mercuric sulfide) versus the amount present in more reactive, mobile species (such as organically complexed mercury). Reactive mercury analyses will help in understanding the hillside mercury loading (likely organically complexed) versus tailings-sourced loading (likely dominated by mercuric sulfide species). These results will be significant to understanding mercury sourcing, particularly if collection of samples of vadose zone groundwater in the hillslope and tailings areas is difficult to achieve.

Furnace Creek and Dennis Creek discharge rates should be continuously monitored using a water level transducer and a weir structure. Garoutte Creek discharge can be gauged using direct measurement methods or can be estimated using USGS gauging data, if available. Consistent with the stream sampling method used by the USGS in the ongoing project to evaluate the mercury flux in CGR, the depth/width composite sampling method can be evaluated for use in this project during preparation of the RI work plan.

To evaluate the influence of storm events on mercury transport (including the “first flush”), preliminary sampling and gauging can be conducted at one station on each creek (Furnace, Dennis, and Garoutte). Ideally, this preliminary sampling and gauging would be conducted during two storm events (preferably with differing antecedent conditions) before surface water grab sampling is initiated for the first season. During first flush, mercury loads may be disproportionately elevated. Determination of first flush timing for each creek before seasonal grab samples are collected will enable the project team to optimize timing of the storm flow grab sampling to coincide with the period of peak loads. To characterize the mercury flux response to precipitation events for each creek, creek discharge, total mercury, dissolved mercury, methylmercury (total), methylmercury (dissolved), reactive mercury (total) (analyzed for a sub-set of samples), and TAL metals (total phase-only), as well as TSS, pH, DOC, and common ions are recommended. This sampling and data collection should be conducted at a regular time interval sufficient to accurately characterize creek discharge and chemistry through the period of each storm. To account for atmospheric mercury contributions in project data evaluations, precipitation amount and chemistry samples can be collected and analyzed during each precipitation event for most of the same analytes as the stream samples. Ideally, the precipitation amount would be continuously monitored throughout the year to help with the interpretation of the stream discharge data.

During the stormflow hydrograph sampling task, coincident sampling of the eight vadose zone piezometers installed in accordance with Section 4.4.1.4.1 can be conducted at a frequency similar to collection of stream samples. The vadose zone groundwater sample analysis can include dissolved mercury, methylmercury (dissolved), reactive mercury (dissolved), TAL metals (dissolved), pH, DOC, and common ions.

Sampling would be initialized based on the observed trend in stream discharge for each storm event. After the event begins, stream discharge will begin to increase after some lag time depending on the intensity and proximity of the rain event. Chemical sampling should begin when the discharge rate begins to increase in response to the storm. The specific intervals of sampling can be identified at a later point based on changes in discharge from the first flush event. Sampling and flow measurements would end during the declining phase of a station's response to the given storm.

4.4.1.2.2 DATA EVALUATION LOGIC

Figure 6 shows the suggested data evaluation logic for surface water sampling at the BBM Site. As indicated, the surface water data would be evaluated using five decision points denoted by diamonds on the figure. The logic associated with each decision point is discussed below:

- **Is the downstream Garoutte Creek mercury flux greater than the upstream Garoutte Creek flux at BBM?** A "yes" result is consistent with the CSM (the mercury flux from Furnace Creek is reflected by an increase in the downstream Garoutte Creek flux). A "no" result is inconsistent with the CSM and suggests that Furnace and Dennis Creeks may not be conveying significant mercury flux to Garoutte Creek. Given a "no" result, a discussion with the technical team and Region 10 management would be necessary to determine the appropriate path forward for the RI.

  Is the Furnace Creek mercury flux large compared to the Garoutte Creek mercury flux? A "yes" result is consistent with the CSM. A "no" result is inconsistent with the CSM. A potential alternative source is mercury contained in the runoff from hillsides in the vicinity that may have been historically contaminated by airborne mercury emissions from the site's former ore processing operations. Another potential mercury source is from seepage of contaminated groundwater to surface water. Results from the groundwater sampling task will assist in the evaluation of a "no" result at this decision point. Given a "no" result, the path forward would be to complete the surface water data evaluation process and then proceed to the soil data evaluation logic diagram (Figure 12) to design an appropriate soil sampling strategy. The comparison of the Furnace and Garoutte Creek mercury fluxes will likely include multiple decision criteria since the flow in Furnace Creek is a fraction of the flow in Garoutte Creek. Two criteria that may be applicable include a straight comparison of the mercury fluxes for the two creeks and a comparison of the downstream versus the upstream Furnace Creek flux. For example, if the downstream Furnace Creek flux exceeds the upstream flux by at least 3-fold, then the Furnace Creek would be considered a significant mercury source. Similarly, if no significant Garoutte Creek concentration change is observed between the Furnace Creek downstream sample and the Dennis Creek downstream sample the likelihood of Dennis Creek being a major source of surface water mercury flux to Garoutte Creek is low.

- **Are suspended load mercury concentrations elevated relative to dissolved load concentrations?** A "yes" result is consistent with the CSM (the dominant source of total mercury in downstream surface water is from the mechanical erosion of fine tailings particles from the Furnace Creek Tailings Area). A "no" result is inconsistent with the CSM and suggests that the mercury flux resulting from groundwater discharge to surface water is significant relative to the mechanical erosion of tailings at the Furnace Creek Tailings Area. Similar to the previous decision point, the results from the groundwater sampling task will assist in this evaluation. Given a "no" at this decision point, the path forward is to complete the groundwater data evaluation and proceed to the soil data evaluation logic diagram (Figure 12) to design an appropriate soil sampling strategy.

- **Do suspended particle mercury concentrations in downstream Garoutte Creek approximate sediment concentrations in Furnace Creek?** The primary input to this decision point is determined by comparing the Garoutte Creek suspended particle mercury concentration (derived using the Garoutte Creek suspended load mercury and TSS concentrations measured just downstream of Furnace Creek but upstream of Dennis Creek) to the Furnace Creek mercury concentration in fine sediment. If the Garoutte Creek suspended mercury concentrations approximate the fine sediment concentrations in Furnace Creek, the CSM is supported. (This result provides evidence that the downstream Garoutte Creek suspended load concentrations likely originated from Furnace Creek.) If the Garoutte Creek suspended particle concentrations are significantly dissimilar to the Furnace Creek fine sediment mercury concentrations and more closely resemble Garoutte Creek fine sediment concentrations, internal loading within Garoutte Creek is likely occurring, a result that is counter to the CSM. Given a "no" result at this decision point, the path forward is to complete the surface water data evaluation process and proceed to the sediment data evaluation logic diagram (Figure 7) to design an appropriate sediment sampling strategy.

- **How do Furnace Creek mercury speciation results compare with Garoutte Creek speciation results?** The primary input to this decision point is determined by estimating the concentration of suspended particulate-bound, non-mobile mercury for the Garoutte and Furnace Creek samples. This estimate is calculated as follows:

Suspended particulate-bound non-mobile Hg =
[HgT-HgD] – [MeHg(total)-MeHg(dissolved] – [HgR(total)-HgR(dissolved)]

Where -

HgT: total mercury
HgD: dissolved mercury
MeHg(total): total methylmercury
MeHg(dissolved): dissolved methylmercury
HgR(total): total reactive mercury
HgR(dissolved): dissolved reactive mercury

A good correlation between the downstream Furnace Creek sample (Figure 5, Station 6) and the nearest downstream Garoutte Creek station (Figure 5, Station 2) supports the CSM (evidence exists that the mercury observed in Garoutte Creek is significantly sourced to the Furnace Creek Tailings Area), whereas a poor correlation is unsupportive (this result suggests an alternative source exists such as mercury sourced to runoff from adjacent hillsides or from groundwater discharge). If the observed correlation is poor, the path forward is to proceed to the soil data evaluation logic diagram (Figure 12) to design an appropriate soil sampling strategy.

After the surface water and groundwater sampling tasks have been completed (discussed later in this section), it is recommended that the combined data set be subjected to the End Member Mixing Analysis (EMMA) data analysis technique (Cary and others 2011). The EMMA is recommended as a check on the data evaluation results obtained from the decision logic described in this section.

EMMA assumes that creek water is a mixture of waters supplied by distinct components of the watershed, each with distinct concentrations of naturally occurring ions. The EMMA uses observed surface water geochemistry to trace the contributions of these watershed components to total creek flow. The EMMA will use the common ion and general chemistry constituent concentrations measured in the surface water and groundwater samples.

4.4.1.3 SEDIMENT CHARACTERIZATION

The objectives of sediment characterization are: (1) to provide total mercury concentration data for comparison with the calculated suspended mercury concentrations (to assess potential internal loading in Garoutte Creek); (2) to provide general characterization data regarding the temporal and spatial variability of total mercury and methylmercury in sediments in the vicinity of the BBM Site; and (3) to provide information that can be used to support risk assessment in accordance with risk assessor-defined data needs.

4.4.1.3.1 SAMPLING APPROACH

The optimization review team recommends collection and analysis of sediment samples from each of the surface water sampling locations during each of the eight surface water sampling events (see Figure 5). Samples collected using incremental composite sampling (ICS) methods (Appendix B) are recommended to control short scale heterogeneity (large differences in concentration in close spatial proximity). These samples can be biased toward finer grain sizes that are potentially more readily mobilized during storm flow conditions, and be analyzed for total mercury, methylmercury, TOC, TAL metals, and grain size. The sediment data will be used in combination with the surface water data to assess the possibility that the surface water suspended mercury load is significantly influenced by mobilized historical creek sediments versus from erosion and mobilization of fine tailings particles from the Furnace Creek Tailings Area.

4.4.1.3.2 DATA EVALUATION

Figure 7 shows the data evaluation logic for sediment sampling. Evaluation of the sediment data should proceed once all surface water and sediment sampling has been completed. As shown on Figure 7, the sediment and surface water data can be evaluated in combination as follows:

- **Are the suspended sediment mercury concentrations in downstream Garoutte Creek similar to the sediment concentrations in Furnace Creek?** The calculation of suspended mercury concentration for each station was discussed in the surface water sampling data logic (Section 6.2). A "yes" result is consistent with the CSM (evidence exists that Furnace Creek is the dominant source of suspended mercury in Garoutte Creek). If the Garoutte Creek suspended mercury concentration more closely resembles the mercury concentration in Garoutte Creek sediment (a "no" result), suspended mercury in Garoutte Creek is likely the result of internal loading (remobilization of Garoutte Creek bed load sediments). After consultation with Region 10, the development of a comprehensive sediment characterization plan may be required to address internal loading within Garoutte Creek.

4.4.1.4 GROUNDWATER CHARACTERIZATION

Consistent with the data gaps identified in the CSM (Section 4.4.1), the objectives of the recommended groundwater characterization task are (1) to directly assess the potential for tailings to leach mercury and other metals to groundwater, and (2) to provide groundwater characterization results to support the evaluation of surface water sampling data. It is suggested that the task be conducted in two phases. Phase 1 consists of initial soil and groundwater characterization sampling of the transient (vadose) and phreatic (saturated) zones and installation and sampling of temporary monitoring wells. Phase 2 would then consist of collection of seasonal groundwater grab samples coinciding with surface water sampling events.

4.4.1.4.1 SAMPLING APPROACH

Vadose Zone Groundwater. Up to nine piezometers are recommended at the BBM Site and on the opposing hillside on the opposite side of Garoutte Creek from BBM to evaluate transient groundwater flow during storm and non-storm events. It is recommended that a direct-push technology (DPT) drilling approach be used as the method for installing the vadose zone piezometers. However, a mini sonic or other drilling platform may be appropriate if geologic conditions adverse to DPT drilling are encountered. The nine suggested locations, eight of which are shown on Figure 2, include:

- Two locations in the Main Tailings Pile adjacent to Dennis Creek,
- Two locations in the Furnace Creek Tailings Area adjacent to Furnace Creek,
- Two locations in the Main Tailings Pile at the approximate ridge crest separating the Dennis and Furnace Creek drainages,
- Two locations on the hillside opposite Garoutte Creek from BBM, and
- One background location (not shown on Figure 2), unaffected by the site.

The one background sampling location (for installation of up to three piezometer wells) should be defined in consultation with the project team before the groundwater sampling tasks begin and with regard to appropriate security and access considerations.

Up to two piezometers are recommended at each location, the first installed with the base of the screen interval coinciding with the bedrock surface and the second screened in a shallower zone selected based on field conditions (such as evidence of perched groundwater conditions). In the absence of any evidence of perched groundwater, only one piezometer may be installed. Groundwater samples will be collected (if sufficient sample volume can be obtained) from the piezometers during each of the surface water grab sampling events. During the piezometer well installation task, use of drive-point or hand augered soil borings will be evaluated to assess, to the extent possible, the potential that saturated tailings exist at the Main Tailings Pile adjacent to Dennis Creek and the Furnace Creek Tailings Area adjacent to Furnace Creek. If the presence of saturated tailings is identified at either location, an additional piezometer well is recommended at that location.

Vadose zone groundwater samples analyzed for dissolved mercury, methylmercury (dissolved), reactive mercury (dissolved), TAL metals (dissolved), as well as pH, DOC and common ions are recommended.

Tailings samples are recommended for collection during the advancement of each piezometer borehole. Sampling is recommended on a 3-foot sampling interval for mercury and other metals analyses by XRF and Lumex. A percentage (10-20 percent is recommended) of these samples, representative of the range of observed field concentrations, may also be submitted for fixed-base laboratory analysis of total mercury and TAL metals.

Saturated Zone Groundwater. Saturated groundwater can be characterized through installation of eight temporary monitoring wells in the Garoutte Creek floodplain located down slope from the BBM. In addition, three staff gauges situated in close proximity to the monitoring wells can be installed in the creek. It is recommended that a rotary sonic DPT drilling approach (for example, Geoprobe Model 8140 or equivalent) be used as the method for installing the wells. Prior to groundwater sampling, the area should be cleared of vegetation and surface soils should be mapped by visual inspection. Soil boring installation is recommended, with first priority given to any identified tailings areas. A subset of borings will also be installed in non-tailings areas. The lithology of soil borings should be logged and soils sampled and analyzed for total mercury and metals analyses via XRF and Lumex. A percentage (10-20 percent is recommended), representative of the range of observed field concentrations, may also be submitted for fixed-base laboratory analysis of total mercury and TAL metals. Representative samples (up to three) of tailings and of the unconsolidated sediments underlying the floodplain are also recommended for grain size analysis.

If the presence of tailings is confirmed, a minimum of eight locations are recommended for drive point groundwater and soil sampling from the tailings areas with an equal number of these samples collected from the non-tailings areas. Temporary monitoring wells, sufficiently durable to withstand multiple sampling events over a 1 year period, can be installed at eight of the drive point soil and groundwater sampling locations. Up to three locations are recommended from the immediate vicinity of the confluence of Dennis Creek and Garoutte Creek (and, if possible Furnace Creek and Garoutte Creek); the remaining samples should be collected from the general floodplain area. Figure 8 shows recommended preliminary locations for groundwater sample collection. The locations shown may be modified to address access and drilling logistics. Each drive point soil and groundwater sampling location, the temporary monitoring wells, and the three staff gauges should be surveyed for Oregon state plane coordinates (to an accuracy of 0.1 foot). Ground surface elevations for drive point soil and groundwater sampling locations should be surveyed to an accuracy of 0.01 foot relative to NGVD; the reference elevation of each staff gauge and the top of casing elevation (relative to NGVD) for each monitoring well should be surveyed to an accuracy of 0.001 foot.

Background Garoutte Creek floodplain groundwater quality can be characterized by sampling two to three locations on the Garoutte Creek floodplain upstream from, and unaffected by, the BBM. Before the groundwater sampling tasks begin, the background well locations should be defined in consultation with the project team and with consideration given to the availability of appropriate security and property access requirements. Up to three background wells are recommended. The wells would be sampled regularly along with the other wells and piezometers.

Groundwater samples collected from the eight temporary monitoring wells on a quarterly basis are recommended. To the extent possible, sampling should be timed to coincide with the seasonal surface water grab sampling as a means to conserve resources and limit mobilizations. The recommended analyte list for the unconsolidated-material, saturated-zone groundwater samples includes dissolved mercury, methylmercury (dissolved), reactive mercury (dissolved), and TAL metals (dissolved), as well as pH, DOC, and common ions.

4.4.1.4.2 DATA EVALUATION

Vadose Zone Groundwater. Figure 9 shows the data evaluation logic for vadose zone piezometer installation and the review of vadose zone groundwater sampling and analytical results. Evaluation of the transient groundwater data should proceed concurrently with the surface water data evaluation. As shown on Figure 9, evaluation of the groundwater data includes two decision points:

- **During baseflow conditions, is evidence for perched groundwater observed in the soil core?** Soil cores can be obtained during the installation of the piezometers at each monitoring location. If evidence of perched conditions is present in at least one of the cores retrieved during drilling, installation of one piezometer is recommended such that its screen interval monitors the perched zone, and the other piezometer installed such that the base of its screen interval coincides with the bedrock surface. If no evidence of perched conditions is observed, only one piezometer is recommended.
- **During stormflow and non-stormflow conditions, is there evidence of vadose zone saturated flow and/or overland flow and are vadose zone concentrations elevated?** Measurement of the water level and groundwater chemistry within piezometers is recommended during stormflow, and, if sufficient water is present for sampling, non-stormflow conditions. Understanding the

hydrology of the mine site during precipitation events is critical for identifying how contaminants may be transported to the area's streams. Understanding the variable source area of saturation near Dennis and Furnace Creeks during storm events is necessary to characterize the area over which mechanical erosion of the tailings may be occurring. The concentration data from the vadose zone groundwater samples will be compared with background. If mercury concentrations are similar to background, this result would support the CSM. Elevated concentrations suggest potential vadose zone mercury loading to surface water. If mercury loading is confirmed, additional vadose zone characterization sampling, designed in consultation with Region 10, may be necessary to estimate mercury and other metals mass loading to Furnace, Garoutte, and Dennis Creeks.

Saturated Zone Groundwater. Figure 10 shows the recommended data evaluation logic for temporary monitoring well installation and the review of groundwater sampling results. Evaluation of the groundwater data should proceed concurrently with the surface water data evaluation. As shown on Figure 10, evaluation of the groundwater data includes three decision points:

- **Presence of tailings confirmed?** After surface mapping and drive point soil sampling of the Garoutte Creek floodplain, the first decision point seeks confirmation regarding the presence of tailings. If tailings are present, groundwater sampling may partially focus on the tailings areas. If tailings are absent, groundwater sampling should focus on the floodplain areas in close proximity to the Dennis and Furnace Creek valleys. Placement of sampling locations in these areas assumes that a greater bedrock fracture density is present and thus an increased likelihood exists that the groundwater samples from these areas may capture potential groundwater impacts from the BBM Site.

