DRAFT FINAL

FOCUSED FEASIBILITY STUDY

UPRIVER DAM PCB SEDIMENTS SITE

Prepared for
Avista Development, Inc.
and
Kaiser Aluminum & Chemical Corporation

For Submittal to
Washington Department of Ecology

Prepared by
Anchor Environmental, L.L.C.
1423 Third Avenue, Suite 300
Seattle, Washington 98101

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List of Acronyms and Abbreviations

μg/kg	micrograms per kilogram
μg/L	micrograms per liter
AET	apparent effects thresholds
ARAR	applicable or relevant and appropriate requirement
Avista	Avista Development, Inc.
CAD	Contained aquatic disposal
CAP	Cleanup Action Plan
CDF	confined disposal facility
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLARC	Cleanup Level and Risk Calculation
cm	centimeters
Corps	U.S. Army Corps of Engineers
CWA	Clean Water Act
CY	Cubic yard
DGPS	differential global positioning system
dw	dry weight
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
FS	Feasibility Study
HPA	Hydraulic Project Approval
Kaiser	Kaiser Aluminum & Chemical Corporation
kg OC/m^2	kilograms organic carbon per square meter
L/KG	liters per kilograms
MCUL	Minimum Cleanup Level
MNR	Monitored natural recovery
MTCA	Model Toxics Control Act
PCB	polychlorinated biphenyls
pcf	pounds per cubic foot
pg/L	picograms per liter
RCW	Revised Code of Washington
RI/FS	Remedial Investigation/Feasibility Study
RM	River mile

List of Acronyms and Abbreviations

RTDF	Remediation Technologies Development Forum
SEPA	State Environmental Policy Act
Site	Upriver Dam PCB Site
SMS	Sediment Management Standards
SPI	sediment profile imaging
SPM	suspended particulate matter
SQS	Sediment Quality Standards
SQV	Sediment quality value
TMDL	Total Maximum Daily Load
TOC	total organic carbon
USC	U.S. Code
WAC	Washington Administrative Code

1 INTRODUCTION

Effective February 6, 2003, the Washington State Department of Ecology (Ecology) entered into a Consent Decree with Avista Development, Inc., a subsidiary of Avista Corporation (Avista), and Kaiser Aluminum & Chemical Corporation (Kaiser). The Consent Decree sets forth requirements for completing a focused Remedial Investigation/Feasibility Study (RI/FS) of polychlorinated biphenyls (PCBs) in sediments at the Upriver Dam PCB Site (Site). The Site study area begins at approximately river mile (RM) 80.0 at Upriver Dam and continues to approximately RM 85.0 upstream of the dam near the Centennial Trail footbridge (Figure 1). The Site is in the County of Spokane, Washington.

1.1 Remedial Investigation Summary

As described in the Draft Final RI Report (Anchor 2004), a considerable amount of water column and sediment quality data have been collected at the Site to characterize the nature and extent of PCBs in the Upriver Dam area. The primary conclusions of the RI can be summarized as follows:

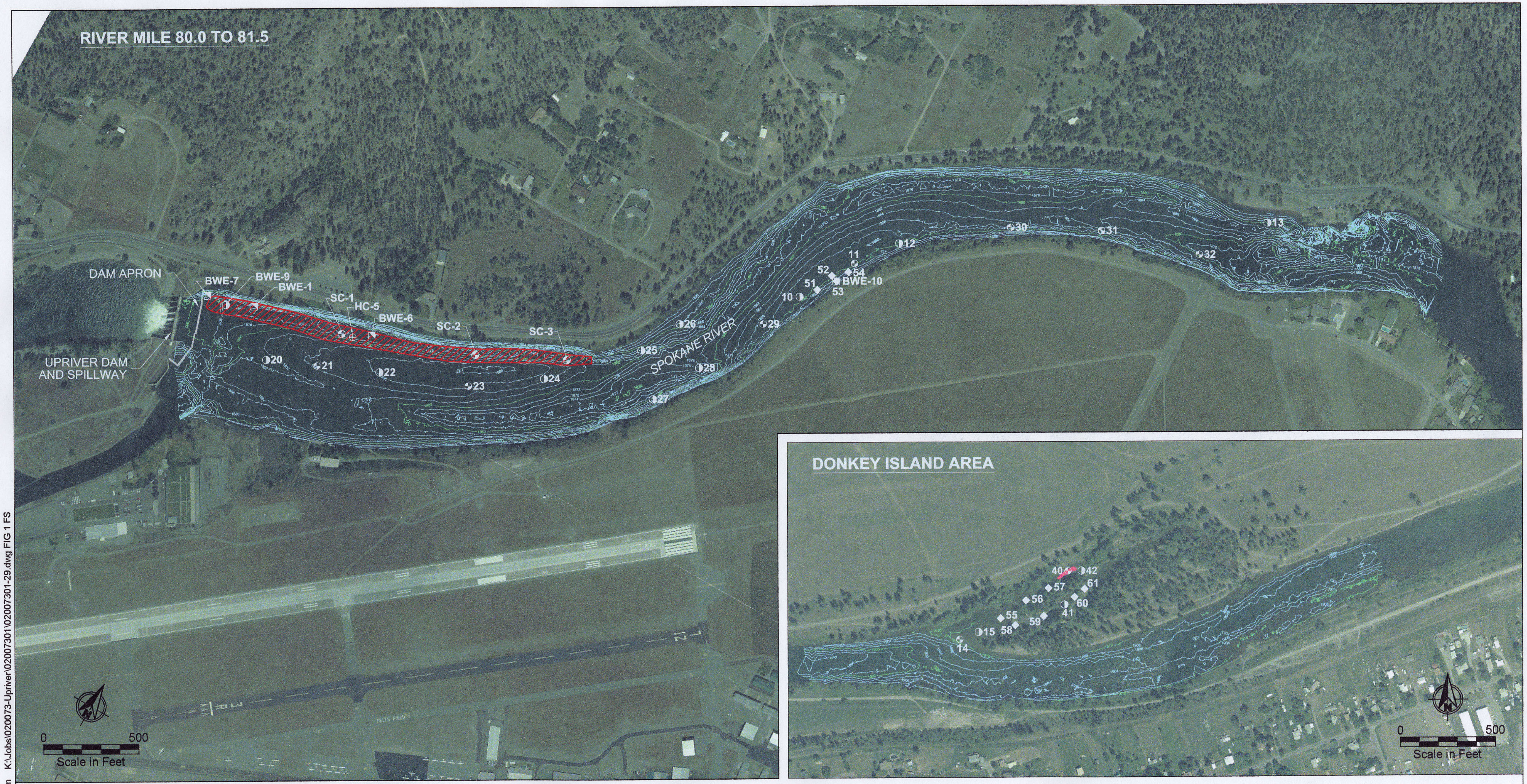
- Surface water total PCB concentrations measured at the Site during low flow conditions during early September 2003 (500 cubic feet per second [cfs] measured at the Spokane gage), reached a maximum concentration of at least 120 picograms per liter (pg/L; U.S. Environmental Protection Agency [EPA]-blank qualifying method results) at Boulder Beach (RM 82.0). Based on EPA-method blank-qualified results, surface water PCB concentrations measured at the Site were below the current surface water quality standard (Chapter 173-201A) of 170 pg/L, though samples collected during September at Boulder Beach and at the Upriver Dam forebay (RM 79.8) exceeded EPA's (2002) recommended water quality criterion for total PCBs of 64 pg/L and alternative blank adjustment method indicates that concentrations were greater than 170 micrograms per liter (µg/L). Surface water total PCB concentrations throughout the Site during approximately median flow conditions in mid-December 2003 (4,000 cfs at the Spokane gage) were less than 30 pg/L, based on EPA qualified results.
- Increases in surface water PCB concentrations in the Site area, relative to more upstream sampling locations, were attributable at least in part to specific congeners (especially PCB 11) apparently associated with treated wastewater from the Inland Empire Paper Company outfall. In addition, increases in bottom water

concentrations of certain PCB homologue groups near the dam forebay were potentially attributable to sediment-associated releases from deposits near the dam (primarily between RM 80.1 and 80.6; see below), though uncertainties associated with low-level PCB analyses and the degree of water column stratification and mixing in this area precluded more definitive source and mass balance analyses.

- Groundwater PCB concentrations were similar to surface water concentrations measured near the dam, and consistent with the site conceptual model verified by local hydrogeologic data of river discharge (exfiltration) to the aquifer in the vicinity of the dam pool. While PCBs were detectable in groundwater, measured concentrations were approximately 3 orders of magnitude below the current drinking water maximum contaminant level.
- On an area-wide basis, averaged surface sediment (0 to 10 centimeters [cm] below mudline) total PCB concentrations throughout most of the Upriver Dam area were typically less than 33 micrograms per kilogram dry weight (μg/kg dw), below the range of risk-based sediment screening levels (roughly 60 to 320 μg/kg dw; Michelsen 2003, Anchor 2004; see below). Sediment PCB concentrations exceeding the screening level range have been identified in two separate sediment deposits at the Site:
  - **Deposit 1** – approximately 3.7 acres in deep-water (20 to 25 feet below normal pool level) zones near Upriver Dam (approximately RM 80.1 to 80.6), containing surface sediment (0 to 10 cm) PCB concentrations as high as 1,430 μg/kg dw. Approximately 13,600 cubic yards (CY) of sediment in Deposit 1 contain PCB concentrations exceeding 60 μg/kg dw, equating to an average thickness of 2.3 feet (70 cm; see Figure 2).
  - **Deposit 2** – a smaller shallow water area on north bank side channels near Donkey Island (RM 83.4), containing surface sediment PCB concentrations as high as 330 μg/kg dw (based on RI sample AN-40 [0 to 10 cm]). The estimated area of sediment with PCB concentrations exceeding 60 μg/kg dw is roughly 0.2 acres. Assuming a nominal thickness of 1 foot, the estimated volume of sediment in Deposit 2 that exceeds 60 μg/kg dw is about 300 CY.

The approximate extent of PCB-contaminated sediments in Deposits 1 and 2 is delineated in Figure 1.

The site characterization data available for the Upriver Dam PCB Site also include several high-resolution and radioisotope-dated cores collected within Deposit 1 (Figure 2; Hart Crowser 1995, Exponent and Anchor 2001). The coring data were consistent between sampling stations located within the 3.7-acre deposit, and defined a pronounced vertical profile of PCB concentrations within the sediments. Sediment total PCB concentrations peaked at depths approximately 20 to 40 cm (8 to 16 inches) below mudline, decreasing steadily in shallower intervals. This vertical profile of PCB concentrations is typical of aquatic sites in the Unites States. Following the restriction and eventual ban on the manufacture and use of PCBs in the 1970s, PCB levels in surface water discharges decreased. As a result, sediments containing elevated PCBs have been overlain and buried with cleaner sediments. The RI data indicate that this process, referred to as natural recovery, is occurring in sediments located behind Upriver Dam, with net sedimentation rates in the four cores ranging between approximately 0.4 and 1.0 cm/year (Hart Crowser 1995, Exponent and Anchor 2001). Moreover, the pronounced stratification/layering apparent in PCB concentrations and the radioisotope record at Deposit 1 suggests that such subsurface sediments have been generally stable over time, with no indication of substantial, deep, or widespread periodic scouring and remobilization.



Dec 03, 2004 10:19am cdavidson K:\Jobs\020073-Upriver\02007301\02007301-29.dwg FIG 1 FS

Notes:

1) Aerial photo provided by Avista dated June 2002.
2) Bathymetry based on survey data provided by Blue Water Engineering dated May 20-22, 2003.
3) Horizontal Datum: State Plane NAD83 Washington, North
4) Vertical Datum: NAVD88

Sample Locations

- ● Core Station Location (2003)
- 10 ◑ Surface Sediment Station Location (2003)
- ◆ 55 Grab Sample Location (2004)
- ▨ Deposit 1
- 🟥 Deposit 2

ANCHOR
ENVIRONMENTAL, L.L.C.

Figure 1
Sediment Deposits & Sediment Sampling Locations
Upriver Dam
Spokane, Washington

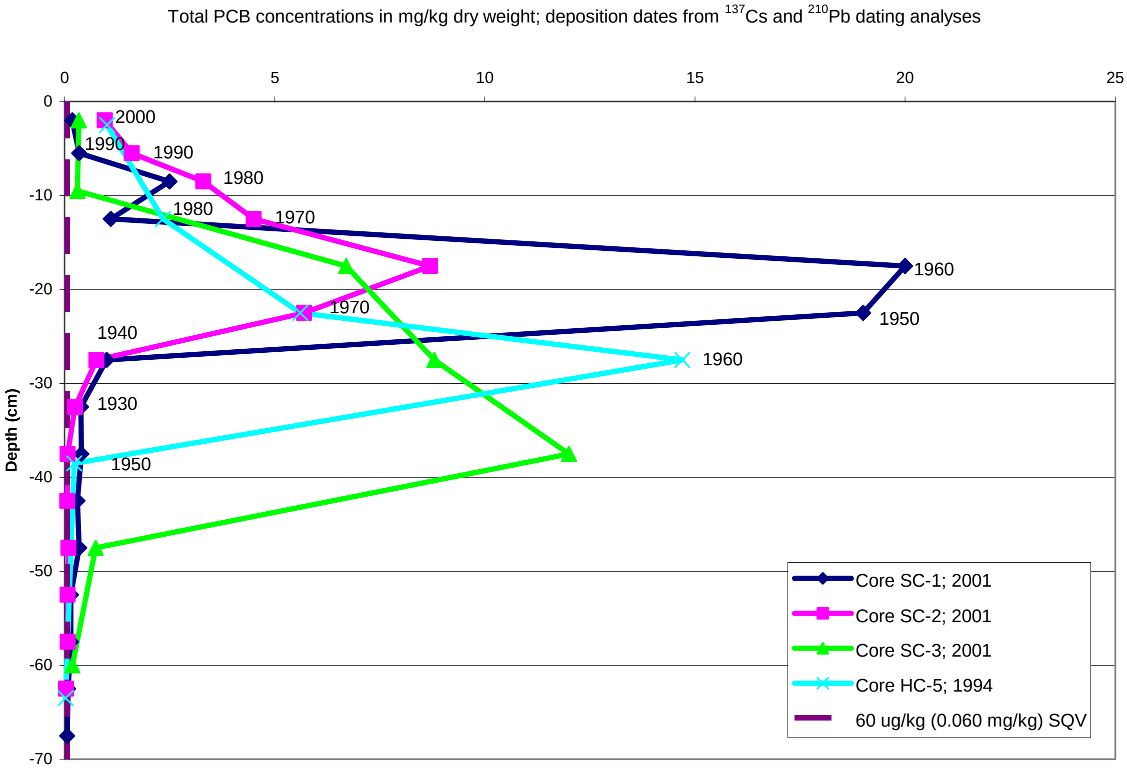


Figure 2

Depth Variation of PCBs in Deposit 1 Sediments Above Upriver Dam

1.2 Focused Feasibility Study Overview

Consistent with Model Toxics Control Act (MTCA; Chapter 173-340 Washington Administrative Code [WAC]) and Sediment Management Standards (SMS; Chapter 173-204 WAC) requirements, the purpose of the FS is to identify and evaluate potential alternatives for cleanup of Site sediments. A range of preliminary sediment remediation options have been developed with Ecology, and evaluated with respect to effectiveness, implementability, cost, and other MTCA/SMS criteria. As directed by Ecology, potentially feasible alternatives were carried forward for more detailed evaluation in this Focused FS, consistent with remedial action objectives developed for the Site. Each alternative was developed to achieve prospective cleanup standards, though the alternatives use different remedial technologies and process options to accomplish this objective. The overall FS evaluation is intended to provide sufficient data and engineering analysis to enable Ecology to select a cleanup action that is protective of human health and the environment.

The Focused FS presented in the sections below build upon the considerable site characterization data collected to date, as summarized in Anchor (2004), which has been incorporated into the existing administrative record for the Site. Remedial alternatives are developed in the sections below using technologies retained from the initial screening of technologies. The identification and assembly of cleanup technologies into site-wide alternatives was performed in accordance with MTCA regulations and associated guidance (e.g., SMS User Manual), along with additional direction provided by Ecology. Each alternative was developed to achieve prospective cleanup standards at the Site (Ecology does not select cleanup standards prior to issuance of the Cleanup Action Plan [CAP]), although the alternatives use different remedial technologies and strategies to accomplish this objective. Detailed analysis of each of the alternatives relative to MTCA evaluation criteria is presented in subsequent sections of this Focused FS Report.

The remainder of this report is presented as follows:

- Section 2 summarizes cleanup standards considered for the Site.
- Section 3 presents a summary of applicable federal, state, and local laws.
- Section 4 presents an initial screening of cleanup technologies.
- Section 5 presents a description of the cleanup alternatives retained for detailed evaluation.
- Section 6 evaluates the alternatives against MTCA criteria for cleanup actions.
- Section 7 presents the references cited in this FS Report.

2 CLEANUP STANDARDS

Consistent with the conceptual site model developed for the Site (Anchor 2004), along with Ecology and EPA regulatory guidance, this Focused FS considered four interrelated remedial action objectives for the Upriver Dam Site:

1. Control of benthic exposure to PCB-contaminated sediments located within the biologically active sediment zone (defined in the RI as 0 to 10 cm below mudline).
2. Minimization of benthic exposure to PCB-contaminated subsurface sediments (i.e., located more than 10 cm below mudline), considering sediment stability under potential future conditions.
3. Reduction of potential remobilization of PCB-contaminated sediments by hydraulic or other physical processes.
4. Reduction of potential transport (flux) of PCBs into the overlying water column.

These remedial action objectives, in turn, were used to develop prospective cleanup requirements for the Upriver Dam Site. Under MTCA, cleanup standards include three components: 1) cleanup levels; 2) points of compliance; and 3) applicable or relevant and appropriate requirements (ARARs). Potential cleanup levels and associated points of compliance were developed for the Site following MTCA Cleanup Regulations (Chapter 173-340 WAC). MTCA Method B procedures, which were used in this Focused FS, employ a risk-based evaluation of potential human health and environmental exposures to Site contaminants. As defined in the MTCA regulation, cleanup levels must also be at least as stringent as established state or federal standards or other laws (i.e., ARARs) developed for human health and environmental protection (see Section 3).

The Method B cleanup level for one medium must also be protective of the beneficial uses of other affected media. For example, since sediment porewater could potentially contribute to surface water PCB flux at the Upriver Dam Site, sediment cleanup levels need to consider surface water and groundwater protection requirements. Sediment cleanup screening levels and surface water protection considerations are discussed separately in the sections below.

