Final
Feasibility Study

South State Street Manufactured Gas Plant
Bellingham, Washington

for
City of Bellingham

January 22, 2019

GeoEngineers
Earth Science + Technology

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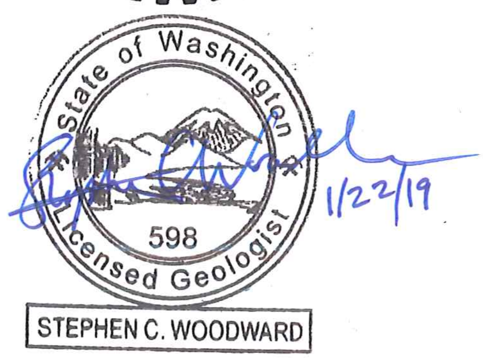

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ABBREVIATIONS AND ACRONYMS

Agreed Order	Agreed Order: DE 7655
AKART	all known and available and reasonable technology
ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
BMPs	best management practices
BNSF	Burlington Northern Santa Fe Railway Company
CAOs	cleanup action objectives
CAP	cleanup action plan
City	City of Bellingham
cm	centimeters
cPAHs	carcinogenic PAHs
CSL	Cleanup Screening Level
CWA	Clean Water Act
DCA	disproportionate cost analysis
DNAPL	dense nonaqueous phase liquids
DNR	Washington Department of Natural Resources
ECs	engineering controls
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
EPA	US Environmental Protection Agency
ESA	Endangered Species Act
GIS	geographic information system
GRAs	general response actions
HPAs	Hydraulic Project Approvals
HPAHs	high molecular weight PAHs
ICs	institutional controls
IHSs	indicator hazardous substances
ISS	in-situ solidification
JARPA	Joint Aquatic Resource Permit Application
LPAHs	low molecular weight PAHs
μg/kg	micrograms per kilogram

µg/L	micrograms per liter
mg/kg	milligrams per kilogram
MGP	manufactured gas plant
MLLW	mean lower low water
MNA	monitored natural attenuation
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NAPL	non-aqueous phase liquid
NPDES	National Pollution Discharge Elimination System
OMM	operation, maintenance and monitoring
PAHs	polycyclic aromatic hydrocarbons
PSE	Puget Sound Energy
PVC	polyvinyl chloride
RCRA	Resource, Conservation and Recovery Act
RCW	Revised Code of Washington
RI/FS	Remedial Investigation/Feasibility Study
SCO	Sediment Cleanup Objective
SCUM II	Sediment Cleanup User's Manual II
SEPA	State Environmental Policy Act
Site	South State Street Manufactured Gas Plant site
SMS	Sediment Management Standards
SVE	soil vapor extraction
SWAC	surface-area weighted average concentration
TEE	terrestrial ecological evaluation
TEQ	toxicity equivalent
UCL	upper confidence limit
USACE	US Army Corps of Engineers
VOCs	volatile organic compounds
WAC	Washington Administrative Code
ZVI	zero-valent iron

1.0 RI CONCLUSIONS AND FS INTRODUCTION

The City of Bellingham (City) and Puget Sound Energy (PSE) are conducting a Remedial Investigation/Feasibility Study (RI/FS) for the South State Street Manufactured Gas Plant site (Site) to address the requirements of the 2010 Agreed Order (Agreed Order: DE 7655) between the Washington State Department of Ecology (Ecology), the City and PSE. The Agreed Order requires the City and PSE to conduct the RI/FS in accordance with Model Toxics Control Act (MTCA) and the Sediment Management Standards (SMS). The 2010 Agreed Order was amended in 2017 to allow an interim action determined necessary to address shoreline erosion at the Site.

The Site is in the general vicinity of Bayview Drive and South State Street as shown on Figure 1-1. The Site is divided into an upland unit and marine unit (Figures 1-2 and 1-3). The upland unit encompasses the northern portion of Boulevard Park and is further divided into three areas: the upper park, the slope, and the lower park. The marine unit includes adjacent aquatic lands located in Bellingham Bay.

The RI for the Site was prepared by Landau Associates (Landau 2017a). Key findings of the RI are summarized below.

1.1. Sources of Contamination

Primary sources (i.e., facilities or actions that initially released hazardous substances to the environment) were identified by reviewing historical records. The primary sources of contamination at the Site were associated with production of manufactured gas, and storage and release of associated manufactured gas plant (MGP) products. Other potential sources of contamination identified in the RI include:

- Lumber mill operations on a pile-supported wharf from 1884 to 1925. The lumber mill existed over portions of the present-day marine unit and lower park before the lower park was developed by filling tidelands at the Site.
- A 1925 fire that destroyed the lumber mill.
- Operation and maintenance of the railroad along the shoreline from 1890 to present.
- Fill materials with undocumented chemical composition in the lower park from the 1930s to the 1970s.
- Discharges from two outfalls conveying untreated urban stormwater to Bellingham Bay along the shoreline of the pocket beach at the Site.
- Contaminant migration in sediment from non-Site sources.

After the lumber mill closed due to fire in 1925, a large area of the lower park and shoreline was filled with various construction and wood waste materials as documented on historical aerial photographs of the Site. The fill materials could be a source of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) or other contaminants in soil and groundwater in the lower park and the nearby marine unit.

Activities associated with the existing Burlington Northern Santa Fe Railway Company (BNSF) railroad tracks and the historical rail lines that bisect the Site could be a source of benzene and cPAHs to all media near the tracks. Oily products (e.g., creosote) have been reportedly used to treat the wood in the ties and to control vegetation along the tracks.

Outfalls convey nonpoint source stormwater runoff from the parking lot in the lower park and from South State Street and the surrounding neighborhood to Bellingham Bay. The stormwater could be a source of cPAHs, metals and other contaminants to the marine environment from general urban runoff.

1.2. Nature and Extent of Contamination

The nature and extent of contamination is described in Section 5 of the RI (Landau 2017a). In the RI, the boundaries of the upland and marine units of the Site were defined based on the spatial extent of Site-related contamination in soil, groundwater and sediment. The boundaries of these units, which collectively define the Site, are shown in Figures 1-2 and 1-3.

1.3. Identification of Indicator Hazardous Substances

Indicator hazardous substances (IHSs) are chemicals that pose the greatest overall risk to human and ecological receptors in Site media, and therefore are used to focus the evaluation of cleanup action alternatives.

In the RI, contaminants detected at concentrations greater than screening levels were identified as preliminary IHSs. This list of chemicals was further reduced to select final IHSs based on the following criteria:

- **Empirical Evidence** – Many of the soil and groundwater screening levels are based on protection of other media. Empirical evidence was used to evaluate whether these transport pathways were complete. For example, if a groundwater screening level for a contaminant is based on the protection of sediment, but that contaminant in sediment were below the sediment screening level, the next lowest, applicable, screening level was used to evaluate the groundwater data. All cross-media screening levels were adjusted in this manner.
- **Statistical Comparisons** – Contaminants were not selected as final IHSs if all the following criteria were met: the frequency of exceedances was less than 10 percent, the maximum detected concentration was less than two times the screening level, and the 95 percent upper confidence limit on the arithmetic mean (95% UCL) was less than the screening level.
- **Geographic (spatial) Footprint, Toxicity, and Exceedance/Detection Frequency** – Contaminants with lower toxicity (lower magnitude of screening level exceedances), lower exceedance frequency, and/or lower detection frequency were not retained as final IHSs. The footprint of screening level exceedances also was considered when selecting IHSs.
- **Grouping** – Individual cPAHs were evaluated as a group by calculating a cPAH toxicity equivalent (TEQ) for each applicable soil, groundwater, and sediment sample.

The following IHSs were identified by this process and will be evaluated in the FS:

IHS	Soil	Groundwater	Sediment
Selenium	√	√	–
Lead	√	–	–
Benzene	√	√	–
Naphthalene	√	√	–
cPAH TEQ	√	√	√
Cyanide	√	√ (total and weak acid dissociable [WAD])	–

1.4. Pathways Evaluated in the FS

Remedies developed in the FS consider the following contaminant transport mechanisms and potential exposure routes:

- Transport mechanisms
  - Soil vapor to indoor air (vapor intrusion)
  - Upland soil erosion and transport to the marine unit
  - Groundwater migration to sediment or surface water
- Exposure routes
  - Direct contact with contaminated soil and sediment - people and ecological receptors
  - Inhalation of volatile contaminants in indoor air – people
  - Ingestion of contaminated fish and shellfish – people and ecological receptors

1.5. Areas Requiring Cleanup

The nature and estimated extent of contamination was established in the RI. Soil, groundwater, and sediment at the Site contain the IHSs identified above at concentrations that represent a potential threat to human and ecological health.

In the upland unit, the most widespread IHSs defining the cleanup areas are cPAH TEQ, naphthalene, and benzene in soil, and cPAH TEQ, naphthalene, benzene, and cyanide in groundwater (RI Figures 32 through 35, 38, 39 and 44). The area requiring cleanup in the marine unit is driven by the spatial extent of cPAHs that exceed the preliminary cleanup level for bioaccumulation-based effects on people and ecological receptors (Figure 1-3). The broad cPAH-exceedance area encompasses the few isolated locations closer to the shoreline where chemicals exceed SMS promulgated chemical criteria based on protection of the benthic invertebrate community (benthic exceedances are shown on Figure 1-4). Chemicals with sediment concentrations greater than benthic criteria include total low molecular weight PAHs (LPAHs), high molecular weight PAHs (HPAHs), some individual PAHs, 2,4-dimethylphenol, benzoic acid, benzyl alcohol, and mercury; these chemicals were not retained as IHSs as discussed in Section 5.6 of the RI. Remedial alternatives presented in this FS for the marine unit address exceedances of both bioaccumulation-based and benthic toxicity criteria.

1.6. Previous Shoreline Actions On and Near the Site

Boulevard Park is subject to marine forces that are capable of eroding the shoreline. To prevent erosion of the shoreline and to improve marine habitat, two projects have been completed which involved stabilizing the shoreline along Boulevard Park, including the shoreline of the Site. These projects are described below.

1.6.1. 2013 Boulevard Park Shoreline Improvement

In 2013, the City of Bellingham completed the Boulevard Park Shoreline Improvement project along the west shoreline of Boulevard Park. This project extended along approximately 450 feet of the shoreline, south of the southern limits of the Site. The shoreline improvement project was unrelated to the Site cleanup action. The limits of the 2013 shoreline improvement project are presented on Figures 1-2 and 1-3. The project consisted of removing large debris from the beach, constructing three drift sills perpendicular to the shoreline, removing a limited amount of surface rubble and fill, placing gravel and sand beach nourishment, and constructing a revetment along the shoreline to the north.

The drift sills constructed perpendicular to the shoreline consist of large (24- to 42-inch-diameter) rock, designed to contain smaller beach material within the newly constructed nourishment areas. Between the drift sills, several feet of gravel and sand beach nourishment was placed, with limited removal of underlying debris and fill. The drift sills and beach nourishment are primarily located south of the limits of the Site (Figures 1-2 and 1-3), but the project also included approximately 120 feet of shoreline revetment constructed adjacent to the upland unit of the Site. This revetment was constructed of 24- to 48-inch rock on a bed of quarry spalls. Limited excavation was completed to provide bedding for the revetment rock, but the resulting surface is up to 4 feet higher than the previous ground surface elevation.

1.6.2. 2017 Shoreline Stabilization Interim Action

Storm weather and marine forces during the winter of 2017 eroded a portion of the shoreline within the boundary of the Site, triggering the need for an interim action to stabilize and protect the shoreline from further erosion prior to conducting a final Site remedy. The purpose of the interim action was to prevent further erosion of potentially contaminated soil along the shoreline of the Site. This would reduce the risk of potential exposures to contaminated soil or transport of this soil into the aquatic environment. The City developed a work plan to mitigate these risks by conducting an interim action (Landau 2017b). The interim action was conducted by the City and PSE in 2017 under an amendment to the Agreed Order.