- **What levels of mercury concentration are detected?** After the initial groundwater characterization and collection of the seasonal groundwater grab samples, the total mercury concentration in groundwater should be evaluated relative to the background level. If the mercury concentration in the floodplain groundwater samples is similar to background, the CSM is confirmed (the tailings areas are not significantly contaminating groundwater). If the concentrations are elevated, the groundwater to surface water mercury flux should be calculated.

- **Is the total mercury flux in groundwater elevated compared with the Garoutte Creek total mercury flux?** A "no" result is consistent with the CSM (mechanical erosion of tailings from the Furnace Creek tailings area is the dominant source of mercury loading to Garoutte Creek). A "yes" result is inconsistent with the CSM, as it suggests that mercury contamination in groundwater is a major contributor to mercury loading in Garoutte Creek. If the mass flux is elevated relative to the mercury flux in Garoutte Creek, the groundwater flux may be considered a significant contributor the mercury flux in Garoutte Creek. Given this result, RI data collection and subsequently FS evaluations may need to consider groundwater source mitigation measures. As a result of the challenges associated with characterizing and identifying effective remedial approaches in fractured bedrock terrain such as exists at the BBM Site, Region 10 risk management assessment and decisions would be necessary to identify the appropriate path forward, given this outcome.

4.4.1.5 TAILINGS CHARACTERIZATION

It is recommended that an initial tailings characterization task be performed during the Phase 1 groundwater and surface water characterization sampling events. After the Phase 1 data have been evaluated and the importance of tailings to identified impacts in surface water and groundwater have been considered, higher density sampling of tailings may be considered, particularly in support of identified risk assessment data needs. The objectives of the initial tailings investigation are:

- To establish the relative strength of the correlation between XRF and Lumex field-based metals analysis results with fixed-base laboratory analytical results, and
- To better characterize the thickness and areal extent of tailings in the Furnace Creek Tailings Area.

As data requirements for human health and ecological risk assessment are considered, tailings sampling to address these objectives may be combined or included as a second phase of tailings investigation.

4.4.1.5.1 SAMPLING APPROACH

The recommended tailings sampling approach includes a focused DMA, followed by sampling and analysis for broader site characterization sampling. The DMA can be conducted to establish the relative strength of the correlation between XRF and Lumex field metals analysis with fixed-base laboratory analyses on a set of paired samples. The samples evaluated in the DMA should include tailings and native soil samples across a range of expected concentrations (based on existing data). Data for the DMA can be generated from the tailings and soil sampling components of the groundwater sampling tasks (see Section 4.4.1.4). The project team may choose to focus DMA-related sampling on one or the other of these two media as determined by the data evaluation logic discussed in the next section.

Tailings can be investigated using an adaptive approach in which initial sampling locations for field analyses are selected before field sampling begins and follow-up field sampling locations are selected based on real-time analysis results to target uncertainties or anomalies. The initial tailings sampling locations should be distributed along specific transects so that a broad characterization (including both elevated and low concentrations) of spatial patterns is established for the site. To further address short scale heterogeneity (large differences in concentration in close spatial proximity) at transect points, use of ICS (Appendix A) for fixed-base laboratory analysis or XRF/Lumex field analysis may be performed in a grid configuration around selected transect points.

Alternatively, the combined Furnace Creek and Main Tailings Areas (approximately 27 acres, Figure 2) may be subdivided into decision units (DUs) and ICS conducted on each DU to satisfy general characterization needs and to generate data potentially appropriate for risk assessment purposes. Appropriate DU delineation is critical to the ICS approach. DUs should be defined via the systematic planning process such that risk characterization objectives are achieved with the optimal number of required samples. ICS samples analyzed for fixed base analyses of total mercury, methylmercury, TAL metals, and grain size are recommended.

4.4.1.5.2 DATA EVALUATION

Figure 11 shows the data evaluation logic for tailings characterization. At the decision point, the degree to which the CSM is confirmed by the Phase 2 surface water, sediment, and groundwater data characterization is assessed. If the CSM is supported by this characterization, the DMA and subsequent site characterization can focus on tailings, with soils characterization as a secondary focus. Specifically, the characterization priority should delineate tailings in the Furnace Creek Tailings Area. If the data evaluation does not support the CSM, the DMA and subsequent site characterization activities can focus on soil, with a secondary focus on tailings characterization. Specifically, the characterization priority will be the identification and delineation of contaminated soil areas that are potentially a significant source for the release of mercury from the site.

4.4.1.6 SOIL INVESTIGATION

It is recommended that the soil characterization task be performed following the evaluation of the data generated by the Phase 2 surface water, sediment, groundwater, and tailings characterization tasks. Similar to the tailings characterization, the focus and objective of the soil characterization will depend on how closely the CSM is supported by the data from the other media.

4.4.1.6.1 SAMPLING APPROACH

At a minimum, surface soil samples collected for XRF, LUMEX and fixed-base laboratory analysis in sufficient quantities to meet human health and ecological risk characterization requirements are recommended. Additional sampling may be necessary to characterize potential alternative sources of mercury contamination once data from surface water, groundwater, and sediment are assessed.

Soil sampling can be conducted using an adaptive approach in which initial sampling locations for field analyses are selected before field sampling begins and subsequent field sampling locations use real-time analysis to target uncertainties or anomalies. The initial soil sampling locations can be distributed along specific transects so that broad characterization (including both elevated and low concentrations) of spatial patterns is established for the site. To further address short-scale heterogeneity at transect points, use of ICS (Appendix A) for fixed-base laboratory analysis or XRF/Lumex grids around transect points should be considered.

Alternatively, broad application of the ICS sampling approach may satisfy general characterization needs and generate data potentially appropriate for risk assessment purposes. For the ICS approach, the BBM Site vicinity (Figure 11a) may be defined based on topography and potential for airborne deposition of elemental mercury that may have occurred during ore processing operations. Curtis (2004) collected soil samples from the hillsides adjacent to Black Butte for a soil sampling event that encompassed a several square mile area centered on the BBM Site and determined that mercury concentrations, although below the EPA Region 9 screening level of 23 mg/kg, were comparably more elevated on the hillsides facing Black Butte than facing the opposite direction. The larger of the two areas shown on Figure 11a includes the adjacent hillsides in the general Black Butte vicinity, while the smaller includes the hillsides immediately adjacent to the site. Given the closer proximity to the airborne mercury source, the smaller area (825 acres) may warrant smaller DUs compared with the larger area (2,900 acres). Appropriate DU delineation is critical to the ICS approach. DUs should be defined via the systematic planning process such that risk characterization objectives are achieved with the optimal number of required samples. ICS soil samples should be analyzed via a fixed base laboratory for total mercury, methylmercury, and TAL metals.

Soil column profile sampling may be considered as an approach for delineating OU boundaries for the BBM Site. The BBM was situated in an area in which the local geology is naturally enriched in mercury. Other zones of mercury mineralization likely exist on the adjoining hillsides. Soil sampling can be performed with the aim of distinguishing between mercury sources (natural geologic versus attributable to BBM emissions). One potential approach to meet this objective would be to collect soil samples using a hand-held soil corer. Mercury concentration data from the surface samples and samples from the base of each core could distinguish between areas with only elevated surface mercury concentrations (attributed to atmospheric inputs) versus areas that also, or exclusively, have elevated subsurface concentrations reflecting geologic sources from weathered bedrock. Identifying the zone of contamination attributable to the BBM will assist with delineating the boundaries of the OU containing the mine site.

4.4.1.6.2 DATA EVALUATION

Figure 12 shows the data evaluation logic for soil sampling. Given confirmation of the CSM (that the Furnace Creek Tailings Area is the dominant source for off-site mercury migration), the primary objective of the soil characterization task will be to meet the sampling requirements of the human health and ecologic risk assessments. If the CSM is not supported, the soil sampling may, in addition to meeting the requirements of the risk assessments, also characterize potential alternative sources of mercury contamination, including the soils at the site and on the adjacent hillsides.

4.4.2 RECOMMENDATIONS FOR RI IMPLEMENTATION AT THE CGR

The objectives of the recommended RI characterization activities at CGR are to (1) generate characterization data from various site media (sediment, sediment pore water, surface water) to enable better understand factors controlling the production of methylmercury; (2) establish baseline levels for the representative biota populations; (3) implement ongoing monitoring of the mercury concentrations in the populations should source mitigation measures be implemented; and (4) define the conditions for which follow-up detailed evaluations of various CGR media are appropriate.

4.4.2.1 CGR ENVIRONMENTAL MEDIA CHARACTERIZATION

The collection of water, sediment, and sediment pore water data are necessary to develop an understanding of the factors controlling the production of methylmercury in the CGR. Mercury methylation likely occurs in at least two subareas of the CGR:

- The anoxic water column and deep bottom sediments in the low pool portion of the reservoir, and
- The sediment/wetland areas submerged only during high pool conditions.

Figure 12a shows the proposed sampling locations for the CGR investigation. Sampling approaches for each medium are discussed in the following sections followed by integrated data evaluation logic for all media.

4.4.2.1.1 WATER SAMPLING

It is recommended that CGR water samples be collected and analyzed quarterly for 1 year. Samples may be collected in January and March to reflect low pool and end-of-low pool conditions. Similarly, samples collected and analyzed in July and September would correspond to high pool and end-of-high pool conditions. Methylation is expected to occur in the anoxic, basal layer of water (or hypolimnion) in a thermally stratified lake such as CGR. The surficial, oxygen-enriched layer of water is known as the epilimnion. Accordingly, before the samples are collected, field parameter profiling, including standard field parameters (oxidation-reduction potential [ORP], pH, dissolved oxygen [DO], temperature, and specific conductance [SC]) are recommended to identify the most reducing depth horizon. A water sample collected at each sampling location from both the epilimnion and the hypolimnion layers and analyzed for the parameters indicated below is recommended.

Suggested sample locations include three samples in the low pool portion of CGR and three samples in the portion of the lake that is inundated under high pool conditions. The geospatial coordinates for each sampling point should be identified before the first round of sampling. Samples for all four quarterly sampling events should be collected from a consistent set of locations. During low pool, the three samples reserved for the high pool portion of the CGR should be collected from the CFW River channel flowing through or incised in the lake bottom sediments exposed during low pool. The samples should be spaced such that one is located immediately upstream from the entry point of the river into the exposed lake bottom sediment area, one from mid-way between the first location and the entry point of the river into the low pool, and the third from immediately upstream of the river's entry point into the low pool. The CFW River lake-bottom channel samples will provide an indication of surface water total mercury loading resulting from erosion of the legacy lake bottom sediments.

All samples are recommended for anlaysis of total mercury, dissolved mercury, methylmercury (total), reactive mercury (total), DOC, major ions (including sulfate) and TSS, as well as the above noted standard field parameters.

4.4.2.1.2 SEDIMENT SAMPLING

A two-phased sediment sampling approach consisting of a high pool and a low pool sampling event is proposed. High pool sediments are sediments exposed to the atmosphere during low pool conditions, while low pool sediments are those from the portion of the CGR that is perpetually inundated.

High Pool Sediment Sampling. High pool sampling is recommended to consist of four sampling events over a period of 1 year. The timing of each event should correspond to the shift from high to low pool and low back to high pool. The objectives of the sampling are to assess sulfide and sulfate cycling as a function of pool level and to obtain data regarding the timing and significance of methylation processes in the high pool sediments. The first sampling event should be performed within 1 week after low pool conditions have been established. The second event is recommended to be performed approximately 1 month after the first event. Likewise, the third event would be performed within 1 week after high pool is established, and the fourth performed 1 month after the third event.

Sampling is recommended at eight locations, evenly distributed across the high pool sediment area. The geospatial coordinates for each sampling point should be identified before the first sampling event. Samples for all four events should be collected from a consistent set of locations Samples can be collected from the surface to a depth of 2 to 4 inches using a stainless steel spoon (low pool time) or a petite Ponar dredge sampler (high pool time). Figure 12b provides a description of the petite Ponar dredge sampler.

The samples recommended for analysis include total mercury, methylmercury, reactive mercury, total organic carbon (TOC), sulfate, and sulfide.

Low Pool Sediment Sampling. Low pool sampling is recommended to consist of two events performed over a period of 1 year. One sampling event should be performed 1 month after low pool is established and the other performed 1 month after water levels are reset at high pool. An objective of the sampling is to obtain preliminary data describing the timing and significance of methylation in the low pool sediments.

Sampling is recommended at eight locations, evenly distributed across the low pool area. The geospatial coordinates for each sampling point should be determined before the first sampling event. Samples for both events should be collected from a consistent set of locations. Samples can be collected from the surface to a depth of 2 to 4 inches using a petite Ponar dredge sampler (high pool time).

The samples should be analyzed for the same parameters specified above for the high pool sediment samples.

4.4.2.1.3 SEDIMENT PORE WATER SAMPLING

Pore water samples collected from the top few inches of sediment will provide constituent concentration data from the shallow sediment zone, which is prime habitat for methylating bacteria. Similar to the collection of sediment samples, a two-phased sediment pore water sampling approach consisting of a high pool and a low pool sampling event is proposed. In situ pore water samples may be collected by pushing a slotted stainless-steel drive point into the sediment to a depth of approximately 2 inches below the lake bottom. A circular, stainless steel flange welded to the drive point can be used to control depth of penetration and to restrict the entry of surface water. Figure 12c shows an example sediment pore water sampling tool. Other methods may also be identified as appropriate for pore water collection.

High Pool Sediment Pore Water Sampling. The recommended high pool sampling approach consists of two events timed to coincide with the high pool conditions. The objectives of the sampling are to assess sulfide and sulfate cycling as a function of pool level and to obtain data regarding the timing and significance of methylation processes in the high pool sediments. The first sampling event is recommended within 1 week after high pool conditions are established. The second event is recommended approximately 1 month after the first event.

Sampling is recommended for the eight locations used to collect the high pool sediment samples. The recommended analyte list includes total mercury, dissolved mercury, methylmercury, reactive mercury, DOC, sulfate, and sulfide as well as the above noted standard field parameters.

Low Pool Sediment Pore Water Sampling. Low pool sampling is recommended to consist of two events performed over a period of 1 year and during the same event as the low pool sediment sampling task discussed above. As such, one event will be performed 1 month after low and high pool conditions are established. An objective of the sampling is to obtain preliminary data describing the timing and significance of methylation in the low pool sediments.

Sampling is recommended for the eight locations used to collect the high pool sediment samples. The recommended analyte list includes dissolved mercury, methylmercury (dissolved), reactive mercury (dissolved), and DOC.

4.4.2.1.4 ENVIRONMENTAL MEDIA DATA EVALUATION

The proposed sampling approach is intended to provide the basis for evaluating the sources of dissolved mercury and methylmercury to CGR and the locations where methylation processes are active in the water body. The data generated across the three media included in the CGR characterization can be evaluated using differing logic and objectives. The approaches described in this section include the evaluation of methylation in the low pool sediments and water column and in the high pool sediments.

Low Pool Sediment Evaluation. Figure 13 shows the logic for evaluating methylation in the low pool sediments and water column. With surface water, low pool sediment, and low pool sediment pore water data as inputs, the diagram includes three decision points. The following discussion pertains to sediment and sediment pore water samples collected from sampling locations defined at low pool. As such, note that "methylmercury concentrations during high pool period" refers to sampling results obtained from the low-pool-defined sampling points under high pool conditions.

- **Are methylmercury concentrations elevated?** The surface water, sediment, and sediment pore water methylmercury concentrations are compared with an appropriate background level or published standard (such as SQuiRT). If methylmercury concentrations are not elevated in these media, the methylation in the low pool sediments is unsubstantiated, given the available data set.

If methylmercury concentrations are elevated, methylation is likely occurring in the low pool sediments and water column.

- **Are methylmercury concentrations measured during the high pool period elevated relative to methylmercury concentrations measured during the low pool period?** Given that water column stratification is likely more dominant under the high pool summer months relative to the low pool winter months, anoxic conditions and, therefore, methylation processes are expected to be most active under high pool conditions. Therefore, a "yes," at this decision point suggests that methylation is most actively occurring during high pool.

- **Is total mercury elevated in the downstream portion of the CFW River lake bottom channel relative to the CFW River entry point to CGR?** A "yes" suggests that the CFW lake bottom channel is actively eroding and mobilizing elevated total mercury concentration sediments before it discharges to low pool. A "no" indicates that the eroded sediment is not significantly increasing the total mercury load in the channel.

High Pool Sediment Evaluation. Figure 14 shows the logic for evaluating methylation in the high pool sediments. With surface water, high pool sediment, and high pool sediment pore water data as inputs, the diagram includes three decision points.

- **Are methylmercury concentrations in sediments and sediment pore water elevated at the end time relative to the start time of high pool?** A "yes" indicates that methylation processes are active in the high pool. At the start of high pool, sulfate concentrations should approximate concentrations in CFW River and methylmercury concentrations should be low. After an extended period (1 month), anoxic conditions should exist in the sediments and methylmercury concentrations will likely show an increase. A "no" indicates that active methylation processes in the high pool sediments are unsubstantiated.

- **Is methylmercury elevated in the downstream portion of the CFW River lake bottom channel relative to the CFW River entry point to CGR?** A "yes" indicates that some high pool sediments exposed during low pool conditions are anoxic and contribute methylmercury to the CFW River before it discharges to the low pool or that active methylation is occurring in the channel itself.

- **Do sulfate concentrations in high pool sediment/sediment pore water increase from the start time to the end time of low pool?** A "yes" indicates that after exposure of the high pool sediments, sulfide is oxidized to sulfate thus generating a necessary compound for the occurrence of mercury methylation and thus providing evidence for sulfate cycling in the high pool sediments.

4.4.2.2 CGR Biota and Mercury Influx Characterization

In addition to environmental media characterization, it is also recommended that baseline total mercury concentrations be characterized in indicator fish species and the baseline mercury influx (total, dissolved, and methylated) (see Figure 15). Baselining these parameters will provide levels that can be used to compare future analytical results to gauge the effectiveness of any source mitigation or reservoir managment measures that have been implemented at the BBM and CGR. Once source mitigation measures are implemented, harvesting, and analysis of an appropriate fish species and determination of the mercury influx on an on-going basis is recommended to evaluate any potential reductions achieved.