2.1 Sediment Screening Levels

MTCA addresses sediment cleanup levels by reference to the SMS. Under the SMS, the primary endpoint for sediment quality evaluations is protection of the environment, specifically the benthic community within the biologically active zone (0 to 10 cm), from adverse effects associated with contaminants. Numeric freshwater sediment quality values (SQVs) for a range of chemicals are still under development by Ecology, though interim guidelines have been released based on probable or apparent effects thresholds (AETs) calculated using the available regional database of synoptic chemistry and toxicity test information (Michelsen 2003). While SMS cleanup levels have been promulgated for sediments in the marine environment, freshwater sediment quality criteria are currently determined on a case-by-case basis (Chapter 173-204-340 WAC).

Sediment quality screening values considered in this Draft FS included the following:

1. Potential for localized toxicity to benthic invertebrate organisms – Ecology's most recent evaluation of SQVs for use in its freshwater sediment management programs is presented in Michelsen (2003), including updates of existing freshwater AETs and evaluations of other SQV measures that may provide improved reliability. Based on Michelsen's recommendations, Ecology is currently considering potential freshwater toxicity-based SQVs ranging from 60 μg/kg dw (floating percentile method at 85 percent sensitivity) to 354 μg/kg dw (second lowest AET). Although site-specific bioassays can be performed to provide a more direct assessment of sediment toxicity, at the Upriver Dam Site this is significantly complicated by the presence of co-occurring metal and wood waste contaminants, which are not addressed under the Upriver Dam PCB Site Focused RI/FS (Anchor 2004).
2. Potential risks to wildlife and human health due to PCB uptake and bioaccumulation – Detailed bioaccumulation studies at other similar freshwater and marine sediment PCB sites have evaluated average surface sediment concentrations across the characteristic home range of the resident biota. As discussed in Anchor (2004), representative applications of sediment bioaccumulation modeling at other sediment PCB cleanup sites have resulted in bioaccumulation-based SQVs ranging from approximately 320 to 1,000 μg/kg dw.

For the purposes of this Focused FS the more conservative of the range of SQVs presented above (i.e., 60 μg/kg dw) was used as a preliminary basis for evaluating prospective remedial action areas at the Upriver Dam PCB Site. The approximate areal extent of contiguous sediments in Deposits 1 and 2 that exceed 60 μg/kg dw is delineated in Figure 1.

As discussed above, the SMS default point of compliance for sediment cleanup standards is the 0 to 10 cm depth interval below the mudline. Radioisotope dating evaluations (Hart Crowser 1995, Exponent and Anchor 2001) support that the biologically active zone at the Upriver Dam PCB Site does not extend across the 10 cm interval, and in several cores is limited to the 0 to 4 cm interval. Existing sediment contamination at the Site (i.e., metals, PCBs, and wood waste) may potentially limit the effective depth of biologic activity. Use of a default 0 to 10 cm point of compliance in the sediment cleanup standard provides an additional level of protectiveness to address potential future improved conditions at the Site.

2.2 Surface Water Screening Levels

The MTCA Method B surface water cleanup level considers Chapter 173-201A WAC requirements, as well as federal Clean Water Act (CWA) aquatic life and human health criteria, National Toxics Rule aquatic life and human health criteria (40 CFR 131.36), federal Drinking Water Standards and Health Advisories, and the State Primary Drinking Water Regulations (Chapter 246-290 WAC). Human health risk calculations for reasonable maximum surface water exposures (including bioaccumulation and drinking water pathways) were performed using the standard MTCA Method B risk equations.

Consistent with the summary provided in Ecology’s current Cleanup Level and Risk Calculation (CLARC) tables, version 3.1, the proposed Method B surface water screening level for PCBs is based on the Chapter 173-201A and current National Toxics Rule ARAR for human health protection of 170 pg/L. Based on the MTCA risk assessment equations, this ARAR provides sufficient human health and environmental protection. Also note that the ambient water quality standard for the protection of aquatic life from chronic PCB exposure (14,000 pg/L), as well as the drinking water maximum contaminant level (500,000 pg/L), are both considerably less stringent than the bioaccumulation-based Method B cleanup level.

While the current National Toxics Rule surface water quality criterion of 170 pg/L provides one basis for developing the Method B cleanup level, Ecology is also considering a second value that could be applied as the MTCA surface water quality standard at the Upriver Dam PCB Site. That is, EPA (2002) recommends that the surface water quality criterion for PCBs be lowered to 64 pg/L, and this value may potentially be used under MTCA as the Method B cleanup level (WAC 173-340-730[2][b][i][B]) and -730[3][b][i][B]). For the purposes of this Focused FS the more conservative of these values (i.e., 64 pg/L) was used as a preliminary basis for evaluating prospective remedial action requirements at the Upriver Dam PCB Site.

As discussed above, surface water total PCB concentrations measured at the Site during low flow conditions in early September 2003 (500 cfs) exceeded the 64 pg/L criterion at Boulder Beach (RM 82.0) and at the Upriver Dam forebay (RM 79.8). However, surface water total PCB concentrations observed at the Site monitoring locations and calculated according to the EPA blank-qualifying method during approximately median flow conditions in mid-December 2003 (4,000 cfs) were less than 30 pg/L, and did not exceed the EPA (2002) recommended value. Increases in surface water PCB concentrations in the site area, relative to more upstream sampling locations, were likely attributable at least in part, to specific congeners (especially PCB 11) apparently associated with treated waste water from the Inland Empire Paper Company outfall. In addition, increases in bottom water concentrations of certain PCB homologue groups near the dam forebay were potentially attributable to sediment-associated releases from deposits near the dam (primarily between RM 80.1 and 80.6), though uncertainties associated with low-level PCB analyses and the degree of water column stratification and mixing in this area precluded more definitive source and mass balance analyses.

Under MTCA, the point of compliance for documenting protection of human health and the environment resulting from potential surface water exposures is within (and throughout) the water column of the Spokane River (WAC 173-340-730[6] and [7]). Surface water samples collected during the RI at water depths several feet above the mudline serve in part to address this point of compliance, as discussed above.

For the purpose of supporting a comparative evaluation of the protectiveness of alternative remedial actions within the Upriver Dam Site (see Section 6), sediment porewater PCB concentrations at a depth of 10 cm below the mudline were estimated and compared with the 64 pg/L criterion. The 10 cm depth represents a conservative point of release into the biologically active zone. While this comparison does not represent a potential bioaccumulation exposure or point of compliance condition (considering the broad home range behavior of fish in this system), such a comparison is nevertheless useful for evaluating the relative protectiveness of different remedies, consistent with MTCA regulatory guidance. Based on detailed core profiling data for PCBs and total organic carbon (TOC) available for the Site (see Figure 2), and applying the equilibrium partitioning model recommended in the MTCA regulation (i.e., an equilibrium partitioning coefficient [K_{oc}] for total PCBs of 820,000 liters per kilograms [L/kg]), the profile of existing porewater PCB concentrations with depth in Deposit 1 can be estimated (Figure 3).

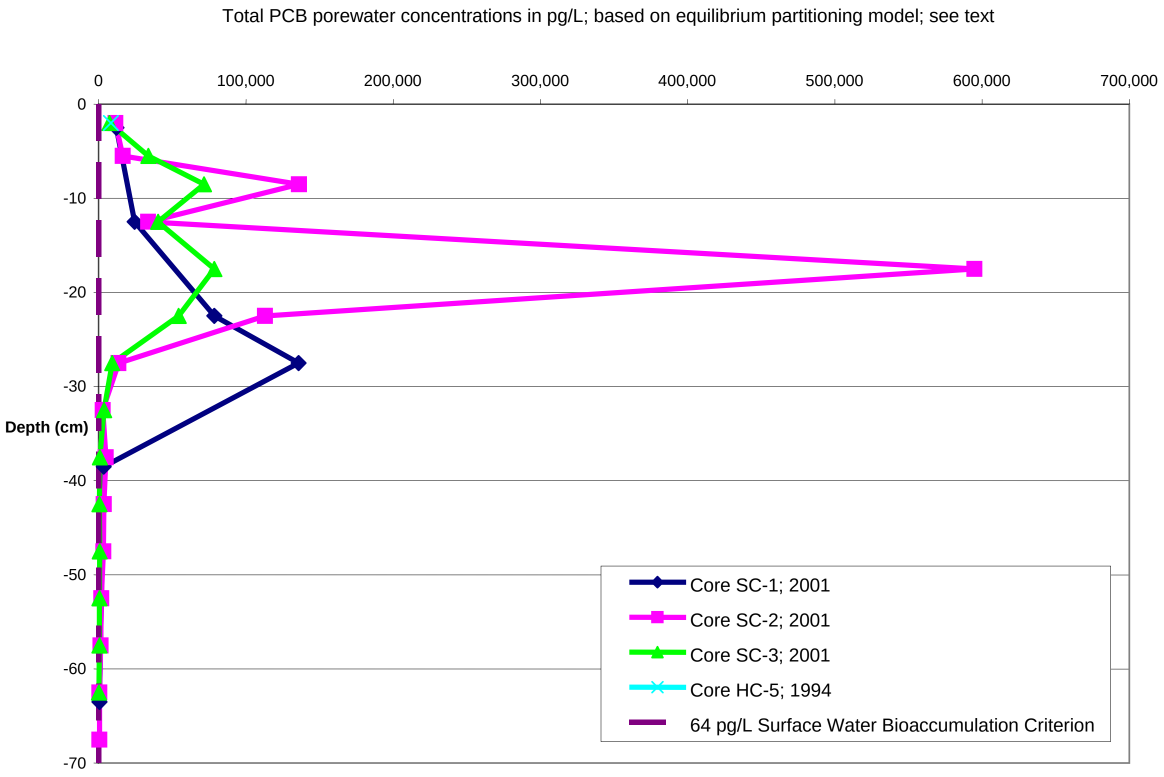


Figure 3

Depth Variation of Predicted Porewater PCB Concentrations in Deposit 1 Sediments

As summarized in Figure 3, calculated porewater concentrations near the sediment surface (i.e., at a depth of 10 cm below the mudline) currently range from approximately 2 to 3 orders of magnitude above the 64 pg/L criterion, and thus could potentially be a (currently unquantified) source of PCBs to the overlying water column. However, porewater concentrations decline 1 to 2 orders of magnitude over the top 20 to 30 cm (8 to 12 inches) of sediment, suggesting that remedies that provide for further sediment confinement may be effective in controlling potential porewater releases.

3 APPLICABLE FEDERAL, STATE, AND LOCAL LAWS

Many environmental laws may apply to a cleanup action. In addition to meeting MTCA cleanup standard requirements, a cleanup action must also meet the environmental standards set forth in other applicable laws. Though a cleanup action performed under formal MTCA authorities (e.g., a Consent Decree) is exempt from the procedural requirements of certain state and local environmental laws, the action must nevertheless comply with the substantive requirements of such laws. Potentially applicable federal, state, and local laws that may impact the implementation of remedial actions at the Site are summarized below.

3.1 Federal Requirements

Potential federal requirements are specified in several statutes, codified in the U.S. Code (USC), and regulations promulgated in the Code of Federal Regulations (CFR), as discussed in the following sections.

The **Clean Water Act** (CWA) (33 USC Section 1251 *et seq*.) requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. Section 304 of the CWA (33 USC 1314) requires the EPA to publish Water Quality Criteria, which are developed for the protection of human health and aquatic life. Federal water quality criteria are published as they are developed, and many of them are included in Quality Criteria for Water 1986, EPA 440/5-86-001, May 1, 1986 (51 FR 43665), commonly known as the "Gold Book." Publications of additional criteria established since the Gold Book was printed are announced in the Federal Register. Federal water quality criteria are used by states, including Washington, to set water quality standards for surface water.

Discharges of Pollutants into Navigable Waters are regulated under Sections 401 and 404 of the CWA (33 USC 1341 and 1344), 40 CFR Part 230 [Section 404(b)(1) guidelines], 33 CFR Parts 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters of the United States). These requirements regulate the excavation of shoreline materials and the placement of fill material (including caps) below the ordinary high water elevation of waters of the United States. The 401/404 regulations are implemented by the U.S. Army Corps of Engineers (Corps) and EPA. Under the Section 404(b)(1) guidelines, 40 CFR 230.10(b), no discharge (i.e., excavation or cap) shall be allowed if it:

- Causes or contributes to violations of water quality standards, pursuant to Section 401 of the CWA, after consideration of local dilution and dispersion.
- Violates any applicable toxic effluent standard or discharge prohibition under Section 307 of the CWA.
- Jeopardizes the continued existence of any endangered or threatened species, or contributes to the destruction or modification of any critical habitat for such species.
- Violates any requirement imposed by the Secretary of Commerce to protect sanctuary areas.

The guidelines in 40 CFR 230.10(c) also provide that no discharge will be authorized that contributes to significant degradation of the waters of the United States. Where there is no practicable alternative to a discharge, 40 CFR 230.10(d) requires the use of appropriate mitigation measures to minimize potential adverse impacts of the discharge on the aquatic ecosystem. The term "practicable" is defined in 40 CFR 230.3(q) to mean "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes." Examples of specific steps that may be taken to minimize adverse impacts are set forth in 40 CFR Part 230, Subpart H.

3.2 Washington State and Local Requirements

MTCA (Chapter 70.105D RCW) authorized Ecology to adopt cleanup standards for remedial actions at sites where hazardous substances are present. The processes for identifying, investigating, and cleaning up these sites are defined and cleanup standards are set for groundwater, soil, surface water, and air in Chapter 173-340 WAC. The levels for cleanup of contaminated sediments are determined under Chapter 173-204 WAC.

In addition to MTCA, potential state requirements are specified in several statutes, codified in the Revised Code of Washington (RCW), and regulations promulgated in the WAC.

Washington Sediment Management Standards (Chapter 173-204 WAC). The SMS establish numerical values for chemical constituents in sediments. The SMS sets forth a sediment cleanup decision process for identifying contaminated sediment areas and determining appropriate cleanup responses. The SMS governs the identification and cleanup of contaminated sediment sites and establishes two sets of numerical chemical criteria against which surface sediment concentrations are evaluated. The more conservative sediment quality standard (SQS) provides a regulatory goal by identifying surface sediments that have no adverse effects on human health or biological resources. The SQS is Ecology's preferred cleanup standard, though Ecology may approve an alternate cleanup level within the range of the SQS and the Minimum Cleanup Level (MCUL), if justified by a weighing of environmental benefits, technical feasibility, and cost. Numerical SQS and MCUL chemical criteria have not yet been developed for freshwater sediments.

State Environmental Policy Act (SEPA) (RCW 43.21C; WAC 197-11). The SEPA is intended to ensure that state and local government officials consider environmental values when making decisions. The SEPA process begins when an application for a permit is submitted to an agency, or an agency proposes to take some official action such as implementing a MTCA CAP. Prior to taking any action on a proposal, agencies must follow specific procedures to ensure that appropriate consideration has been given to the environment. The severity of potential environmental impacts associated with a project determines whether a SEPA is required.

Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173 201A WAC). The Water Pollution Control Act provides for the protection of surface water and groundwater quality. Chapter 173-201A WAC establishes water quality standards for surface waters of the state. Consistent with the requirements of Chapter 90.48 RCW, Ecology issues a water quality certification for any activity, including MTCA cleanup actions, requiring a federal permit for discharge to navigable state waters.

Washington Shoreline Management Act (Chapter 90.58 RCW; Chapter 173-14 WAC). The Shoreline Management Act and regulations promulgated thereunder establish requirements for substantial developments occurring within water areas of the state or within 200 feet of the shoreline. Local shoreline management plans are adopted under state regulations, creating an enforceable state law.

Washington Hydraulics Code (Chapter 75.20 RCW; Chapter 220 110 WAC). The Washington Hydraulics Code establishes requirements for performing work that would use, divert, obstruct, or change the natural flow or bed of any salt or fresh waters. Shoreline excavation, dredging, and/or capping actions would likely be required to meet the substantive requirements of a Hydraulic Project Approval (HPA) permit under this state regulation.

4 SCREENING OF CLEANUP TECHNOLOGIES

In this section, cleanup technologies are evaluated following MTCA guidance for possible application to the Upriver Dam Site. Potentially applicable technologies are identified and retained for assembly of site-specific alternatives in Section 5.

This Focused FS builds upon the results of the Draft Final RI Report (Anchor 2004), and is intended to provide sufficient data, analysis, and engineering evaluations to enable Ecology to select a cleanup action alternative that is protective of human health and the environment. Alternatives for sediment cleanup generally have three components:

1. General response actions – major categories of cleanup activities such as natural recovery, containment, or treatment.
2. Cleanup technologies – general categories of technologies such as capping.
3. Process options – specific technologies within each technology type such as alternative cap designs (e.g., sand versus other confining and sequestering media).

In this section, general response actions and cleanup technologies are screened in accordance with the MTCA regulations and associated guidance (e.g., SMS User Manual). Based on the results of the screening, a range of proposed alternatives are identified that use different remedial technologies and strategies to accomplish the overall Site cleanup objective.

Natural recovery of PCBs in sediment may occur over time through a combination of physical, chemical, and biological processes that lower the concentrations at the point of exposure/compliance over time. As discussed above and depicted in Figure 2, site characterization data have documented natural sediment recovery processes, following previous source controls implemented in the basin. Thus, monitored natural recovery is a proven technology and was retained for further consideration in this Focused FS.

Containment involves either confining hazardous substances in situ through placement of cap materials, or confining excavated and/or dredged materials within an on- or off-site engineered disposal facility after removal. Containment technologies have been used extensively in remediation of contaminated sediments. Thus, containment is a proven technology and was retained for further consideration in this Focused FS.

Treatment technologies can potentially reduce the concentration, mobility, and/or toxicity of PCBs. Most prospective treatment technologies rely on ex situ methods that first require removal, followed by chemical destruction, conversion, separation, extraction, or stabilization. Recently, various in situ treatment technologies have also been developed and applied successfully at the field scale, including potentially promising reactive cap/treatment technologies that are currently undergoing pilot-scale testing in the Anacostia River (Washington D.C; http://www.hsrc-ssw.org/anacostia/). To the extent that treatment technologies for sediment PCBs have been successfully demonstrated at the field scale, they were considered in this Focused FS.

As described in various MTCA guidance, the identification of applicable remedial technologies and process options for each general response action should initially consist of a broad evaluation of the applicable remedial technologies that are available and effective in remediating threats identified at the Site. Process options and cleanup technologies may be eliminated from further evaluation on the basis of technical implementability, and may also be screened on the basis of the following three criteria:

1. Effectiveness – Ability to handle estimated volumes and meet cleanup levels, ability to reduce potential human health and environmental risks, and reliability.
2. Implementability – Technical and administrative feasibility, such as the ability to obtain permits for offsite actions and availability of treatment, storage, and disposal facilities.
3. Cost – Differences among process options within particular technology types.

The remainder of this section presents the evaluation and screening of natural recovery, in situ and ex situ containment, removal, and treatment technologies.