The 2017 interim action generally consisted of placing a riprap revetment along the west shoreline of the Site, stabilizing a concrete bulkhead, and removing the public pier, wood piles and decking. The limits of the interim action are shown on Figures 1-2 and 1-3. Similar to the 2013 shoreline improvement completed further to the south, the interim action generally consisted of adding erosion protection materials to the shoreline environment; there was no soil or sediment removal from the interim action area. This resulted in the elevation of the shoreline area being raised approximately 3 feet relative to pre-construction conditions.

The interim action was completed in fall of 2017 (Landau 2018). In accordance with MTCA requirements for conducting interim actions prior to selection of a final cleanup action, the 2017 interim action was designed and constructed in a manner that will not preclude the selection of alternatives for the final cleanup action. Materials used for the interim action may be modified, reused or removed during implementation of the final cleanup action.

1.7. Purpose of the FS

The objective of the FS is to develop and evaluate a range of cleanup action alternatives for the contaminated media identified at the Site in accordance with the MTCA and the SMS and to identify a preferred alternative for the final cleanup action.

This FS report follows procedures outlined in MTCA (Washington Administrative Code [WAC] 173-340-350[8]) and SMS (WAC 173-204-550[7]). This FS report identifies applicable or relevant and appropriate requirements (ARARs) for cleanup; proposes cleanup standards protective of human health and the environment; identifies the extent of contaminated media requiring remedial actions; identifies and screens potentially applicable remedial technologies; and assembles technologies into cleanup action alternatives to address contaminants at the Site. Procedures for evaluating cleanup alternatives and selecting a preferred alternative under MTCA are described in WAC 173-340-370 and WAC 173-340-360, respectively, and in SMS WAC 173-204-570. The FS presents a comparison of the cleanup action alternatives based on protectiveness, effectiveness, permanence, implementability, cost and consideration of public concerns (MTCA evaluation criteria). Under MTCA, a disproportionate cost analysis (DCA) is used to identify a preferred remedy for Washington Department of Ecology's (Ecology) consideration.

The FS builds on information presented in the RI report about Site conditions and associated contamination. This FS follows procedures outlined in MTCA (WAC 173-340-350[8]) and SMS (WAC 173-204-550[7]) and is organized as follows:

- Section 2.0 Basis for Cleanup Action – identifies ARARs, associated cleanup action objectives (CAOs) and cleanup standards for the Site to ensure the constructed remedy is protective of human health and the environment, meets regulatory requirements, and is compatible with existing Site uses and ownership requirements. Remediation levels, and the basis for them, are also described.
- Section 3.0 Identification and Screening of Remedial Technologies – identifies remediation approaches, general response actions (GRA), processes, and remediation types and screens potentially applicable remedial technologies relative to demonstrated success at similar sites with similar conditions, their compatibility with defined Site CAOs, and their applicability to the Site.
- Section 4.0 Description of Cleanup Action Alternatives – assembles technologies into cleanup action alternatives to address contaminants at the Site and describes cleanup action alternatives that would be implemented for each portion of the Site. Expectations and requirements for cleanup actions are provided in WAC 173-340-370, WAC 173-340-360 and WAC 173-204-570.
- Section 5.0 Evaluation of Cleanup Action Alternatives – evaluates the proposed cleanup action alternatives and compares them based on protectiveness, effectiveness, permanence, implementability, cost and consideration of public concerns (MTCA and SMS evaluation criteria). Components of the evaluation include, among other factors, an estimate of relative risk reduction, potential for and magnitude of recontamination, and the need for institutional controls (ICs). This comparative evaluation produces scores that are used to select a preferred cleanup action alternative, consistent with the DCA process described in MTCA.
- Section 6.0 Preferred Cleanup Action Alternative – provides a detailed description of the preferred alternative recommended for design and implementation at the Site.

2.0 BASIS FOR CLEANUP ACTION

CAOs form the basis for evaluating and selecting remedial technologies and cleanup actions that will be successful at a given site. CAOs consist of location-, chemical- and medium-specific goals for protecting human health and the environment. CAOs are dependent on the chemicals and pathways that pose a risk to people and natural resources associated with a site. Development of CAOs involves several steps, as described below and in the following sections:

- Identify laws and regulatory standards (ARARs) that set the framework and requirements for the development of cleanup standards and implementation of a cleanup action;
- Develop cleanup levels and points of compliance at which an acceptable risk level is attained; and
- Identify locations and media requiring cleanup based on selected cleanup standards.

2.1. Potentially Applicable or Relevant and Appropriate Requirements and Anticipated Permits

This section discusses the potential ARARs and anticipated permits associated with the cleanup action at the Site.

2.1.1. Potential ARARs

Cleanup actions conducted under MTCA and SMS must comply with all state and federal laws (WAC 173-340-710) that have jurisdiction over the cleanup (i.e., are applicable) or that Ecology determines may apply to the cleanup (i.e., are relevant and appropriate). Collectively these laws, implementing regulations, standards, limitations or other requirements are referred to as ARARs.

The ARARs identified for cleanup of the Site are listed in Table 2-1. The procedures, standards and other requirements specified in MTCA and SMS are the primary ARARs governing cleanup actions at the Site. Additional ARARs regulate specific components of the cleanup including land use, disposal of hazardous waste, management of stormwater during construction, resource protection and worker safety during implementation.

Most of the requirements associated with the additional ARARs are specified as part of various permit conditions; however, cleanup actions conducted under an Agreed Order are generally exempt from the procedural requirements of many state and local permits. Typically, cleanup actions are exempt from the procedural requirements of the Washington State Clean Air Act, solid waste management, construction projects in state waters (specifically Hydraulic Project Approvals [HPAs]), water pollution control, the Shoreline Management Act, and local regulations. However, permits associated with two national programs that are administered by the State — the Clean Water Act (CWA) National Pollution Discharge Elimination System (NPDES) permits, and those permits required for treatment, storage or disposal of hazardous waste under the Resource, Conservation and Recovery Act (RCRA) — still apply, as do all federal regulations and permits. Regardless of the permit exemptions, all cleanup actions must meet the substantive requirements of the subject regulations. Ecology is responsible for consulting and coordinating with the regulatory and permitting agencies for the exempted permits and identifying the substantive requirements.

2.1.2. Anticipated Permits

A number of the ARARs governing cleanup of sediment will be addressed through the Joint Aquatic Resource Permit Application (JARPA). The JARPA coordinates information applicable to the US Army Corps of Engineers (USACE)-issued CWA Section 10 and Section 404 permits (Nationwide 38 or individual 404 permit), Ecology-issued CWA Section 401 Water Quality Certifications, Washington Department of Natural Resources (DNR) Use Authorizations for State-Owned Aquatic Lands, among others. The USACE is also responsible for consultation with natural resource trustees regarding potential project impacts on species and habitats protected under the Endangered Species Act (ESA) and subsequent requirements. An NPDES permit may be required for any on-site water treatment or discharge of stormwater from the cleanup site during implementation of the remedy.

Many of the permits likely to be associated with the upland cleanup action are either exempted from the corresponding procedural requirements per MTCA, although substantive requirements must be met, or would be coordinated as part of City land use permit requirements.

Ecology will be responsible for issuing the final approval for the cleanup action, following consultation with other federal, tribal, state and local agencies. The USACE will separately be responsible for issuing approval of the project under Nationwide Permit 38, following ESA and historic preservation consultations with the federal trustees and tribes, and incorporating Ecology's 401 Water Quality Certification.

2.2. Cleanup Action Objectives

The general objective of the cleanup action is to eliminate, reduce, or otherwise control to the extent practicable, unacceptable risks to human health and the environment posed by hazardous substances in impacted media in accordance with the MTCA cleanup regulation (Chapter 173-340 WAC), SMS (Chapter 173-204 WAC), and other applicable regulatory requirements. The individual CAOs for the cleanup action at the Site are specific to certain media and contaminants of concern, exposure routes and receptors. The CAOs will be addressed by the cleanup action alternatives described in subsequent sections of the FS. The media and exposure pathways of concern for the Site are identified in Section 1.4, and include potential human and ecological exposures by direct or indirect contact with soil, groundwater, sediment, and soil vapor associated with Site sources.

In addition to addressing unacceptable risks to people and ecological receptors, the cleanup action will need to be compatible with continued use of the Site as a public park (Boulevard Park).

Specific CAOs for the impacted media at the Site are presented below.

2.2.1. Upland Unit CAOs

The objective of the upland cleanup is to reduce or control to the extent feasible, risks from hazardous substances in soil, soil vapor and groundwater associated with the following potential exposure routes:

- People contacting contaminants in soil (dermal contact, including incidental ingestion);
- Ecological receptors contacting a potential PAH hot spot in the upper park (dermal contact, including incidental ingestion);
- People being exposed to volatile contaminants resulting from soil vapor migrating to indoor air (inhalation of indoor air);
- Transport of upland contaminants to marine sediment or surface water via groundwater migration; and
- Erosion of upland contaminated soil and transport to the marine unit.

As described in Section 3.6 of the RI report, groundwater beneath the Site is classified as non-potable. Therefore, the CAOs do not include preventing use of groundwater as potable water; however, ICs will be included in each cleanup action alternative that prevent withdrawal of groundwater from the Site for potable and non-potable uses.

2.2.2. Marine Unit CAOs

The objective of the in-water cleanup is to reduce or control to the extent practicable, risks from hazardous substances in sediment associated with the following potential exposure routes:

- People contacting contaminants in sediment (dermal contact, including incidental ingestion);
- Exposure of aquatic organisms to contaminants in sediment within the biologically active zone (the upper 12 centimeters [cm] of sediment);
- Exposure of people and higher trophic level receptors (fish, aquatic-dependent birds and mammals) to contaminants in sediment via the bioaccumulation/seafood ingestion pathway.

2.3. Cleanup Standards

Cleanup standards are used to develop cleanup action alternatives that will ultimately achieve CAOs and lead to post-remedy conditions that are protective of human health and the environment. Cleanup standards consist of: (1) chemical concentrations in environmental media or biological effect thresholds that are protective of human health and the environment, and (2) the locations where the cleanup levels must be met (i.e., point of compliance). The screening levels and proposed cleanup levels compiled in the RI report (RI Sections 4.0 and 5.6, respectively) provide a basis for developing preliminary cleanup levels in the FS for Site media.

Proposed points of compliance are identified in this FS and evaluated relative to each cleanup action alternative. However, the points of compliance along with other aspects of the cleanup standards will be finalized by Ecology in the cleanup action plan (CAP). Media-specific preliminary cleanup levels and points of compliance for soil, groundwater, sediment and air are presented in the following sections.

Preliminary cleanup levels were not developed for the vapor intrusion to indoor air pathway; however, this pathway is addressed in this FS.

2.3.1. Soil

Preliminary soil cleanup levels are based on protection of human health from direct contact (incidental soil ingestion) and protection of groundwater. Potential terrestrial ecological exposures to soil, and erosion of soil to sediment were also considered in the development of soil cleanup levels. A site-specific terrestrial ecological evaluation (TEE) was performed for the upland soils in the RI and, based on the TEE findings, soil cleanup levels based on terrestrial ecological exposure are not required, except for a small area where naphthalene was detected at relatively high concentrations in the southern portion of the upper park (at monitoring well MW-24; see naphthalene discussion below). Soil cleanup levels also are not required to determine cleanup needs related to the erosion of upland soil because any upland remedy will prevent soil erosion and provide for stormwater management.

Preliminary cleanup levels for soil IHSs are presented in Table 2-2 along with the basis for each value. Some of these cleanup levels are different than cleanup levels presented in the RI. Values that have changed, and the basis for those changes, are described below.