Continuation of the influx measurements associated with the current USGS investigation may be an appropriate approach for monitoring CGR mercury loading on an ongoing basis.

4.4.2.2.1 DATA EVALUATION

Figure 15 shows the data evaluation logic for the recommended environmental sampling at CGR. An explanation of the various decision points follows:

- **Are fish tissue total mercury concentrations greater than established fish consumption advisories for the area?** This decision applies following the collection of fish tissue from a range of trophic levels. A sufficient number of fish (as determined by human health and ecological risk assessment needs) can be harvested over a range of size classes. From this data, a regression can be developed of fish mercury concentration versus fish length. Numerous studies have shown that fish mercury concentrations increase with fish length. Assuming that mercury concentration is correlated with fish length, the mercury concentration of typical size classes of fish that humans consume from the lake can be identified and evaluated against fish consumption guidelines.

- **Are aquatic tissue total mercury concentration levels related to trophic position?** The anticipated condition is that mercury concentrations in fish tissue increase with trophic level. If this condition is verified, evidence exists that methylmercury is entering the reservoir food web through the base level. To evaluate effectiveness of any remedial actions taken at BBM or CGR, a baseline can be established for low trophic level species, which should respond earlier than higher level species. However, in recognition of public and human health concerns, a mercury level baseline may also be established in high trophic level sport fish. If mercury concentration levels in fish tissue are unrelated to trophic level, this result suggests fish uptake mercury by an undefined process or that trophic level sampling results are unrepresentative of the actual conditions. Given this result, ongoing fish tissue monitoring should proceed using a species selected based on professional judgment.

- **Does the CGR mercury mass balance suggest a downward trend in resident total and methylmercury mass in CGR?** At this decision point, it is assumed that source mitigation measures have been implemented (either at the site or in the CGR) and that the CGR mercury influx monitoring is ongoing. If the mercury influx monitoring indicates that the mercury influx is trending downward, the potential exists that mercury concentrations in fish tissue are also trending downward and the potential for rescinding the consumption advisory can be considered. If the methylmercury mass is stable or increasing, the development of a CGR characterization plan should be considered, with the initial focus on evaluating methylation processes in the sediments and the anoxic water column.

- **Do the aquatic tissue concentration trends and the CGR mass balance results merit consideration of the planning of a CGR environmental media investigation?** Given that sufficient aquatic tissue and mercury mass balance data have been collected for meaningful trend analysis, this decision point seeks to determine whether to continue fish tissue and mercury influx sampling or initiate planning for a more intensive reservoir characterization effort that would include sediment and other media. If downward trends are observed in the mercury concentrations in fish tissue and influx data, but additional sampling is needed to confirm these trends, then sampling aquatic tissue and CGR mercury mass fluxes should continue. If trends are stable or increasing, then, in addition to the continuation of the aquatic tissue and CGR mercury mass balance sampling, additional reservoir characterization to evaluate the factors controlling methylation can be considered.

4.4.2.3 CGR Sampling Sequencing

CGR sampling is proposed to occur in two phases that can be conducted independent of the BBM Site investigations discussed in Section 4.4.1. However, conducting the CGR investigations coincident with the BBM Site investigations is recommended so that all data are contemporaneous, thus facilitating potential co-analysis and preserving project resources. The first CGR sampling phase includes one-time sampling associated with the investigation of environmental media to evaluate the factors controlling the production of methylmercury (Section 4.4.2.1 sampling tasks). The second phase includes recurring sampling associated with establishment of baseline mercury concentrations in biota and surface water inflow to the CGR (Section 4.4.2.2 sampling tasks).

Section 4.4.2.1 One-Time Sampling Tasks. The environmental media sampling tasks discussed in Section 4.4.2.1 are timed to coincide with the establishment of high and low pool levels. It is recommended that all sampling tasks proposed in Section 4.4.2.1 be performed in the same calendar year. The proposed surface water sampling should occur on a different schedule than sediment and sediment pore water sample collection. Surface water sampling should occur in January and March for low pool conditions and in July and September for high pool conditions. The proposed sediment and sediment pore water sampling should occur within 1 week of a change in pool level (estimated as the end of October for high pool and the end of March for low pool) and 1 month after the first event for the given change. To facilitate data comparability, these two media should be sampled together in each sampling event, with sediment pore water sampling first, followed by sediment sampling.

Section 4.4.2.2 Recurring Sampling Tasks. It is recommended that sampling to establish baseline concentrations in biota and surface water inflow to the CGR proceed at the earliest opportunity in the RI. These tasks are recurring, with no specific end time specified in this review. To facilitate comparability with potential future CGR sampling events, it is further recommended that the Section 4.4.2.1 environmental media sampling tasks be timed to occur after the baseline sampling begins.

5.0 FINDINGS

The findings in this section are the combined interpretations of the optimization review team based on historical information and data review, a site visit conducted on January 10, 2012, and SPP efforts conducted with team members January 9 and 11, 2012. These findings are not intended to imply a deficiency in the any of the previous characterization work, or the RA performed, but are offered as constructive, forward looking suggestions in the best interest of Region 10, the public, ODEQ, and other stakeholders. These observations also have the unique benefit of being formulated based on the collection of additional data after the RA.

The mercury contamination concerns associated with the site include human and ecologic exposure to mercury in soil and tailings at the site and the off-site migration of mercury with potential to bioaccumulate in the tissues of fish inhabiting the downstream surface water features, including CGR. Findings viewed by the optimization review team as significant to defining the optimal approach for conducting the RI are presented first for the BBM Site and vicinity, followed by the findings for CGR. These findings are provided in addition to the data gaps identified in for the BBM Site and CGR in Section 4.3.

Key findings related to the BBM Site and vicinity include:

- During the site visit, the optimization review team noted very steep terrain (see photograph log prepared by Tetra Tech, 2012, Appendix A), evidence of flood and mechanical erosion events, and the presence of significant tailings in Furnace Creek. Historical data (EPA 2008) also indicate the presence of higher concentrations (EPA 2008) and more bioavailable forms (Ecology and Environment 2006) of mercury occurring in this drainage.

- A post-RA surface water loading assessment (Thoms 2008) suggests that the transport of suspended solids containing mercury appears to be the primary mode of mercury transport from the site. Based on one sampling campaign during non-storm conditions, the assessment estimates that Furnace Creek could contribute between 50 and 75 percent of the mercury load in the CFW River. Re-calculation of this value by the optimization review team suggests that contribution may be lower (26 to 59 percent); however, it still represents a potentially significant source.

- Although the available data indicate that the mercury present in site tailings generally occurs in insoluble forms that are not readily leached and methylated, these conclusions are based on a relatively small number of samples (six or fewer, depending on the analysis) with detection limits that are several orders of magnitude above environmentally relevant concentrations. Since nearly all of the tailings are underlain by bedrock, collection of a groundwater sample beneath the tailings at the site may be problematic for achieving this objective because of the challenges associated with drilling in bedrock and the uncertainties regarding groundwater flow patterns in fractured bedrock.

- During the site visit, the caretaker of the site and a former BBM worker (Mr. Michael Pooler) identified a portion of the Garoutte Creek floodplain where tailings were historically stockpiled. Groundwater sampling beneath and adjacent to tailings and at locations where groundwater may enter surface water features may provide justification for removal of the groundwater medium from further consideration in the RI. If groundwater sampling indicates leaching is occurring at concentrations and fluxes of concern, consideration of additional groundwater characterization options may be warranted.

- SSE analysis of the soil samples collected from the ridge tops and hillsides in the vicinity of the site indicated that less than 20 percent of the mercury contained in these samples was present in relatively insoluble mercuric sulfide forms, and 44 to 87 percent of mercury was complexed with organic matter. The organic matter-complexed forms are more readily converted to methylmercury. These sampling results suggest that, in addition to contributions from the site, soil erosion and surface water transport and groundwater discharge from nearby hillsides (potentially previously contaminated by site mining operations through the deposition of elemental mercury) may also be a source of mercury to surface water.

- Historical data indicate the presence of potential mercury impacts in surface water sediments from the site downstream to CGR. The mercury contribution of this material present in surface water body sediments versus the flux of new fined grained material with elevated mercury from BBM is not well understood.

- The pH of the groundwater discharging to two of the mine adits visited during the site visit was in the neutral range, suggesting the general absence of acid mine drainage impacts at the site.

Key findings that relate to CGR include:

- Surface water reservoirs in areas without mercury mining are known to contain fish with elevated mercury levels in their tissue. Atmospheric deposition from the global mercury pool is believed to be the source of this mercury. This source is likely responsible for some of the CGR mercury burden. Neighboring Dorena Reservoir, with no known mercury mines in its watershed, contains fish with elevated mercury in their tissue, although at lower concentration levels compared with CGR. Given that one of the sources of mercury to CGR is deposition from the global mercury pool, reductions in mercury concentrations in fish tissue may be limited to some baseline level that reflects this ongoing source. Whereas controlling atmospheric sources is well beyond the scope of this project, management actions occurring locally within the CGR watershed (for example, forestry operations) and within CGR itself (such as changes in water level) can be important in affecting the amount of atmospheric mercury that accumulates in fish tissue.

- Analysis of mercury transformation processes in CGR requires a detailed evaluation of all mercury complexes and rate limiting constituents (organic carbon and sulfate). Conclusions from such an undertaking would require significant extrapolation and inferences from a limited spatial and temporal data set. In addition, any mass balance determination will be subject to uncertainties regarding atmospheric deposition, watershed contributions, and internal methylation and demethylation processes operating within the CGR.

- The mercury profiles in the available sediment cores from CGR indicate that significantly elevated mercury concentrations are present in the sediments deposited up to 40 years ago. As observed during the site visit, sediment exposed in the shallow portions of the reservoir during low pool periods is actively being eroded by the CFW River and deposited in the low pool. The eroded sediment includes the sediment with elevated mercury concentrations deposited decades ago. The remobilization of mercury by CFW River erosion of older, legacy sediments exposed during low pool may be an important ongoing source of mercury to the reservoir.

- Direct determination of the contribution of mercury from the site to CGR would require the quantification of mercury fluxes to CGR and the collection of mercury speciation data to define the key mercury methylation processes that occur in the reservoir. In addition, any mass balance determination will be subject to uncertainties regarding the significance of atmospheric deposition or other watershed contributions. Development of a detailed mercury mass balance for the reservoir and definition of the important methylation processes may require time and resources beyond the scope of the current RI.

- Although uncertainties exist regarding the factors controlling the net mercury methylation rate in the CGR, methylmercury generation generally requires the presence of three constituents: mercury in a bioavailable form, microbial labile organic carbon, and sulfate. Methylating bacterial processes typically involve the reduction of sulfate to sulfide. Once all sulfate has been converted to sulfide, or the supply of mercury in a bioavailable form or microbial labile organic carbon is exhausted, the bacteria become dormant and methylation ceases. Assuming relatively abundant organic carbon and mercury, sulfate availability may be the likely rate limiting constituent for the methylation process. Organic carbon and bioavailable mercury may also play a role in limiting methylation. If data collection indicates sulfate is the rate limiting factor, a potential approach for limiting mercury methylation processes in CGR is to permanently increase the reservoir's operating level. It is recognized that USACE would allow this action only if a proper balance of other management priorities for the CGR can be achieved. By increasing the reservoir's operating level, sulfate concentrations (and as a result methylation rates) may be reduced because sulfide would not be recycled and fresh sulfate inputs would be limited only to those from atmospheric and watershed inputs. Perhaps more importantly, permanently raising the reservoir level would essentially eliminate the erosion and remobilization of historical sediments with elevated mercury concentrations that has been ongoing over the years during low pool conditions.

- Review of the available data for mercury concentration in fish tissue for CGR suggests that even if only a small fraction of the total mercury is present in dissolved phase, sufficient mercury methylation will occur to result in elevated mercury in fish tissue. Based on existing data, calculations by the project team indicate that the percentage of total mercury that is methylated in CGR water is only 6 percent. In sediments, the percentage is only 0.1 percent. These low levels are apparently sufficient to support methylation.

6.0 RECOMMENDATIONS

The purpose of this optimization review was to evaluate site conditions and identify optimal approaches for conducting an RI of the site. The recommended sampling approach and data evaluation objectives were presented in Section 4.3. This section summarizes the key recommendations reflected in the proposed media characterization approaches, first for the BBM Site followed by the CGR. Note that while the recommendations provide some details to consider during RI work plan preparation, they are not intended to replace the RI work plan or other more comprehensive planning documents.

Recommendations for the BBM portion of the RI include:

- A major objective to consider for the BBM RI is an improvement of the understanding of the mercury flux (total, dissolved, methylated) from BBM Site environmental media to Furnace, Dennis, and Garoutte Creeks and to evaluate the mercury flux from Garoutte Creek to downstream surface water features including CFW River and CGR. Consistent with this objective, quarterly analysis for mercury and metals during storm and non-storm events with coincident measurement of storm and non-storm stream flow discharge is recommended. This data will provide the foundation for determining the important pathways for the release of mercury from the site and quantify the site contributions to the downstream mercury load for each of the three site creeks. Installation of weirs or use of direct measurement techniques for gauging flow in Furnace, Dennis, and Garoutte Creeks should be considered.

- Limited, existing data suggest that site groundwater concentrations are not altered by mercury and other metals leaching at elevated concentrations from site tailings. To understand whether leaching is occurring at lower (but still environmentally relevant) levels, groundwater samples should be collected from saturated native alluvial sediments underlying site tailings. Since nearly all of the tailings are underlain by bedrock and the water table occurs within the bedrock, collection of a groundwater sample beneath the tailings piles at the site is complicated by the practical challenges that exist in accurately sampling fractured bedrock groundwater. During the site visit, a portion of the Garoutte Creek floodplain adjacent to BBM was identified as a potential location for historical tailings storage/disposal. Assuming that the floodplain is underlain by unconsolidated materials, this potential tailings area provides an opportunity for assessing possible impacts to groundwater from tailings leachate. Based on the ground elevation relative to Garoutte Creek and the relatively broad floodplain in the vicinity, the water table likely occurs in unconsolidated material and should be easily accessible using a drive point sampling approach. The presence or absence of tailings in the area could not be confirmed during the site visit because of the thick vegetation.

- If BBM environmental media, and Furnace Creek tailings in particular, are not found to provide major contributions to the introduction of new mercury and trace metal contamination in Garoutte Creek, the project team may consider increased sediment sampling in Garoutte Creek and sediment sampling in CFW River to further assess the contribution of historical sediments to methylmercury in surface water and CGR fish tissue. If appropriate, the additional sediment sampling and analysis may be combined with human health or ecological risk exposure assessments.

- A DMA analysis is recommended for XRF and Lumex field-based metals analysis. Results of this analysis can be used to assess confidence in RA characterization results and the utility of field-based methods for metals analysis during the RI. Similarly, the results can be used to establish correlations between methods necessary to provide appropriate confidence in field screening tools and develop field based action levels for these tools. The resulting action levels will provide high confidence in clean/dirty decisions or can indicate where the collection of collaborative laboratory data would be most beneficial.

Recommendations for the CGR RI:

- Development of the data necessary to understand the source of methylmercury in CGR fish tissue requires investigation of the major sources of mercury mass influx to the reservoir (in addition to the current contribution from BBM) and of the factors controlling the availability of the rate-limiting constituents (dissolved mercury, organic carbon, and sulfate). The annual cycling of the CGR water level between low and high pool and the potential release of mercury through CFW River erosion of legacy sediments with elevated mercury concentration during low pool will complicate the investigation effort. In light of the technical, administrative, funding, and schedule challenges, it may prove beneficial for Region10 to consider conducting activities at BBM and CGR as separate OUs.

- A major objective to consider for the CGR RI is the establishment of baseline mercury concentration levels in fish tissues and of the influx of mercury (total, dissolved, and methylated) to the reservoir. It is recommended that mercury in fish tissue be monitored on an annual basis and that both game species and species at the base of the food web be included. The collection of fish tissue and mercury influx data will provide the basis for assessing the effects of any mitigation efforts at the BBM Site or in CGR itself.

- Consideration should be given to the generation of analytical data from the various CGR environmental media to enable a preliminary assessment of the factors controlling methylmercury generation. These efforts may include the collection and analysis of quarterly or semiannual surface water, sediment, and sediment pore water samples. Specific objectives of this sampling would include acquiring evidence to confirm the existence of sulfate cycling in the high pool sediments and assessing potential temporal variation in the methylation process.

6.1 Comparison of Recommendations to Traditional Optimization Focus Areas

As discussed in Section 1.0, optimization review recommendations have traditionally been provided to maximize protectiveness, cost-effectiveness, technical merit, and closure efficiency while minimizing the environmental footprint of sites with planned or operating remedies. For sites that are in the RI phase (such as BBM), potential or likely remedy options are presently not well understood. The goal for optimizing sites in this phase is to provide a framework for planning an optimal RI focusing on CSM refinement, sequencing of activities to identify contaminants and pathways of greatest concern, and collection of data for risk assessment.

To the extent practical, this section compares the recommendations with each of the traditional optimization focus areas.

- **Protectiveness.** While not specific to remedy protectiveness, the recommendations provided in this document are based on refinement of the CSM to provide a basis for designing an effective

RI. RI goals are to determine site risks, and as applicable, support the evaluation and selection of an appropriately protective remedy. Recommended sampling and sequencing are provided to identify dominant controls on the release and transport of mercury and metals from the site to nearby surface water bodies, including CGR. Recommendations for sequencing and applying an effective characterization for surface water, groundwater, sediment, tailings, and soil are provided as a means to offer an accurate identification of fate and transport issues necessary for the selection and design of appropriately protective remedies. The data collection framework and accompanying decision logic enable the collection of important human health and ecological risk data. The logic seeks to ensure that all potentially specific site pathways are considered.

- **Cost-effectiveness.** The recommended framework maximizes the use and value of data and other results from previous site investigations and removal actions to form a CSM for both the site and the CGR. The recommended sampling approach uses prioritized sampling results to address critical data gaps and provides the ability, as necessary, to react dynamically to site conditions identified during initial surface water, groundwater, and sediment sampling. The scale of hillside soil sampling, site soil, and tailings sampling can be optimized based on estimated contributions of these media to contaminant flux in surface water features. Optimization supports improved cost effectiveness of sampling. The recommended sampling approach also seeks to establish baseline conditions in the CGR, while defining the requisite conditions for when a more intensive investigation of CGR may be appropriate.