4.1 Monitored Natural Recovery

Natural recovery of PCBs in sediment may occur over time through a combination of physical, chemical, and biological processes that lower the concentrations at the point of exposure/compliance over time. Biodegradation of PCBs is a complex process that involves different mechanisms under aerobic and anaerobic conditions. Based on studies of PCB biodegradation in other similar freshwater systems, PCB degradation processes and half-lives on the order of years to multiple decades may be expected.

The site characterization data indicate that sediment PCB levels, particularly in Deposit 1, peak at depths below the sediment surface, and PCB concentrations decrease steadily in shallower intervals. This vertical profile of PCB concentrations, depicted in Figure 2, is typical of natural sediment recovery processes, following previous source controls implemented in the basin. Net sedimentation rates ranging from 0.4 to 1.0 cm/year have been measured in Deposit 1. Along with prior implementation of PCB source controls in the basin, sedimentation and burial below clean surface sediments helps to drive the natural recovery process.

If natural recovery were to be implemented as a response action at the Upriver Dam PCB Site, periodic long-term monitoring would need to be performed to confirm recovery predictions and verify that recovery achieves the cleanup standard(s). Compliance with the cleanup level may be performed using chemical and/or confirmatory biological testing, as appropriate under existing MTCA/SMS regulations. MTCA also requires that Ecology review cleanups no less than every 5 years in those cases where contamination has been left in place, to ensure the remedy remains protective.

Subject to a balancing of environmental benefits and cost compared to other practicable alternatives, as defined by the MTCA regulation, natural recovery is considered implementable and cost effective at the Site. Therefore, monitored sediment natural recovery was carried forward for more detailed analysis in this Focused FS.

4.2 In Situ Containment

Containment can involve both in situ actions, such as in situ caps, and ex situ actions, such as removal and disposal in an upland landfill facility. Each of these technologies is addressed separately in the sections below.

A common response action to control exposure of sediments containing elevated concentrations of chemicals of potential concern, including PCBs, is to place an engineered cap over the materials, and ensure its long-term integrity through implementation of appropriate institutional controls. Since the deposition of overlying clean sediment plays a role in the process of natural recovery, as discussed above, the natural recovery process can be enhanced by actively providing a layer of clean sediment to the target area. This is often referred to as "enhanced" natural recovery or thin sand cap, and generally consists of placing a nominal 6-inch-thick layer of clean sediment over existing contaminated sediments. Alternatively, a thicker cap (typically 1 foot thick with an overlying armor layer) could be constructed over the contaminated sediments to provide more immediate isolation of underlying contaminated sediments.

Surface layers of the cap system would likely be constructed of clean sand, and could be placed by a number of mechanical and hydraulic methods. Capping has been utilized relatively frequently in sediment cleanup projects conducted in Washington State. Monitoring results to date in the region have shown that capping can provide an opportunity for effective and economical sediment remediation, without the risks that can be involved in removing and mobilizing contaminants by dredging.

If selected as part of the overall cleanup remedy at the Site, the final cap thicknesses would be determined as part of remedial design. The cap would be designed to effectively contain and isolate contaminated sediments from the overlying point of exposure/compliance. The cap would be designed to be thick enough and of sufficient grain size to maintain its integrity under reasonable worst-case environmental and human use conditions (e.g., to resist shear stresses under a 100-year flood or log deposition condition; see Section 5.3).

Subject to a balancing of environmental benefits and cost, capping is considered implementable and cost effective. Therefore, in situ capping was carried forward for more detailed evaluation in this Focused FS.

4.3 Removal and Disposal

Removal and disposal of contaminated sediments has been performed within the Pacific Northwest and elsewhere using a range of different process options appropriate for site-specific conditions. Contaminated sediments can be removed by dredging using one or more of the following representative process options:

1. Mechanical Dredging and Transport – Typical mechanical dredging involves the use of a clamshell bucket on a derrick barge, with delivery to a nearshore sediment processing and/or disposal facility. Because this Site is isolated and equipment will

need to be brought to the Site by truck, a contractor would likely use a crane on a small barge to complete the dredging.

2. Trackhoe – Application is limited to nearshore sites in shallow water.
3. Hydraulic Dredging and Transport – Typically utilizing a hydraulic cutterhead dredge to accomplish dredging and delivery of contaminated sediments to a nearshore dewatering and/or disposal site. Because of water quality control requirements, hydraulic dredging would likely require a relatively large temporary (for dewatering) or permanent (for disposal) nearshore confined disposal facility (CDF) or similar process option for this purpose.

There are generally three types of CDFs available for the disposal of contaminated sediments:

1. Upland – With this option, contaminated sediments are dredged and placed in a specially designed landfill that is on dry land, away from the aquatic environment. The landfill would include liners and a special water collection system so that leachate draining through the landfill does not escape and contaminate groundwater. Dredged sediment from the Upriver Dam Site could be disposed at regional landfills such as the Roosevelt facility.
2. Nearshore – A nearshore CDF could potentially be constructed along the shoreline area, either on uplands or within the aquatic environment. In this situation, a berm would be constructed of clean material near the shoreline, but typically there would not be a liner required, particularly for PCBs (because of limited mobility). The lower layer of the area between the berm and the shoreline would then be filled with contaminated sediment, and the surface of the CDF covered with clean sediment or fill material. Nearshore fills create new land that can potentially be used for public shoreline access or other purposes. Nearshore CDFs have often been integrated with upland redevelopment, and can also be sited on existing contaminated sediment areas to provide further efficiencies.
3. Contained aquatic disposal (CAD) – This type of CDF entails building a submerged berm or depression, filling the constructed basin with contaminated sediments delivered by barge, and then capping the facility with clean sediment. Although CAD facilities can also be sited on existing contaminated sediment areas to provide

further efficiencies, potential application within the Upriver Dam area is likely relatively limited.

Subject to a balancing of environmental benefits and cost, dredging (likely using mechanical methods) and upland or nearshore dewatering/disposal is potentially implementable at the Upriver Dam Site. Therefore, such removal and disposal technologies were carried forward for more detailed evaluation in this Focused FS.

4.4 Treatment

In addition to natural recovery and containment technologies, sediment or contaminant treatment technologies were also evaluated in this Focused FS. However, with the exception of certain technologies such as in situ reactive caps (see below), the feasibility of most treatment technologies has not yet been demonstrated for application to contaminated sediments. Moreover, the combined PCB and wider spread metal contamination present within the Site area present a higher level of difficulty for addressing the potential use of available treatment technologies. Sediment treatment was also not carried forward in the Coeur d'Alene Basin FS prepared by EPA (2001) to address metal contaminants present in Upriver Dam and upstream areas. Thus, with the exception of possible in situ reactive cap amendments (see Section 5), treatment of sediments was not carried forward for more detailed analysis in this Focused FS.

5 DESCRIPTION OF CLEANUP ALTERNATIVES

Section 4 describes potentially applicable remedial technologies and process options for the Upriver Dam Site, and evaluates those technologies based on initial MTCA screening criteria including effectiveness, implementability, and cost of application to the Site. In this section, these retained technologies are combined to formulate a range of remedial action alternatives.

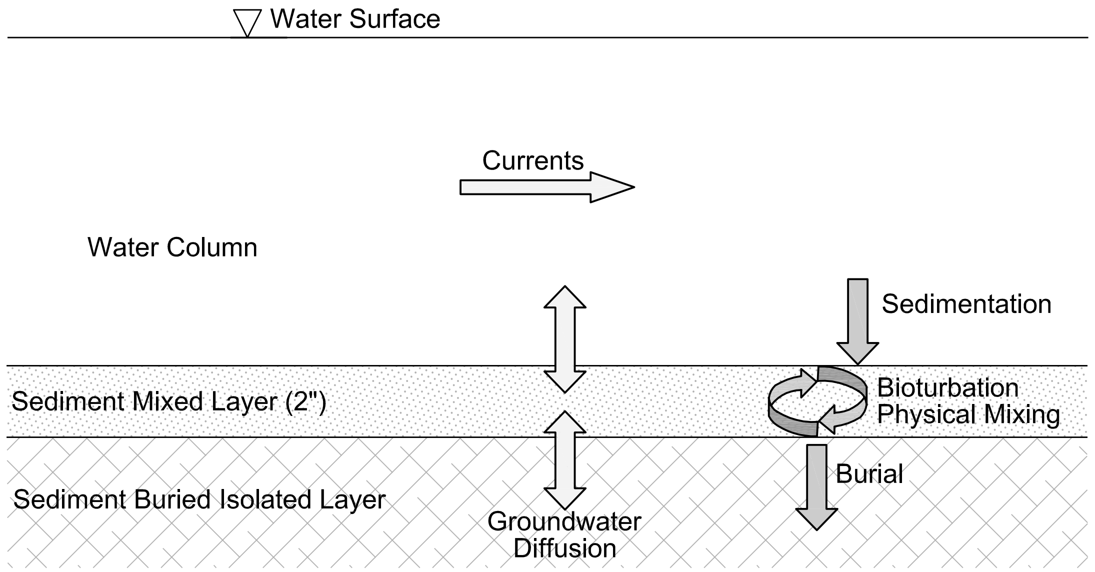
Four different remedial action options, spanning the range of potentially feasible response actions typically available for sediment sites, were developed for the Site, including:

1. Monitored natural recovery (MNR)
2. Enhanced natural recovery
3. Engineered sediment capping, considering a range of process options including different cap thickness and isolation layer material specifications as follows:
    a. Permeable sand layer
    b. Low permeability clay layer
    c. Permeable reactive sorptive layer
4. Removal and off-site disposal

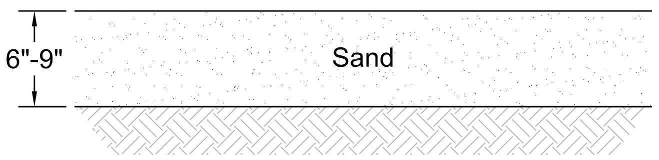
At Ecology's direction, the No Action alternative was not carried forward in this Focused FS. The sections below discuss development of each remedial action alternative carried forward for detailed FS evaluations of Deposits 1 and 2 (Figure 1).

5.1 Alternative 1: Monitored Natural Recovery

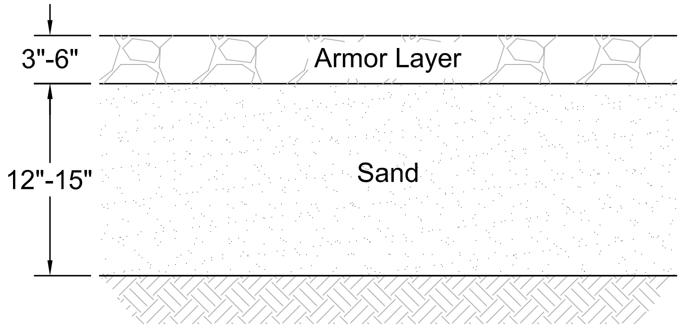
As discussed in Davis et al. (2004), MNR is a risk management alternative that relies upon natural environmental processes to permanently reduce exposure and risks associated with contaminated sediments. Figure 4 presents a schematic of sediment management alternatives including the MNR process. This option relies on sediment deposition (burial) and contaminant attenuation processes which have been documented in Deposit 1 (see Figure 2). Under this option, along with all other remedial alternatives, it is assumed that upstream source controls for PCBs, as necessary, would be implemented by independent third parties under existing wastewater discharge permits and future total maximum daily loading (TMDL) allocation-based limits. The effectiveness of MNR would be verified through long-term monitoring.



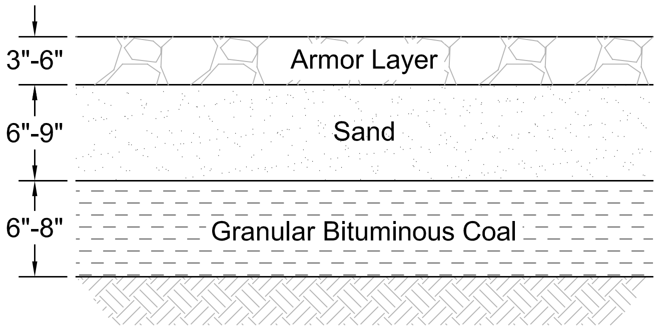
Alternative 1: Natural Recovery Process



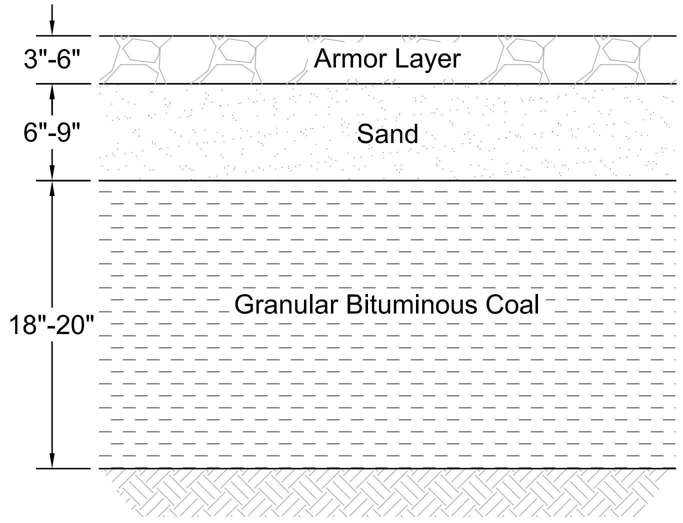
Alternative 2: Enhanced Natural Recovery



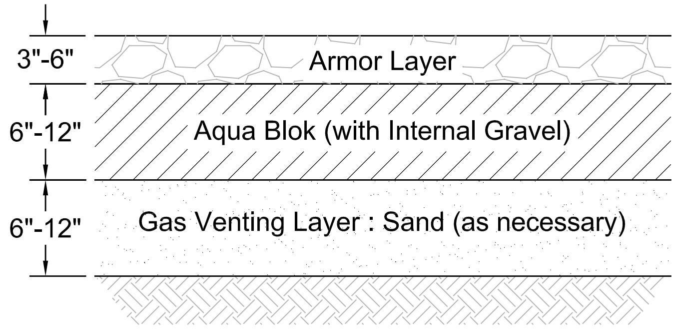
Alternative 3A: Isolation Cap



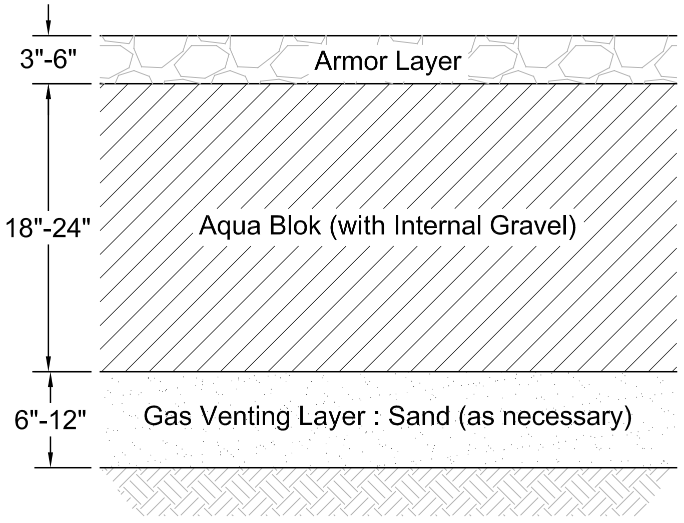
Alternative 3D: Reactive Cap



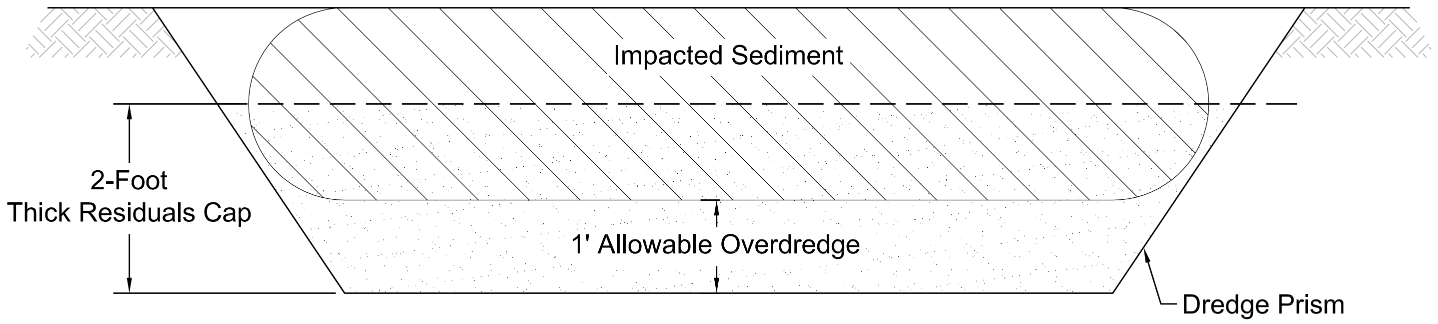
Alternative 3E: Reactive Cap



Alternative 3B: Isolation Cap



Alternative 3C: Isolation Cap



Alternative 4: Removal, Offsite Disposal & Residuals Capping

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Figure 4
Remedial Alternatives
Upriver Dam
Spokane, Washington

A weight-of-evidence approach for developing and evaluating appropriate MNR remedies at contaminated sediment sites has recently been developed by the Remediation Technologies Development Forum (RTDF) Sediment workgroup (Davis et al. 2004), and has been adopted by EPA in its sediment management guidance. The approach includes steps such as data assessment, modeling, and site monitoring, employing methods and approaches that have been successfully applied at other similar sites. The framework includes five interrelated elements:

1. Characterize contamination sources and controls.
2. Characterize fate and transport processes (both sediment and contaminant).
3. Establish historical record for contaminants in sediments.
4. Corroborate MNR based on biological endpoint(s) trends, if possible.
5. Develop acceptable and defensible predictive tools.

Each of these elements is briefly described below.

Characterize external contamination sources and controls. A critical component in the evaluation of any sediment management option, including MNR, is to characterize historic and current contaminant loading to the sediment site from external sources. Part of this understanding involves quantifying ongoing contaminant loading (e.g., annual mass releases of PCBs) to the site, and how such loading compares with historical releases. Because of the complexities often associated with contaminant loading processes, source characterization can be difficult, and the level of effort required highly site-specific.

As discussed above and generally depicted on Figure 2, chemical and radioisotope profiling performed in Upriver Dam PCB Deposit 1 reveals that current PCB loadings are far lower than conditions that existed at the Site in the 1950s and 1960s. Present-day sediment PCB inputs to the Site are currently being characterized by Ecology as part of TMDL sampling activities, and include total PCB analyses of suspended particulate matter (SPM) collected in 2003 near Plante's Ferry (roughly RM 85); initial results indicate total PCB concentrations of approximately 9 μg/kg dw measured in SPM at this location (J. Roland, personal communication 2004). Similarly low sediment input concentrations (i.e., in surface sediment "fluff" materials) were also reported by Hart Crowser (1995). Thus, based on the available data, existing PCB inputs to the Upriver Dam Site appear to be below the conservative SQV of 60 μg/kg dw. Nevertheless, additional PCB source controls may be implemented under existing wastewater discharge permits and future TMDL allocation-based limits.