- **Lead**: For saturated soil, the RI presented a proposed cleanup level of 200 milligrams per kilogram (mg/kg) based on the protection of groundwater. This cleanup level is not needed, however, based on empirical groundwater data. For this reason, the preliminary cleanup level for lead in saturated soil has been revised to 250 mg/kg based on direct contact.
- **Naphthalene**: The naphthalene soil cleanup levels for vadose and saturated zone soils in the RI and FS are based on the protection of groundwater. The preliminary groundwater cleanup level for naphthalene in the FS is 83 micrograms per liter (µg/L), based on the protection of sediment. The RI included a proposed groundwater cleanup level of 8.9 µg/L, based on protection of vapor intrusion. It is more appropriate, however, to evaluate cleanup actions for the vapor intrusion pathway using actual soil vapor data in comparison to the air cleanup level, as discussed in Section 2.3.4. The preliminary FS soil cleanup levels for naphthalene are also protective of terrestrial ecological receptors.
- **cPAH TEQ**: The cPAH TEQ cleanup level of 140 micrograms per kilogram (µg/kg) presented in the RI was based on direct contact. However, this cleanup level has been changed in the FS to a value of 6.6 µg/kg based on the protection of groundwater, adjusted up to the practical quantitation limit.

Point of Compliance: The standard point of compliance for soil based on the protection of groundwater is throughout the Site. For the protection of human health via direct contact, the standard point of compliance for soil is from ground surface to 15 feet below ground surface (bgs). MTCA recognizes that soil cleanup levels would typically not be met at the standard point of compliance for cleanups involving containment and that cleanup alternatives involving containment still comply with cleanup standards under certain conditions (WAC 173-340-740[6][f]). The six conditions ([i] through [vi]), specified to demonstrate soil compliance where containment remedies are used are outlined below followed by an explanation of applicability to the Site.

- *The selected remedy is permanent to the maximum extent practicable.* This requirement is evaluated in the cleanup alternatives evaluation of the FS (Section 5).
- *The cleanup action is protective of human health.* This requirement is evaluated in the cleanup alternatives evaluation of the FS.
- *The cleanup action is protective of terrestrial ecological receptors.* Based on the TEE results, the Site is protective of terrestrial ecological receptors except for an isolated hot spot with elevated naphthalene concentrations (monitoring well MW-24). Future capped areas will prevent ecological receptor exposures to naphthalene at this location under the proposed alternatives.
- *Institutional controls are put in place to prohibit or limit activities that could interfere with the long-term integrity of the containment system*. ICs established to maintain an engineered cap will be included as part of the respective cleanup alternatives.
- *Compliance monitoring and periodic reviews are designed to ensure the long-term integrity of the containment system*. Monitoring and periodic reviews will be included as part of any remedy implemented at the Site.

- *The draft CAP specifies the hazardous substances remaining and the measures used to prevent migration and direct contact*. This information will be included in the draft CAP.

2.3.2. Groundwater

Preliminary groundwater cleanup levels are based on protection of marine surface water and sediment. As discussed in Section 3.6 of the RI, shallow groundwater at the Site is classified as non-potable; therefore, groundwater ingestion is not a potentially complete exposure pathway and was not considered in the development of groundwater cleanup levels. The preliminary groundwater cleanup levels are protective of the vapor intrusion pathway.

Preliminary cleanup levels for groundwater IHSs are presented in Table 2-2 along with the basis for each value. Some of these cleanup levels are different than the cleanup levels presented in the RI. Values that have changed, and the basis for those changes are described below.

- **Benzene**: The proposed benzene groundwater cleanup level of 2.4 µg/L presented in the RI was based on the protection of vapor intrusion. The preliminary benzene groundwater cleanup level of 1.6 µg/L in the FS is based on protection of people who consume fish.
- **Naphthalene**: The proposed groundwater cleanup level of 8.9 µg/L for naphthalene in the RI was based on the protection of vapor intrusion. It is more appropriate, however, to evaluate cleanup actions for the vapor intrusion pathway using actual soil vapor data in comparison to the air cleanup level, as discussed in Section 2.3.4. For this reason, the preliminary naphthalene groundwater cleanup level of 83 µg/L in the FS is based on the protection of sediment.

Point of Compliance: The standard point of compliance for groundwater under MTCA is throughout the site. MTCA allows use of a conditional point of compliance, however, when it can be demonstrated that it is not practicable to meet cleanup levels throughout the site within a reasonable restoration time frame (WAC 173-340-720[8][c]). At sites where groundwater cleanup levels are based on the protection of surface water beneficial uses, MTCA allows Ecology to approve use of a conditional point of compliance located as close as technically possible to the point where groundwater flows into surface water (WAC 173-340-720[8][d][i]). Use of this conditional point of compliance is subject to several conditions. Those conditions and their applicability to the Site are described below.

- *Contaminated groundwater enters the surface water and will continue to enter the surface water even after implementation of the selected cleanup action*. This condition is demonstrated in the RI by groundwater quality at shoreline monitoring wells and the continuity of contamination from the upland into sediment, and based on the cleanup alternatives as described in the FS (Section 4).
- *It is not practicable to meet the cleanup level at a point within the groundwater before entering the surface water, within a reasonable restoration time frame*. This condition is established through the technology screening and cleanup alternatives evaluations described in the FS (Section 5).
- *A mixing zone is not used to demonstrate compliance with surface water cleanup levels*. Methods to document remedy compliance with cleanup levels will not utilize the mixing zone concepts.
- *All known available and reasonable methods of treatment shall be used for groundwater before discharge to surface water*. An evaluation of all known available and reasonable technology (AKART)

methods of groundwater treatment is presented in the FS and applicable methods are incorporated into the cleanup alternatives.

- *Groundwater discharges do not result in exceedances of sediment quality values in Chapter 173-204 WAC*. Groundwater cleanup levels are protective of marine sediment.
- *Groundwater and surface water monitoring are performed to evaluate performance of the cleanup action including consideration of the potential for discharges at levels below method detection limits to cause bioaccumulative effects*. Compliance monitoring for remedy performance will be conducted following implementation; details will be specified in the CAP.
- *Notice of proposed conditional points of compliance is made to natural resource trustees, DNR and USACE*. Required notice and request for comment will be made by Ecology after the cleanup alternative has been selected.

2.3.3. Sediment

Preliminary sediment cleanup levels are presented in Table 2-2. Cleanup levels for sediment are selected from a range of numerical values. The SMS Sediment Cleanup Objective (SCO) is the low end of the range, below which no adverse effects or unacceptable risks are anticipated to human health or the environment; the Cleanup Screening Level (CSL) is the higher end of the range, above which adverse effects or unacceptable risks can sometimes be expected to human health and the environment.

Preliminary sediment cleanup levels for cPAH TEQ, the only sediment IHS, were chosen for protection of two primary exposure pathways – direct contact and bioaccumulation:

- For the direct contact pathway, the exposure scenarios involve benthic organisms living in sediment and people engaged in beach play, clamming, or net-fishing.
- For the bioaccumulation pathway, the exposure scenarios involve people and ecological receptors (higher trophic species) consuming seafood foraged from the Site.

Sediment cleanup levels are initially established at the SCO and may be adjusted up to, but not higher than, the CSL. The direct contact pathway (for people and benthic organisms) was evaluated in the RI and was considered in the FS. However, the cPAH cleanup level for the direct contact pathway is higher than the cleanup level for the bioaccumulation pathway.

PAHs are bioaccumulative compounds; typically, risk-based cleanup levels for bioaccumulative compounds are far below background levels or our ability to quantify their concentrations in environmental media. Under the SMS, ultra-low cleanup levels for ubiquitous bioaccumulative compounds are adjusted up to background values or analytical practical quantitation limits, whichever is higher. In the 2013 modifications to the SMS, natural background represents the SCO, whereas regional background (indicative of urban sources to a watershed) is equivalent to the CSL. Selection of cleanup level for bioaccumulative IHSs is discussed further below.

- **cPAHs:** The sediment cleanup level for cPAHs is set at 86 µg/kg, the regional background concentration established by Ecology for Bellingham Bay. This regional background value was selected as the preliminary cleanup level because it represents the prevailing sediment quality in eastern portions of Bellingham Bay not influenced by specific contaminant sources or cleanup sites. As such, regional background concentrations represent the levels to which surface sediment will equilibrate (i.e., recontaminate) over time after sediment cleanup. Although it may be possible to attain lower sediment concentrations initially following cleanup, lower levels cannot be maintained due to the influence of ongoing, contaminant loading from aerial deposition, stormwater runoff and sediment transport by marine processes on a regional basis. Sediment cleanup levels based on regional background concentrations can be achieved in a reasonable timeframe and maintained.

Risk-based sediment concentrations for three direct-contact potential exposure scenarios (Beach Play Child, Subsistence Tribal Clam Digging Adult, and Subsistence Tribal Net Fishing Adult) are presented in Table 9-2 of Ecology's Sediment Cleanup User's Manual II (SCUM II; Ecology 2015). These risk-based sediment concentrations have been revised to account for new U.S. Environmental Protection Agency (EPA) toxicity factors for benzo(a)pyrene and early life exposures using age-dependent adjustment factors. The SCUM II and revised risk-based sediment concentrations are presented in Table 2-3; the calculations are presented in Appendix A (Tables A-1 and A-2). These values were not selected as preliminary cPAH cleanup levels for sediment because they are higher than the cleanup level based on bioaccumulation. These direct contact criteria, however, were used in the FS to evaluate protectiveness of the proposed cleanup actions.

Point of Compliance: For marine sediment, the point of compliance for the protection of benthic organisms is the biologically active zone, which is considered the upper 12 cm of sediment in Bellingham Bay. This same point of compliance addresses protection of humans and higher trophic level ecological receptors with respect to consumption of seafood gathered from subtidal areas. The point of compliance for the protection of human health from consumption of shellfish (specifically clams) collected from the intertidal zone is the upper 45 cm (1.5 feet).

Compliance with seafood-consumption-based cleanup levels is assessed on an area-weighted average basis.

2.3.4. Air

Preliminary air cleanup levels established in this FS are based on the protection of human health (inhalation; Table 2-2). The standard point of compliance is ambient air throughout the Site. However, inhalation of outdoor air was not identified as a significant exposure pathway in the RI. The preliminary air cleanup levels are, therefore, would be considered relevant to indoor air if buildings were ever constructed at the Site in the future.

Air cleanup levels were established for benzene and naphthalene. Other volatile organic compounds (VOCs) were detected in soil vapor at the Site at concentrations greater than screening levels; however, cleanup levels for these VOCs were not established because of the greater toxicity of benzene relative to the other VOCs and because benzene was detected at the highest concentrations in soil vapor samples.

2.4. Remediation Levels

Remediation levels were developed for soil and sediment to identify concentrations where different cleanup components will be applied, as allowed by WAC 173-340-355. Soil remediation levels were developed to determine where a cleanup action was required to prevent unacceptable exposures for park users and park workers in the upland unit. Sediment remediation levels were developed to delineate where an active (e.g., capping, etc.) versus passive technology (i.e., monitored natural recovery [MNR]) would be used.

2.4.1. Soil Remediation Levels

Soil remediation levels were developed to support the evaluation of cleanup alternatives, consistent with MTCA (WAC 173-340-355). The remediation levels are based on exposure to surface soil (0 to 2 feet bgs).

The remedial alternatives presented in Section 4 employ both cleanup and remediation levels to protect human health and the environment. The cleanup levels incorporate MTCA default exposure assumptions for human health, which are based on unrestricted (e.g. residential) land use. The remediation levels are based on alternative exposure assumptions that reflect the actual use of the Site as a park. Exposure scenarios were considered for park users (children and adults) and park workers (adults). These scenarios reflect actual reasonable maximum exposures in the upland unit.

The use of soil remediation levels in Section 4 accounts for the relatively small area where naphthalene was detected at relatively high concentrations (based on potential terrestrial ecological exposure) in the southern portion of the upper park (at monitoring well MW-24 only). Each of the proposed upland cleanup action alternatives includes a 2-foot soil cap at MW-24. Following implementation of the selected remedy, the relatively high naphthalene concentration detected at MW-24 will be at a depth of 7 to 8 feet bgs, which is below the conditional point of compliance of 6 feet bgs for terrestrial ecological receptors.