- **Technical merit.** The recommendations establish an adaptive framework for the investigation. As a result, the potential for expenditure of time and resources on non-critical portions of the site or specific constituents should be minimized. In addition, in accordance with investigation BMPs, sampling logistics, schedule and locations can be optimized to maximize resources and limit site mobilizations. For example, groundwater seasonal grab sampling can coincide with planned storm and non-storm seasonal surface water and sediment sampling. Similarly, soil sampling locations can be assessed and refined in the field based on real-time field analysis, such as XRF measurements. Use of real-time measurement technologies such as XRF and Lumex can beneficially increase data density while optimizing sampling for ecological and human health risk assessments.

- **Site closure.** The recommendations define an RI framework for accurately identifying the key factors controlling the release of site constituents and, thus, may lead to the effective design of appropriate mitigation measures and efficient site closure. Similarly, timing, milestones, budget, and logistics may make it administratively attractive to separate activities at the site and CGR into multiple OUs.

- **Environmental footprint reduction.** Traditional footprint considerations for optimization remedy reviews focus on energy use, water use, and other factors that may significantly influence the project footprint. For investigation stage optimization reviews, footprint reduction should focus on use of energy efficient and low emission equipment, minimizing investigation-derived waste, and use of field and mobile laboratory services. Recommendations for the site and CGR are focused on closing data gaps in the understanding of the release and transport of site constituents and in the needs for assessing site risks. A fact sheet describing best practices for consideration of green remediation principles for investigation activities can be found at www.clu-in.org/greenremediation/docs/GR_Fact_Sheet_SI_12-31-2009.pdf.

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TABLES

Table 1 - Screening Levels Referenced in Previous Investigations

PART 1 - GENERIC MEDIA-SPECIFIC[1]				
Waste Rock/Tailings/Soil			Total Mercury	Total Arsenic
Environmental Protection Agency Region 9 PRGs	Residential Soil	mg/kg	23	0.39
Environmental Protection Agency Region 9 PRGs	Industrial Soil	mg/kg	310	1.6
Oregon DEQ Maximum Allowable Soil Concentrations	Residential Soil	mg/kg	80	0.4
Oregon DEQ Maximum Allowable Soil Concentrations	Industrial Soil	mg/kg	600	3
Sediment			Total Mercury	
National Oceanic and Atmospheric Administration SQuiRT – TEL	Sediment	mg/kg	0.174	
National Oceanic and Atmospheric Administration SQuiRT – PEL	Sediment	mg/kg	0.486	
Oregon DEQ Level II Screening Level Values - Plants	Soil	mg/kg	0.3	
Oregon DEQ Level II Screening Level Values - Invertebrates	Soil	mg/kg	0.1	
Oregon DEQ Level II Screening Level Values - Birds	Soil	mg/kg	1.5	
Oregon DEQ Level II Screening Level Values - Mammals	Soil	mg/kg	73	
Surface Water			Total Mercury	
EPA National Recommended Water Quality Criteria (Freshwater CMC)	Water	µg/L	1.4	
EPA National Recommended Water Quality Criteria (Freshwater CCC)	Water	µg/L	0.77	
Oregon DEQ Level II Screening Level Values - Aquatic	Water	µg/L	0.77	
Oregon DEQ Level II Screening Level Values - Birds	Water	µg/L	3,300	
Oregon DEQ Level II Screening Level Values - Mammals	Water	µg/L	10,000	
Leachate			Mercury	
Oregon DEQ Leachate Reference Concentration	Leachate	mg/L	0.2	
Waste Rock/Tailings/Soil			Methylmercury	
Environmental Protection Agency Region 9 PRGs	Residential Soil	mg/kg	6.1	
Environmental Protection Agency Region 9 PRGs	Industrial Soil	mg/kg	6.2	
Oregon DEQ Level II Screening Level Values – Plants	Soil	mg/kg	0.0002	
Oregon DEQ Level II Screening Level Values - Invertebrates	Soil	mg/kg	—	
Oregon DEQ Level II Screening Level Values – Birds	Soil	mg/kg	0.025	
Oregon DEQ Level II Screening Level Values - Mammals	Soil	mg/kg	4	
PART 2 - SITE-SPECIFIC ACTION LEVELS USED DURING THE REMEDIAL ACTION BLACK BUTTE MINE REMOVAL ASSESSMENT[2]				
Waste Rock/Tailings/Soil	Area	Unit	Total Mercury	
Environmental Protection Agency Region 9 PRGs	Old Ore Furnace Area	mg/kg	23	
Oregon DEQ Maximum Allowable Soil Concentrations	New Furnace Area/Main Tailings Pile	mg/kg	115	
Oregon DEQ Maximum Allowable Soil Concentrations	Dennis Creek	mg/kg	10	

Key:
- PRGs = Preliminary Remediation Goals
- DEQ = Department of Environmental Quality
- mg/kg = milligrams per kilogram
- SQuiRT = Screening Quick Reference Tables
- PEL = probable effects level
- TEL = threshold effects level
- CMC = Criteria Maximum Concentration
- CCC = Criterion Continuous Concentration
- µg/L = micrograms per liter

1 *Ecology and Environment, Inc., 2006*
2 *Region 10, 2008*

Table 2 - Summary of Proposed Sampling

CSM Element	Media	Report Section	Proposed Sampling Approach Summary (Fixed-Base Laboratory)	Proposed Analytes
BBM	Surface Water, vadose zone groundwater, and precipitation	4.4.1.2	Phase 1 (Storm event hydrograph Sampling) Estimate 30 total samples, 3 locations; 2 storm events; grab; plus precipitation	HgT, HgD, MeHg (total), MeHg (dissolved), HgR (total), Tal metals (total), DOC, TSS, pH, common ions
			Phase 1 Vadose zone groundwater sampling associated with storm event hydrograph sampling 24 total samples, 8 locations	HgD, MeHg (dissolved), HgR (dissolved), TAL metals (dissolved), pH, DOC, common ions
			Phase 2 64 total samples: 8 locations; quarterly – storm/non-storm; grab	HgT, HgD, MeHg (total), MeHg (dissolved), HgR (total), HgR (dissolved), TSS, pH, DOC and common ions
BBM	Dennis, Furnace, Garoutte Creek Sediment	4.4.1.3	64 total samples: 8 locations; quarterly – coinciding with surface water sampling events; combination: incremental composite	HgT, MeHg, TAL metals, TOC, grain size
BBM	Groundwater (and tailings during piezometer installation) Vadose Zone (Unconsolidated Material)	4.4.1.4	Phase 1 Tailings Estimate 8 samples, drive point grab	HgT and TAL metals
			Phase 2 Groundwater 72 total samples: 9 locations; quarterly – coincide with surface water sampling events; grab (vadose zone piezometers)	HgD, MeHg (dissolved), HgR (dissolved), TAL metals (dissolved), DOC, pH, and common ions
BBM	Groundwater Saturated Zone (Unconsolidated Material)	4.4.1.4	Phase 1 Groundwater 16 total samples: 16 drive point locations; grab	HgD, MeHg (dissolved), HgR (dissolved), DOC, pH, and common ions
			Phase 1 Soil/Tailings Estimate 16 samples, drive point grab	HgT and TAL metals
			Phase 2 Groundwater 36 total samples: 9 locations; quarterly – coincide with surface water sampling events; grab (temporary monitoring wells)	HgD, MeHg (dissolved), HgR (dissolved), DOC, pH, and common ions
BBM	Groundwater Saturated Zone (Bedrock)	Not Evaluated[1]	Potential RFI task: resample the 11 bedrock monitoring wells that were sampled for TAL metals by Ecology and Environment (1998)	HgD, MeHg (dissolved), HgR (dissolved), DOC, pH, and common ions
BBM	Tailings	**4.4.1.5**	See Phase 1 vadose zone (tailings sampling) and Phase I saturated zone (soil/tailings sampling), Section 4.4.1.4	HgT and TAL metals
			ICS sample count dependent on number of DUs and other ICS parameters that require stakeholder input	HgT, MeHg TOC, TAL metals, grain size

Table 2 - Summary of Proposed Sampling (Continued)

CSM Element	Media	Report Section	Proposed Sampling Approach Summary (Fixed-Base Laboratory)	Proposed Analytes
BBM	Hill Slope Soil	4.4.1.6	ICS sample count dependent on number of DUs and other ICS parameters that require stakeholder input	HgT, MeHg, TOC TAL metals
BBM	Garoutte Creek Fish	Not Evaluated	Approximately 10 fish per species representing a range in size classes	HgT, plus carbon and nitrogen stable isotopes
CFW River	Surface Water	Not Evaluated	Sufficient number of samples to quantify variability; grab. Include background location from Big River.	HgT, MeHg (total), HgR (total), , TSS, DOC, and common ions
CFW River	Sediment	Not Evaluated	Sufficient number of samples to quantify variability; ICS. Include background location from Big River.	HgT, MeHg, TAL metals, grain size
CFW River	Fish	Not Evaluated	Sufficient number of samples to quantify variance and seasonable variability. Include background sampling from Big River.	HgT plus carbon and nitrogen stable isotopes
CGR	Surface Water	4.4.2.1.1	48 total samples : 6 locations; 2 sample depths per location (epilimnion and hypolimnion) quarterly – low pool/high pool; grab	HgT, HgD, MeHg (total), HgR (total), DOC, common ions (including sulfate), sulfide, pH and TSS
CGR	Sediment	4.4.2.1.2	High Pool 32 total samples, 8 locations, 4 sampling events, grab	HgT, MeHg, sulfate, sulfide, TOC
			Low Pool 16 total samples, 8 locations, 2 sampling events, grab	HgT, MeHg, sulfate, sulfide, TOC
CGR	Sediment Pore Water	4.4.2.1.3	High Pool 16 total samples, 8 locations, 2 sampling events, grab	HgD, MeHg (dissolved), HgR (dissolved), DOC, sulfate, sulfide, pH,
			Low Pool 16 total samples, 8 locations, 2 sampling events, grab	HgD, MeHg (dissolved), HgR (dissolved), DOC, sulfate, sulfide, pH,
CGR	Fish	4.4.2.2	8 sport fish /year 8 lower trophic /year	HgT, plus carbon and nitrogen stable isotopes
CGR	Surface Water	4.4.2.2	Annual Inflow Monitoring 40 total samples, quarterly for estimated 10 years	HgT, MeHg (total), TSS, DOC

1. Sampling for this media was not evaluated in this review.

Key:

BBM = Black Butte Mine
CGR = Cottage Grove Reservoir
DOC = Dissolved organic content
HgD = Dissolved phase mercury
HgT = Total mercury
HgR = Reactive mercury
MeHg = Methylmercury
TAL = Target analyte list
TOC = Total organic carbon
TSS = Total suspended solids

FIGURES

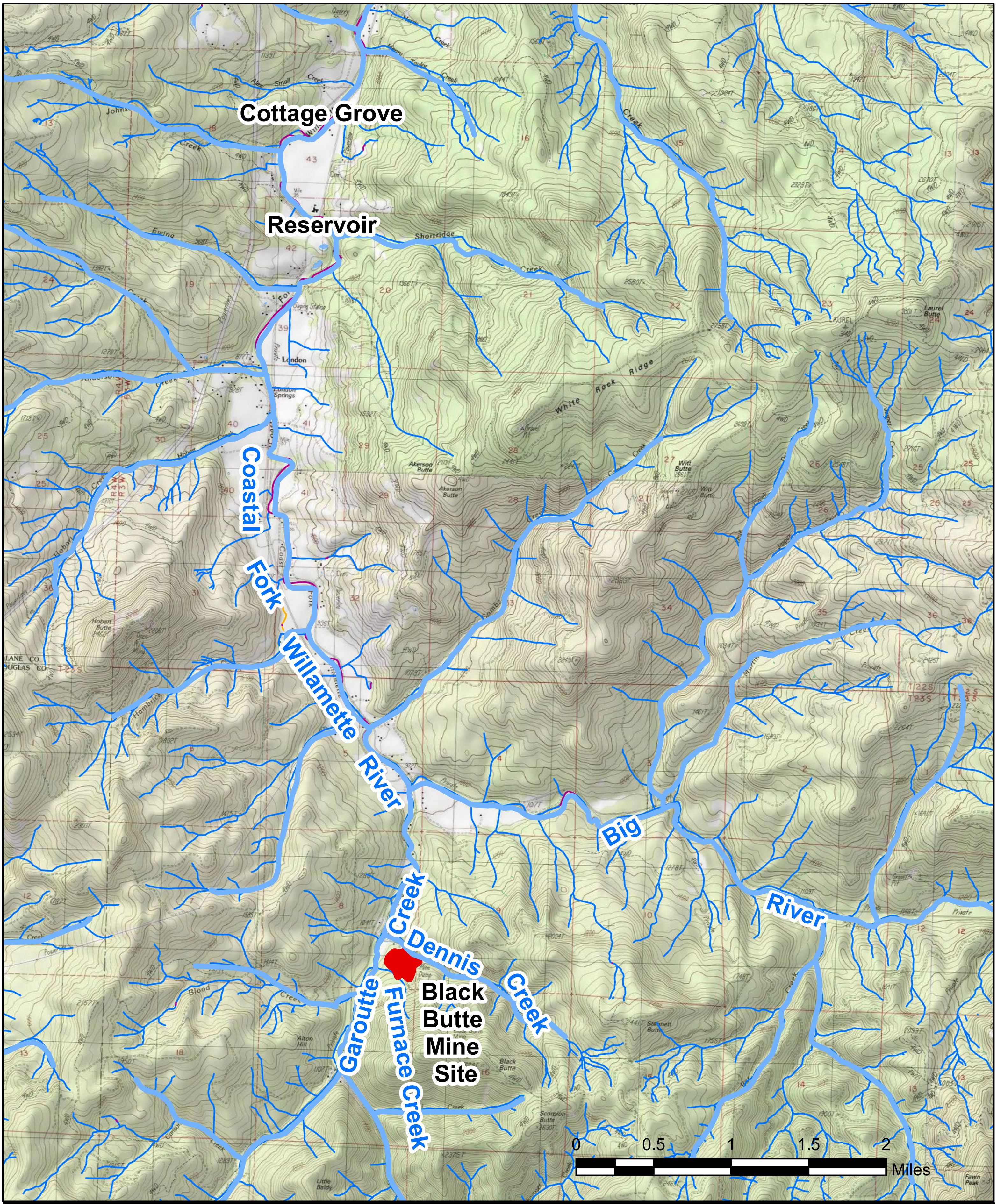


FIGURE 1: SURFACE WATER FEATURES SURROUNDING BLACK BUTTE MINE SITE

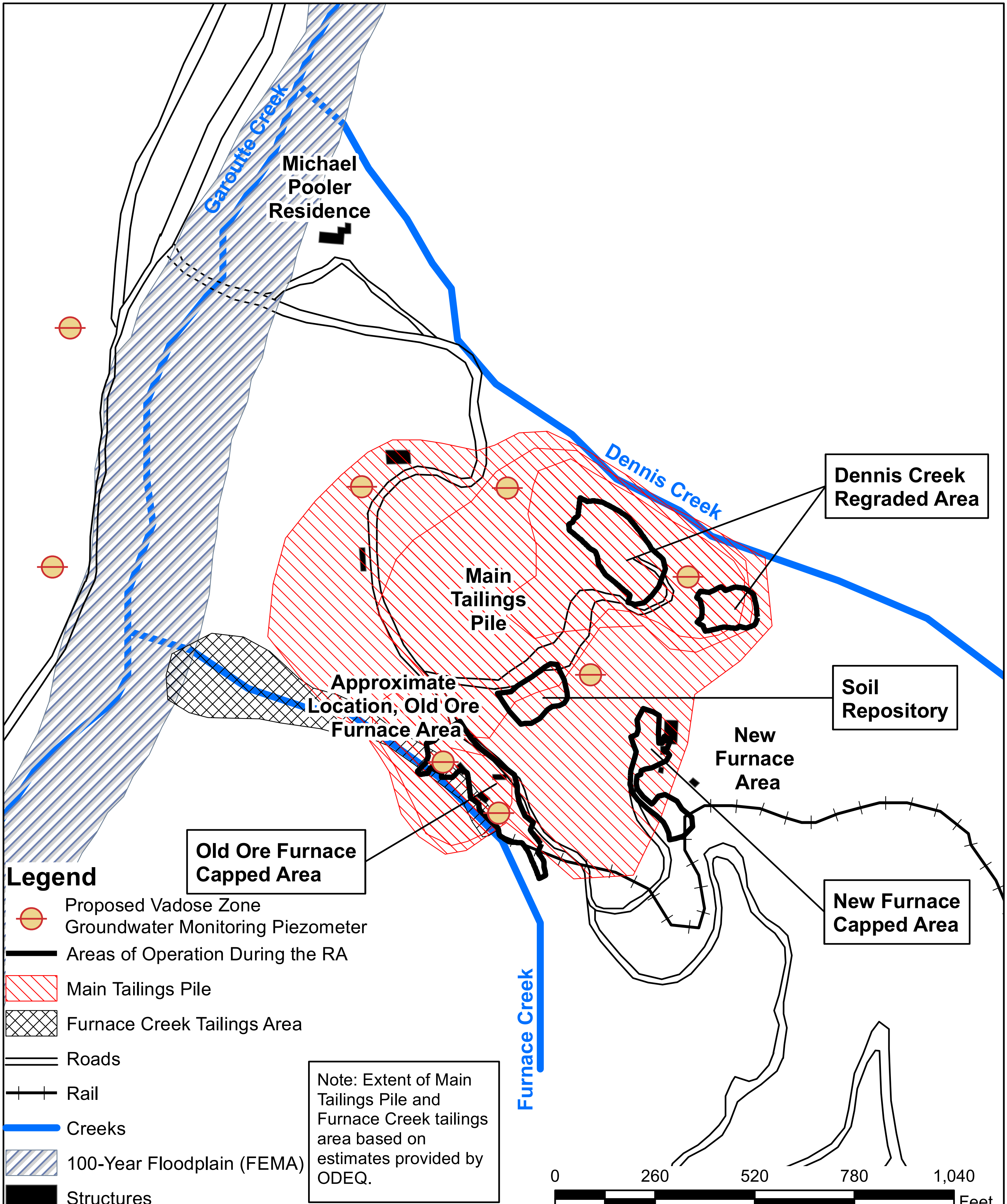
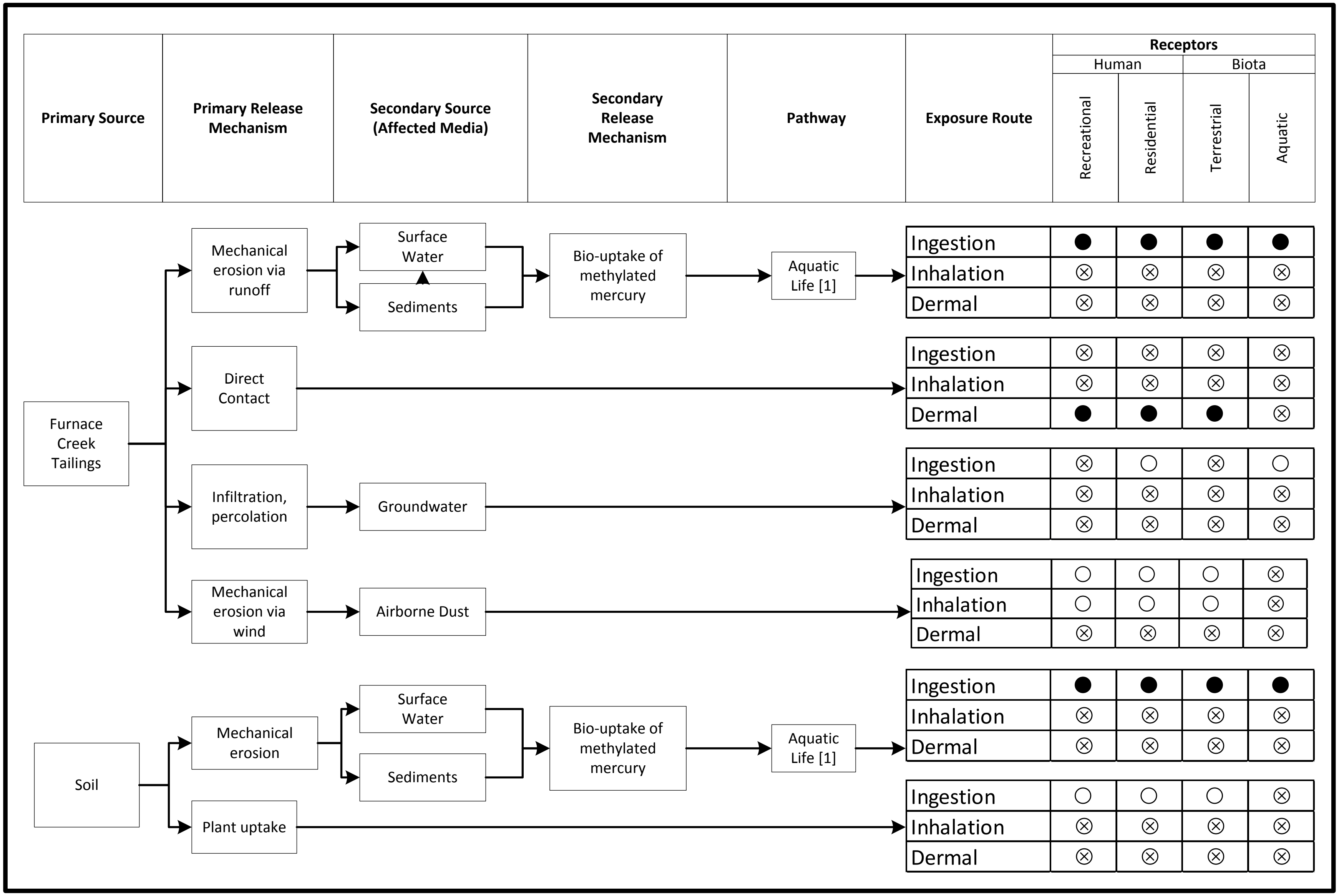