Characterize fate and transport processes (both sediment and contaminant). Assessment of contaminant fate and transport processes in support of MNR requires understanding of environmental processes affecting both sediment and contaminants (Magar et al. 2003). Primary processes of interest include settling/deposition, long-term burial, bioturbation and biological mixing in the bed, porewater diffusion and advection, and chemical partitioning. As discussed above, many of these parameters, including the net sedimentation rate (0.4 to 1.0 cm/yr) and depth of the bioturbation/mixing layer (the top 4 cm of the 10 cm biologically active zone) have been characterized through prior radioisotope core profile analysis (see Figure 2).

Information on sediment stability is often necessary to assess the long term integrity of the sediment bed and understand the effects of rare, extreme event conditions on contaminant and sediment mobility (Erickson et al. 2003). Evaluation of MNR requires assessing long-term stability, to ensure contaminant isolation under normal and relatively extreme hydrodynamic events that can cause elevated erosional conditions (e.g., 100-year return frequency events). Evaluation of future bed stability can be conducted in a number ways, including inference from empirical evaluation of historical data (see Figure 2 core profiles), and/or prediction based on deterministic models of extreme event stresses and potential sediment transport (see Appendix A). This approach coupled with a review of historical hydrodynamic records can indicate whether the observed historic record reflects impacts of past extreme events.

The maximum daily flow measured over that past 110+ years in the Spokane River (i.e., since 1891 at the downstream Spokane gage) is approximately 49,000 cfs (Figure 5). For comparison, daily flows above 40,000 cfs have occurred twice since the period of peak sediment PCB deposition within the Site (i.e., 1950 to 1960; Figure 2). In addition, breaching and washout/failure of the Upriver Dam powerhouse (and concurrent lowering of the pool) occurred in response to a lightning strike and resultant overflows in 1986 (http://emd.wa.gov/3-map/a-p/hiva/36-hiva-table-9.htm). Thus, sediments in identified PCB deposits at the Site have already been subjected to certain extreme hydrodynamic events.

For Deposit 1, dam failure along the north boundary of the channel is an example of a worst case scenario where scour and remobilization might occur. More likely but less dramatic erosion forces include flood event velocities and disturbances caused by foreign objects such as sunken trees and limbs. In general, the stability of these sediments as reflected in the core profile data (Figure 2) indicates that the bed in these areas has remained generally stable over time under the range of dynamic processes in the river system including the overflow in 1986.

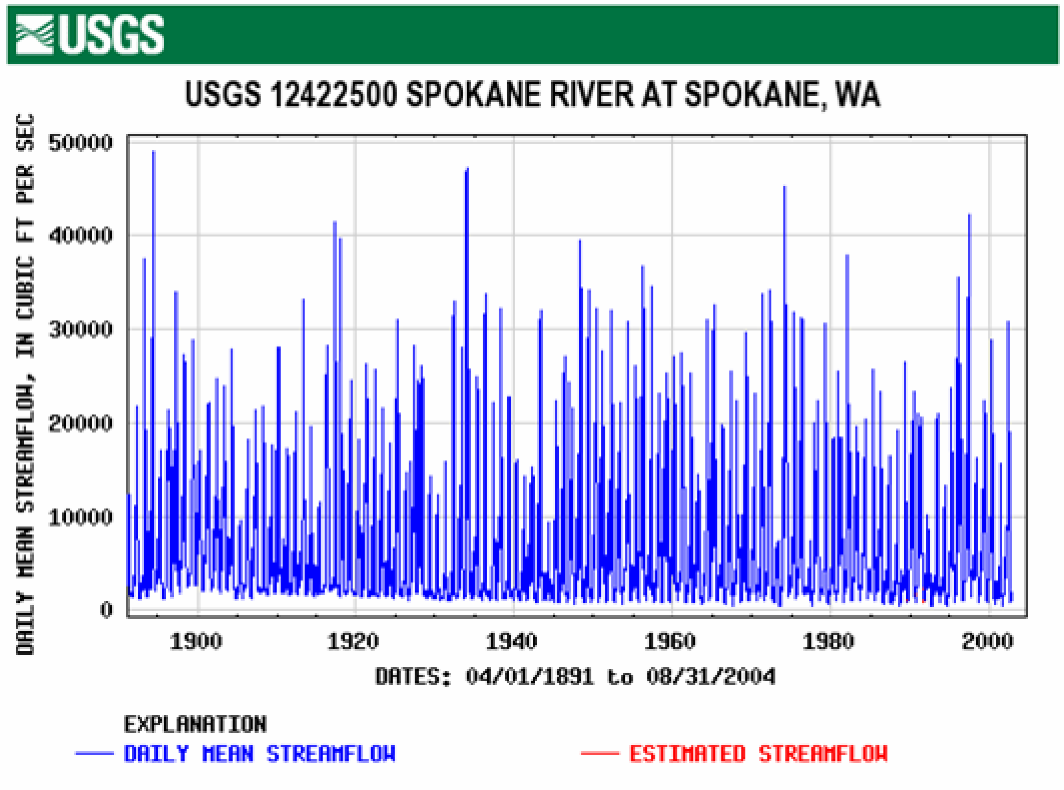

Figure 5
Historical Flows in the Spokane River, 1891 to 2003

In addition, porewater diffusion and/or advective processes represent another mechanism of potential PCB transport into the water column or into groundwater, as discussed in the RI (see Section 1.1 above).

Establish historical record for contaminants in sediments. Chemical concentration data assembled from past sampling events or from radioisotope-dated cores can be used to establish a historical record for contaminated sediments, and confirm the rate and extent of prior natural recovery (Magar et al. 2002; Patmont et al. 2003). As discussed above, the available coring record within Deposit 1 at the Upriver Dam Site provides evidence of recovery following peak loadings of PCBs to the river system that occurred in the 1950s and 1960s (Figure 2).

Corroborate MNR based on biological endpoint(s) trends, if possible. The objective of this MNR element is to confirm that risk reduction, as may be indicated by evaluation of chemical conditions, is corroborated using relevant biological measurements (Patmont et al. 2003). In many sediment site risk assessments, biological endpoints serve as the primary line of evidence for assessing human health and/or ecological protection. As a result of a range of EPA and Ecology sponsored studies, the ecological and human health risks associated with metals and other co-occurring contaminants in Spokane River sediments, including within the Upriver Dam area, have been well documented. For example, sediment toxicity measured throughout large areas of the Coeur d'Alene basin, extending into the Upriver Dam area, is consistent with risk-based models of metals toxicity (EPA 2001, Johnson and Norton 2001). Potential ecological risks associated with PCBs at the Site, including those associated with fish bioaccumulation pathways, are discussed in Johnson (2001). Potential human health risks associated with fish consumption is discussed in health consults prepared by the Washington Department of Health.

Depending on the specific site conditions, particularly relevant natural recovery biological monitoring data often include fish tissue sampling of key biological endpoints such as tissue PCB residues. While currently there are not sufficient, comparable biological endpoint data available to support a robust statistical evaluation of declining temporal trends in fish tissue PCB concentrations at the Site, further data are being collected as part of Ecology's TMDL program to evaluate this condition. This Focused FS is directed towards control of sediment and surface water PCB exposures, using bioaccumulation model relationships previously incorporated by Ecology and EPA into promulgated water quality standards.

Develop acceptable and defensible predictive tools. The final element in developing MNR alternatives is evaluation of whether observed reductions in sediment risks can reasonably be expected to continue into the future at desired rates. Future forecasts of MNR effectiveness are most often accomplished though the use/development of predictive tools such as computer models (Dekker et al. 2003). In systems in which fate and transport processes driving recovery may be complex and may change with time, simple extrapolation of historical trends may not be appropriate. In such cases, models such as the SEDCAM model discussed in Ecology's Sediment User Manual can be useful tools to predict future behavior of the system. Key SEDCAM input parameters required for the Upriver Dam site model includes the following estimations:

- Net sedimentation rate = 0.4 to 1.0 cm/yr (this range of values was used in the SEDCAM model)
- Depth of the bioturbation/mixing layer = 4 cm (based on radioisotope and chemical concentration profile data, and consistent with literature reports at other similar freshwater sediment sites; Boudreau 1997)
- Depth of the biologically active zone = 10 cm (default value from Ecology's Sediment Cleanup User Manual)
- Sediment input PCB concentration = 9 µg/kg dw (from SPM measurements; J. Roland, personal communication 2004)

Results of the SEDCAM model applied to the maximum surface sediment (0 to 10 cm) PCB concentration detected at the Site (1,430 µg/kg dw measured in Deposit 1 during Ecology's October 2000 sampling) are summarized in Figure 6. The modeling output suggests that natural recovery (at this maximum PCB concentration location) will likely achieve the 60 µg/kg dw low-range SQV between approximately 2020 and 2050, depending upon the sedimentation rate. Recovery to the 350 µg/kg dw high-range SQV would occur sooner, likely between 2010 and 2020. If Alternative 1 were to be implemented at the Site, it is assumed that monitoring at approximately 5-year intervals would be performed to verify actual rates of recovery.

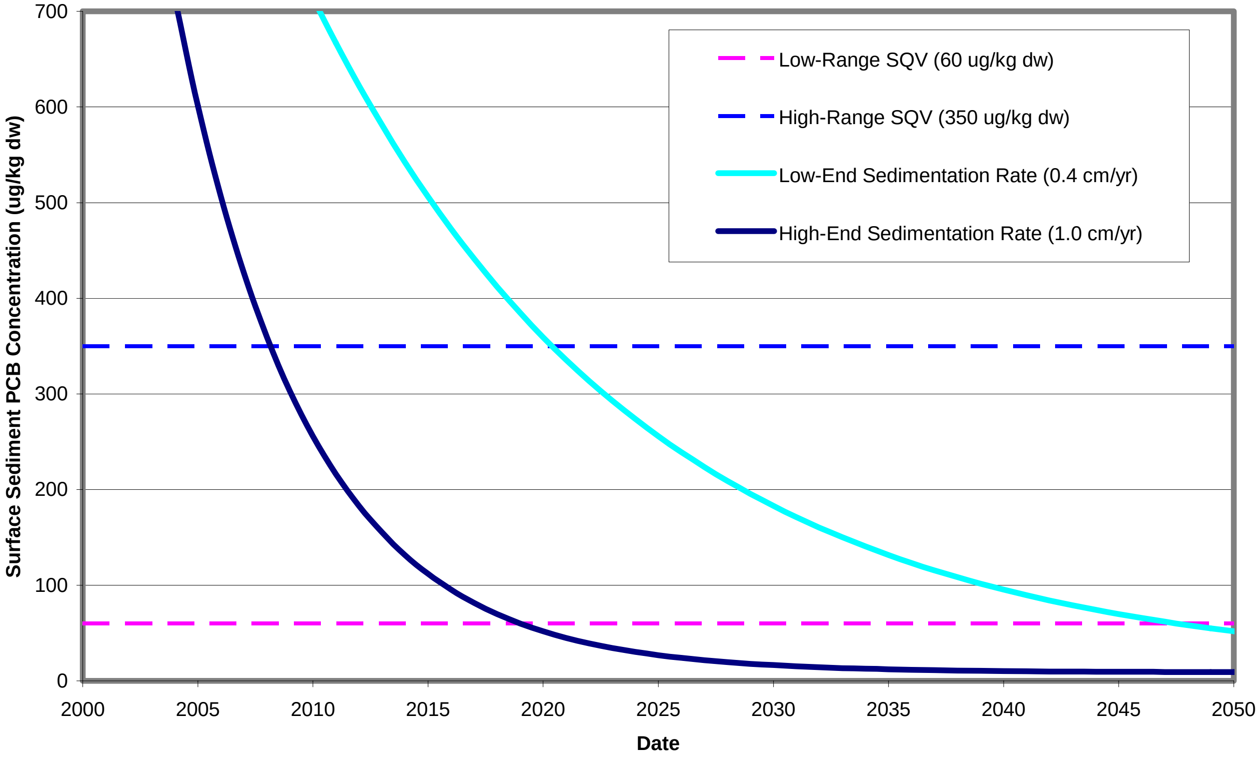

Figure 6
Predicted Natural Recovery of Maximum Surface Sediment PCB Concentrations in Upriver Dam Deposit 1; SEDCAM Model Predictions

5.2 Alternative 2: Enhanced Natural Recovery (Thin-Layer Capping)

This option would enhance the rate of natural recovery by placing a nominal 6-inch (15-cm) layer of clean sand over sediments that exceed the preliminary SQV (60 µg/kg dw). Figure 4 shows a typical cross-section of the alternative. Placement of the thin layer on top of existing sediments would facilitate more rapid attainment of the SQV within the top 10 cm biologically active zone. Compared with thicker sediment caps (see Alternative 3 below), application of thin-layer placement technologies is typically associated with significantly less short-term environmental impact, as existing sediment-dwelling benthos populations are able to migrate through the nominal 6-inch layer with relatively little mortality. The grain size composition of the cap would likely be a fine to medium sand. As discussed under Alternative 1, upstream source controls for PCBs, as necessary, would be implemented under existing wastewater discharge permits and future TMDL allocation-based limits. The effectiveness of enhanced natural recovery would be verified through long-term monitoring, though it is assumed that fewer monitoring events would be required to verify attainment and maintenance of the SQV, compared with Alternative 1.

The thin layer cap could be placed by a contractor using a number of different methods. At Deposit 1, the contractor would utilize either a mechanical or hydraulic system from the water. At Deposit 2, the contractor would likely place a thin cap from shore.

Placement of a thin-layer cap over Deposit 1 would require approximately 6,600 tons of sand, and could be completed over a period of approximately 1 to 2 weeks. Based on equipment tolerances and experiences at other similar sites, a contractor may need to place up to 12 inches of fine to medium sand to ensure that they obtain a 6-inch minimum thickness specification across the bottom. The sand would likely be brought to the site by truck and stockpiled on shore. If the contractor were to place the material mechanically, they would transfer the material to a barge. A crane on a barge would then use a clamshell bucket or equivalent equipment to place the material. The contractor would likely use differential global positioning system (DGPS) equipment to ensure location control during placement, and would monitor placement with soundings and/or cores.

Alternatively, the contractor could place the material hydraulically. In this case, the contractor would load the material from the stockpiles into a hopper and slurry the sand. The sand slurry would be pumped out to a diffuser barge located over the capping area. The diffuser barge would reduce the energy in the slurry, allowing the sand to fall through the water column and deposit on the sediment. The barge would be moved back and forth over the capping area using DGPS for location control. As with the mechanical approach, the contractor would use soundings and/or cores to monitor progress.

Placement of a thin-layer cap over Deposit 2 would likely be performed from shore. Based on an estimated 0.2 acres of sediment with PCB concentrations exceeding 60 µg/kg dw, construction of the thin-layer cap would require approximately 300 tons of sand, and would require roughly 1 week to complete. The sand would be hauled to the site by truck and stockpiled nearby. The contractor would either place the material by bucket and crane or pneumatically from shore. Surveys and/or cores would be used to monitor thickness during placement.

Design and construction of the enhanced natural recovery option described above could be completed within 1 to 2 years of execution of a Consent Decree.

5.3 Alternative 3: Sediment Capping (5 Process Options)

This option includes placement of a clean sediment cap over areas of the Site that exceed the SQV (60 µg/kg dw), to isolate underlying materials from the biologically active zone and water column. Consistent with EPA and Corps regulatory guidance for conducting in situ capping at contaminated sediment sites (Palermo et al. 1998a and 1998b), the cap would be designed to provide three different functions:

1. Physical isolation of PCB-contaminated sediments below the biologically active zone (10 cm thick benthic environment)
2. Further stabilization of subsurface PCB-contaminated sediments from potential worst-case hydrodynamic forces (i.e., erosion protection)
3. Reduction of transport (flux) of dissolved PCBs into the overlying water column

EPA and Corps cap design guidance also includes long-term monitoring, maintenance, and adaptive management elements to ensure the long-term integrity and performance of the cap system. Remedial design of the cap system is normally based on engineering analyses applied to reasonable worst-case conditions (e.g., a 100-year flood event), to ensure the long-term integrity and performance of the remedial action. Typically, performance and confirmation monitoring of contaminated sediment cap systems constructed in Washington State and elsewhere in the U.S. has occurred during Years 2, 4, and 9 following completion of the remedial action, with subsequent monitoring triggered by the occurrence of a design level hydrodynamic event such as a 50-year flood.

5.3.1 Capping Materials

Fine-grained as well as granular (sandy) materials have been demonstrated to be effective sediment caps (Brannon et al. 1985). However, most remedial in situ capping projects conducted to date have used sand materials, largely because of availability, relatively low cost, ease of placement, and stability in sloped areas (Palermo et al. 1998a and 1998b). While finer-grained material can provide a better chemical flux barrier than sands because of higher sorption capacity and lower permeability, use of finer-grained materials in remedial cap design to date has been limited by logistical difficulties associated with effective placement of such material on inundated substrates. Finer grained caps can often hinder movement of porewater and groundwater contaminants, and thus can control flux into the overlying water column and/or underlying groundwater.

Coarser grained caps are often more suitable for sediments with significant upwelling groundwater discharge into surface water, as finer-grained caps placed in such environments may be prone to uplift. Based on available regional hydrogeologic data (Patmont et al. 1985; Anchor and Hart Crowser 2003), the delineated sediment deposits in Upriver Dam (Figure 1) are in groundwater recharge areas (river exfiltration into the aquifer). Thus, hydraulic uplift is likely not a significant limitation of fine-grained caps that may be considered at the Upriver Dam PCB Site. Conceptual designs of capping systems for Deposits 1 and 2 developed for this Focused FS also considered site preparation (e.g., wood debris removal), armoring, and potential gas production, as discussed below.

Several commercial products have recently been developed that allow for the placement of finer-grained cap materials in freshwater environments. The material that has been used most often in this capacity is AquaBlok™ (Hull et al. 1999, Hull and Stephens 2000), which is a patented technology including a blend of clay minerals, polymers, and other additives surrounding a dense aggregate nucleus such as gravel. For typical product formulations, the clay component is often comprised largely of bentonite, although other clay-sized materials can be used in product preparation to address specific requirements. When applied in sediment capping applications, AquaBlok™ particles settle through the water column to the mudline. Within several weeks, the applied layer of AquaBlok™ particles hydrates and expands, coalescing into a cohesive and low-permeability barrier cap between the contaminated sediments and the overlying water. The gravel component of the mixture (e.g., nominal 1-inch material) provides erosion protection, or can be supplemented if necessary with more conventional armor designs. AquaBlok™ has been used in several successful in situ capping demonstration projects (e.g., Grasse River, New York; McShea et al. 2002) and in full-scale applications (Eagle River Flats, Anchorage, Alaska; Kate and Racine 1996, Hull and Stephens 2000).