Soil remediation levels were derived using alternative reasonable maximum exposure scenarios in accordance with WAC 173-340-740(3)(d), -708(3)(d), and -708(10)(b). The potential risks to human health associated with exposure at the park are lower than the potential risks associated with residential land use. This is because park users and workers are expected to be exposed to Site soil less frequently than what is assumed for the residential (or unrestricted land use) scenario, which assumes that residents are exposed to Site soil every day.

Soil remediation levels were calculated using the MTCA modified Method B cleanup level equations that account for concurrent exposure due to ingestion and dermal contact (WAC 173-340-740[3][c][iii], Equations 740-4 and 740-5).

2.4.1.1. Park User

Park users were evaluated based on child exposure for noncarcinogenic contaminants and combined child and adult exposures for carcinogenic contaminants. Child and adult exposure assumptions used to develop the park user remediation levels are based on those used to develop Modified MTCA soil cleanup levels for children and adults and are consistent with exposure assumptions Ecology provided to GeoEngineers for another waterfront site, with one exception: the child and adult park users are assumed to visit the Site 2 days per week (or 104 days per year).

The exposure duration of 30 years assumed for the park user is different from exposure durations used to develop MTCA soil cleanup levels for children (Method B) and adults (Method C). This is because the MTCA soil cleanup levels do not account for combined child and adult exposure. The exposure duration for child and adult park users are 6 and 24 years, respectively. The 6 years for children is consistent with the exposure duration assumed for the Modified Method B soil cleanup levels. An exposure duration of 24 years for adults and a combined child/adult exposure duration of 30 years are consistent with typical residential exposure scenarios.

The park user remediation level for cPAHs account for new EPA toxicity factors for benzo(a)pyrene and early life exposures using age-dependent adjustment factors.

Park user remediation levels are shown in Table 2-4 and the calculations are included in Appendix A (Tables A-3 and A-4).

2.4.1.2. Park Worker

Park user remediation levels, which are primarily based on residential exposure assumptions, are also protective of park workers; therefore, park worker remediation levels were not calculated.

2.4.2. Sediment Remediation Levels

Sediment remediation levels are used to delineate portions of the marine unit that will be actively remediated. The use of remediation levels is consistent with SMS guidance. For the Site, remediation levels were developed to evaluate cleanup actions needed to achieve compliance with the bioaccumulation-based cleanup level for cPAHs. This is the key contaminant group that not only defines the Site boundary but drives cleanup needs within the Site. Portions of the Site exceeding SMS criteria for benthic toxicity are very limited, comprising a small subset of the cPAH exceedance area.

Under the SMS, compliance with the cleanup level for bioaccumulative compounds can be achieved based on the surface-area weighted average concentration (SWAC) in sediment. That is, the cleanup level has been met when the SWAC is equal to or less than the sediment cleanup level. SWACs can be derived by different methods (Thiessen polygons or geographic information system [GIS] interpolation); the GIS interpolation method was used for the Site as follows:

- Interpolate surface sediment cPAH TEQ concentrations within the marine unit using the nearest neighbor interpolation method.
    - The GIS software creates a grid of 1-foot by 1-foot cells.
    - cPAH TEQ concentrations are assigned to each grid cell based on the interpolation results.
- The SWAC is the arithmetic mean of the grid cell values across the marine unit.

The remediation level for cPAHs was derived using a process referred to as "hill-topping." Using hill-topping, grid cell concentrations in the marine unit are ranked from highest to lowest and the highest concentrations are iteratively removed from the dataset and replaced with a post-cleanup concentration. For this exercise, a replacement value of 21 µg/kg was used, which is the Puget Sound natural background value for cPAH TEQ. This process is repeated until a desired post-remedy SWAC is achieved.

Following this approach, two remediation levels were developed to support the evaluation of remedial alternatives for the marine unit. An upper remediation level of 965 µg/kg produces an estimated post-remedy SWAC of 300 µg/kg. This value (300 µg/kg) is the maximum concentration anticipated to meet the cPAH cleanup level (86 µg/kg) in a 10-year restoration timeframe based on natural recovery processes.[1] A lower remediation level of 345 µg/kg produces a post-remedy SWAC equivalent to the bioaccumulative cleanup level (86 µg/kg). Alternatives meeting this post-remedy SWAC require no natural recovery to achieve compliance with the cPAH cleanup level. All the alternatives incorporate one or both of these remediation levels.

[1] It is estimate that a post-remedy SWAC of 300 µg/kg will recover within 10 years based on the ITRC risk reduction equation that accounts for the deposition rate, biologically active zone depth, reasonable timeframe for recovery and the cleanup level (ITRC 2014). Cleanup actions were developed assuming that natural recovery processes are effective at the Site in water depths equal to or greater than -10 feet MLLW.

3.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section identifies and presents a screening evaluation of potentially applicable GRAs and associated remedial technologies for developing cleanup action alternatives in accordance with MTCA requirements, WAC 173-340-350. Sources of information used to develop the list of GRAs and technologies include EPA publications and databases, text references, vendor information, and professional experience at similar sites.

The technology screening evaluation was performed for environmental media at the Site: upland soil and groundwater, and marine sediment. Based on the screening evaluation, selected GRAs and technologies were carried forward for use in developing cleanup action alternatives (Section 4).

GRAs are actions that can be taken to reduce or eliminate the adverse impact of chemicals on human health and the environment (e.g., containment). The technology screening tables (Tables 3-1 through 3-4) first identify GRAs that can potentially achieve CAOs. Remedial technology types (e.g., cap) and specific remedial technology process options (e.g., vegetated soil cap) that could be used to implement the GRAs are then identified. Technology process options were screened based on EPA's criteria of effectiveness, implementability and cost (EPA 1988). In the final step of technology screening, the technology process options least suitable to address impacted media and achieve CAOs were eliminated from further evaluation and the most suitable technologies were carried forward in the development of cleanup action alternatives.

3.1. Screening of Technology Process Options

The remedial technology screening is presented in Tables 3-1 through 3-4. The results of the screening are discussed further in Sections 3.1.1 through 3.1.3. Those technology process options considered effective and technically implementable given current knowledge of the Site, and cost-effective relative to competing options were retained for inclusion in cleanup action alternatives, which are described in Section 4. The components of each of the three primary screening criteria -- effectiveness, implementability and relative cost – are explained below.

3.1.1. Effectiveness

The effectiveness evaluation focused on the ability of each technology process option to address CAOs, site-specific IHSs, and protect human health and the environment relative to the other remedial technologies. The effectiveness evaluation was based on the following:

- The ability of a technology process option to achieve the established CAOs.
- The degree to which the technology process option protects human health and the environment during construction and implementation.
- Likely effectiveness considering Site-specific conditions.

3.1.2. Implementability

The implementability evaluation focused on the technical and administrative feasibility of a technology process option. The implementability evaluation was based on the following:

- The institutional aspects of implementation, including the ability to obtain necessary permits and public acceptance.
- The availability of support services and equipment, and the degree to which the technology process option has been demonstrated to be implementable at other sites.

3.1.3. Relative Cost

This criterion was used to compare relative capital, and operation, maintenance and monitoring (OMM) costs between the technology process options. Each technology was evaluated based on whether relative costs (based on engineering judgment) are expected to be low, moderate, or high compared to other remedial technologies.

3.2. Soil Remedial Technologies

A range of potential GRAs and remedial technologies were evaluated for upland soil at the Site to support the development of cleanup action alternatives. The GRAs considered in the screening evaluation included ICs, engineering controls (ECs), soil containment, soil removal, ex-situ treatment, off-site management, and in-situ treatment (Table 3-1). GRAs that were evaluated are discussed further below. Table 3-1 presents the evaluation of these technologies and Table 3-4 presents the resulting retained technology process options. The retained technologies include removal and off-site disposal, bioventing, soil vapor extraction (SVE), in-situ solidification (ISS), permeable and low-permeability soil capping, synthetic vapor barrier membranes, fencing and warning signs, and environmental covenants.

3.2.1. In-situ Soil Treatment

This GRA is defined as the in-place treatment of soil without removing it from its natural/native location (Watts 1998). Several common in-situ soil treatment technologies were evaluated for applicability to the contaminants and conditions at the Site including chemical, biological, and physical treatment methods (Table 3-1). The retained in-situ treatment technologies include bioventing and ISS.

Bioventing – Bioventing is an in-situ soil remedial technology that relies on indigenous microorganisms in vadose zone soil to aerobically degrade organic contaminants. Bioventing relies on inducing air flow through vadose zone soil to increase the oxygen concentration in soil vapor and stimulate aerobic respiration of the microorganisms. Commonly implemented using components of SVE, bioventing at the Site would be implemented as an add-on to SVE, utilizing passive vent wells that promote air flow through the vadose zone during periods of extraction. While SVE is primarily effective at remediating VOCs through mass transfer and removal, the aerobic conditions resulting from the bioventing process can stimulate biological degradation of residual VOCs as well as heavier organic compounds, such as PAHs, that are not amenable to removal by SVE.

In-situ Solidification – ISS is the process of encapsulating contaminated soil to form a solid material and restrict contaminant migration by decreasing the surface area exposed to leaching or by coating the contaminated soil with low-permeability materials. Solidification traps the contaminated material within a granular or monolithic matrix (EPA 2000a). ISS involves mixing treatment materials directly into the contaminated soil to change the contaminant/soil environment such that contaminants are bound to soil and/or treatment reagents, or physically isolated from surrounding groundwater, significantly reducing the potential to partition into groundwater. Soil treatment by ISS is most commonly employed by mixing contaminated soil with Portland cement or another cementitious material. Where high concentration organic contaminants (i.e., non-aqueous phase liquid [NAPL]) are present, additives such as organophilic clay are used to adsorb the contaminants and allow the Portland cement to cure (CETCO 2008) to achieve a stable matrix.

For the contaminants present at the Site, ISS may rely on the addition of additives such as organoclays, fly ash, or slag to be added to Portland cement to facilitate the curing process in soil that contains substantial concentrations of organic contaminants that may otherwise inhibit the curing of Portland cement (Conner 1990). ISS would be implemented at the Site using standard excavation equipment for shallow applications (approximately less than 15 feet bgs).

3.2.2. Removal and Management

Technologies that rely on removal of contaminants from soil, or removal of the contaminated soil itself, consist of proven and effective remediation technologies that are expected to be effective for soil contaminants at the Site. The primary retained removal technology for soil contaminants was SVE.

Soil Vapor Extraction – SVE is categorized as a removal technology in the FS because it relies on physical processes to facilitate the transfer of VOCs from vadose zone soil to soil vapor, which is subsequently removed from the subsurface through wells under moderate to high levels of vacuum. The vacuum generated at the SVE wells induces the flow of soil vapor through the subsurface to the wells. This flow of air and soil vapor through soil contaminated with VOCs facilitates mass transfer of the contaminants to the soil vapor, reducing soil concentrations through removal of contaminants without disturbing the soil. The extracted soil vapor is processed in above-ground treatment components that remove contaminants from the extracted soil vapor, if required to meet emissions limits. Common treatment methods for extracted soil vapor consist of adsorption with activated carbon and thermal oxidation. The contaminant is adsorbed to the activated carbon, and this material is subsequently transported off-site for disposal or recycling. Thermal oxidation uses thermal mechanisms to destroy the contaminant during treatment. The cost-effectiveness of effluent treatment generally depends on contaminant concentrations and the treatment method is commonly selected following pilot testing.

3.2.3. Soil Containment

Methods for preventing people and ecological receptors from being exposed to contaminated soil include various types of surface engineered caps. For the Site, permeable as well as low-permeability cap technologies were retained for use in the cleanup action alternatives. Capping is a well-established and proven containment technology that prevents direct contact by maintaining a physical barrier between contaminated soil and potential receptors. Contaminated soil can be contained using caps constructed of soil, geotextiles, geomembranes, aggregate, pavement or structures such as buildings. The location and design of caps should be compatible with land use. A capping remedy would require maintenance and long-term monitoring to ensure its continued effectiveness.

Permeable Vegetated Soil Cap – A permeable vegetated soil cap involves placement of a clean soil barrier on the ground surface to prevent exposure to underlying contaminated soil, control erosion of potentially contaminated material, and allow stormwater infiltration.