FIGURE 2: BLACK BUTTE MINE SITE AREA

Figure 3: Preliminary Pathway Receptor Network Diagram



Legend

[1] Assumes fish for human consumption; others for general aqualtic life

● Completed pathway

○ Possible complete pathway (data required)

⊗ Incomplete pathway

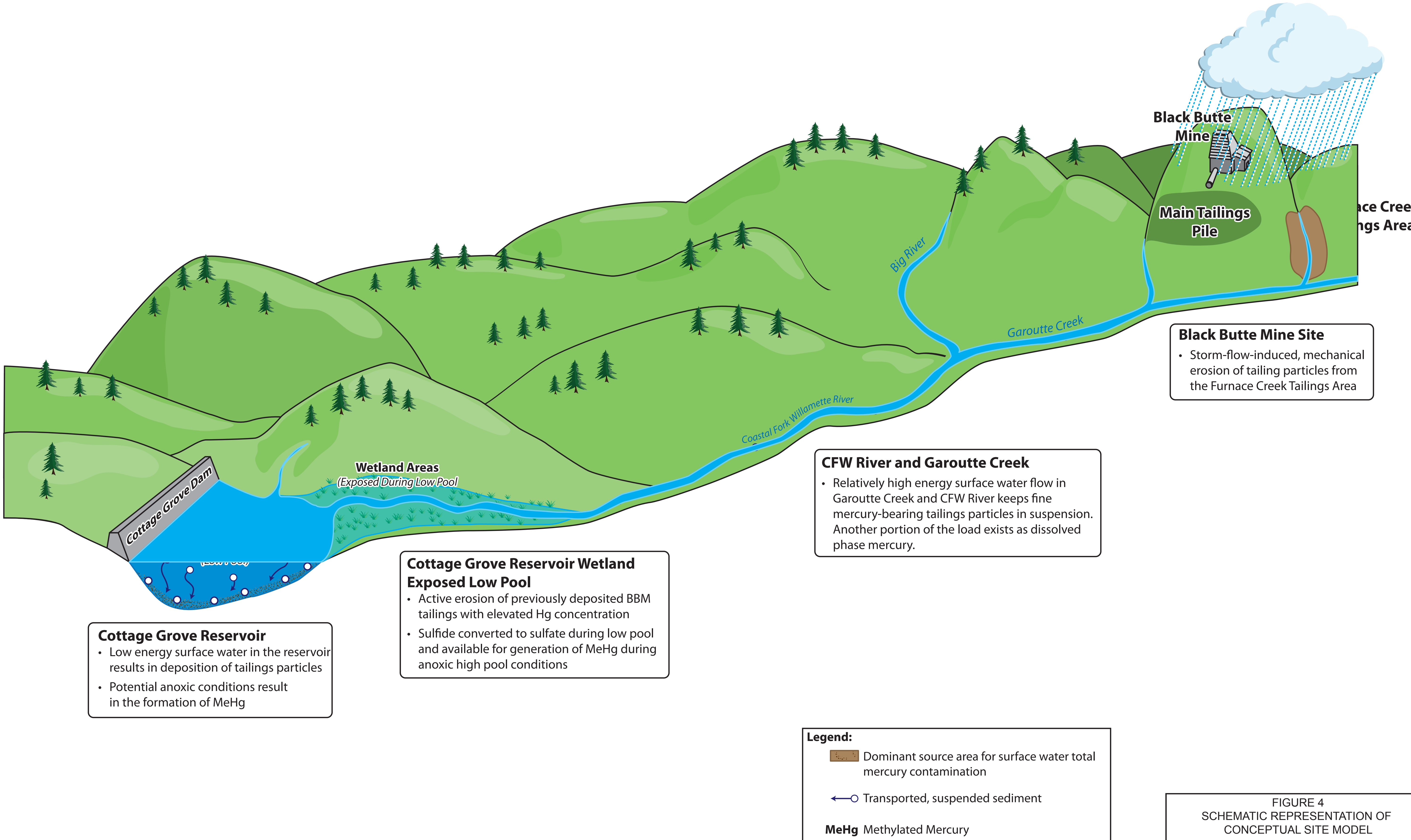


FIGURE 4
SCHEMATIC REPRESENTATION OF
CONCEPTUAL SITE MODEL

TETRA TECH EM INC.

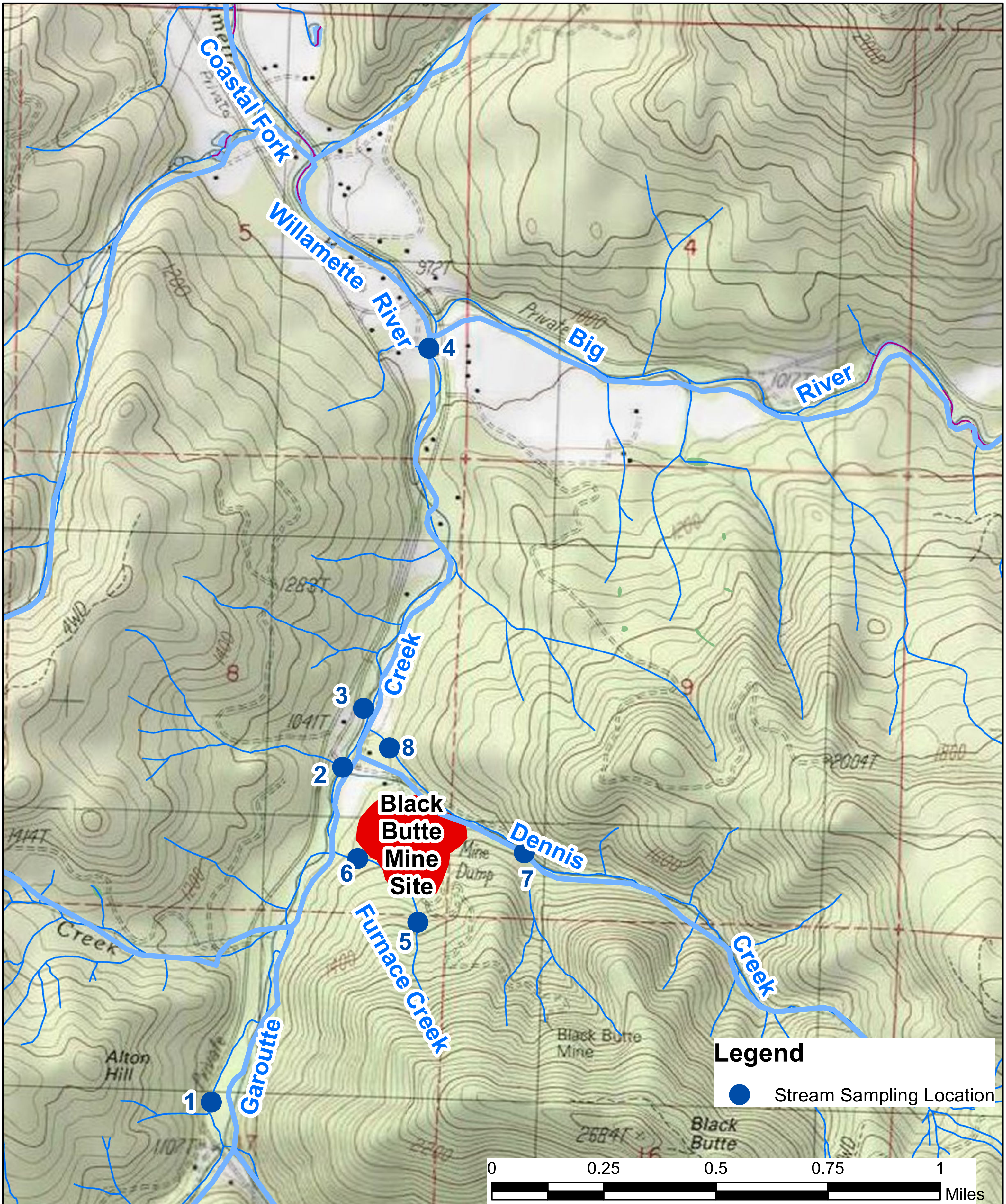


FIGURE 5: SURFACE WATER SAMPLING LOCATIONS AT BLACK BUTTE MINE SITE

Surface water samples will be collected for one year from Garoutte Creek, Furnace Creek, and Dennis Creek at a total of eight locations. Sampling will occur seasonally at high and low flow conditions for a total of 64 samples (eight at each location for the year). Analyses will include HgT, HgD, MeHg (total), MeHg (dissolved), HgR (total), HgR (dissolved), TAL metals (total), TSS, and common ions. This combination of analytes will allow the estimation of the amount of mercury in dissolved and suspended phases and will provide insight on the speciation of the suspended phase. Stream discharge will also be measured at each sampling station during each sampling event. Furnace Creek and Dennis Creek discharge will be measured by installing a weir structure and monitoring the water level using a transducer. Garoutte Creek discharge will be measured by direct gauging or estimated using available gauging data. Sediment samples will be collected at each station during each surface water sampling event and evaluated using separate logic.

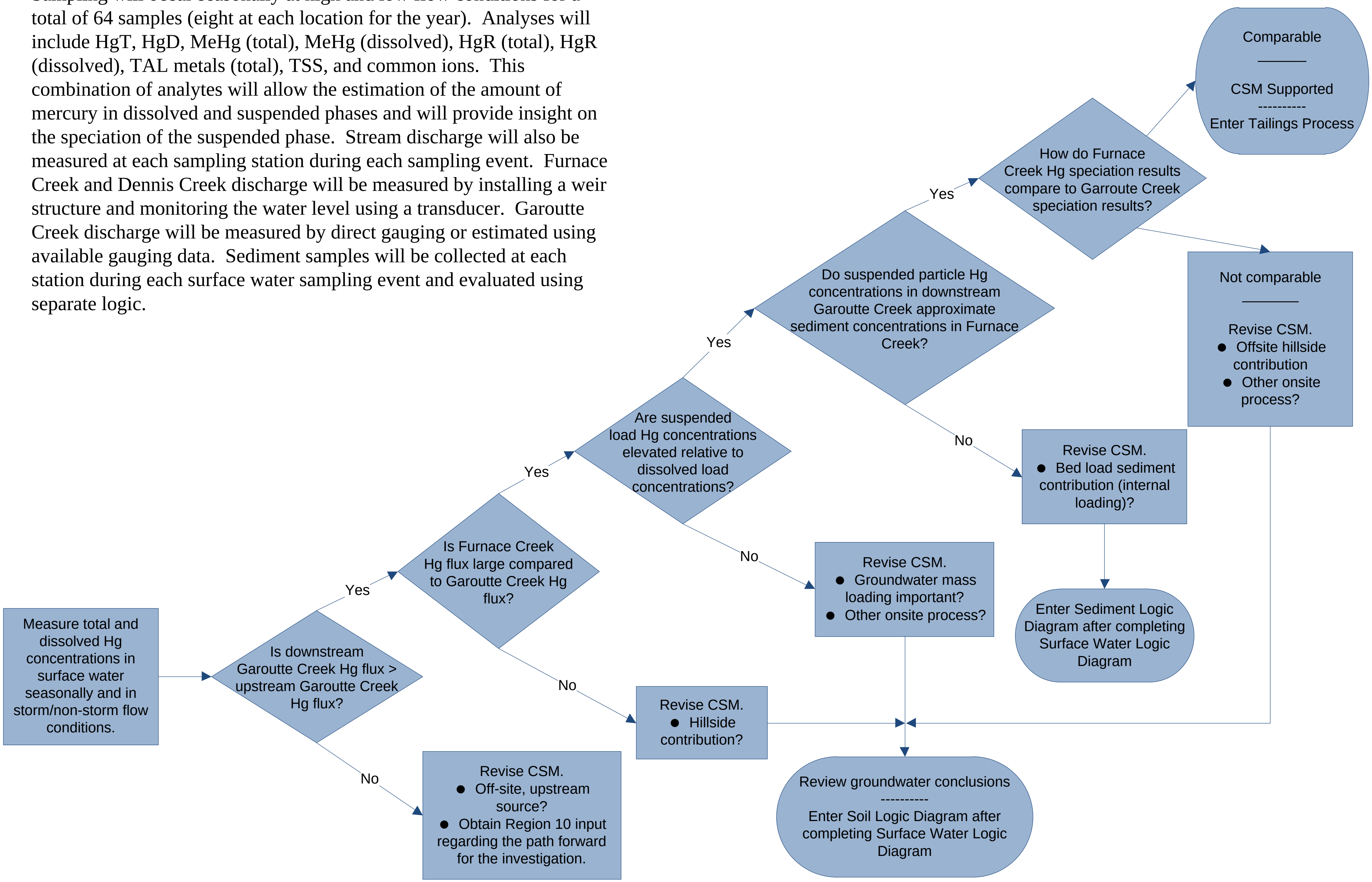


Figure 6. Data Evaluation Logic for Black Butte Mine Surface Water Sampling Task

Sediment samples will be collected during each of the eight surface water sampling events. Samples will be biased toward finer grain sizes that could potentially be mobilized during storm flow conditions and will be analyzed for total and monomethyl mercury. The sediment data will be used in concert with the surface water data to evaluate the potential that surface water suspended Hg load is the result of mobilized creek sediments and not from erosion and mobilization of fine tailings particles from the Furnace Creek Tailings Area. Sediment samples will be analyzed for HgT, MeHg, TOC, TAL metals, and grain size.