More recently, sediment cap design has become increasingly focused on the addition of a range of "active" materials to cost-effectively control contaminant mobility and/or encourage degradation by sequestering the chemical onto a suitable media (see McLeod et al. 2004). A major demonstration of several of the more promising active cap designs is now underway on the Anacostia River in Washington, DC (Reible and Constant 2004). The objective of the Anacostia River demonstration project, which began field trials in spring 2004, is to provide information on the design, construction, and placement of active caps. Initial bench-scale treatability testing assessed the feasibility and expected effectiveness of a range of active cap technologies, and identified the most promising technologies for field-scale demonstration. While various cap technologies were evaluated, the following were selected for use in the demonstration:

- Sand, used in the Anacostia River demonstration as a control
- AquaBlok™, a commercial product designed to enhance chemical sequestering (e.g., through TOC amendments to the cap) and reduce permeability at the sediment-water interface (see above)
- Apatite, which encourages precipitation and sorption of metals (though not directly applicable to the Upriver Dam PCB Site)
- Coal and/or coke breeze materials, which can strongly adsorb hydrophobic organic contaminants such as PCBs

A range of the most promising sand, AquaBlok™, coal, and armor material options that provide for containment and mobility control of PCBs at the Upriver Dam Site were considered as potential capping options in this Focused FS, as discussed in more detail below.

5.3.2 Cap Thickness and Placement Considerations

Conceptual designs and evaluations of in situ caps performed for this Focused FS followed the detailed cap design guidance developed by the EPA and Corps (Palermo et. al. 1998a and 1998b). The guidance recommends that caps be designed and constructed (i.e., sufficient thicknesses of suitable materials placed above contaminated sediments) to ensure protection from surface erosion/mixing forces and groundwater/porewater transport processes. The surface armor layer of a cap is designed to resist the following reasonable worst-case erosion/mixing forces:

- **Peak river currents** – 100-year peak flood conditions (addressed in this Focused FS with conservative modeling; see below and Appendix A).
- **Wind and vessel generated waves** – Since Deposit 1 sediments are located in water depths greater than 20 feet, and because wave effects even under peak conditions will be limited to the upper 4 to 5 feet of the water column, this potential erosion force is minimal, particularly in comparison with the 100-year flood condition.
- **Vessel propeller wash** – Vessel use in the prospective capping areas are predominantly recreational craft, with the relatively low potential to generate significant propwash currents, particularly in comparison with the 100-year flood condition.
- **Ice** – Because of the depth of Deposit 1, potential ice scour is not an issue within these areas, but may be a consideration in Deposit 2. However, ice in the Donkey Island side channel area typically would not freeze down to the cap surface, and thus has a low potential for ice gouging and associated erosion.
- **Anchor drag and other potential human contact** – Again, because of the depth of the prospective caps and use of the area by recreational craft, anchor drag and contact by humans from wading or walking is not expected to be an issue. Anchors dropped onto or dragged across a granular cap may induce temporary, isolated injuries to the cap. However, the granular material side walls created by the anchor impact are expected to slough back into the impact area and are thus self healing. Consequently, potential anchor effects are not expected to materially impact cap integrity.
- **Bioturbation** – As discussed above, the depth of the bioturbation/mixing layer measured in Deposit 1 is 4 cm (approximately 2 inches), however for the purpose of cap design the surface bioturbation layer was conservatively set at 10 cm (4 inches), corresponding to the maximum depth of the biologically active zone (from Ecology's Sediment Cleanup User Manual).

An additional capping consideration in the Upriver Dam area is the potential for disturbance of the sediment cap caused by foreign objects such as sinking trees or limbs that may settle onto the capped areas. For the purpose of this Focused FS, shallow foundation bearing capacity models were used to evaluate the effect of a worst-case 3-

foot-diameter log that could potentially settle onto the cap. For this analysis, the log was evaluated as a long strip footing (Das 1984). Strength parameters for regional sand and AquaBlok™ cap materials were based on available laboratory test data, along with past experience with similar materials. Loads from the log bearing on the different caps were calculated assuming a range of different unit weights of sunken logs, as specific data were not available on the density of sunken logs in the Spokane River.

For the range of potential sand, AquaBlok™, and cap armor materials considered in this Focused FS, the foundation analysis revealed that log densities greater than 100 pounds per cubic foot (pcf), or more than 50 percent greater than that of water, would be required to exceed the bearing strength of the cap. Since log densities of this magnitude are not expected (typical sunken log densities range up to 70 to 80 pcf), prospective cap designs developed for this Focused FS provide an additional safety factor against potential bearing failure. Therefore, a log settling or resting on any of the caps evaluated in this Focused FS is not expected to materially injure the cap(s) under static conditions.

The potential for a log to injure the cap under a dynamic condition, such as a storm event, was evaluated qualitatively, as there is a low likelihood that a log would impact the cap during a high flow event. That is, all of the sediment areas being considered for capping are in backwater regions protected from primary river currents by upstream river meanders and/or banks (e.g., inside bends; Figure 1). Larger debris moving through the river would be directed towards the outside of the river bends, and away from Deposits 1 and 2.

As discussed above, long-term monitoring and adaptive management of the cap surface is included as an element of all of the capping alternatives developed and evaluated in this Focused FS to ensure the long-term integrity and performance of the cap system. In the event that monitoring data reveal that logs settle onto the cap, and in the unlikely scenario that material damage to the cap were to be observed, repair of the cap surface would be performed as part of long-term contingency and adaptive management actions.

Below the surface erosion/armor layer, the isolation layer is designed to ensure that groundwater/porewater/sediment transport from contaminated subsurface layers will not recontaminate the biologically active zone of the cap in the future. One dimensional groundwater transport analytical modeling, discussed in more detail in Section 6.2.3, was performed to determine the thickness of the required isolation layer under different capping options. The thickness of the isolation zone is also determined by the precision of placement methods, as cap placement in some settings can potentially result in mixing of cap materials with the underlying contaminated sediments.

All of the conceptual cap designs developed and evaluated in this Focused FS, including those with thinner layers of erosion and/or isolation materials, were developed in conformance with EPA and Corps cap design guidance (Palermo et. al. 1998a and 1998b). While the detailed cap specifications would need to be verified during final remedial design based on more detailed engineering analyses, all of the conceptual cap designs carried forward in this Focused FS are consistent with current regulatory design guidance, and thus should provide for long-term effectiveness and protection. At the request of Ecology, options employing greater cap thicknesses were also developed to evaluate whether additional protection or biological benefits beyond cleanup may be provided by further increasing cap thickness above the design guidance.

As discussed above, one of the key considerations in cap design is material placement capabilities. To test the ability to place active cap layers in thin lifts using available technologies, the layers were deposited at the Anacostia River demonstration site with a conventional clamshell bucket in 6-inch lifts. Since the specific gravity of coke is typically less than that of water, and because of the high reactivity of these materials (i.e., requiring much less than 6 inches of material to provide the desired adsorption characteristics), coke breeze was placed in a 1-inch mat enclosed in a geotextile. (Alternatively, similarly active materials such as peat or crushed bituminous coal, which have specific gravities greater than water, could have been placed directly on the site using a clamshell bucket, as has been suggested and demonstrated at various Puget Sound capping projects, and further evaluated in this Focused FS.)

The active sediment cap designs for the Anacostia River demonstration included two layers: a reactive layer of variable thickness, and an overlying protective sand layer of 6 inches (15 cm). Both the reactive layer and the overlying sand layer isolate the contaminated sediments physically and chemically. The upper sand layer is typically designed to contain the lower active layer (and associated contaminants) and provide a substrate suitable for benthic organisms. AquaBlok™ provides a finer-grained sediment surface that can also provide a suitable habitat for benthic macroinvertebrates, particularly compared with sand (Hull et al. 1999), and thus does not often require a sand cap.

In the Anacostia River demonstration pilot, only the AquaBlok™ layer was placed slightly thicker than the targeted design, a result caused by the difficulty in placing thin layers of this material, and by swelling due to hydration. Researchers from Louisiana State University, University of Texas and elsewhere are currently confirming initial results and will be evaluating the performance of the caps over the next several years.

All of the cap designs carried forward in this Focused FS include an initial debris sweep of the capping area to ensure that relatively uniform layers of cap materials are placed. As a general design "rule of thumb," in order to ensure that cap layers cover the site entirely, surface debris equal to or larger than the target cap thickness should be removed. Thus, for a nominal 6-inch cap, surface debris currently protruding more than 6 inches above the mudline should be removed prior to cap placement. Both sand and AquaBlok™ caps typically conform to and cover smaller debris. Costs for initial debris removal have been incorporated into all cap designs. In addition, the AquaBlok™ cap includes placement of a lower sand gas venting layer to ensure that gas buildup does not adversely affect long-term cap performance (Mutch et al. 2004; see Figure 4). The need for such a layer would be verified during final design.

Based on the results of pilot and full-scale capping projects performed to date, and in order to inform evaluations of potential remedies applicable to the Upriver Dam PCB Site, this Focused FS evaluated a number of different potential sediment capping process options, as follows:

- **Alternative 3A** – A nominal 12-inch thickness of sand, overlain with 3 inches of appropriate gravel armor cover (see below).
- **Alternative 3B** – 6 to 12 inches of sand (gas venting layer), overlain with a nominal 6 inches of AquaBlok™, and covered with an additional 3 inches of gravel armor (gravel is also incorporated into the AquaBlok™ product).
- **Alternative 3C** – 6 to 12 inches of sand (gas venting layer), overlain with a nominal 18 inches of AquaBlok™, and covered with an additional 3 inches of gravel armor.
- **Alternative 3D** – A nominal 6-inch thickness of granular bituminous coal, overlain with 6 inches of sand, and covered with an additional 3 inches of gravel armor. The nominal thickness of the coal layer in Alternative 3D was based on the results of chemical transport modeling and safety factor considerations, as discussed in more detail in Section 6.2.3.
- **Alternative 3E** – A nominal 18-inch thickness of granular bituminous coal, overlain with 6 inches of sand, and covered with an additional 3 inches of gravel armor.

Figure 4 shows generalized cross sections of Alternatives 3A through 3E. As discussed under Alternatives 1 and 2, upstream source controls for PCBs, as necessary, would be implemented under existing wastewater discharge permits and future TMDL allocation-based limits.

The reactive materials included in the above alternatives, including higher organic carbon components of AquaBlok™ and granular bituminous coal, provide for greater adsorption of chemicals such as PCBs from sediment porewater prior to diffusion into overlying cap layers, further improving the long-term effectiveness and permanence of the remedy (McShea et al. 2002, McLeod et al. 2004, Reible and Constant 2004). The effectiveness of capping would be verified through long-term monitoring, though fewer sampling events are anticipated to document the effectiveness of this option, compared with Alternative 2.

As discussed in Palermo et al. (1998a and 1998b), the surface of the cap would be designed to be thick enough and of sufficient grain size to maintain its integrity under reasonable worst-case environmental and human use conditions (e.g., to resist shear stresses under a 100-year flood condition). In order to ensure sufficient thickness to prevent significant scour under this flood condition, the armor layer would likely consist of a nominal 3 inches of material with a mean grain size of 1 inch, with a likely gradation specification of 50 percent of the material ranging between 1 and 4 inches, the other 50 percent passing 1 inch, and no more than 5 percent passing a number 200 sieve. This preliminary armor specification was based on initial, conservative stress calculations under a 100 year flow event for the Spokane River of 53,900 cfs (see Figure 5), normal pool elevation, and analysis of shear stresses at various locations within and adjacent to Deposit 1 (Appendix A). As part of final design, a more detailed hydrodynamic analysis may be completed using a more refined modeling analysis (e.g., 2-D SEDZL or HEC-RAS), that could more specifically address the effects of river meander and dam configuration/operation characteristics on hydrodynamics and bottom shear stresses at the Site. The design-level hydrodynamic model would be used to refine conservative shear stress estimates used in this Focused FS (Appendix A), and would likely conclude that a smaller armor grain size would suitably resist erosion potentially associated with peak flow events.

As discussed above, gravel components of the standard AquaBlok™ formulation as well as the cohesive strength of the clay fraction appear to be sufficient to resist the design erosive forces due to the presence of engrained gravels and the cohesive nature of the AquaBlok™ material. As generally described by the Hjulstrom diagram (see Appendix A), both the gravel and bentonite/clay components included as part of standard AquaBlok™ formulations have the capacity to resist erosion during peak flood flows at the Upriver Dam PCB Site. Nevertheless, in order to ensure the long-term integrity of the AquaBlok™ alternatives, an additional nominal 3-inch layer of gravel armor was included as the final cover, similar to the other capping alternatives (Figure 4). Again, more detailed hydrodynamic analyses would be performed during remedial design to develop final cap and armor specifications.

Based on various field trials and full-scale applications (Kate and Racine 1996, Hull et al. 1999, McShea et al. 2002, Reible and Constant 2004), AquaBlok™ is best placed mechanically. Similarly, cap armor material would be too coarse to place hydraulically with typically-available pump sizes. As with the thin-layer cap, all proposed alternatives for the cap sections at Deposit 2 would likely be placed mechanically from shore.

The sand and granular bituminous coal material could be placed using either the mechanical or hydraulic means described above for the thin layer cap (Section 5.2). The granular bituminous coal material may need to be saturated before placement to ensure even and effective coverage. The unit dry weight of the coal material is roughly 1 ton/CY. If the material were placed hydraulically, the contractor would likely use a submerged diffuser to place the material. The pipeline would have a 90 degree turn at the water surface and extend down to within 5 feet of the sediment surface. A horizontal plate would be located perpendicular to the slurry flow to dissipate the energy of the coal slurry. After dissipation, the material would settle to the bottom.

Many different regional and national sources exist for granular bituminous coal. Depending on the specific source, there could be potential concerns associated with accessory hazardous substances present in the coal, such as certain metals (e.g., mercury) and polynuclear aromatic hydrocarbons. However, there are also available sources of these materials that contain relatively low concentrations of accessory chemicals at or below existing freshwater AET and SQV guidelines (Michelsen 2003). If a coal or equivalent amendment to the cap system were selected as part of the final cleanup remedy, detailed specifications for acceptable material quality (e.g., chemical concentrations at or below minimum cleanup level criteria and with elutriate testing data demonstrating low leachability) would be developed during remedial design to ensure the protectiveness of the remedial action. Placement of a nominal 6-inch thickness of sand on top of the coal, along with the overlying gravel armor layer, would also ensure isolation of coal-associated chemicals from the biologically active layer (Figure 4).

The sections below summarize estimated tonnage requirements and estimated construction duration for each capping alternative applied to Deposits 1 and 2. Tonnage estimates assume typical overplacement allowances to address normal precision tolerances. The following cap material tonnages were estimated based on typical unit weights for placed materials in the region: 1.6 tons/CY for gravel, 1.5 tons/CY for sand, and 1.0 tons/CY for coal. Because of the relatively small size of Deposit 2, and since the relative performance of the different capping process options are already addressed for Deposit 1, only a single representative capping option (Alternative 3A; 12-inch nominal thickness of sand) was carried forward for Deposit 2. Due to its sheltered location behind Donkey Island, Deposit 2 would also likely not require armor protection, so no such gravel cover was included in the capping option developed for this area. Design and construction of all of the capping process options described herein could be completed within 1 to 2 years of execution of a Consent Decree.

5.3.3 Alternative 3A—12 Inches of Sand with Armor

At Deposit 1 approximately 11,000 tons of sand material would be placed under 5,000 tons of gravel armor material. This work would take 6 to 8 weeks to complete.

At Deposit 2 approximately 500 tons of sand material would be placed. An armor layer is likely not needed in Deposit 2. This work would take 2 to 3 weeks to complete.

5.3.4 Alternative 3B—6 Inches of AquaBlok™ with Armor

At Deposit 1 approximately 9,000 tons of sand would be placed as a gas venting layer (if required), overlain with 800 tons of AquaBlok™ material, and 5,000 tons of gravel armor. This work would take 5 to 8 weeks to complete.

5.3.5 Alternative 3C—18 Inches of AquaBlok™ with Armor

At Deposit 1 approximately 9,000 tons of sand would be placed as a gas venting layer (if needed), overlain with 2,400 tons of AquaBlok™ material, and 5,000 tons of gravel armor. This work would take 6 to 9 weeks to complete.

5.3.6 Alternative 3D—6 Inches of Coal and 6 Inches of Sand with Armor

At Deposit 1 approximately 4,000 tons of granular bituminous coal material would be placed under 7,000 tons of sand material, overlain with 5,000 tons of gravel armor. This work would take 8 to 10 weeks to complete.

5.3.7 Alternative 3E—18 Inches of Coal and 6 Inches of Sand with Armor

At Deposit 1 approximately 10,000 tons of granular bituminous coal material would be placed under 7,000 tons of sand material, overlain with 5,000 tons of gravel armor. This work would take 14 to 16 weeks to complete.

5.4 Alternative 4: Dredging, Off-Site Disposal, and Residuals Capping

Under this option, the top 3.5 feet (70 cm to bottom of impacted sediment; Figure 2; plus overdredge allowance) of sediments at Deposit 1 and the top 2 feet (30 cm to bottom of impacted sediment; plus overdredge allowance) at Deposit 2 that exceed the potential SQV (e.g., 60 μg/kg dw) would be dredged or excavated as practicable (i.e., excluding potentially problematic cobble/boulder areas), removing roughly 95 percent of the sediment PCB mass from the system and relocating it to a disposal site. A relatively small mechanical clamshell would be used to remove approximately 23,000 CY of in-place sediments and associated debris from Deposit 1, and the materials dewatered as necessary in a temporary shoreline dewatering facility located near the dredge area. Water from the dewatering process may require treatment to remove PCB particles prior to discharge.

While several different dredging technologies are available that can accomplish submerged sediment removal, mechanical dredges appear best suited to conditions in Deposit 1. The dredging system contemplated under Alternative 4 would consist of a barge-mounted excavator equipped with a hydraulically operated watertight bucket. Deposit 1 sediments, along with associated debris dredged with this equipment would likely be placed into a barge for transport to a shoreline offloading/rehandling/decanting facility. Based on site characteristics and experiences at other similar dredging projects, anticipated production rate for Deposit 1 dredging would be roughly 500 CY/day, requiring approximately 10 to 15 weeks of construction.

Dredged sediments, including residual water, are currently acceptable for landfill disposal at regional facilities (e.g., Roosevelt Regional Landfill). Cost estimates developed for this FS assumed that residual water generated during mechanical dredging operations would be transported to the landfill along with the dredged sediment.