Low-Permeability Vegetated Soil Cap – Low-permeability caps will prevent direct exposure to contaminated soil, while also significantly reducing or eliminating stormwater infiltration in the upland portion of the Site. The reduced infiltration reduces contaminant leaching to groundwater and contaminant flux from the upland unit. A low-permeability vegetated soil cap would include a subsurface low-permeability geomembrane to impede stormwater infiltration. The low-permeability function of any upland cap would necessitate the collection and management of Site stormwater. Subsurface soil vapors may be present, requiring a soil vapor collection and ventilation system to mitigate the buildup of vapor beneath the cap.

Both permeable and low-permeability vegetated soil caps have been retained as capping process options for upland portions of the Site. It is proven, effective, implementable, can be designed to address Site-specific contaminants, and is compatible with the City's long-term plans to use the Site as a public park.

3.2.4. Engineering Controls

ECs can include a variety of engineered methods used to mitigate the effects of contaminants and prevent exposure to contaminants by people and ecological receptors. For this FS, ECs are reserved for application on future construction within the completed cleanup action. In particular, physical vapor barriers would be utilized, if needed, to prevent the intrusion of soil vapors into indoor air space of future park structures. These vapor barriers would be utilized in areas of the Site where VOCs exceed concentrations protective of the indoor air pathway. There are no existing plans for such a park structure, but an EC would address this pathway if plans change.

3.2.5. Institutional Controls

ICs include regulatory or legal restrictions and access controls to reduce risk to people or ecological receptors by preventing contact with contaminants. Environmental covenants that limit or dictate specific land use activities are typical legal mechanisms for preventing exposure, while fencing and warning signage are typical access control methods. If the PLPs are unable to have environmental covenants recorded for parcels/properties at the Site, other administrative mechanisms may be used for those parcels/properties. Examples of such administrative mechanisms include zoning overlays, placing notices in local zoning or building department records or state lands records, public notices and educational mailings. These mechanisms would provide notification to property owners, interested parties, and local municipalities about the likely existence of contamination. Any ICs implemented at the Site would require long-term monitoring to ensure continued integrity of the completed remedial action.

An environmental covenant would not be an acceptable cleanup action on its own because it would not achieve the CAOs for upland soil. However, land use restrictions accomplished using an environmental covenant were retained as a component of cleanup action alternatives, as they can be effective and implementable in combination with engineered containment controls and other GRAs. As an example, a covenant can require maintenance of a protective barrier that keeps people and ecological receptors from being exposed to impacted soil. ICs may be needed to protect the integrity of the selected remedy; these restrictions would be compatible with the planned use of the Site as a park.

Despite the public park setting and continued land use for the Site, access controls such as permanent fencing were determined to be applicable and potentially effective in some scenarios to prevent exposure of human receptors to contaminants in some areas of the Site. In particular, existing site fencing separating the park area from the railroad track could be expanded to prevent access to the slope area between the upper and lower park.

3.3. Groundwater Remedial Technologies

A range of groundwater remedial technologies were evaluated for potential use in cleanup alternatives at the Site. The GRAs considered in the screening evaluation included in-situ groundwater treatment, groundwater collection, containment and ICs. Table 3-2 presents the evaluation of these technologies and Table 3-4 presents the resulting retained technologies. Specific technology process options that were retained are discussed further below. GRAs that were evaluated are discussed further below.

3.3.1. In-situ Groundwater Treatment

Several common in-situ groundwater treatment technologies were evaluated for applicability to the contaminants and conditions at the Site including chemical, biological, and physical treatment methods (Table 3-2). The retained in-situ groundwater treatment technologies include aerobic bioremediation and monitored natural attenuation (MNA).

Enhanced Bioremediation – Naturally occurring microbes can degrade hydrocarbon compounds in aquifers by processes such as aerobic or anaerobic respiration. Enhanced bioremediation involves the stimulation of these biological processes to increase contaminant degradation. Nutrients, oxygen, or other amendments may be used to enhance aerobic or anaerobic biodegradation. The Site contaminants most susceptible to biodegradation, naphthalene and benzene, are commonly remediated using aerobic bioremediation. Anaerobic bioremediation may be more effective at the Site, however, because the high organic content of soil (particularly in the lower park) produces reducing conditions in the aquifer. The high organic content in lower park soil is primarily caused by the presence of wood waste.

Additional characterization of groundwater geochemistry, as well as treatability testing, would be required to evaluate the most effective bioremediation technology for Site contaminants and conditions.

Monitored Natural Attenuation – Natural attenuation relies on a combination of physical, chemical and biological processes to reduce the concentrations of contaminants in groundwater (EPA 2012). Specific natural processes that facilitate the reduction in contaminant concentrations in groundwater include biodegradation, sorption, dilution, evaporation and chemical reactions that modify the mobility or toxicity of the contaminants. The treatment occurs using natural processes without assistance, and monitoring is conducted to document the effectiveness of the processes at attenuating site contaminants in groundwater prior to reaching the selected receptor. MNA has typically been reserved for dissolved phase contaminant plumes of lower concentration that are remain after removal of upgradient sources.

3.3.2. Institutional Controls

ICs include land use restrictions to reduce risk to receptors by preventing contact with contaminants. Land use restrictions in the form of environmental covenants are required as a component of remedial actions when contamination remains above Method A or B cleanup levels or where conditional points of compliance are used. The environmental covenants prevent actions that might threaten the integrity of the remedy. They also dictate the maintenance and monitoring requirements of ECs.

3.4. Sediment Remedial Technologies

A range of remedial technologies was evaluated for Site marine sediment. The SMS (WAC 173-204-570 [4][b]) provides a list of likely technologies that may be used to clean up contaminated sediment. GRAs considered in the screening evaluation for sediment included in-situ sediment treatment, sediment removal, management of excavated sediment, sediment containment, enhanced natural recovery (ENR), MNR and ICs, (Table 3-3). Specific GRAs, technology types, and process options that were retained for use in alternatives development are discussed below.

3.4.1. Sediment Removal

Sediment removal (by either dredging or excavation) is an established GRA for source control and risk reduction in aquatic environments where sediment represents a long-term reservoir of contamination. Dredging is done by one of two methods—mechanical or hydraulic equipment. Excavation can be implemented using shore-based equipment in shallow-water nearshore areas within reach of an excavator or in areas that can effectively be dewatered through use of coffer dams, sheet pile walls or other temporary structures.

Challenges associated with dredging include the resuspension of contaminated sediment (dredge residuals) in the water column, followed by deposition both inside and outside the area of removal. Removal of all targeted sediment also can be difficult because dredging is conducted under water. Dredged sediment also typically must be dewatered prior to transport to a transloading or disposal facility. In many cases, the remedial design and use of best management practices (BMPs) can address challenges associated with sediment removal and dewatering.

Sediment removal was retained for use in the FS, but was incorporated only in two of the alternatives at nearshore locations. Broader applications of dredging were not incorporated because contaminant concentrations are generally higher at greater depths, increasing the risk of mobilizing these contaminants during dredging. The two alternatives that incorporate removal target nearshore contaminated sediment in the pocket beach area. This sediment would be removed using land-based equipment and shoring or other ECs to enable excavation “in the dry.” This approach would reduce the risk associated with disturbing deeper, more contaminated sediment. Capping would be required in the excavation area because it would not be practicable to remove the entire vertical profile of contaminated sediment at this location. Dredging is not proposed for locations farther from shore because of concerns related to dredge residuals and the inability to remove the entire vertical profile of contaminated sediment. In addition, sediment removal over widespread subtidal areas would not be practicable in comparison to other (capping and natural recovery) technologies.

Sediment removal technologies require associated actions that drive costs. The removed material needs to be transported and disposed of; water removed during the process may also require containment, treatment and disposal. The costs associated with waste handling and disposal typically drive the overall cost of sediment removal. Handling and treatment costs of the large volume of water generated by hydraulic dredging resulted in this process option being rejected.

Short-term risks associated with any construction activities conducted within the marine environment include disturbance and resuspension of contaminated sediment, partitioning of contaminants into the water column from disturbed sediments with a short-term increase in bioavailability and off-site migration, and destruction of benthic communities and aquatic vegetation. Removal of nearshore sediment using land-based equipment during low tides or under induced dry conditions, and the use of other common in-water work BMPs, significantly reduces these short-term risks. Land-based excavation of nearshore sediment using these methods is the only sediment removal process option retained in this FS.

3.4.2. Handling and Disposal of Sediment

Sediment removal would require handling, transport and off-site disposal of the materials generated, including sediment, debris, decanted water and any amendments used to stabilize dredged material. Off-site disposal of contaminated media is controlled by state and federal solid waste regulations that restrict acceptable disposal methods for contaminated sediment. Depending on the contaminant concentrations and characteristics of the dewatered sediment, the dredged material will be classified as either RCRA Subtitle D or Subtitle C regulated waste. This classification will affect the selection of licensed off-site disposal facility and the requirements imposed on material transport and handling.

Removal of nearshore sediment would involve upland-based equipment and methods, with excavated material stockpiled on-site or loaded for immediate transport to an off-site disposal facility. Sediment removed using over-water methods would be barged to an off-site transloading facility for train or truck transport to a solid waste handling facility. Depending on the dredged material volume and available on-site space, the sediment may be dewatered on-site, at the transload facility or at the final disposal location. Transport of free liquids generally requires additional management to prevent leakage during transport. Free water can be removed mechanically via centrifuges, belt presses or filters, or passively by storing sediment slurry and allowing particulates to settle, sometimes assisted by chemical flocculants. Although passive dewatering is generally less costly than mechanical, its significant storage space and time requirements would limit dredging production rates.

3.4.3. Sediment Capping

Sediment capping is a common containment technology that involves placement of clean material over contaminated sediment. Caps stabilize the underlying sediment to prevent disturbance, resuspension and transport of contaminants to other areas and reduce migration of dissolved contaminants to the biologically active zone and the overlying water column, thus preventing exposure of ecological and human receptors. Caps can also be designed to function as habitat once constructed.

Caps meet the objectives of physical and chemical isolation by placing cap material (commonly clean dredged sediment or pit-run sand or gravel) of various thicknesses on the sediment surface; amendments (e.g., activated carbon, organophilic clay, and other materials) or geotextiles (e.g., fabric layers or media-filled mats) can also be used to provide containment or treatment-specific functions. Conventional sand caps are generally effective where the contaminants of concern tend to be strongly bound to sediment, groundwater flux is low, and erosive forces are fairly weak (ITRC 2014). Where these conditions are not met, effective caps can still be designed. Amendments such as activated carbon or organophilic clay can provide chemical treatment and isolation functions but with a thinner cap profile. Geotextiles can be used to contain sediment and introduce amendments or treatment materials within the cap profile. Geotextiles can also serve as physical barriers to prevent biological disturbance or erosion of the contaminated sediment, depending on the design and performance objectives.

The final cap construction needs to meet site-specific requirements for land use, navigation, and habitat. The composition and design of a cap must accommodate land and aquatic uses of the Site and local area as well as all local natural processes (e.g., bioturbation, consolidation, storm and vessel-induced erosion, groundwater flow) and conditions (e.g., slope, bathymetry). These factors, in addition to contaminant isolation and attenuation requirements, typically result in a layered approach to containment, as recommended by USACE and EPA (USACE 1998; EPA 2005), meaning that the typical cap construction consists of multiple layers combined to meet all of the requirements presented by the area to be capped.

Cap placement technologies vary based on the type of material being placed, water depth, and the geotechnical properties of the in-place contaminated sediment. Caps are typically constructed by releasing material at the surface of or within the water column and allowing it to settle to the bottom. Release mechanisms include dumping from a barge or hopper, hydraulic spreading (washing from a barge), broadcasting, and pumping a slurry through a floating or fixed pipeline or diffuser. Cap material can be directly placed on the bottom by a tremie tube, by a barge or land-based backhoe or dredge bucket, or by divers (USACE 1998). If amendment or treatment materials are to be incorporated in the cap, additional mixing or handling will be required prior to placement, unless the amendments are introduced as a discrete layer.