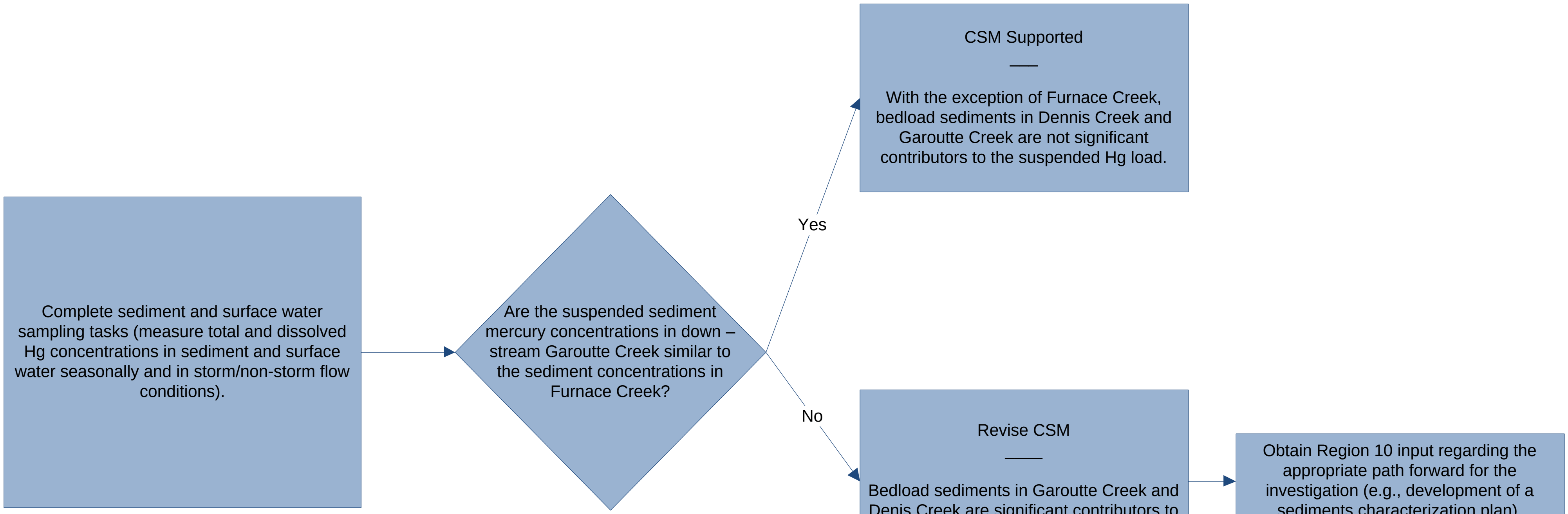


Figure 7. Data Evaluation Logic for Black Butte Mine Sediment Sampling Task

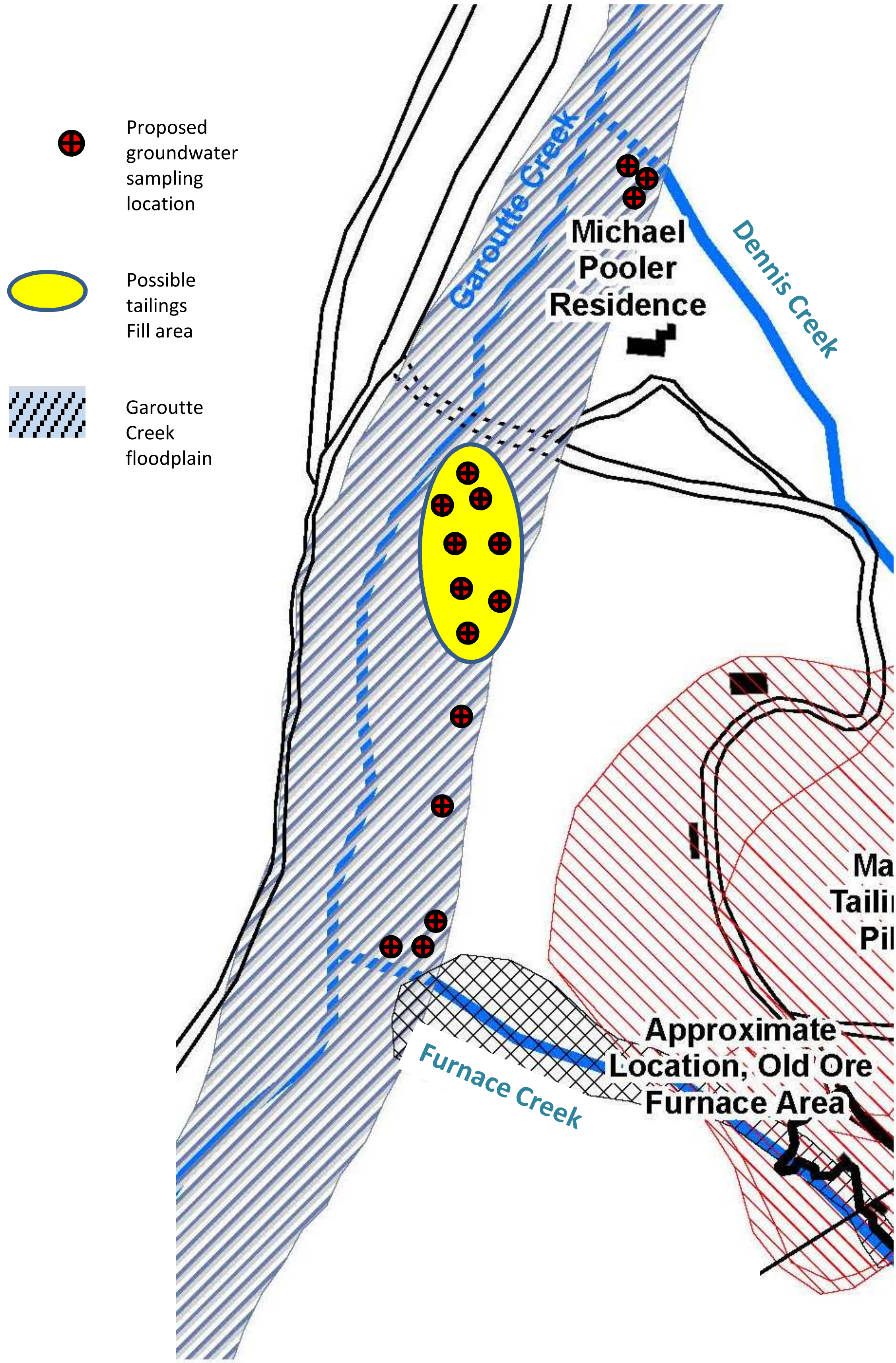


Figure 8. Proposed Groundwater Sampling Locations

Using direct push methods, nine vadose zone piezometers will be installed to collect vadose groundwater samples from the hill slopes at the BBM Site, from the hillslope opposite Garoutte Creek from the BBM Site, and a background location. The piezometers will be installed at 2 locations in the Main Tailings Pile upslope from Dennis Creek, 2 locations in the Furnace Creek Tailings Area upslope from Furnace Creek, 2 locations along the approximate ridge crest that forms the drainage divide between Dennis and Furnace Creeks, 2 locations on the hill slope on the opposite side of Garoutte Creek from BBM, and at a background location, up-gradient and unimpacted by BBM. Two piezometers will be installed at each location, the first installed with the base of the screen interval coinciding with the bedrock surface and the second screened in a shallower zone determined based on field conditions (e.g. evidence of perched groundwater conditions). In the absence of any evidence of perched groundwater, only one peizometer will be installed. Groundwater samples will be collected (if sufficient sample volume can be obtained) from the piezometers during Phase I stormflow hydrograph sampling and seasonally to coincide with the surface water grab sampling events. The samples will be analyzed for HgD, MeHg (dissolved), HgR (dissolved), TAL metals (dissolved), pH, DOC, and common ions. Low to non-detect mercury concentrations in the vadose zone groundwater samples support the CSM. Conversely, elevated mercury in hillside vadose zone groundwater suggests groundwater loading to surface water may potentially be significant, a result counter to the CSM. Additional vadose zone characterization sampling, designed in consultation with Region 10, will be necessary to estimate mercury and other metals mass loading to Furnace, Garoutte, and Dennis Creeks.

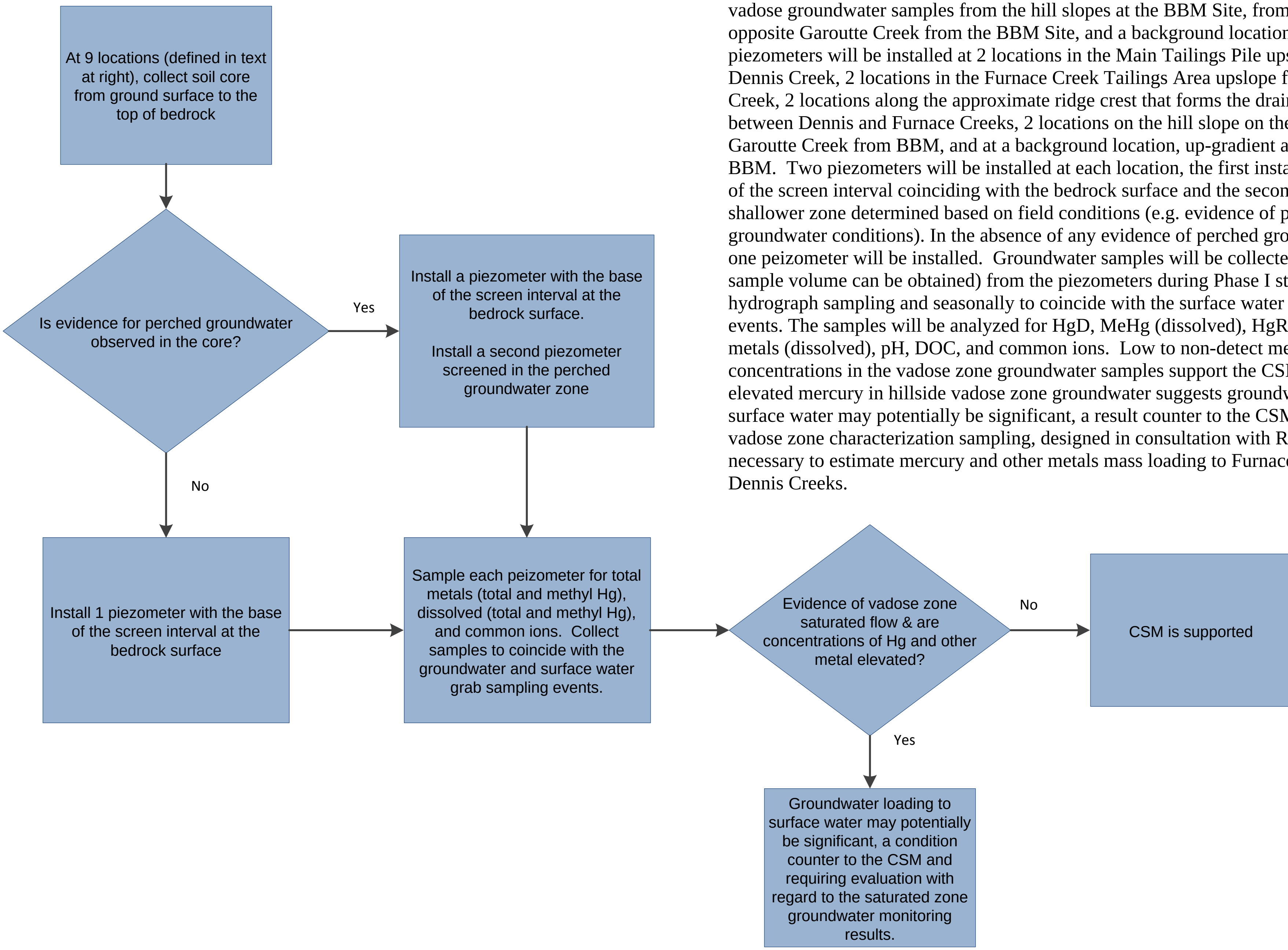


Figure 9. Data Evaluation Logic for Black Butte Mine Vadose Zone Groundwater Sampling Task

The rotary sonic drilling method will be used to collect groundwater samples from beneath the Garoutte Creek floodplain at the base of the Site. Prior to sampling, tailings areas will be mapped by visual inspection. Soil borings will be installed in both tailings and non-tailings areas. The soil borings will be lithologically logged and sampled for mercury and other metals analyses via XRF and laboratory analyses. A minimum of eight groundwater samples will be collected from the tailings areas identified. In addition, a minimum of eight samples will also be collected from non-tailings areas. Up to three groundwater samples will be collected from the immediate vicinity of the confluence of Dennis Creek and Garoutte Creek (and, if possible Furnace Creek and Garoutte Creek); the remaining samples will be collected from the general floodplain area. Eight temporary monitoring wells will be installed. Groundwater samples will be collected from these wells seasonally to coincide with the seasonal surface water grab sampling. The samples will be analyzed for HgD, MeHg (dissolved), HgR (dissolved), TAL metals (dissolved), pH, DOC, and common ions. Low to non-detect mercury concentrations in the groundwater samples from the Garoutte Creek floodplain support the PCSM. However, if the mercury concentrations in the samples are elevated, additional data collection (hydraulic conductivity testing and gradient determination) will be conducted to determine the groundwater mercury mass flux to Garoutte Creek. If the mass flux is elevated relative to the Garoutte Creek mercury flux, the groundwater flux will be considered a significant contributor the Garoutte Creek mercury flux. Given this result, Region 10 risk management assessment/decisions will be necessary to determine the appropriate path forward.

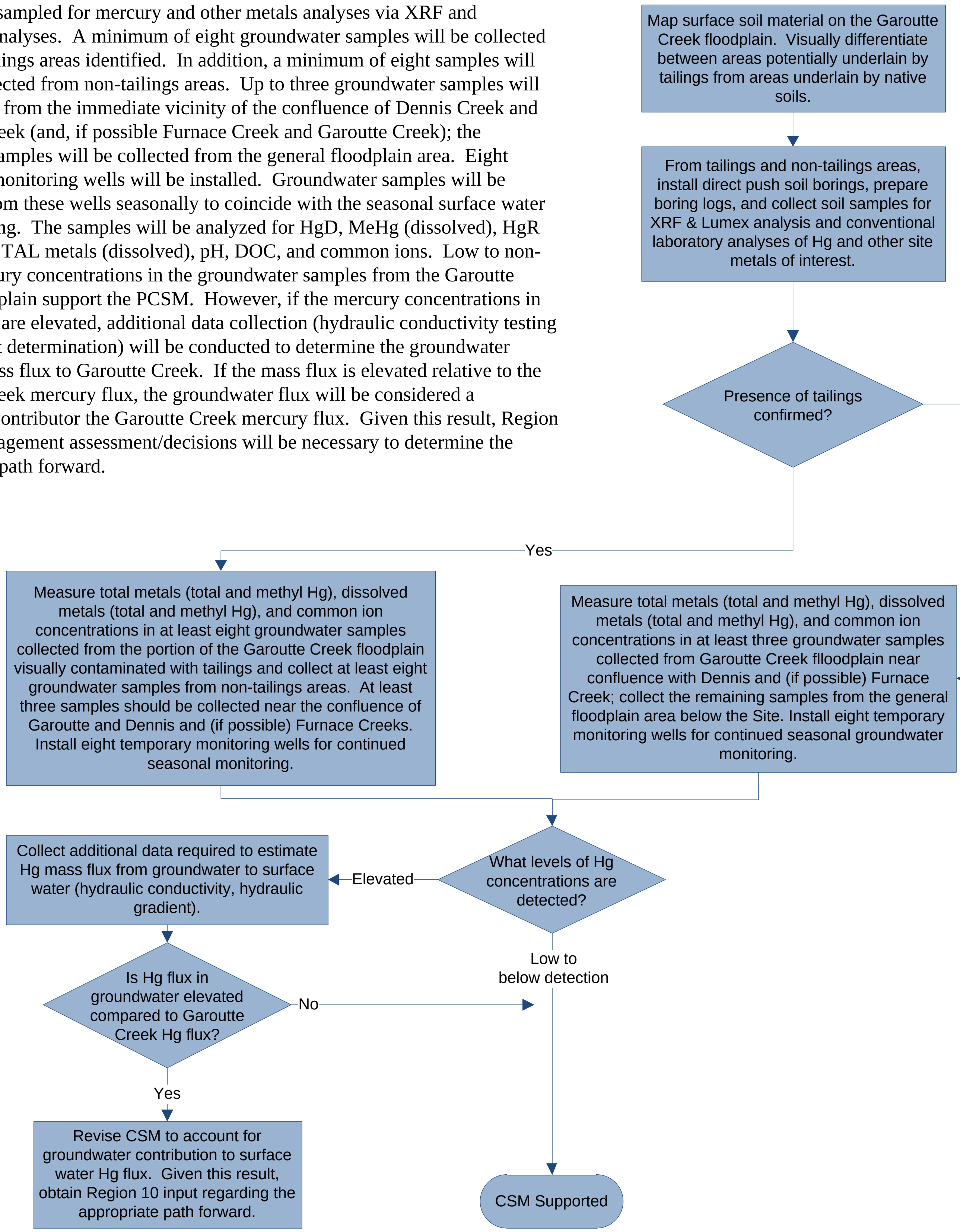


Figure 10. Data Evaluation Logic for Black Butte Mine Groundwater Sampling Task

If the results from the surface water sampling task support the CSM, a Demonstration of Methods Applicability (DMA) will be conducted to establish the relative strength of the correlation between XRF and Lumex field-based metals analyses with laboratory analyses on a set of paired samples of primarily tailings with a secondary focus on native soil. Characterization sampling will then target the Furnace Creek Tailings Area. If the surface water sampling task results are unsupportive of the CSM, a DMA will also be conducted, but will focus on establishing the correlation of XRF and Lumex field-based analyses with laboratory analyses of site native soils with a secondary focus on tailings. Characterization sampling will then target native soils at the Site and on the surrounding hillsides. Tailings samples will be analyzed for HgT, MeHg, TAL metals, and grain size.