Given the presence of woody debris, cobble, boulders, and other potential obstructions within Deposit 1 that will likely impede dredge efficiency and contribute to the development of residuals, a relatively thin layer of sediment residuals is anticipated to result from the dredging process, irrespective of the number of dredge passes performed. Thus, sediment residual remaining on the post-dredge surface, particularly in the relatively deep-water Deposit 1, would be allowed to remain in place, and would be contained below a nominal 2-foot-thick backfill/sand cap layer to prevent exposure to the biologically active zone or water column. The 2-foot-thick backfill would also restore existing grades in the area, minimizing habitat disturbances. Figure 4 illustrates Alternative 4.

For the purpose of this Focused FS, the Deposit 2 excavation area was assumed to be isolated during construction from the Spokane River by placement of a small sand dam to control water quality releases associated with excavation within this area. Under Alternative 4, approximately 700 CY of sediment would be removed from Deposit 2, requiring 1 to 3 weeks of construction.

Excavation of sediment in Deposit 2 could also be cost-effectively integrated into a larger habitat restoration action in the Donkey Island area. However, since habitat restoration actions (over and above construction mitigation requirements) are not required as part of a cleanup action mandated under MTCA, evaluation of such integrated actions was not addressed in this Focused FS.

The effectiveness of the dredge and cap remedy would be verified through water and sediment quality monitoring. Under this alternative, all dredge material (including residual water) was assumed to be hauled by rail to the Roosevelt Regional Landfill. As discussed under Alternatives 1 through 3 above, it is assumed that upstream source controls for PCBs, as necessary, would be implemented under existing wastewater discharge permits and future TMDL allocation-based limits.

Owing to the more complex nature of the Alternative 4 action, design and construction of Alternative 4 applied to Deposit 1 would likely require 2 to 4 years following execution of a Consent Decree. By comparison, design, permitting, and construction of Alternative 4 applied to Deposits 2 would likely be fully completed within a period of 1 to 2 years.

6 EVALUATION OF REMEDIAL ALTERNATIVES

This section provides a comparative evaluation of the four remedial alternatives (and sub-alternatives) described in Section 5, to support selection of a preferred cleanup action in accordance with MTCA requirements. MTCA identifies specific criteria against which alternatives are to be evaluated, and categorizes them as either "threshold" or "other" criteria. All cleanup actions must meet the requirements of the threshold criteria. The other MTCA criteria are considered when selecting from among the alternatives that fulfill the threshold requirements. The remedial alternatives are evaluated against the threshold criteria in Section 6.1, and against the other MTCA criteria in Section 6.2.

Although this section is organized to specifically address MTCA evaluation criteria, cleanup action requirements under other ARARs (as summarized in Section 3) are also incorporated into the discussion as appropriate. For example, the guidelines in 40 CFR 230.10(c) regulating discharges to waters of the United States were considered in evaluations of short-term risks (e.g., potential for contaminant releases during construction) and the effectiveness over the long term (e.g., potential for long-term discharges to surface water).

6.1 Threshold Criteria

The threshold MTCA requirements for a selected cleanup action are as follows:

- Protect Human Health and the Environment
- Comply with Cleanup Standards and Applicable State and Federal Laws
- Provide for Compliance Monitoring

The assessment against these criteria evaluates how the alternative complies with applicable risk-based cleanup standards and other applicable laws, including compliance with water quality protection components. This assessment also considers potential MTCA and SMS freshwater sediment cleanup standards.

All of the alternatives described in Section 5, including Alternative 1 – Monitored Natural Recovery, would be predicted with varying degrees of uncertainty to result in compliance with even the most stringent potential PCB cleanup standards and applicable laws, though the different alternatives would achieve this condition under varying time frames (see

Restoration Time Frame Section 6.2.1 below). All of the alternatives also provide for compliance monitoring.

6.2 Other MTCA Criteria

In this section, the remedial alternatives are comparatively evaluated against the following MTCA criteria:

- Provision for a reasonable restoration time frame
- Permanence
- Effectiveness over the long term
- Management of short-term risks
- Technical and administrative implementability
- Consideration of public concerns
- Cost

6.2.1 Provision for a Reasonable Restoration Time Frame

As defined in MTCA (Chapter 173-340-360[6]), this criterion evaluates when cleanup levels will be met at the point of compliance and potential risks alleviated. The practicability of achieving a shorter time frame is also assessed with this criterion.

The alternatives associated with the shorter restoration time frame and time required to implement and complete construction are Alternative 2 – Enhanced Natural Recovery (Thin Sand Cap) and all of the Alternative 3 Capping options (3A to 3E), which can be completed within 1 to 2 years of execution of a Consent Decree.

Alternative 4 – Dredging, Off-Site Disposal, and Residuals Capping could be implemented in an intermediate time frame, likely requiring 2 to 4 years following execution of a Consent Decree.

Finally, Alternative 1 – Monitored Natural Recovery, is associated with the longest restoration time frame in terms of achieving cleanup requirements, as the lowest potential cleanup standards may not be met for a period of 5 to 40 years (Figure 6), depending on sediment rates during the recovery period, and the final cleanup level selected by Ecology for the Site.

6.2.2 Permanence

As defined in MTCA (Chapter 173-340-360[5]), a permanent solution is one in which the cleanup standards can be met without further action being required at any site involved with the cleanup action. MTCA ranks the following types of cleanup action components in descending order of relative permanence:

- Reuse and recycling (and waste minimization under SMS)
- Destruction or detoxification
- Immobilization or solidification
- On-site or off-site disposal in an engineered, lined, and monitored facility
- On-site isolation or containment with attendant engineering controls
- Institutional controls and monitoring

Evaluations of remedial alternatives under MTCA to determine whether a cleanup option uses permanent solutions to the maximum extent practicable are discussed in WAC 173-340-360(3)(f)(ii), and focus on: "The degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated." Sequestration of PCBs as provided by reactive (organic) cap amendments are intended to enhance sorption onto the reactive media and irreversibly reduce hazardous substance mobility into surface sediment porewater and surface water under current ambient conditions, and in this capacity results in a higher permanence score under MTCA than caps without amendments. However, the degree of mobility control is dependent on the amount of sequestration provided, such as the TOC content incorporated into the cap design.

Thus, among the remedial alternatives evaluated in this FS, Kaiser and Avista interpret the MTCA preference for permanent solutions should rank Alternatives 3D and 3E, which achieve at least partial chemical immobilization due to organic sequestration with organics (e.g., see McLeod et al. 2004), the highest and Alternative 4 – Dredging, Off-Site Disposal, and Residuals Cap, which includes confinement at an engineered containment facility, the second highest. Alternative 4 provides off-site disposal in an engineered, lined, and monitored facility. As defined by the MTCA regulation, Alternative 4 is more permanent than on-site containment/capping, but less permanent than chemical immobilization. Since both immobilization and containment technologies have been integrated into Alternatives 3D and 3E, these alternatives were ranked as similarly permanent with respect to this MTCA evaluation criterion. Depending on the final TOC content of the AquaBlok™ cap design, Alternatives 3B and 3C may also provide a similar degree of permanence.

Alternative 2 – Enhanced Natural Recovery (Thin Sand Cap) and the Alternative 3A sand cap/armor option, are ranked intermediate on the MTCA preference scale, since such technologies rely solely on in situ isolation/containment.

Finally, Alternative 1 – Monitored Natural Recovery, which relies on natural sedimentation processes and monitoring to isolate contaminants, is associated with the lowest MTCA permanence score.

6.2.3 Effectiveness Over the Long Term

Long term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the restoration time frame, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage remaining hazardous substances.

Part of the long term effectiveness evaluation, specifically as it is applied to the in situ capping and immobilization alternatives (Alternatives 2 and 3), was based on the results of one-dimensional chemical transport modeling performed for each alternative. The model presented in Reible (1998) was used, which is an appendix to current EPA and Corps Guidance for Subaqueous Dredged Material Capping (Palermo et al. 1998a and 1998b).

Specifically, the model described by Equation B32 of Reible (1998) was executed in Microsoft Excel to inform evaluations of long-term effectiveness of the various remedial alternatives. This model describes advective/diffusive transport of a dissolved chemical through a homogeneous porous media, such as an amended cap. The output of the model is expressed as the concentration of the chemical of concern (PCBs) in porewater at a specified time and depth within the cap. The model assumes no biodegradation of the chemical takes place over time. For this Focused FS assessment, the maximum porewater concentration of PCBs was calculated at the top of the cap isolation layer (i.e., 10 cm below the bottom of the armor layer, ignoring the additional containment benefit provided by the nominal 3-inch [8 cm] gravel armor) up to 500 years following construction. The model output thus also provides a relative assessment of surface water flux controls provided by the various alternatives, which in turn provides a measure of the magnitude of residual risk remaining under each alternative.

Table 1 presents the input parameters required by the model and the input values used for each alternative. Because the Reible (1998) model assumes a homogeneous sediment layer, it is not possible with the existing Corps/EPA guidance (Palermo et al. 1998a and 1998b) to directly model combined layers like those in Alternatives 3B to 3E. However, the layer that would most effectively retard chemical migration was modeled, and these results can be used as a conservative estimate of the overall effectiveness of combined layer alternatives. For Alternatives 3B to 3E, this "controlling" layer is either the AquaBlok™ or the coal layer, both of which more effectively control PCB migration due to their lower porosity and higher organic carbon content. Neglecting the additional attenuation properties of any upper sand and/or armor layer included with the alternatives provides a conservative FS-level estimate of the overall effectiveness of these cap alternatives.

Upward advection of groundwater through a cap can accelerate the rate of chemical migration and flux into surface water. However, these reaches of the Spokane River are known to have net exfiltration of river water to groundwater (Patmont et al. 1985, Anchor and Hart Crowser 2003). Therefore, the overall groundwater advection is assumed to be downward for this site, retarding the overall rate of chemical migration. However, for this modeling it was conservatively assumed that there is no net groundwater advection.

The concentration of PCBs in porewater in sediments to be remediated was estimated from the bulk sediment chemistry in subsurface cores. The porewater concentrations were calculated using standard PCB organic carbon partitioning coefficients (Table 1) and the measured TOC content of the sediments. Under existing conditions, the maximum calculated porewater concentration for any sample at any depth was approximately 600,000 pg/L of PCBs, which was from a sample collected 15 to 20 cm below the existing mudline (Core SC-2; Exponent and Anchor 2001; Figure 3). This maximum value for underlying sediment porewater concentration was used in all modeling runs, again to provide a conservative estimate of the long-term effectiveness of the remedial alternatives.

All other model input parameter values were obtained from standard sources noted in Table 1 including values for: cap porosity, specific gravity of cap material, cap material organic carbon content, partition coefficients for PCBs, and molecular diffusion coefficients for PCBs in water.

In addition to supporting the evaluation of long-term effectiveness, the transport model described above was also used in this Focused FS to determine the thickness of coal required to ensure the long-term effectiveness of Alternative 3D. The model was applied to potential placed coal thicknesses ranging from 0.5 to 6 inches, which equates to organic carbon loading of the cap isolation layer ranging from 7 to 85 kilograms organic carbon per square meter (kg OC/m^2), assuming a high degree of surface area and reactive efficiency from the coal (see Table 1 on grain size assumptions).

Results of the Alternative 3D cap effectiveness modeling are presented in Table 2. With the exception of the thinnest coal layer modeled (0.5-inch thick; 7 kg OC/m^2), the maximum predicted porewater concentrations at the top of the isolation layer were well below the EPA (2002) recommended surface water criterion of 64 pg/L for all Alternative 3D options that incorporated at least a .75-inch thickness of coal (greater than approximately 10 kg OC/m^2; defined by the approximate midpoint between the first two modeling runs summarized in Table 2).

Table 1
Summary of Cap Modeling Input Parameters

		Alternative							
Parameter	**Units**	**2**	**3A**	**3B**	**3C**	**3D**	**3E**	**4**	**Information Source**
Controlling Cap Layer	NA	Sand	Sand	AquaBlok	AquaBlok	Carbon[1]	Carbon[1]	Sand	FS alternatives
Cap Isolation Layer - Minimum Thickness	cm	5	30	15	46	8	46	61	Alt 3a: Assumed effective thickness was 91 cm less 10 cm at cap surface for bioturbation. Alts. 3b-3e: Assumed minimum thickness of controlling layer, which is overlain by a gravel armor layer in each case.
Cap Grain Size	microns	100 - 500	100 - 500	1 - 10	1 - 10	100 - 500	100 - 500	100 - 500	Typical values for placed sand, AquaBlok, and coal.
Cap Material Porosity	unitless	0.4	0.4	0.3	0.3	0.4	0.4	0.4	Typical values for placed sand (either mineral or carbon) and AquaBlok after hydration.
Specific Gravity of Cap	g/cm^3	2.6	2.6	1.9	1.9	1.1	1.1	2.6	Typical values for these materials (bitumious coal assumed for 3d and 3e).
In situ Bulk Density Cap	g/cm^3	1.6	1.6	1.3	1.3	0.7	0.7	1.6	Calculated from porosity and specific gravity per page B24 of Reible (1998).
Cap TOC Content	fraction	0.001	0.001	0.005	0.005	0.80	0.80	0.001	Typical values for these materials.
PCB K_{oc}	L/kgOC	820,000	820,000	820,000	820,000	820,000	820,000	820,000	MTCA Table 747-I.
PCB Cap K_d	L/kg	820	820	4,100	4,100	656,000	656,000	820	$K_d = K_{oc}$ * TOC.
Groundwater Upward Seepage Velocity	cm/yr	0	0	0	0	0	0	0	Groundwater advection downward due to exfiltration. Conservatively assumed zero velocity.
PCB Diffusion Coefficient	cm^2/yr	190	190	190	190	190	190	190	Conservatively high value from range of diffusion coefficients for PCBs (Reible 1998).
PCB Porewater Concentration in Underlying Sediments	pg/L	600,000	600,000	600,000	600,000	600,000	600,000	40,000	Maximum porewater concentration calculated from bulk PCB chemistry from subsurface cores (see Figure 3).

Notes:

1 - Granular bituminous coal

Koc - Organic Carbon Partitioning Coefficient

Kd - Calculated partitioning equilibrium coefficient

TOC - Total Organic Carbon

Table 2
Summary of Modeling Results for Alternative 3D Cap Options

Alternative 3D Cap Option	Cap Isolation Layer Carbon Loading (kg OC/m^2)	Maximum Future (500 Yr) Porewater PCB Concentration 10 cm Below Mudline (pg/L)
.5 inch Coal and 6 inches Sand	7	240
1 inch Coal and 6 inches Sand	14	< 0.000001
2 inches Coal and 6 inches Sand	28	< 0.000001
3 inches Coal and 6 inches Sand	43	< 0.000001
4 inches Coal and 6 inches Sand	57	< 0.000001
5 inches Coal and 6 inches Sand	71	< 0.000001
6 inches Coal and 6 inches Sand	85	< 0.000001

Based on the modeling described above, long-term effectiveness of Alternative 3D could be achieved by specifying a minimum coal thickness of .75-inch, and/or a minimum organic carbon loading of the cap isolation layer of 10 kg OC/m^2. Considering the range of cap material placement accuracies and monitoring methods used successfully in other similar applications (e.g., see http://www.hsrc-ssw.org/pdf/RB28.pdf), and incorporating additional safety factors into the conceptual design to ensure its permanence, this performance specification could be achieved using one of three possible Alternative 3D design options:

- **Alternative 3D-1** – Precision hydraulic or mechanical placement of approximately 6 to 8 inches of coal, verified in the field with detailed construction monitoring observations (e.g., sediment profile imaging [SPI] on a nominal 50-foot grid pattern), to ensure that a minimum 4 inches of coal material is placed at all SPI stations. The coal layer placed in this manner would provide a minimum factor of safety of 4 to the overall cap design (see above). The coal layer would then be overlain with a minimum 6 inches of sand, and covered with a minimum 3 inches of gravel armor.
- **Alternative 3D-2** – Standard mechanical or hydraulic placement of 6 to 9 inches of coal, verified in the field with more conventional construction monitoring observations (e.g., bathymetric surveys on 25-foot transects, along with diver-monitored stakes), to ensure that a minimum 4 inches of coal material is placed along all bathymetric transects. The coal layer would then be overlain with a minimum 6 inches of sand, and covered with a minimum 3 inches of gravel armor.

- **Alternative 3D-3** – Onshore/upland mixing of coal and sand materials to achieve a minimum blended TOC content of approximately 20 percent. Placement of 9 to 12 inches of the blended coal/sand mixture would be performed using standard mechanical or hydraulic methods, verified in the field with conventional construction monitoring observations (e.g., bathymetric surveys on 25-foot transects), to ensure that a minimum 6 inches of the blended coal/sand mixture is placed along all bathymetric transects. The blended coal/sand layer applied in this manner would ensure organic carbon loading of at least 40 kg OC/m^2, providing a minimum factor of safety of 4 to the overall cap design (see above). The coal/sand layer would then be covered with a minimum 6 inches of clean sand and capped with a minimum 3 inches of gravel armor.

All three of the options outlined above are considered protective and implementable. Selection of specific process options will be made in the CAP or engineering design phase after more detailed cost analyses are completed. Since preliminary FS-level analyses suggest that the most cost-effective option in this application is likely to be Option 3D-1, as described above, this representative process option has been carried forward as Alternative 3D in this Focused FS document (e.g., forming the basis for cost estimates of this alternative as discussed below).

Results of long-term effectiveness modeling are presented in Table 3 in terms of the maximum subsurface sediment porewater PCB concentration at the top of the cap isolation layer (10 cm below mudline), up to 500 years following construction. Significantly, the maximum porewater concentration below the top of the isolation layer for all engineered cap alternatives (i.e., Alternates 3A to 3E and 4) was below EPA's (2002) recommended surface water criterion of 64 pg/L, suggesting that all such alternatives are associated with a high degree of long term effectiveness. Placement of additional thicknesses of AquaBlok™ or coal materials, as provided in Alternatives 3C and 3E, respectively, did not result in significantly greater chemical sequestration or long-term effectiveness (see model output summarized in Table 3). By comparison, Alternative 2 – Enhanced Natural Recovery and Alternative 1 – Monitored Natural Recovery, had intermediate and low scores on this criterion, respectively.