Short-term risks associated with cap placement include disturbance and resuspension of contaminated sediment (albeit much less than dredging), displacement of potentially contaminated porewater into the water column upon sediment consolidation, and smothering of benthic communities and aquatic vegetation. The degree of resuspension is affected by the type of material being placed, the degree of consolidation of the in-place sediment, and contact or potential impact of the capping material with bottom materials. If clean dredged sediment or denser material is to be used for capping, sediment descent rates can be fairly high, which can disturb the contaminated sediment. Hydraulic placement or use of diffuser or baffle/spreader plates can mitigate contaminated sediment resuspension.

Where a thick cap is constructed, temporary loss of the benthic community and aquatic vegetation is inevitable, although subsequent benthic invertebrate recruitment would provide some degree of restoration for caps with unarmored surfaces. Incorporation of habitat material as part of the cap surface can enhance recolonization by benthic invertebrates and aquatic vegetation; benthic community recovery occurs within months to years. Where warranted (e.g., provides valuable ecological function), aquatic vegetation (e.g., eelgrass) can be replanted as part of restoration. Thinner caps (less than or equal to the depth of the biologically active zone) can be placed in thin lifts to limit smothering and accelerate benthic community recovery or preserve aquatic vegetation.

Capping methods that chemically and physically isolate contaminated sediment as well as those that provide treatment have been retained for consideration in this FS: conventional sand cap, thin sand cap, and amended/reactive cap. Further discussion of the application of the capping methods are described below:

- Conventional Sand Cap – The design thickness of a conventional cap varies based on site-specific conditions. The sand cap provides a physical barrier between the sediment biologically active zone and/or surface water and the underlying contaminated sediment, while also providing clean media through which contaminants subject to transport by advection and diffusion attenuate; however, the low-organic content of a conventional sand cap limits the degree of attenuation, particularly for organic contaminants.
- Thin Sand Cap – Where sediment contaminant concentrations, or other factors affecting cap design, indicate that a thin cap profile is adequate to isolate and attenuate contaminants, a thin sand cap would be utilized. Constructed similarly to a conventional sand cap, but with a 1-foot layer of sand cap material, the thin sand cap is called out separately in this FS for areas where less cap material is needed.
- Reactive Cap – The cap design can include specialized materials to treat contaminants in groundwater. Various types of amendments (e.g., activated carbon, organophilic clay, zero-valent iron [ZVI]) attenuate the flux of contaminants from the underlying contaminated sediment to pore water in the biologically active zone and the overlying water column. Activated carbon amendments would be used for areas affected principally by benzene and naphthalene. ZVI would be used in areas affected principally by cyanide. Reactive cap methods are reserved for use in nearshore areas as needed based on design-level evaluations.

3.4.4. Natural Recovery Processes

The natural recovery of sediment refers to processes such as chemical and biological degradation, sedimentation (i.e., burial beneath naturally deposited clean sediment) and bioturbation (e.g., mixing) that result in reduced contaminant concentrations in surface sediment and increased isolation of contaminated sediment over time. When natural recovery is expected to yield sediment that meets cleanup goals within a reasonable time frame (defined as 10 years in SMS), or when other technologies are determined to be impracticable, MNR can be considered. This cleanup approach requires long-term monitoring to demonstrate the rate of recovery and ensure that CAOs are met. The monitoring program associated with a MNR remedy typically includes a combination of physical and chemical testing. Where chemical concentrations are low and deposition rates are sufficient to support natural recovery (typically 1 cm/year or more), MNR is considered for implementation in deeper, depositional environments of the marine unit.

Where natural recovery rates are too low or existing sediment concentrations too high to achieve cleanup levels within a reasonable time, a thin layer of clean sediment (commonly about 6 inches [15 cm]) may be placed to reduce surface sediment concentrations and accelerate natural recovery processes. The ENR process allows cleanup goals to be met in an acceptable timeframe; as with MNR, long-term monitoring is conducted to document the rate of recovery and success in meeting the CAOs. ENR has been retained as a component of sediment remedial alternatives for areas where sediment concentrations are elevated, and natural recovery processes need to be accelerated to meet cleanup goals within a reasonable restoration timeframe.

3.4.5. Institutional Controls

ICs have been included both to prevent human exposure to contaminants left in place and to protect the physical integrity of the remedy over time. By regulation (WAC 173-340-440[6]), ICs can be proposed as the sole response action only where an active remedy is not feasible; however, ICs are typically combined with various engineered responses. ICs can be applied during implementation, post-remediation and even after CAOs have been achieved. Environmental covenants that restrict the aquatic uses in order to meet one or more of the CAOs (e.g., protection of human health) would likely be part of most remedies. Activities such as navigational dredging, boat anchoring, large vessel maneuvering or in-water construction that could potentially damage any sediment cleanup action may be prohibited under such restrictions. Restrictions in the form of covenants are legally binding regardless of property ownership or future land use; however, most covenants take into account likely future use scenarios. In addition, covenants are enforceable by Ecology and parties to the covenant. Public notice, education and consumption advisories may also be applicable to the sediment remedy. Retained as an applicable technology for the Site, ICs will likely be included in the final remedy for the Site.

4.0 DESCRIPTION OF CLEANUP ACTION ALTERNATIVES

Cleanup alternatives were developed based on current approaches for upland and sediment remediation projects in the United States, with special attention to Washington State, following regulations and guidance developed by Ecology, EPA and USACE. Each alternative was designed to meet MTCA and/or SMS threshold requirements. The remedial alternatives are generally presented in order of increasing levels of removal and/or treatment of contaminated media, with the last alternative for each Site unit involving complete removal of contaminated media to the extent practicable. The alternatives were sufficiently developed on a conceptual basis to perform a comparative evaluation of the alternatives and identify a preferred alternative. The final design for the selected alternative may differ somewhat from the alternative descriptions presented in this FS depending on agency decisions, input from the public and other stakeholders as required by MTCA, permit requirements, and supplemental data that may be collected to support design.

The remedial alternatives include a range of treatment, removal, and containment technologies to achieve cleanup standards for impacted media. The alternatives include actions that satisfy the expectations of MTCA (WAC 173-340-350 through -370) and SMS (WAC 173-204-550(7), -570 and -575). For example, the alternatives include various technologies that remove, destroy, immobilize, and/or contain contaminants in soil, groundwater and sediment. Collectively, these actions will minimize or control to the extent practicable contaminant migration from the upland to the marine unit.

Section 4.1 describes cleanup components common to each alternative. Section 4.2 describes the primary components of each alternative, along with the key assumptions, basis and rationale for including the alternative in the FS.

4.1. Common Elements of Each Remedial Alternative

Each remedial alternative includes the same actions to address potential risks associated with four features at the Site: remnant gas holder structures in the upper park, the steep slope between the upper and lower park, the BNSF Railroad right-of-way, and remnant treated piles in the marine unit.

Options for dealing with these features were relatively limited and straightforward; they were, therefore, evaluated independently as “common elements” of each alternative. The common elements are described below but not repeated in the subsequent alternative descriptions. Costs associated with the common elements are included in the FS cost estimates for the individual alternatives, with one exception. The cost of removing remnant piling was not included due to uncertainties regarding the number of piles and removal methods. Proposed actions associated with the common elements are summarized in Table 4-1 and details are described below.

4.1.1. Remaining Gas Holder Structure

A concrete cylindrical wall associated with the former central gas holder (No. 2) is the only above-grade component of the former MGP facility remaining at the Site today. This concrete structure and its contents will be removed and transported off-Site for disposal. Portions of the base of this gas holder will be removed, to the extent practicable, to observe whether a NAPL source is present and warrants removal. Minor residual NAPL occurrences would not be removed because they would not be mobile. Remnants of the northern gas holder (No. 3) will not be disturbed if there is not a significant NAPL source present beneath the central gas holder. This will avoid potentially destabilizing the top of the steep slope that is present at the western edge of the former northern gas holder.

4.1.2. Slope Between Upper and Lower Park

Contaminated soil on the steep slope between the upper and lower park is currently stabilized by vegetation. The vegetation also prevents access by and exposure to park users. This portion of the Site is also addressed in this FS as a common element of each alternative (Table 4-1). The steep slope will be addressed using monitoring and ICs, as follows:

- Monitor the slope for continued stability, the presence of vegetated cover and lack of erosion.

- Install additional fencing at the top and bottom of the slope to restrict access.
- Limited areas of bare soil, if present, would be covered with soil and/or vegetation if practicable given the steep inclination of the slope.
- Loose MGP-related debris, if present, would be removed. If it is not possible to remove the debris, it would be covered as described above.
- ICs would be used to ensure continued monitoring and maintenance of the steep slope, vegetated cover and fencing.

4.1.3. BNSF Railway Right-of-Way

The area within the footprint of the BNSF Railway right-of-way falls within the footprint of contaminated subsurface soil and groundwater that, if accessible, would present a direct-contact risk to park users or workers. However, access restrictions to the right-of-way and the railroad structure itself currently provide a significant barrier to exposure. Potential contamination beneath the railroad right-of-way would be addressed using ICs or possibly administrative mechanisms to document the likely existence of contamination and prevent actions that might cause uncontrolled exposures in the future. These ICs or administrative mechanisms are a common element of all remedial alternatives.

4.1.4. Remnant Piling

Several creosote-treated piles associated with former over-water structures remain in the marine unit of the Site. The piles are a potential ongoing source of contaminants (PAHs) to the marine environment and would likely impede construction of the sediment remedy if left in place. The remnant piles would be removed and disposed off-Site as a common element of each alternative. Due to uncertainties associated with the number of piles requiring removal and removal methods, costs associated with pile removal are not included in the FS cost estimates for the alternatives.

4.2. Cleanup Action Alternatives

This section describes five cleanup action alternatives using the remedial technologies presented in Section 3. Each alternative includes cleanup actions for the Site as a whole (both upland and marine units) because of the significant influence that protection of sediment has on the technologies applied in the upland portion of the site. In particular, the relationship between the lower park soil and groundwater and adjacent intertidal sediment warranted developing alternatives that holistically address the most critical CAOs; those ultimately associated with preventing unacceptable exposures to contaminants in marine sediment. The relative benefits and costs of these alternatives are evaluated holistically for the Site in the DCA (Section 5.1.4).

Various treatment, removal and containment technologies are included to achieve the CAOs described in Section 2.2. The alternatives reflect an appropriate range of aggressiveness and costs. More extreme approaches that would clearly have disproportionately high costs relative to benefits were screened out from consideration as provided in MTCA (WAC 173-340-350(8)(b)(i)). This includes, for example, alternatives that would incorporate exceptionally large-scale applications of removal and off-site disposal technologies. The costs of such an approach dramatically outweigh the benefits at the Site because the significant depth of historic dense nonaqueous phase liquids (DNAPL) impacts make total removal impracticable; remaining contamination would still require the use of containment technologies. The alternatives are summarized in Table 4-2 and discussed in Sections 4.2.1 through 4.2.6.

The key technologies used for each alternative are shown in the matrix below.

Key Remedial Technologies	Remedial Alternative				
	1	2	3	4	5
Upland Unit					
Permeable vegetated upland soil cap	●	●		●	●
Low-permeability vegetated upland cap			●		
SVE and bioventing				●	
In-situ soil solidification					●
Groundwater bioremediation		●		●	●
Groundwater natural attenuation	●	●	●	●	●
Soil and groundwater ICs	●	●	●	●	●
Marine Unit					
Conventional sand cap	●	●	●	●	●
Thin sand cap		●	●		
Amended sand cap (if needed)	●	●	●		
Sediment removal and off-site disposal				●	●
ENR	●	●		●	
MNR	●	●	●	●	●
Sediment ICs	●	●	●	●	●

Remedial alternatives for Site sediment are primarily driven by bioaccumulative risks associated with cPAHs, as discussed in Section 2.4. As a result, cleanup actions for sediment were developed using remediation levels that produce certain post-remedy cPAH concentrations on a SWAC basis. The sediment alternatives are described below relative to these cPAH-related remediation levels. All alternatives are estimated to achieve compliance with the bioaccumulation-based cleanup level for cPAHs on a SWAC basis: some within an estimated 10-year timeframe (Alternatives 1, 2 and 4) and some at the time construction would be completed (Alternatives 3 and 5).