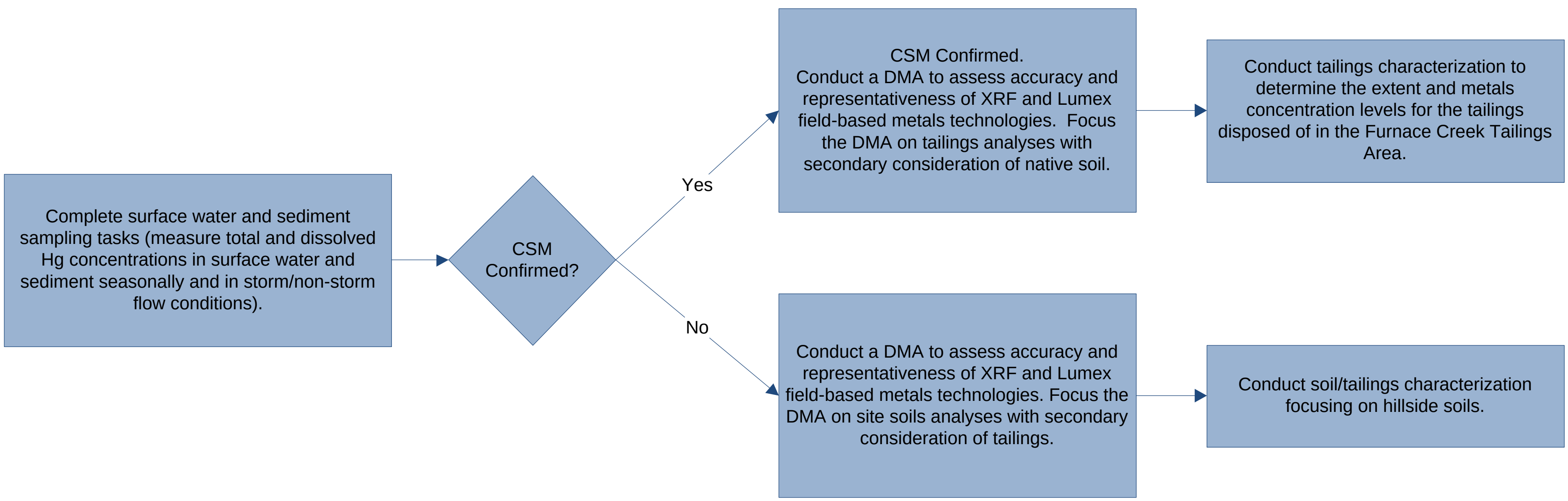


Figure 11. Data Evaluation Logic for Black Butte Mine Tailings Sampling Task

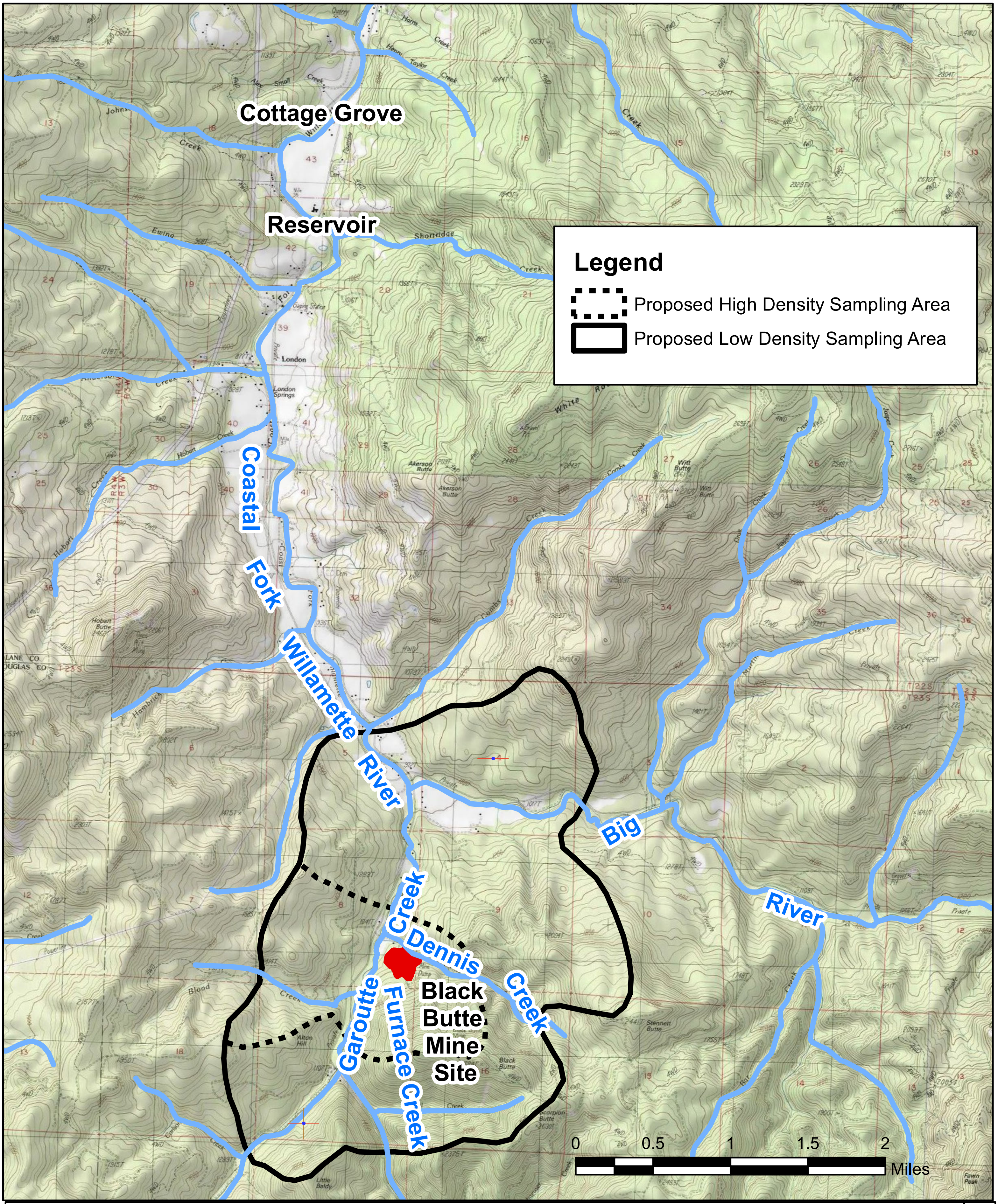


FIGURE 11A: PROPOSED AREA FOR HILL SLOPE SOIL SAMPLING

The objective and focus of the soil sampling task will be defined based on the results of the surface water sampling task. Specifically, if surface water sampling results are supportive of the CSM (e.g., Furnace Creek mercury flux is a significant greater than the Garoutte Creek mercury flux, suspended load mercury concentrations are elevated relative to dissolved load mercury, down-gradient speciation of suspended mercury correlates with the down-gradient Furnace Creek suspended mercury species, and the groundwater mercury flux is negligible), soil sampling for the RI will be conducted to satisfy risk assessment/characterization objectives. If the surface water sampling results are unsupportive of the CSM, evidence exists that the main source of mercury loading to surface water is from non-tailings soil runoff or the groundwater mercury flux to surface water. Given this situation, in addition to sampling to support risk assessment, soil sampling for the RI will also focus on source-characterization of soils underlying the site and the hillsides in the site vicinity. Soil samples will be analyzed for HgT, MeHg, and TAL metals.

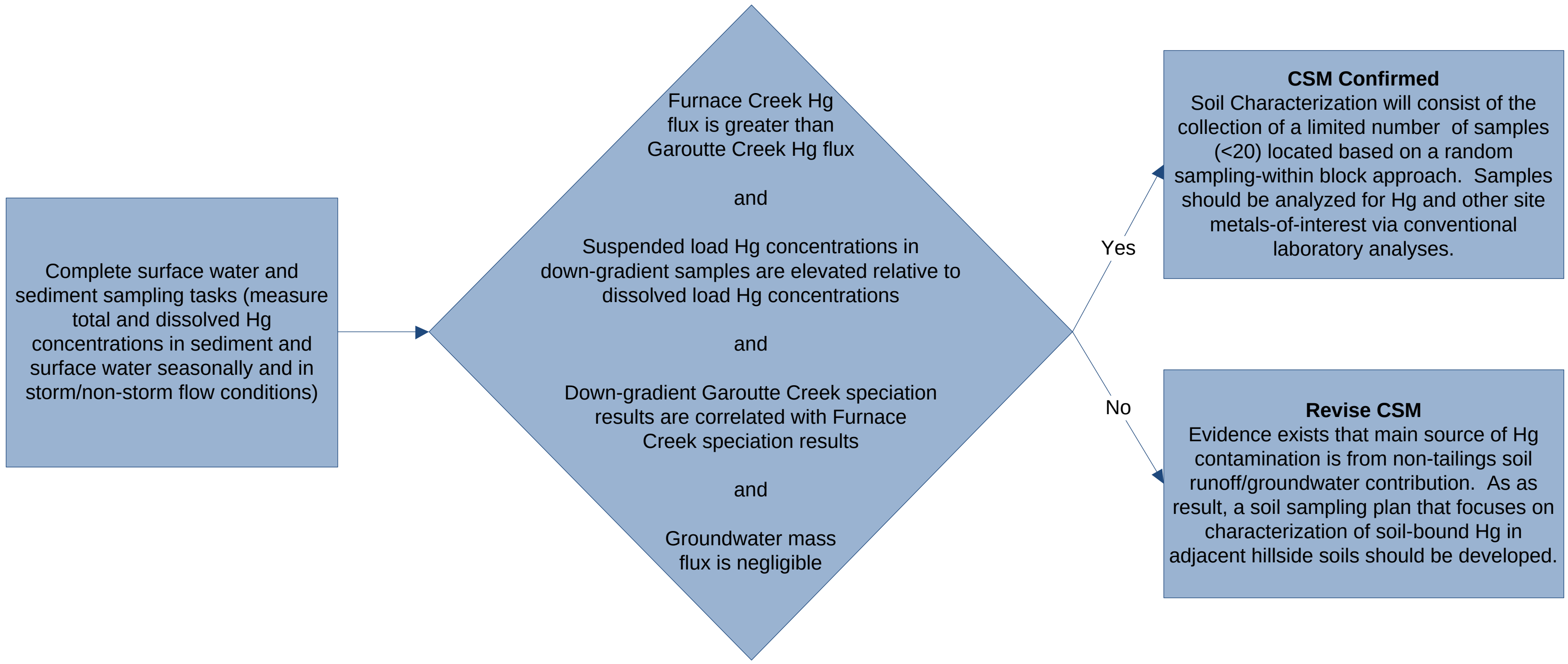


Figure 12. Data Evaluation Logic for Black Butte Mine Soil Sampling

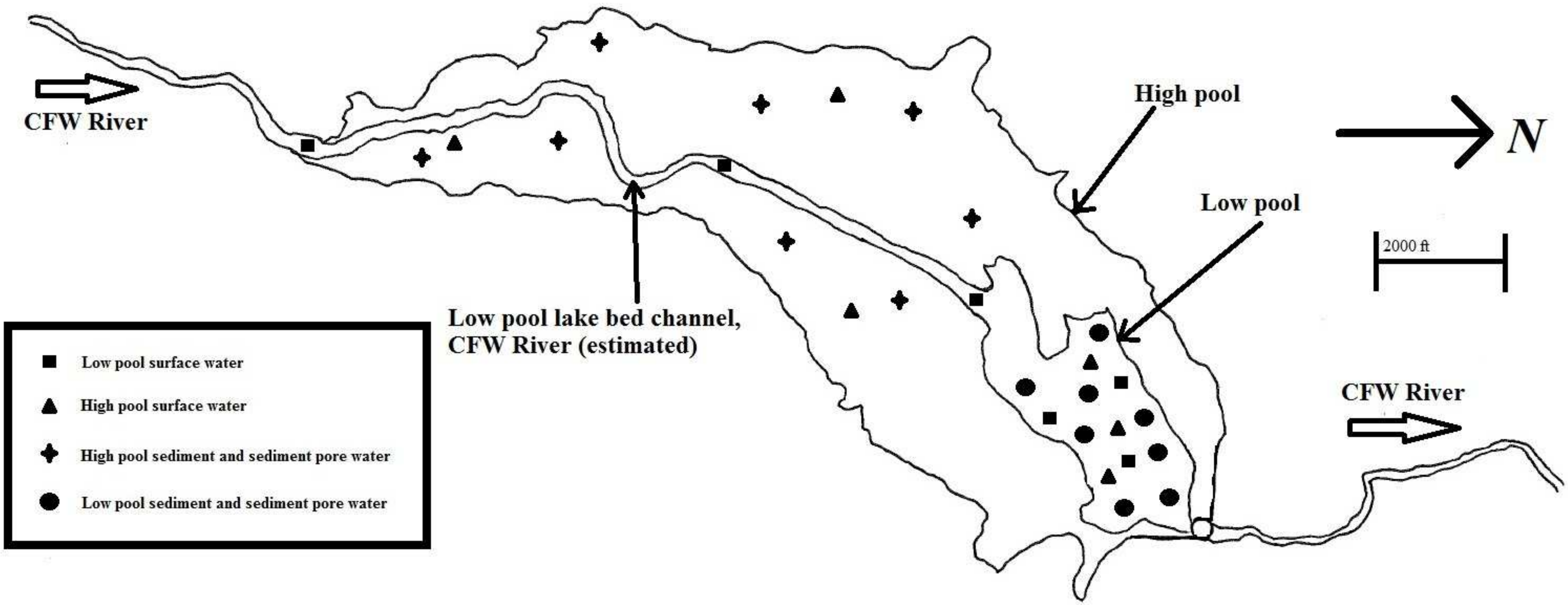


Figure 12a Proposed Sampling Locations for Cottage Grove Reservoir

Petite Ponar Grab Sampler Operation (Blakley, 2008). The petite Ponar grab sampler is equipped with a pair of weighted, tapered jaws that are held open by a catch bar held in place by a spring-loaded pin. The sampler is triggered by impact with the bottom, which relieves the weight on the catch bar, allowing the spring-loaded pin to eject. The upper side of the jaws is covered with a fine mesh screen that allows water to flow through the jaws during descent. This reduces the bow wave created by the sampler and disturbance of the sediment surface. After the sampler is retrieved, the mesh screen can be removed to gain access to the sediment sample.

Open position for sample collection

Closed position for sample retrieval

Figure 12b. Petite Ponar Dredge Grab Sampler

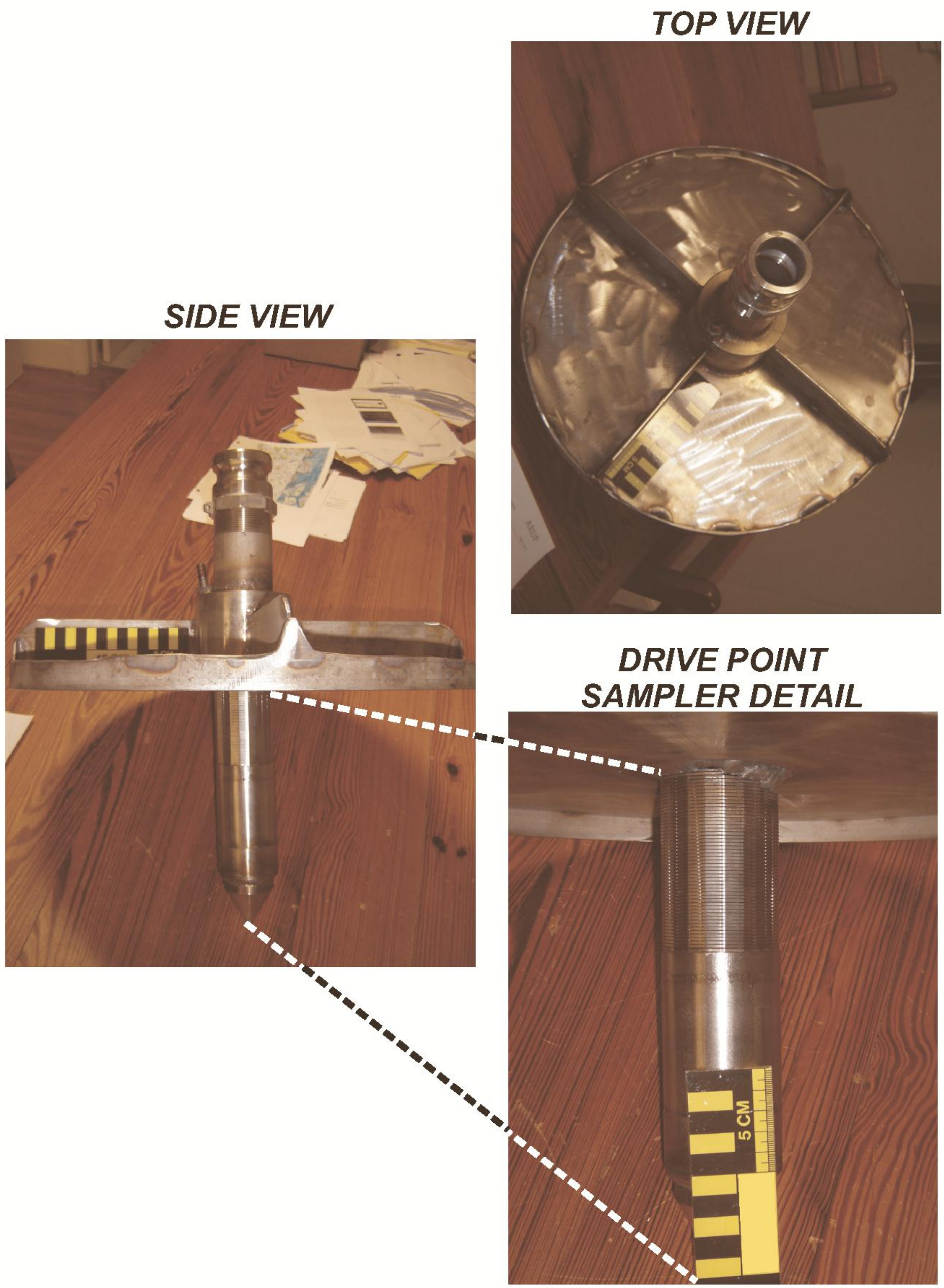


Figure 12c. Example tool for performing pore water sampling in soft sediments

Surface water samples, low pool sediment, and low pool sediment pore water samples will be collected from CGR. Two sampling rounds for sediment and sediment pore water sampling will be conducted (one for high and one for low pool). Surface water sampling will be conducted quarterly from both the high pool and the low pool portions of the CGR. During low pool, surface water samples will be collected from the CFW River channel incised into exposed CGR sediments. Sediment will be analyzed for HgT, MeHg, HgR, TOC, sulfate, and sulfide. Surface water will be analyzed for HgT, HgD, MeHg (total), HgR (total), DOC, common ions (including sulfate), TSS, and standard field parameters (pH, temperature, ORP, DO, and specific conductance). Sediment pore water will be analyzed for HgD, MeHg (dissolved), HgR (dissolved), DOC, common ions (including sulfate), sulfide, and standard field parameters.