Table 3
Summary of MTCA Remedial Alternative Evaluation

		Evaluation Criterion (1,2)							
Alternative	**Compliance with Cleanup Standards; Protection of Human Health and the Environment**	**Reasonable Restoration Time Frame**	**Permanence**	**Maximum Future (500 Yr) Porewater PCB Conc. 10 cm Below Mudline (pg/L; see text)**	**Long-Term Effectiveness**	**Short-Term Risk Management**	**Implement-ability**	**Cost - Deposit 1 (see Table 4)**	**Cost - Deposit 2 (see Table 5)**
Alternative 1 – Monitored Natural Recovery	+	-	-	100,000	-	+	+	$806,000	$471,000
Alternative 2 – Enhanced Natural Recovery (Thin Sand Cap)	+	+	o	10,000	o	+	o	$959,000	$352,000
Alternative 3A – Thick Sand Cap	+	+	o	2	+	+	o	$1,226,000	$215,000
Alternative 3B – Thin AquaBlok™ Cap	+	+	o/+ (4)	< 1	+	+	o	$1,643,000 (5)	-
Alternative 3C – Thick AquaBlok™ Cap	+	+	o/+ (4)	< 1	+	+	o	$2,626,000	-
Alternative 3D – Thin Coal and Sand Cap	+	+	+	< 1	+	+	o	$1,578,000 (5)	-
Alternative 3E – Thick Coal and Sand Cap	+	+	+	< 1	+	+	o	$2,408,000	-
Alternative 4 – Dredging, Off-Site Disposal, and Residuals Cap	+	o (3)	+	< 1	+	-/o (3)	-/o (3)	$5,061,000	$360,000 (4)

Legend:

- \- The alternative satisfies the criterion to a low degree.
- o The alternative satisfies the criterion to a moderate degree.
- \+ The alternative satisfies the criterion to a high degree.

Notes:

1 - The threshold MTCA criteria, which must be satisfied for an alternative to be acceptable under MTCA, are not included in this table. All alternatives are judged to satisfy the threshold criteria.

2 - Consideration of public concerns is not addressed in this table since the public has not yet had an opportunity to provide comments.

3 - Short-term risk management and implementability characteristics are very site- and location-specific. Because of its relatively small size and off-channel location, Alternative 4 applied to Deposit 2 (Donkey Island side channel deposit) can be more readily implemented and effectively controlled (see text).

4 - Permanence of the AquaBlok™ remedy is dependent in part on the final TOC content of the cap material, which may vary depending on final design.

5 - The decision on whether Alternative 3B or 3D would be implemented in Deposit 1 would be based on which of these two options is less expensive, based on the outcome of more detailed final design and cost analyses.

Yellow highlighted cells summarize the recommended remedial alternative for the Upriver Dam PCB Site, as discussed in Section 6.3.

The long-term effectiveness of low-permeability sediment caps constructed with AquaBlok™ must also consider potential long-term instability of the cap due to potential buildup of decomposition gas from the sediments and organics under the cap. Post-cap evaluations have documented intermittent gas releases from AquaBlok™ caps that have been constructed without a gas venting layer, resulting in localized jointing of the cap surface, and reduced cap thickness near gas vents (Mutch et al. 2004). Preliminary evaluations suggest that the relatively narrow width of Deposit 1 (Figure 1) will likely allow for passive diffusion of methane and other gases laterally, reducing the potential for buildup of gas pressure beneath the cap. However, in order to ensure the long-term effectiveness of the cap, a 6- to 12-inch-thick gas diffusion layer (e.g., coarse sand) was integrated into conceptual design, placed below the AquaBlok™ layer, to vent gas laterally to the margins of the cap (Figure 4). Downward advective flow conditions occur at the Site (Patmont et al. 1985, Anchor and Hart Crowser 2003). Thus, the additional sand layer would improve physical isolation and upward diffusion potential (containment), while providing a safety component to mitigate potential gas effects on the cap. Detailed cap specifications, including evaluation of the need for a subsurface gas venting layer, would be developed during remedial design.

6.2.4 Management of Short-Term Risks

Management of short-term risks (a.k.a. short-term effectiveness) is the degree to which human health and the environment are protected during construction and implementation of the alternative. Potential risks of implementing each alternative and the potential effectiveness of best management practices at controlling short-term risks are discussed below.

Alternative 1 – Monitored Natural Recovery, does not present additional short-term risks to human health and the environment because there is no construction or implementation planned with this alternative. Alternatives 2 and 3A to 3E present minimal additional short-term risks to human health or the environment associated with implementation of the remedy, as the cap placement methods are not expected to result in water quality impacts beyond localized, minor turbidity increases. As discussed above, elutriate and sediment transport testing of alternative coal materials used in Alternatives 3D and 3E may be required to ensure that water quality and adjacent sediments are protected during and after construction. These alternatives thus would provide effective management of short-term risks resulting from implementation of the remedy.

Implementation of Alternative 4 – Dredging, Off-Site Disposal, and Residuals Cap, would result in potential releases of a range of contaminants (PCBs, metals, wood waste, and other associated chemicals) to surface water during excavation and/or dredging of sediments. Construction-related impacts to surface water quality and fluidized sediment residuals that may remain in and adjacent to the dredging area are highly site-specific. Short-term impacts associated with dredging PCB-contaminated sediments from Deposit 1 could be mitigated to varying degrees by using appropriate best management practices, though typical control measures such as silt curtains have often been proven to be relatively ineffective when applied in other similar riverine environments. The level of protection against short-term impacts for Deposit 1 is effectively correlated with cost and complexity. Thus, the greater the degree of protection required, the higher the cost will be. Relative to the other alternatives, Alternative 4 applied to Deposit 1 PCB sediments provides less effective management of short-term risks than other alternatives.

Depending on site-specific factors, dredging of certain locations within Upriver Dam may potentially be performed with relatively minimal short-term water quality and sediment residuals impacts. For example, because of its relatively small size and off-channel location, Alternative 4 applied to Deposit 2 (Donkey Island side channel deposit) can be more readily implemented and could be designed to provide effective short-term controls. As discussed in Section 5.4 above, the Deposit 2 excavation area under Alternative 4 was assumed to be isolated during construction from the Spokane River by placement of a small sand dam to control water quality and sediment residuals releases associated with excavation within this area. Thus, Alternative 4 applied to Deposit 2 PCB sediments can readily provide effective management of short-term risks.

6.2.5 Technical and Administrative Implementability

Evaluating an alternative’s technical and administrative implementability includes consideration of the following:

- Potential for landowner cooperation
- Whether the alternative is technically possible
- Availability of necessary facilities, services, and materials
- Administrative and regulatory requirements
- Scheduling
- Size and complexity of the alternative
- Monitoring requirements
- Access for construction and monitoring
- Integration of existing operations with the remedial action

Alternative 1 – Monitored Natural Recovery, by definition, is the easiest to implement.

Alternatives 2 and 3A through 3E consist of demonstrated technologies that have been proven to be relatively easy to implement. However, federal CWA permits (likely Nationwide Permit 38) and accompanying Endangered Species Act consultation, along with pre-design engineering analyses and Ecology design approvals, would be required to implement this project. Although existing water uses in Upriver Dam would likely not be significantly affected by construction actions under these alternatives, coordination with river users would be required to implement this action. Compared with the other alternatives, Alternatives 2 and 3A to 3E are moderately implementable.

Alternative 4 – Dredging, Off-Site Disposal, and Residuals Cap includes dredging PCB-, metal-, and wood waste-contaminated sediment. The potential for short-term impacts from dredging relatively highly contaminated materials will make meeting regulatory requirements more difficult. Current site uses and operations in the area would also be more significantly affected by this action. Thus, particularly within Deposit 1, this alternative has a lower implementability relative to the other alternatives evaluated. Because the Donkey Island side channel can be more effectively isolated during construction (see Figure 1), and also because of better access of land-based construction equipment to this deposit, Alternatives 3A and 4 are moderately implementable within Deposit 2, relative to the other alternatives.

6.2.6 Consideration of Public Concerns

The Draft RI/FS Report will be made available for public review and comment. The degree to which each alternative considers public concerns will be evaluated after public comments are received. Public participation processes are described in more detail in Ecology's Public Participation Plan for the Upriver Dam PCB Site.

6.2.7 Cost

Cost estimates include design, capital long-term operation and maintenance, and agency oversight costs, but do not include legal costs. Material costs are based on discussion with local suppliers. Placement costs are based on our understanding of the likely construction techniques. A contingency of 30 percent was used to cover unanticipated changes in the scope (extent of contamination) and construction approach. Based on comparisons with actual design and construction costs from similar projects, as well as the variability in the conceptual-level cost estimates developed for the Focused FS, cost estimates summarized in Tables 4 and 5 for Deposits 1 and 2, respectively, are likely accurate to within a range of approximately -30 percent to + 20 percent.

Table 4
Cost Estimate of Sediment Remediation Alternatives: Deposit 1, Upriver Dam PCB Sediments Site

			Alt 1 - Monitored Natural Recovery		Alt 2 - Enhanced Natural Recovery (6-in Sand Cap)		Alt 3A - 12-in Sand Cap with Armor		Alt 3B - Gas Vent & 6-in AquaBlok^{TM} with Armor		Alt 3C - Gas Vent & 18-in AquaBlok^{TM} with Armor		Alt 3D - 6-in Coal with 6-in Sand Cap with Armor		Alt 3E - 18-in Coal and 6-in Sand Cap with Armor		Alt 4 - Removal with Sediment Residuals Sand Cap	
Remedial Component	**Units (3)**	**Unit Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**
A. Remedial Design																		
Pre-Remedial Design Evaluation/Pilot Studies	Percentage	10%	$451,000	$45,000	$536,000	$54,000	$685,000	$69,000	$919,000	$92,000	$1,469,000	$147,000	$884,000	$88,000	$1,347,000	$135,000	$2,831,000	$283,000
Design Documentation	Percentage	10%	$451,000	$45,000	$536,000	$54,000	$685,000	$69,000	$919,000	$92,000	$1,469,000	$147,000	$884,000	$88,000	$1,347,000	$135,000	$2,831,000	$283,000
Project Management	Percentage	5%	$451,000	$23,000	$536,000	$27,000	$685,000	$34,000	$919,000	$46,000	$1,469,000	$73,000	$884,000	$44,000	$1,347,000	$67,000	$2,831,000	$142,000
B. Mobilization/Demobilization & Site Prep	LS	(1)	0	$0	1	$40,000	1	$50,000	1	$50,000	1	$50,000	1	$60,000	1	$60,000	1	$100,000
C. Remove and dispose surface debris	LS	$50,000	0	$0	1	$50,000	0.8	$40,000	1	$50,000	0.8	$40,000	1	$50,000	0.8	$40,000	1	$50,000
D. Sand Cap																		
Purchase and haul	Ton	$14	0	$0	6,600	$92,000	11,100	$155,000	8,900	$125,000	8,900	$125,000	6,600	$92,000	6,600	$92,000	22,200	$311,000
Mechanical placement of sand	Ton	$12	0	$0	6,600	$79,000	11,100	$133,000	8,900	$107,000	8,900	$107,000	6,600	$79,000	6,600	$79,000	22,200	$266,000
E. Armor Layer																		
Purchase and haul	Ton	$14	0	$0	0	$0	4,800	$67,000	4,800	$67,000	4,800	$67,000	4,800	$67,000	4,800	$67,000	0	$0
Mechanical placement	Ton	$11	0	$0	0	$0	4,800	$53,000	4,800	$53,000	4,800	$53,000	4,800	$53,000	4,800	$53,000	0	$0
F. AquaBlok^{TM}																		
Formulation of material	Ton	$150	0	$0	0	$0	0	$0	800	$120,000	2,400	$360,000	0	$0	0	$0	0	$0
Mechanical placement	Ton	$200	0	$0	0	$0	0	$0	800	$160,000	2,400	$480,000	0	$0	0	$0	0	$0
G. Granular Bituminous Coal																		
Purchase and haul	Ton	$36	0	$0	0	$0	0	$0	0	$0	0	$0	4,000	$144,000	10,400	$374,000	0	$0
Precision mechanical placement of coal	Ton	$38	0	$0	0	$0	0	$0	0	$0	0	$0	4,000	$152,000	10,400	$395,000	0	$0
H. Deposit 1 Dredging and Disposal																		
Dredging	CY	$23	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	23,400	$538,000
Offloading	CY	$3	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	23,400	$70,000
Haul and dispose	Ton	$40	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	35,100	$1,404,000
Bathymetric controls	LS	$5,000	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	1	$5,000
Water quality monitoring	LS	$10,000	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	1	$10,000
I. Long-term Monitoring (2)																		
Bathymetric surveys	EA	$10,000	10	$100,000	6	$60,000	4	$40,000	4	$40,000	4	$40,000	4	$40,000	4	$40,000	1	$10,000
Surface sediment sampling & analysis	EA	$20,000	10	$200,000	6	$120,000	4	$80,000	4	$80,000	4	$80,000	4	$80,000	4	$80,000	2	$40,000
Water column sampling and analysis	EA	$5,000	2	$10,000	2	$10,000	2	$10,000	2	$10,000	2	$10,000	2	$10,000	2	$10,000	2	$10,000
Monitoring reports	EA	$10,000	10	$100,000	6	$60,000	4	$40,000	4	$40,000	4	$40,000	4	$40,000	4	$40,000	1	$10,000
Project management	Percentage	10%	$410,000	$41,000	$250,000	$25,000	$170,000	$17,000	$170,000	$17,000	$170,000	$17,000	$170,000	$17,000	$170,000	$17,000	$70,000	$7,000
J. Agency Oversight	Percentage	10%	$564,000	$56,000	$671,000	$67,000	$857,000	$86,000	$1,149,000	$115,000	$1,836,000	$184,000	$1,104,000	$110,000	$1,684,000	$168,000	$3,539,000	$354,000
K. Contingency	Percentage	30%	$620,000	$186,000	$738,000	$221,000	$943,000	$283,000	$1,264,000	$379,000	$2,020,000	$606,000	$1,214,000	$364,000	$1,852,000	$556,000	$3,893,000	$1,168,000
TOTAL ESTIMATED COST				**$806,000**		**$959,000**		**$1,226,000**		**$1,643,000**		**$2,626,000**		**$1,578,000**		**$2,408,000**		**$5,061,000**

(1) Mobilization costs were assumed similar for the different capping projects with variations accounting for more complex set up requirements. Mobilization costs for dredging were assumed higher.

(2) Long-term monitoring to verify the continued performance of the remedy was assumed to occur at 2- to 5-year intervals following construction, with the scope of monitoring varying depending on the alternative.
Sampling activities were assumed to include bathymetric and surface sediment sampling within Deposit 1, and water quality monitoring of bottom waters immediately upstream and downstream of Deposit 1

(3) Material tonnages were estimated based on typical unit weights for placed materials in the region: 1.6 tons/cy for gravel; 1.5 tons/cy for sand and in-place Upriver Dam sediments; and 1.0 tons/cy for coal.

Table 5
Cost Estimate of Sediment Rememdiation Alternatives:
Deposit 2, Upriver Dam PCB Site

Remedial Component	Units (3)	Unit Cost	Alt 1 - Monitored Natural Recovery		Alt 2 - Enhanced Natural Recovery		Alt 3A - 12-in Sand Cap		Alt 4 - Removal with Sediment Residuals Sand Cap	
			# of Units	Cost	# of Units	Cost	# of Units	Cost	# of Units	Cost
A. Remedial Design										
Pre-Remedial Design Evaluation/Pilot Studies	Percentage	10%	$264,000	$26,000	$196,000	$20,000	$120,000	$12,000	$202,000	$20,000
Design Documentation	Percentage	10%	$264,000	$26,000	$196,000	$20,000	$120,000	$12,000	$202,000	$20,000
Project Management	Percentage	5%	$264,000	$13,000	$196,000	$10,000	$120,000	$6,000	$202,000	$10,000
B. Mobilization/Demobilization	LS	(1)	0	$0	1	$10,000	1	$15,000	1	$40,000
C. Sand Cap										
Purchase and haul	Ton	$14	0	$0	300	$4,000	500	$7,000	900	$13,000
Mechanical placement	Ton	$19	0	$0	300	$6,000	500	$10,000	900	$17,000
D. Area 2 Dredging and Disposal										
Isolate reach with temporary dam	LS	$1,000	0	$0	0	$0	0	$0	1	$1,000
Dredging	CY	$24	0	$0	0	$0	0	$0	700	$17,000
Haul and dispose	Ton	$40	0	$0	0	$0	0	$0	1,100	$44,000
Survey controls	LS	$2,000	0	$0	0	$0	0	$0	1	$2,000
Water Quality monitoring	LS	$2,000	0	$0	0	$0	0	$0	1	$2,000
E. Long-term Monitoring (2)										
Bathymetric surveys	LS	$10,000	6	$60,000	4	$40,000	2	$20,000	1	$10,000
Surface sediment sampling & analysis	LS	$20,000	6	$120,000	4	$80,000	2	$40,000	2	$40,000
Monitoring reports	LS	$10,000	6	$60,000	4	$40,000	2	$20,000	1	$10,000
Project management	LS	10%	$240,000	$24,000	$160,000	$16,000	$80,000	$8,000	$60,000	$6,000
F. Agency Oversight	Percentage	10%	$329,000	$33,000	$246,000	$25,000	$150,000	$15,000	$252,000	$25,000
G. Contingency	Percentage	30%	$362,000	$109,000	$271,000	$81,000	$165,000	$50,000	$277,000	$83,000
TOTAL ESTIMATED COST				**$471,000**		**$352,000**		**$215,000**		**$360,000**

(1) Mobilization costs were assumed similar for the different capping projects with variations accounting for more complex set up requirements. Mobilization costs for dredging were assumed higher.

(2) Long-term monitoring to verify the continued performance of the remedy was assumed to occur at 2- to 5-year intervals following construction, with the scope of monitoring varying depending on the alternative. Sampling activities were assumed to include bathymetric and surface sediment sampling within Deposit 2.

(3) Material tonnages were estimated based on typical unit weights for placed materials in the region: 1.6 tons/cy for gravel; 1.5 tons/cy for sand and in-place Upriver Dam sediments; and 1.0 tons/cy for coal.

6.3 Recommended Remedial Alternative

The preceding sections present and evaluate different remediation alternatives and sub-alternatives that represent a wide range of remedial technologies and process options. When viewed together, the relative benefits and tradeoffs associated with implementation of different alternatives are apparent. The comparative MTCA evaluation of remedial alternatives is summarized in Table 3.

This section identifies the recommended cleanup action alternative for the Site, consistent with MTCA requirements. As discussed above, the community's comments will also be considered by Ecology when selecting the cleanup remedy for the site under MTCA.

Pending public comment, based on a comparative evaluation of the other evaluation criteria presented above, the provisional preferred alternative for the Upriver Dam PCB Site for Deposit 1 is Alternative 3D – Capping with 6 inches of coal overlain with sand and gravel armor (see Section 6.2.3 for a more detailed description of representative process option 3D-1). The contingent remedy for Deposit 1 is Alternative 3B – Capping with 6 inches of AquaBlok™ underlain with a gas venting layer and covered gravel armor, to be implemented in the event that more detailed final design and cost analyses indicate that Alternative 3B can be implemented at less cost than Alternative 3D (both options are equally protective, as summarized in Table 3). Alternative 4 – Dredging, Off-Site Disposal, and Residuals Cap, would be implemented in Deposit 2. The integrated cleanup remedy for the Upriver Dam PCB Site blends a number of remedial technologies, including in situ treatment, off-site disposal, in situ engineered containment, and compliance monitoring with adaptive management. The following attributes contribute to the provisional identification of the combined remedial option as the recommended cleanup remedy for the Site.