Although not discussed in the sections below, all of the alternatives also achieve compliance with the SMS (benthic toxicity) criteria on a point-by-point basis. The few exceedances of human health direct-contact cleanup levels also are addressed on a point-by-point basis in all of the alternatives, even though compliance with these cleanup levels can be measured on an area-weighted average basis. The limited locations where Site sediment exceeds benthic toxicity and human health direct-contact cleanup levels are addressed by active components of the alternatives, and compliance would be achieved at the time construction is completed.

Cost estimates for the remedial alternatives are presented in Appendix B. Table B-1 includes a summary of the cost estimates for each remedial alternative and Table B-2 includes the unit costs used to develop the detailed cost estimates. The cost estimates for the five remedial alternatives are presented in Tables B-3 through B-7.

4.2.1. Alternative 1: Soil and Sediment Capping with Natural Attenuation and Recovery

Alternative 1 relies primarily on capping technologies to prevent exposure to contaminants in upland soil and marine sediment, while MNA is utilized to reduce concentrations of IHSs in groundwater. Sediment in subtidal areas deeper than -10 feet mean lower low water (MLLW) is addressed using natural recovery technologies. Figures 4-1 and 4-2 present conceptual plan views for the upland and marine components of Alternative 1. This alternative would require ICs to maintain the integrity of the cleanup in the upland and marine units. Alternative 1 also would include the common elements described in Section 4.1.

Alternative 1 includes a permeable vegetated soil cap at locations in the upper and lower park where contaminant concentrations exceed remediation levels in the upper 2 feet of soil. The remediation levels are based on potential direct contact exposures by park users. Figure 4-1 presents the limits of the upland cap under Alternative 1. ICs would ensure cap performance and restrict activities that may result in exposure to underlying contaminated soil. For the purpose of developing the FS cost estimates, the conceptual design of the upland cap would include the following components from bottom to top:

- A flexible geotextile to prevent finer-grained underlying soils from mixing with overlying cap materials and to demarcate underlying contaminated soil from overlying clean media.
- A layer of clean fill soil of variable thickness (assumed to be an average of 1-foot thickness), graded to achieve desired design grade prior to placement of a topsoil growing medium.
- A topsoil horizon (assumed to be a 1.5-foot-thick layer of topsoil) assumed to be vegetated.

All remedial alternatives include upland capping to varying extents. The design of the caps and other elements of the upland remedy will need to account for the City's continued use of the Site as a public park. This and other issues related to compatibility of a future cleanup with land use are addressed in Section 6.3.

Protection against shoreline erosion would be partly addressed in this alternative by the nearshore sediment cap, which, where present, would be integrated with the upland cap at the transition between the marine and upland units. The sediment cap, as described below, would include rock armoring to an elevation high enough to resist coastal erosion under conditions resulting from the anticipated effects of climate change, such as sea level rise.[2] In portions of the shoreline with no adjacent sediment cap, a shoreline stabilization revetment would be constructed to stabilize the shoreline and protect upland soil from erosion. Erosion protection materials placed along the shoreline in the 2017 Interim Action (Section 1.6.2) would be incorporated, to the extent practicable, in the shoreline armoring.

Groundwater in the upland unit would be addressed by MNA. Under this alternative, it is assumed that PAHs and VOCs in groundwater would attenuate prior to reaching the biologically active zone. Existing Site groundwater data suggests that PAH and VOC concentrations in groundwater decrease near the shoreline, likely as a result of natural biological degradation and adsorption to natural and/or anthropogenic organic

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[2] All remedial alternatives described in this FS assume a 100-year sea level rise of 2.4 feet, which is consistent with assumptions used for planning other Bellingham Bay cleanup projects. This amount of sea level rise is based on analyses completed for the Port of Bellingham (Blumen 2010).

material in saturated soil. Cyanide in groundwater may also be attenuating as a result of adsorption onto the soil matrix. Additional groundwater data would be required to evaluate the effects of natural attenuation.

The marine unit includes a combination of conventional sand caps, ENR and MNR to achieve cleanup standards (Figure 4-2). The areas of active sediment remediation (capping and ENR) were identified using the hilltopping approach described in Section 2.4. This alternative includes conventional sand caps at (and slightly beyond) areas exceeding the upper remediation level for cPAHs in the intertidal and shallow subtidal zones.[3] ENR would be used in the deeper subtidal zone where cPAH concentrations exceed the lower remediation level. MNR would be used in remaining portions of the Site, where cPAH concentrations are between the lower remediation level and the bioaccumulation cleanup level.[4] Note that all alternatives include MNR in some areas shallower than -10 feet MLLW. Natural recovery is not required in these areas to achieve SWAC-based compliance with the bioaccumulation cleanup level; however, these areas would be included in the compliance monitoring program. Alternative 1 would achieve compliance with cleanup standards on a point-by-point basis in the capped areas at the time construction is completed. It is estimated that compliance with the bioaccumulation cleanup level would be achieved on a Site-wide SWAC basis within 10 years.

Details of the conventional sediment cap would be developed during design. For purposes of estimating costs, it is assumed the cap would generally consist of approximately 2 feet of sand with an overlying armor horizon, where needed, to prevent erosion at elevations higher than -10 feet MLLW. All components of this and other sediment alternatives would be designed to meet functional objectives of the remedies (e.g. chemical containment and erosion resistance) and address habitat considerations that would be identified during the permitting process.

Design of the cap adjacent to the pocket beach would be modified, if needed, to enhance attenuation of Site contaminants in sediment porewater. At this location, the cap could be thicker, or amendments could be added to enhance attenuation. For cost estimating purposes, it is assumed amendments (activated carbon and ZVI) would be incorporated at different locations in the cap adjacent to the pocket beach.

As described in Section 3.4.4, a 6-inch-thick (15 cm) layer of clean sand would be placed in the ENR area to reduce surface sediment concentrations and accelerate natural recovery processes. The thin layer is not intended to isolate contaminants as with the conventional cap, but rather, provide a cleaner layer of sediment for benthic colonization while continued natural deposition further reduces bioavailability and ultimately isolates contaminants.

Surveys conducted by other parties indicate that eelgrass is present in the lower intertidal and shallow subtidal zones within the Site boundary. Alternative 1 and all the other alternatives presented in this FS include capping in the eelgrass area because contaminant concentrations are elevated at this location. Once a remedial alternative is selected for the Site, an updated eelgrass survey would be completed and the remedial design would be advanced while considering impacts on eelgrass and other habitat-related

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[3] For purposes of describing remedial alternatives, the intertidal and shallow subtidal zones include aquatic lands at elevations above -10 feet MLLW. Areas with elevations lower than 10 feet MLLW are considered to be the deeper subtidal zone.

[4] cPAH concentrations exceed the lower remediation level in a small portion of the MNR area located near the southern shoreline of the marine unit (only in Alternatives 1, 2 and 4).

issues identified during the permitting process. Habitat considerations affect all alternatives similarly and therefore have no impact on selection of a preferred alternative.

Alternative 1 would require OMM activities to ensure long-term performance of the cleanup action. Monitoring costs to evaluate performance of the cleanup action are included in the FS cost estimates. Periodic monitoring of groundwater, upland and sediment caps, and natural recovery areas would be required. Additional costs associated with periodic maintenance and repairs for upland and sediment caps are included in the OMM costs for this alternative. FS cost estimates assume long-term maintenance and monitoring of remedy components and groundwater conditions will be required for 30 years.

The estimated cost of Alternative 1 is $7,950,000 (Appendix B Table B-3). For all alternatives, cost estimates are in 2017 dollars, include contingencies, and represent order-of-magnitude estimates with a range of -30 percent to +50 percent based on EPA guidance (EPA 2000b).

4.2.2. Alternative 2: In-situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery

Alternative 2 utilizes containment, in-situ groundwater treatment and natural attenuation in the upland unit. Sediment capping and natural recovery technologies would be utilized in the marine unit. Figures 4-3 and 4-4 present conceptual plan views for the upland and marine components of Alternative 2. This alternative would require ICs to maintain the integrity of the cleanup in the upland and marine units. Alternative 2 also would include the common elements described in Section 4.1.

A permeable vegetated soil cap would be constructed in the upland unit similar to Alternative 1, except the cap would cover areas where soil exceeds MTCA cleanup levels for unrestricted land use, excluding the steep slope (Figure 4-3). The use of MTCA cleanup levels would result in upland soil caps covering most of the upper and lower parks. This approach addresses potential direct contact risks with greater certainty compared to Alternative 1. In addition, the elevated grades over a larger portion of the lower park would reduce the risk of upland soil erosion and potential increases in contaminant leaching due to future sea level rise. ICs would ensure cap performance and restrict activities that may result in exposure to underlying contaminated soil.

Shoreline erosion would be addressed for Alternative 2 in the same manner as Alternative 1, by integrating the upper part of the nearshore sediment cap with the adjacent upland soil cap. This shoreline transition would be designed to resist coastal erosion. In areas where there is no active sediment remedy, a permanent shoreline stabilization revetment would be constructed to reduce the risk of coastal erosion. This feature would be integrated with the waterward edge of the upland soil cap and extend as far off-shore as necessary to prevent erosion of upland soil. As with all alternatives, shoreline erosion protection materials placed during the 2017 Interim Action would be incorporated in the permanent shoreline stabilization revetment to the extent practicable.

Enhanced bioremediation would be used to degrade organic contaminants in groundwater in the northern portion of the lower park. Groundwater impacts are greatest in this portion of the upland unit. In-situ groundwater treatment by bioremediation would occur through the addition of oxygen, nutrients, or other amendments to the saturated zone to stimulate biodegradation mechanisms most suitable for Site contaminants and conditions. Characterization of groundwater geochemistry and bioremediation treatability testing would be required to determine the most effective bioremediation process and to develop design parameters for treatment. For the purpose of developing cost estimates for the FS, aerobic bioremediation is assumed to be most suitable and would involve repeated application of an oxygen-releasing material to induce aerobic conditions in groundwater. Other portions of the upland unit, where groundwater impacts are less, would be addressed by natural attenuation.

Cleanup actions in the marine unit would be the same as Alternative 1, except portions of the deeper subtidal zone (below -10 feet MLLW) with higher cPAH concentrations would be addressed using a thin cap instead of ENR (Figure 4-4). The footprint of the thin cap approximates the area where cPAH concentrations exceed the upper remediation level. Subtidal areas with cPAH concentrations between the lower and upper remediation levels would be addressed by ENR. MNR would be used in remaining portions of the Site, where cPAH concentrations are between the lower remediation level and the bioaccumulation cleanup level.[5] This alternative would achieve compliance with cleanup standards on a point-by-point basis in all capped areas, including the subtidal thin cap, at the time construction is completed. It is estimated that compliance with the bioaccumulation cleanup level would be achieved on a Site-wide SWAC basis within 10 years. Compared to Alternative 1, addition of the subtidal thin cap increases the certainty that cleanup standards will be achieved within 10 years, or possibly sooner.

The footprint and conceptual design of the conventional cap in Alternative 2 is the same as Alternative 1. The thin sand cap would have a nominal thickness of 1 foot and would be intended to provide adequate containment in this deeper, depositional zone. The thin cap would not require armoring.

Alternative 2 would require similar OMM activities as other alternatives to maintain and monitor long-term performance of the cleanup action. Costs associated with OMM are included in the estimated cost to complete Alternative 2, and include long-term monitoring of groundwater, upland and sediment caps, and natural recovery areas. Periodic maintenance and repairs for upland and sediment cap components are included in the OMM costs. Maintenance and monitoring are assumed to be required for 30 years.