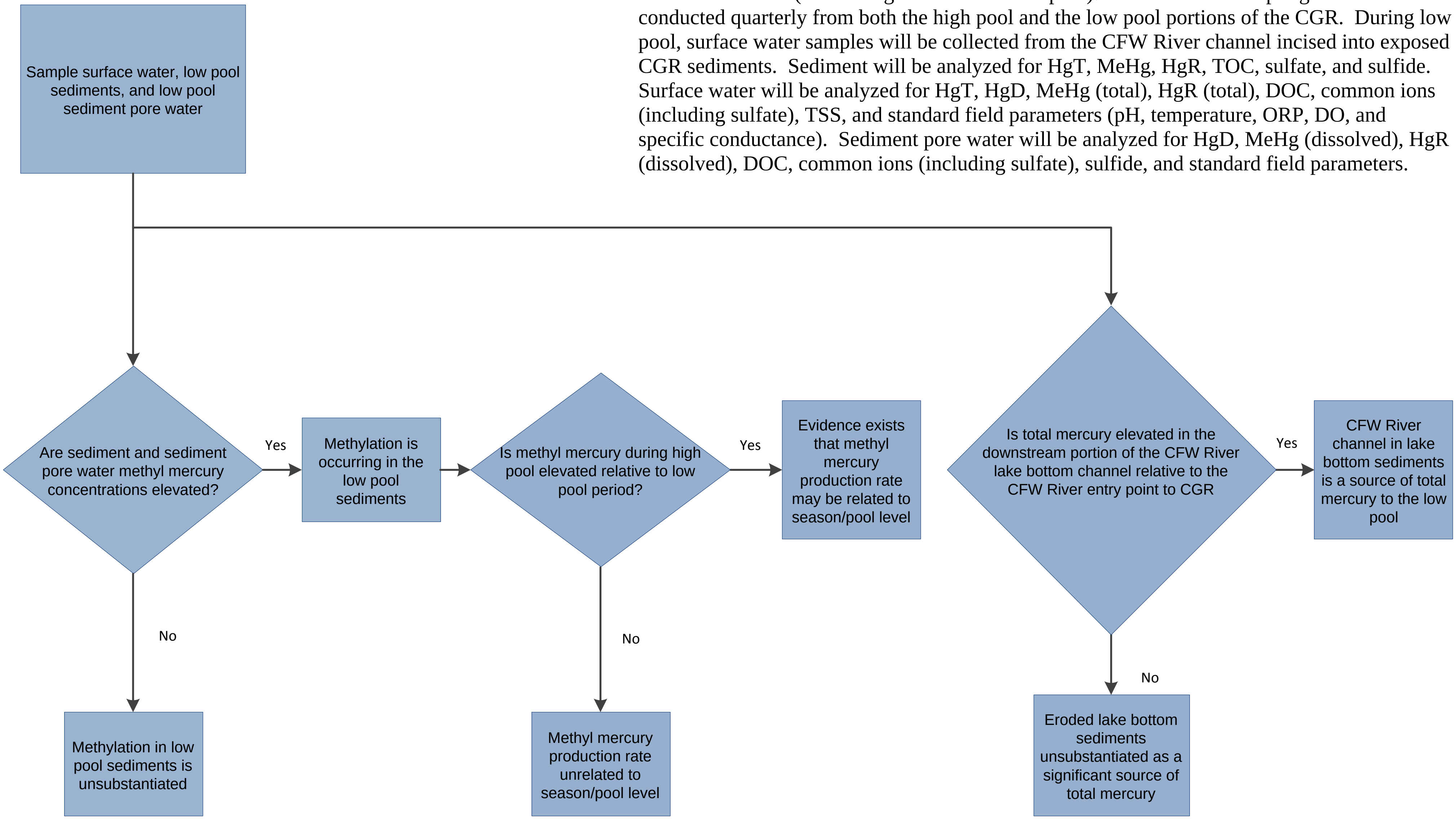


Figure 13. Evaluation of CGR Internal Loading – Low Pool Sediments

Surface water samples, high pool sediment, and high pool sediment pore water samples will be collected from CGR. Four sampling rounds will be conducted. Sampling of high pool sediments and sediment pore water and sediment pore water will occur within one week of the establishment of high pool and after a period of one month of high pool water levels. Similarly, sampling of low pool sediments and sediment pore water will occur within one week of the establishment of low pool and after a period of one month of low pool water levels. Sediment will be analyzed for HgT, MeHg, HgR, TOC, sulfate, and sulfide. Surface water will be analyzed for HgT, HgD, MeHg (total), HgR (total), DOC, common ions (including sulfate), TSS, and standard field parameters (pH, temperature, ORP, DO, and specific conductance). Sediment pore water will be analyzed for HgD, MeHg (dissolved), HgR (dissolved), DOC, common ions (including sulfate), sulfide, and standard field parameters.

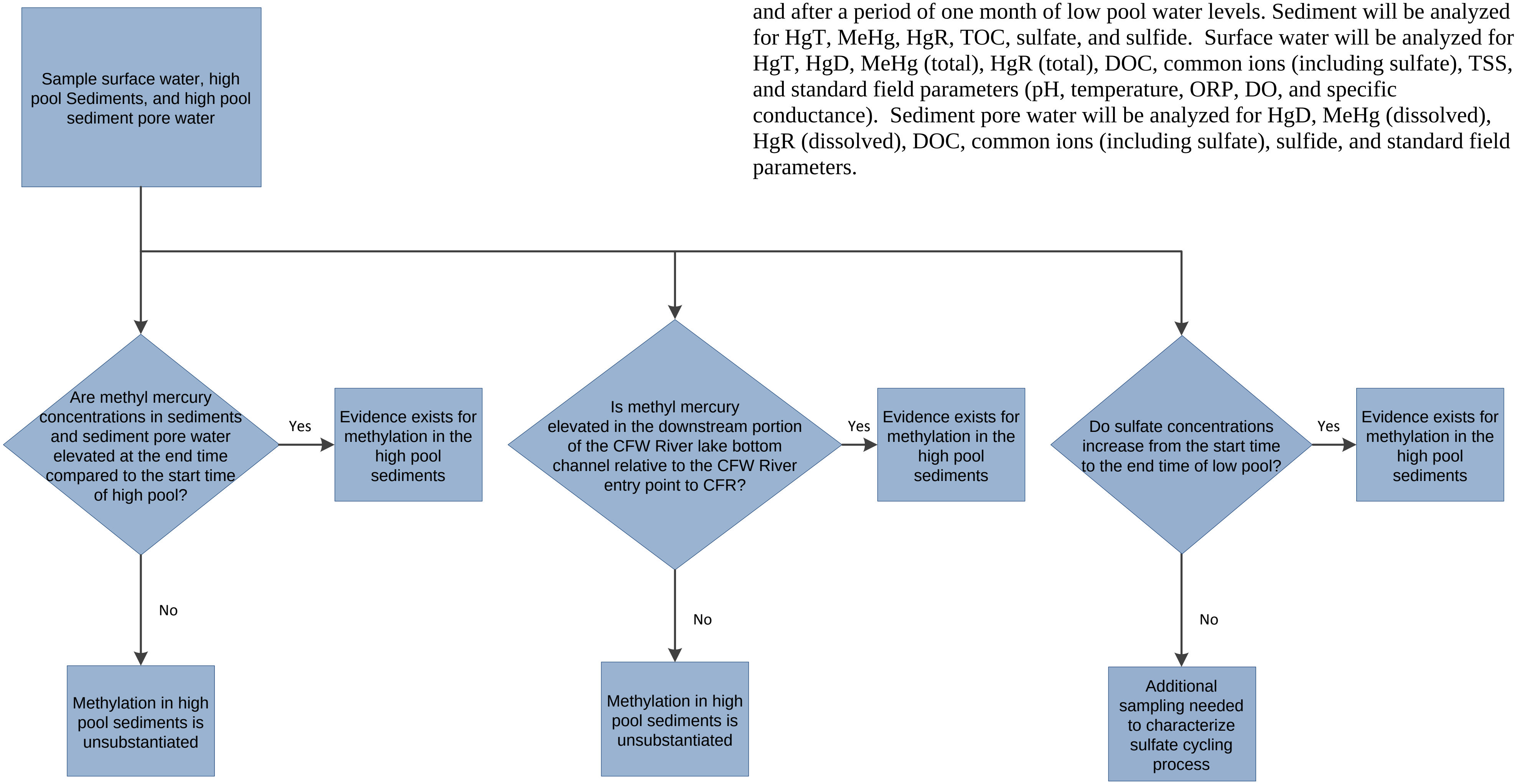


Figure 14. Evaluation of Potential of Internal Loading – High Pool Sediments

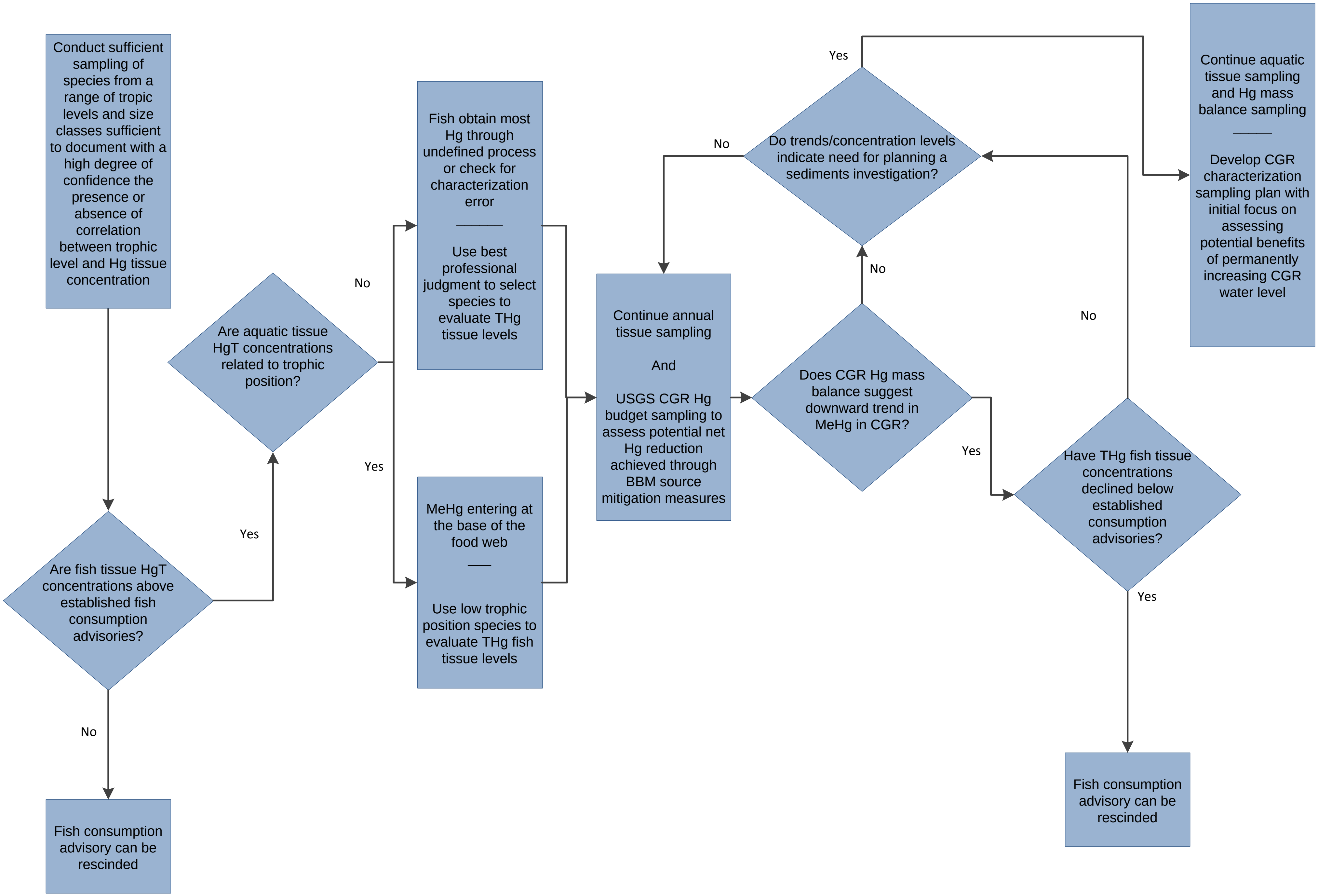


Figure 15. Data Evaluation Logic for Cottage Grove Reservoir Sampling

ATTACHMENT A:
Site Visit Photo Log

Attachment A - Site Visit Photo Log
Site Visit Occurred on January 10, 2012

Photo: 1 **Description:** Bulletin Board at Cottage Grove Reservoir.	

Photo: 2 **Description:** Cottage Grove Reservoir – At main parking lot, Looking down stream toward dam. Note mud flat and low water level.	

Photo: 3 **Description:** Cottage Grove Reservoir – View from boat ramp adjacent to parking lot near dam. Note mud flat and low water level.	

Photo: 4 **Description:** Cottage Grove Reservoir – View from boat ramp adjacent to parking lot near dam. Close-up of mud flat; note fine grain size.	

<table>
<tr><td>Photo: 5

Description:
Cottage Grove Reservoir – Looking upstream from boat ramp adjacent to parking lot near dam. Note mud flat and low water level.</td><td></td></tr>
</table>

<table>
<tr><td>Photo: 6

Description:
Cottage Grove Reservoir – Looking toward dam from boat ramp adjacent to main parking lot. Note mud flat and low water level.</td><td></td></tr>
</table>

Photo: 7 **Description:** Garoutte Creek – Looking upstream from bridge for entrance to the BBM site. Note stream velocity and distribution of sediment grain sizes.	
Photo: 8 **Description:** Garroute Creek flooplain & base of Black Butte slope (in distance) as viewed from the bridge to Site caretaker's residence. Note uneven/elevated hummocky surface of floodplain. Caretaker (a former mine worker) indicates that mine tailings were stockpiled historically in this area.	

Photo: 9 **Description:** Garoutte Creek floodplain. Note uneven/elevated hummocky surface of floodplain. Site caretaker indicates that mine tailings were stockpiled historically in this area.	

Photo: 10 **Description:** View downslope toward Dennis Creek from the Main Tailings Pile. Note excessive vegetation (Scotch Broom) and steep slope. Trees to the right are growing in tailings.	

Photo: 11 **Description:** View downslope toward Dennis Creek from the Main Tailings Pile. Note excessive vegetation (Scotch Broom) and steep slope. Trees shown are growing in tailings.	

Photo: 12 **Description:** Surface of Main Tailings Pile. Note range in sizes (gravel to fines).	

Photo: 13 **Description:** Spring and associated water storage tank located below Main Tailings Pile.	

Photo: 14 **Description:** Looking east downstream direction in Furnace Creek Valley.	

Photo: 15 **Description:** Furnace Creek bank. Note pile up of sediment on upstream side of this tree; suggests active mass wasting/mobilized sediment during flood conditions.	

Photo: 16 **Description:** On-site supply well located upslope of the Main Tailings Pile. Well appeared to be actively flowing at a low rate (seeping).	

Photo: 17

Description:
On-site supply well located upslope of the Main Tailings Pile. Casing cap has two pipes protruding from it. Orange discoloration marks seeping water.

Photo: 18

Description:
Tipple-type superstructure associated with the New Furnace & Rotary Kiln.

Photo: 19 **Description:** Structures at the base of the tipple-type superstructure associated with the New Furnace & Rotary Kiln.	

Photo: 20 **Description:** Rotary kiln at the base of the tipple-type superstructure associated with the New Furnace.	

Photo: 21 **Description:** Downslope view toward the exit point of the rotary kiln associated with the New Furnace.	
Photo: 22 **Description:** View of the rotary kiln and mill. Note Hg vapor capture device installed at left side of building.	

Photo: 23 **Description:** First (lower) adit encountered. Field pH measured in the exterior pool (result: approx. 8.0).	
Photo: 24 **Description:** First (lower) adit encountered.	

Photo: 25 **Description:** First (lower) adit encountered.	

Photo: 26 **Description:** Second (upper) adit encountered; possibly the “404” adit.	

<table>
<tr><td>Photo: 27

Description:
Second (upper) adit encountered; possibly the “404” adit. View to the right.</td><td></td></tr>
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<table>
<tr><td>Photo: 28

Description:
Abandoned equipment near Old Furnace.</td><td></td></tr>
</table>

Photo: 29 **Description:** Potential tailings on the Garoutte Creek floodplain; observed while searching for down gradient confluence of Graroutte and Furnace creeks.	

Photo: 30 **Description:** At CG Reservoir, Wilson Creek boat ramp. CFW River flowing on bedrock, incised in lake bottom sediments. Estimated sediment thickness is 3 - 5 ft.	

Photo: 31 **Description:** At CG Reservoir, Wilson Creek boat ramp. CFW River flowing through lake bottom sediments.	

Photo: 32 **Description:** At CG Reservoir, Wilson Creek boat ramp. CFW River flowing through sediments deposited on bottom.	

Photo: 33 **Description:** At CG Reservoir, Wilson Creek boat ramp. CFW River flowing through sediments deposited on bottom.	

Photo: 34 **Description:** At CG Reservoir, Wilson Creek boat ramp. CFW River flowing through sediments deposited on bottom. Note sediment thickness (estimate 3 – 5 ft).	

Photo: 35 **Description:** At CG Reservoir, Wilson Creek boat ramp. CFW River flowing through sediments deposited on bottom. Note sediment thickness (estimate 3 – 5 ft).	

ATTACHMENT B:
Description of Incremental Composite Sampling

Incremental Composite Sampling Methodology:

Source: ITRC. 2012. *Incremental Sampling Methodology*. February.

The incremental composite sampling (ICS) methodology is a composite sampling approach that statistically reduces data variability associated with discrete sampling and provides mean concentrations of contaminants within a specified area or volume of soil referred to as a decision unit (DU). The mean concentrations are used for comparison to regulatory threshold values and action levels, or are used for risk assessment calculations. Conventionally, discrete samples have been collected to estimate average contaminant concentrations, but use of ICS has been increasing.

Using an ICS sampling approach, soil increments of equal mass are collected from multiple, un-biased locations across a defined DU. The sampling locations within the DU must be evenly distributed to ensure representativeness. The soil increments are mixed together and homogenized to produce one uniform ICS sample. A sub-sample is collected from the homogenized ICS soil sample and sent to a laboratory for analysis. The analytical results for the sample are referred to as the average or mean concentrations of the DU. Generally, the collection of three replicate ICS samples is recommended so that reliability of the sampling methodology can be assessed.

In comparison to more conventional sampling approaches involving the collection of discrete samples, results from ICS applications have shown concentration data to be more consistent, less variable, and more reproducible. The use of an ICS sampling methodology is also more likely to provide a better representation of the DU and is more effective in identifying heterogeneous contamination. ICS replicate samples generally exhibit a normal data distribution as opposed to the positively skewed data distribution often observed from discrete samples.

The use of an ICS approach requires the use of systematic planning. Elements of the planning required include: establishing a conceptual site model (CSM), defining data quality objectives (DQOs), defining suitable DU locations and size, and developing an ICS sampling protocol that states the number and size of increments that will be sampled for each DU. Typically, an incremental composite sample is comprised of 30 to 100 increments.

Cost savings associated with the use of ICS methodology arise from the reduced number of samples that are sent for laboratory analysis compared to the discrete sampling approach. It should be noted, however, that cost per analysis is higher for ICS due to the additional processing required before conducting the analytical procedures.