- Complies with MTCA and with other applicable standards and laws.
- Achieves human health and environmental protection in a relatively rapid time frame, compared with the range of alternatives evaluated.
- Uses in situ treatment technologies to sequester porewater PCBs below the biologically active layer, to the maximum extent practicable.
- Includes protective, engineered in situ confinement of subsurface sediments that are not practicable to remove.

- Has minimal short-term construction risks, compared with the range of alternatives evaluated.
- Uses multiple technologies (e.g., active caps) to provide maximum long-term effectiveness.
- Is implementable.
- Is cost effective, relative to the range of alternatives evaluated (the total estimated cost of this combined remedy, including agency oversight and long-term monitoring/adaptive management costs, is approximately $1.9 million).
- Is consistent with the range of cleanup remedies evaluated and selected by EPA (2001) to address co-occurring metal contamination in the Upriver Dam area.

Alternatives 3C and 3E provide for thicker layers of AquaBlok™ and coal materials placed in Deposit 1, relative to Alternatives 3B and 3D, respectively. However, the costs associated with implementing either Alternative 3C or 3E are substantial and disproportionate relative to the incremental degree of increased environmental protection provided by the thinner cap sections provided in Alternatives 3B and 3D. For example, the surface erosion protection/bioturbation layer included in Alternatives 3B and 3D, along with subsurface layers of AquaBlok™ and underlying gas venting materials incorporated into Alternative 3B, already provide for protection from the 100-year flood condition and long-term (greater than 500 year) porewater and gas migration concerns, and equal or exceed the cap design requirements set forth in EPA and Corps capping guidance (Table 3; Palermo et al. 1998a and 1998b). Thus, the selection of Alternative 3D or 3B incorporated into the preferred remedy provides a high degree of human health and environmental protection.

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APPENDIX A

CAP ARMORING EVALUATION

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Memorandum

To: John Verduin, P.E.

From: Greg Guannel

CC: Clay Patmont

Date: September 24, 2004

Re: Upriver Dam Cap Stable Sediment Size Determination

Contaminated sediments have accumulated in a 3.7-acre area (denoted Deposit 1) within the old thalweg of the Spokane River, located immediately above the Upriver Dam in Spokane, Washington (Figure 1). One option that is being evaluated to remediate the Site, which has been a backwater area since the construction of the dam, is to cap these sediments with clean material that will remain stable during the strongest storm events. This memorandum presents the results of an analysis conducted to provide an initial Feasibility Study-level determination of cap armor material size.

Stable sediment size that could compose the erosion layer of a cap at the Site was determined based on maximum predicted velocities that can occur at the Site. These velocities were computed by dividing design flow value in the river by river cross-sectional area at the Site. Flow values have not been computed for river segments located above the dam. However, Avista (2004) conducted a flow analysis in the lower portion of the river and developed a 100-year flow value of 53,900 cubic feet per second (cfs). This value was used as the design flow value for our analysis.

Two representative river cross-sections were used to compute design velocity in the river (Figure 2). Cross-section A-A′ is located within Deposit 1, and cross-section B-B′ is located upstream end of the deposit, at the bend in the river. Design river average velocities at these two cross-sections are presented in Table 1.

Table 1
Design Velocities in Project Area

Section	Flow [cfs]	Area [sf]	Avg. Velocity [ft/s]
A-A'	53,900	10,725	5.0
B-B’	53,900	6,079	8.9

Based on these velocities, stable sediment size was computed using the following methods:

1. Hjulstrom’s diagram, as presented in Vanoni (1975)
2. Plate B-28, entitled “Noncohesive Sediment Gradation and Permissible Velocity,” as presented in U.S. Army Corps of Engineers’ (Corps) “Hydraulic Design of Flood Control Channel" (1994)
3. Plate B-29, entitled “Stone Stability: velocity vs stone diameter”, as presented in the Corps’s “Hydraulic Design of Flood Control Channel" (1994)
4. Shield’s diagram, as presented in Shields (1936), based on bottom shear stress associated with channel average velocity. A Shield coefficient of 0.047 corresponding to gravel size material was used (Grindeland 2003). Bottom shear stress associated with design velocities was computed based on the following equation (WES 1998):

$$\tau = \frac{1}{2}\rho f_c U^2$$

Where: τ represents the bottom shear stress
ρ represents the density of freshwater
f_c represents a friction coefficient
U represents the average velocity in the river

The friction coefficient was approximated using the equation presented in WES’ Technical Note (1998).

Stable sediment sizes at the Site were computed using the four different methods, for the two different cross-sections defined at the Site. Results are presented in Table 2.

Table 2
Stable Sediment Size that can Resist Design Flow Values at Section A-A’ and B-B’

Section	Velocity [ft/s]	Stable Sediment Size (inches)			
		Hjulstrom	Plate B-28	Plate B-29	Shields
A-A’	5.0	0.6	0.2	N/A	1.0
B-B’	8.9	2.4	5.1	6.6	3.4

Under all four methods, the median stable sediment size computed for the Deposit 1 area (Section A-A’) is at or below 1 inch (Table 2). As expected based on the design velocities values, a somewhat larger stable sediment size may be needed in the vicinity of the Section B-B′ cross-section. However, specification of a 1-inch median sediment size as the preliminary cap armor layer should provide for sufficient stability and resistance to erosion in Deposit 1 for the following reasons:

- Deposit 1 is located in a deeper portion of the Site, in a backwater area where fine sediments have accumulated.
- The bottom slope at the project area is very flat (approximately 1:170), and shear stress computed based on Site slope and hydraulic radius (Henderson 1966) led to a relatively small size in the required erosion protection layer, indicating that finer material is theoretically stable in this region.

Consequently, it is reasonable to assume that a preliminary specification for the cap erosion layer in Deposit 1 could consist of a material with a mean grain size of 1 inch, with a possible gradation specification of 100 percent passing 4 inch, 50 percent passing 1 inch and no more than 5 percent passing a number 200 sieve. As part of final design, a more detailed hydrodynamic analysis would likely be completed using a more refined modeling analysis (e.g., 2-D SEDZL or HEC-RAS), that could address the effects of river meander and dam configuration/operation characteristics on hydrodynamics and bottom shear stresses at the Site. The design-level hydrodynamic model would be used to refine conservative shear stress estimates developed above, and would likely conclude that a smaller armor grain size (i.e., less than 1-inch diameter) would suitably resist erosion potentially associated with peak flow events.

Gravel components of the standard AquaBlok™ formulation as well as the cohesive strength of the clay fraction should already be sufficient to resist the design erosive forces due to the presence of engrained gravels and the cohesive nature of the AquaBlok™ material. As generally described by the Hjulstrom diagram (Figure 3), both the gravel (nominal 20 mm materials) and bentonite/clay components (nominal 0.01 mm materials) included as part of standard AquaBlok™ formulations have the capacity to resist erosion during peak flood flows (velocities up to 5 feet/second). Again, more detailed hydrodynamic analyses would be performed during remedial design to develop final cap and armor specifications.

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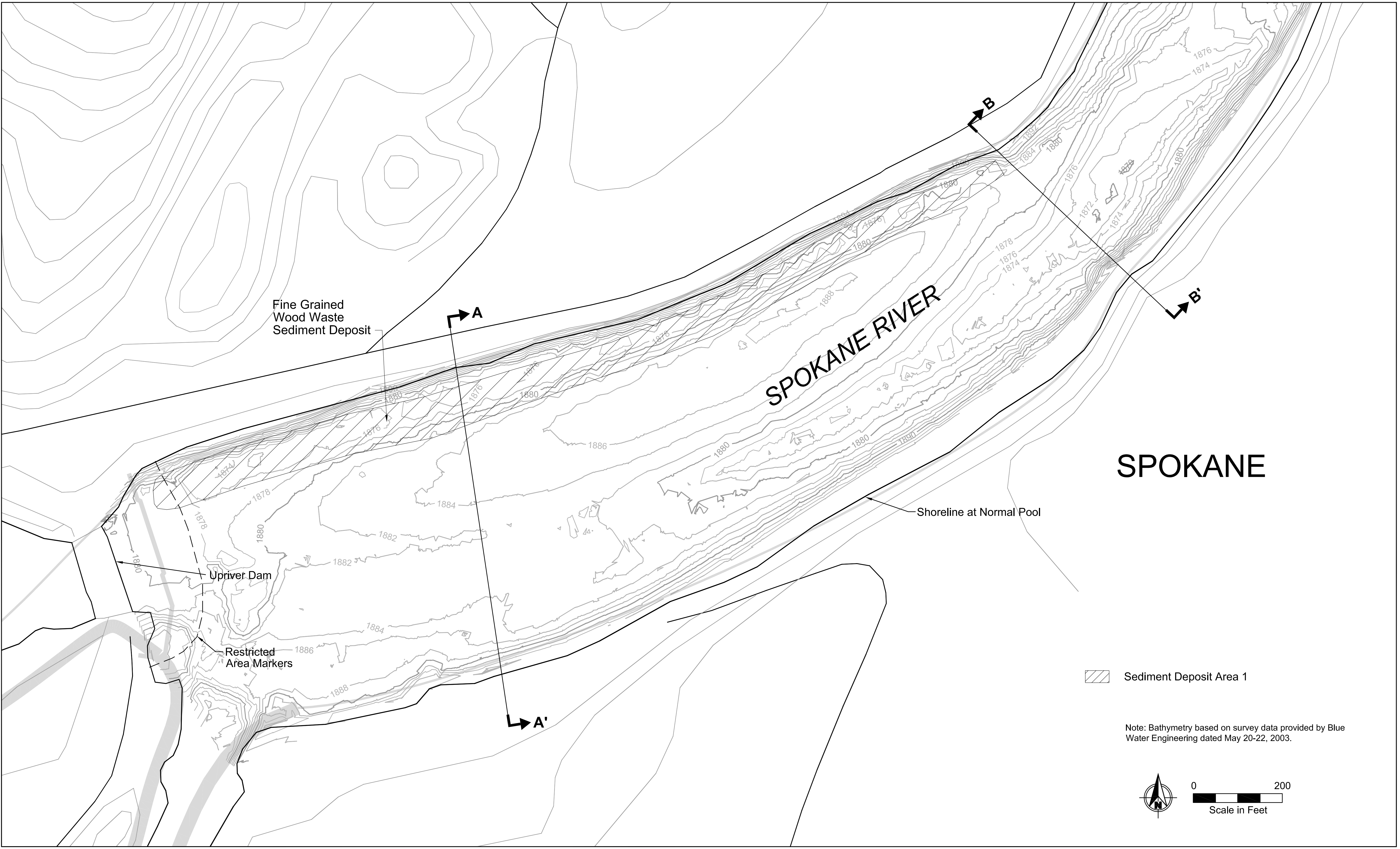

Note: Bathymetry based on survey data provided by Blue Water Engineering dated May 20-22, 2003.

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Figure 1
Cross Section Locations
Upstream of Upriver Dam
Spokane River, Washington

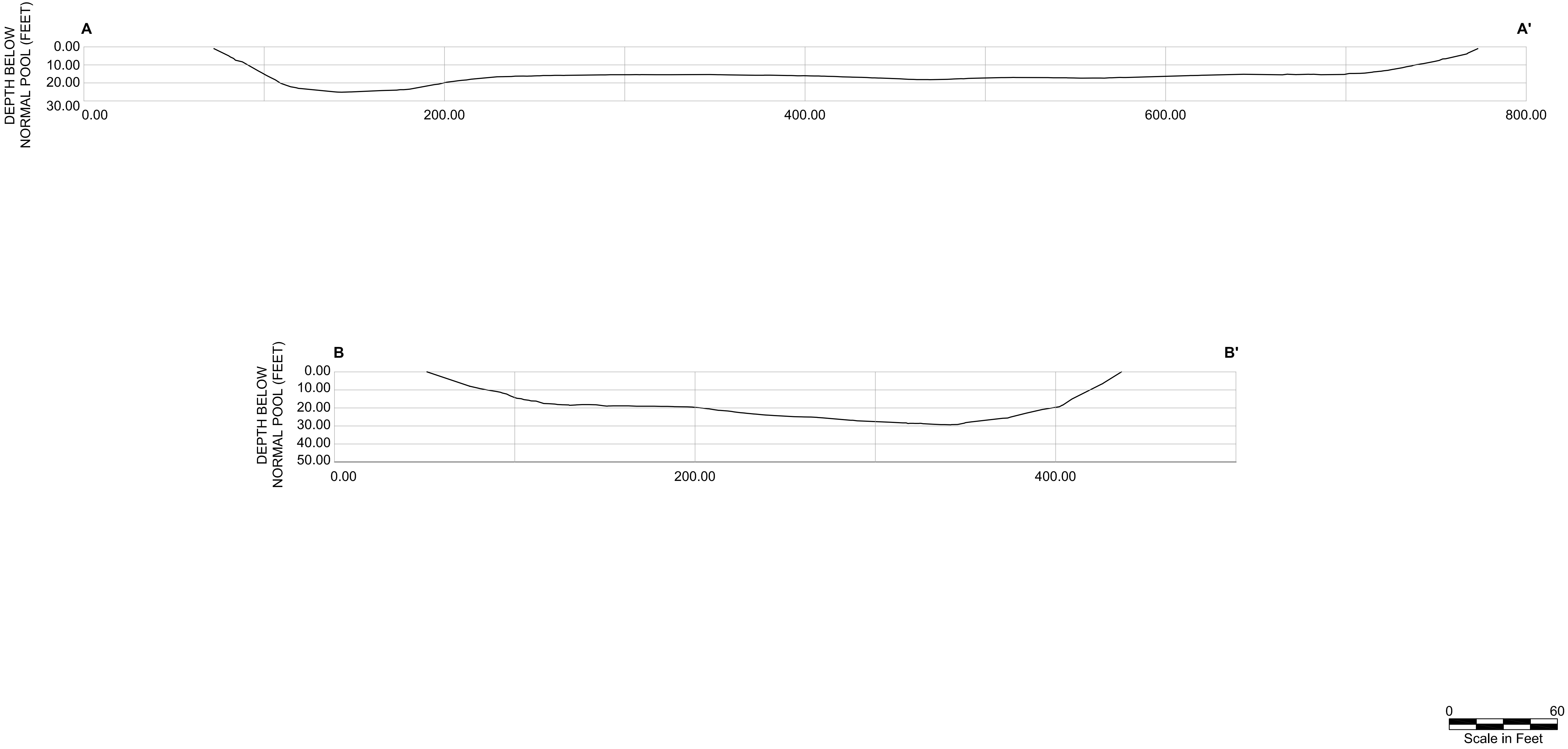

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Figure 2
Cross Sections A-A' and B-B'
Upstream of Upriver Dam
Spokane, Washington

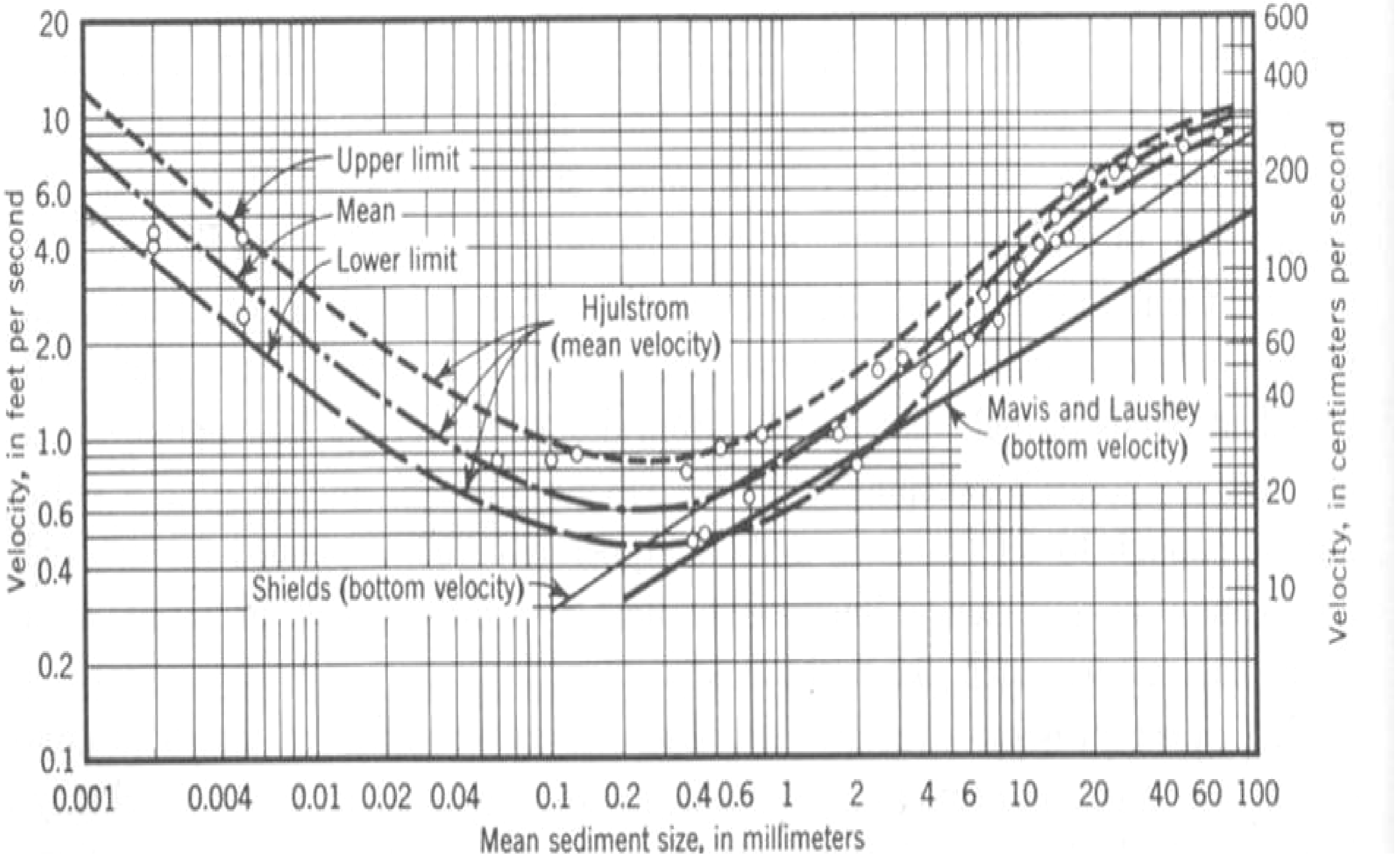

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Figure 3
Critical Water Velocities for Quartz Sediment as Function of Mean Grain Size
Upstream of Upriver Dam