The estimated cost of Alternative 2 is $9,330,000 (Appendix B Table B-4). For all alternatives, cost estimates are in 2017 dollars, include contingencies, and represent order-of-magnitude estimates with a range of -30 percent to +50 percent based on EPA guidance (EPA 2000b).

4.2.3. Alternative 3: Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery

Alternative 3 would include a low permeability cap in the upland unit to reduce stormwater infiltration and groundwater flux from the upland to marine units (Figure 4-5). MNA would augment the effects of the low permeability cap to further reduce contaminant flux from the upland unit. Sediment in extensive portions of the intertidal and subtidal zones would be capped; MNR would be used to address remaining portions of the subtidal zone where contaminant concentrations are lower (Figure 4-6). Similar to previous alternatives, this alternative would require ICs to maintain the integrity of the cleanup in the upland and marine units. Alternative 3 also would include the common elements described in Section 4.1.

[5] cPAH concentrations exceed the lower remediation level in a small portion of the MNR area located near the southern shoreline of the marine unit (only in Alternatives 1, 2 and 4).

The low-permeability vegetated soil cap in the upper and lower parks would prevent direct contact with contaminated soil and reduce the infiltration of stormwater. Reducing stormwater infiltration would decrease contaminant leaching from soil to groundwater and reduce groundwater (and contaminant) flux from the upland to marine units.

The low-permeability cap (described further below) would use a synthetic low-permeability liner covered by a layer of clean soil of appropriate thickness for drainage and planting. For purposes of the FS, the conceptual design of the low permeability upland cap would include the following components from bottom to top:

- A flexible geotextile separation layer to prevent finer-grained underlying soils from mixing with overlying cap materials and to demarcate underlying contaminated soil from overlying clean media.
- A layer of clean fill of varying thickness to create a properly elevated and sloped grade for the synthetic liner.
- A gas-collection layer, if needed, to manage VOCs and gases potentially being produced by the biological degradation of natural and anthropogenic organic materials in, and beneath, Site fill (e.g. wood waste, organic-rich soil). It is assumed this horizon would be 6 inches thick and would allow for passive migration of vapors and venting to ambient air. For purposes of FS cost estimating, it is assumed this feature would be required for the low permeability cap, but its actual need would be evaluated during design-related activities.
- A low-permeability synthetic liner such as a polyvinyl chloride (PVC) geomembrane on top of the gas-collection layer.
- A high-permeability drainage horizon, assumed to be approximately 1 foot thick, to collect and convey infiltrated stormwater to a discharge point. Drainage details would be developed during remedial design.
- A flexible geotextile separation layer on top of the drainage layer to separate it from the surface horizon.
- A cap surface horizon consisting of a growing medium and vegetated (hydroseeded) surface.

The low permeability cap would extend as close to the edge of paved surfaces (e.g. parking lot and sidewalks) and buildings as practicable. In limited areas where it may not be practicable to implement the conceptual design, the cap would be constructed of fill materials without the low permeability synthetic liner, or gas collection and drainage horizons. An example of this could be the narrow strip of cap shown in Figure 4-5 between the railroad tracks and the shoreline. The cap would be designed to accommodate park features such as landscaping, an irrigation system and utility access to the extent practicable. The lower park soil cap would extend to, and be integrated with, the permanent shoreline stabilization revetment and sediment cap described in Alternatives 1 and 2.

Similar to Alternative 1, groundwater in the upland unit would be addressed by MNA. It is assumed this approach would effectively address PAHs, VOCs and cyanide in groundwater, although additional groundwater data would be required to evaluate the effects of natural attenuation on groundwater quality.

In Alternative 3, the extent of sediment capping is significantly increased relative to Alternative 2. Alternative 3 would use a conventional cap in all areas where cPAH concentrations exceed the upper remediation level, and a thin cap where cPAH concentrations are between the lower and upper remediation levels (Figure 4-6). Disregarding the broader footprint, aspects of the conventional and thin caps (e.g.

thickness, armoring, potential use of amendments) would be the same as described in Alternatives 1 and 2. Remaining portions of the Site, where cPAH concentrations are between the lower remediation level and the bioaccumulation cleanup level would be addressed using MNR. ENR is not a component of this sediment alternative. This alternative would achieve compliance with cleanup standards on a point-by-point basis in the capped areas at the time construction is completed. Unlike Alternatives 1 and 2, it is estimated this alternative also would achieve compliance with the bioaccumulation cleanup level on a Site-wide SWAC basis at the time construction is completed.

Alternative 3 would require similar OMM activities as other alternatives to maintain and monitor the long-term performance of the cleanup action. Costs associated with OMM are included in the estimated cost to complete Alternative 3, and include long-term monitoring of groundwater, upland and sediment caps, and natural recovery areas. Periodic maintenance and repairs for upland and sediment cap components are included in the OMM costs. Maintenance and monitoring are assumed to be required for 30 years.

The estimated cost of Alternative 3 is $12,100,000 (Appendix B Table B-5). For all alternatives, cost estimates are in 2017 dollars, include contingencies, and represent order-of-magnitude estimates with a range of -30 percent to +50 percent based on EPA guidance (EPA 2000b).

4.2.4. Alternative 4: SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping

Alternative 4 is very similar to Alternative 1, except for the addition of upland in-situ treatment components and nearshore sediment removal (Figures 4-7 and 4-8). These additional components would be relatively expensive and were paired with the other lower-cost elements of Alternative 1 to provide a fair opportunity for the more aggressive add-ons (treatment and removal) to be selected as part of an alternative via the DCA process. Alternative 4 also would include the common elements described in Section 4-1.

A permeable vegetated soil cap would be constructed in the upland unit similar to Alternative 2, extending throughout most of the upper and lower parks, excluding the steep slope. ICs would ensure cap performance and restrict activities that may result in exposure of underlying contaminated soil. The shoreline margin of the lower park soil cap would extend to, and be integrated with, the shoreline stabilization revetment and sediment cap described in prior alternatives.

SVE and bioventing would be used in the upper park to address petroleum-related contamination including VOCs and, to a lesser extent, PAHs in vadose zone soil. Enhanced bioremediation would be used to target the same contaminants in groundwater in the upper and lower parks. In-situ groundwater treatment by bioremediation would occur through the addition of oxygen, nutrients, or other amendments to the saturated zone to stimulate biodegradation mechanisms most suitable for Site contaminants and conditions. Characterization of groundwater geochemistry and bioremediation treatability testing would be required to determine the most effective bioremediation process and to develop design parameters for treatment. For the purpose of developing cost estimates for the FS, aerobic bioremediation is assumed to be most suitable and would involve repeated application of an oxygen-releasing material to induce aerobic conditions in groundwater. The in-situ treatment technologies utilized in Alternative 4 would reduce contaminant mass in vadose zone soil and groundwater, resulting in greater protection of groundwater and increased long-term effectiveness. Groundwater outside of the active remediation areas would be addressed using MNA.

Alternative 4 would include nearshore sediment removal in the pocket beach, but other aspects of the sediment remedy would be the same as Alternative 1 (Figure 4-8). Sediment in the pocket beach area would be removed to a depth of approximately 6 feet below the mudline in this nearshore area where groundwater flux would be expected to be greatest. Sediment removal in this intertidal area would be performed using land-based excavation equipment, with the assistance of shoring or similar methods that would temporarily prevent tidal inundation and allow excavation "in the dry." Excavated intertidal sediment would be dewatered or conditioned to the extent needed to enable off-site transport to an upland landfill facility for disposal. The excavation area would be capped to contain contaminated sediment remaining below the excavation depth. Details of the conventional cap would be similar to those described for Alternative 1, except the cap thickness would be greater within the excavation footprint and no amendments would be used.

This alternative would achieve compliance with cleanup standards on a point-by-point basis in the excavation and capped areas at the time construction is completed. It is estimated that compliance with the bioaccumulation cleanup level would be achieved on a Site-wide SWAC basis within 10 years.

Alternative 4 would require similar OMM activities as other alternatives to maintain and monitor the long-term performance of the cleanup action. Costs associated with OMM are included in the estimated cost to complete Alternative 4, and include long-term monitoring of groundwater, upland and sediment caps, and natural recovery areas. Periodic maintenance and repairs for upland and sediment cap components are included in the OMM costs. Maintenance and monitoring are assumed to be required for 30 years.

The estimated cost of Alternative 4 is $13,300,000 (Appendix B Table B-6). For all alternatives, cost estimates are in 2017 dollars, include contingencies, and represent order-of-magnitude estimates with a range of -30 percent to +50 percent based on EPA guidance (EPA 2000b).

4.2.5. Alternative 5: ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping

Alternative 5 includes the most aggressive upland in-situ treatment components, nearshore sediment removal and a widespread conventional cap in the marine unit (Figures 4-9 and 4-10). Alternative 5 also would include the common elements described in Section 4-1.

Similar to Alternative 4, this alternative includes a permeable vegetated soil cap throughout most of the upper and lower parks, excluding the steep slope. ISS would be used in a significant portion of the upper park to sequester contaminants in vadose zone and saturated zone soil. This technology would reduce contaminant leaching to groundwater, groundwater recharge on the Site and soil vapor generation. ICs will be implemented to ensure cap performance and restrict activities that may result in exposure of underlying contaminated soil. The shoreline margin of the lower park soil cap would extend to, and be integrated with, the shoreline stabilization revetment and sediment cap described in prior alternatives.

Alternative 5 would include significant use of in-situ groundwater treatment in the form of bioremediation of organic contaminants, similar to Alternatives 2 and 4. The in-situ groundwater treatment would be applied to portions of the lower park with elevated concentrations of VOCs and petroleum hydrocarbons. Lighter PAHs co-located with the targeted contaminants (benzene, naphthalene, petroleum hydrocarbon mixtures) also would be expected to degrade, but likely at a slower rate. The in-situ treatment technologies utilized in Alternative 5 would reduce or isolate contaminant mass in vadose zone soil and groundwater, resulting in greater protection of groundwater and increased long-term effectiveness. Groundwater outside of the active remediation areas would be addressed using MNA.

Alternative 5 would include the same nearshore sediment removal action (and off-site disposal) described in Alternative 4 for the pocket beach area (Figure 4-10). All areas exceeding the lower remediation level for cPAHs would be addressed using a conventional cap, including the nearshore excavation area. Disregarding the broader footprint, details of the conventional cap would be the same as described for Alternative 1, except the cap thickness would be greater within the excavation footprint and no amendments would be used. Remaining portions of the Site, where cPAH concentrations are between the lower remediation level and the bioaccumulation cleanup level would be addressed using MNR.

This alternative would achieve compliance with cleanup standards on a point-by-point basis in the excavation and capped areas at the time construction is completed. Similar to Alternative 3, it is estimated this alternative also would achieve compliance with the bioaccumulation cleanup level on a Site-wide SWAC basis at the time construction is completed.

Alternative 5 would require similar OMM activities as other alternatives to maintain and monitor long-term performance of the cleanup action. Costs associated with OMM are included in the estimated cost to complete Alternative 5, and include long-term monitoring of groundwater, upland and sediment caps, and natural recovery areas. Periodic maintenance and repairs for upland and sediment cap components are included in the OMM costs. Maintenance and monitoring are assumed to be required for 30 years.

The estimated cost of Alternative 5 is $20,400,000 (Appendix B Table B-7). For all alternatives, cost estimates are in 2017 dollars, include contingencies, and represent order-of-magnitude estimates with a range of -30 percent to +50 percent based on EPA guidance (EPA 2000b).

5.0 EVALUATION OF CLEANUP ACTION ALTERNATIVES

This section presents the evaluation of cleanup alternatives with respect to threshold and other requirements for cleanup actions set forth in MTCA and SMS.

5.1. Evaluation Criteria

5.1.1. MTCA Threshold Requirements

Cleanup actions performed under MTCA must comply with several basic requirements, termed “threshold requirements.” Cleanup action alternatives that do not comply with these criteria are not considered suitable cleanup actions under MTCA. As provided in WAC 173-340-360(2)(a), the four threshold requirements that cleanup actions must meet are:

- *Protect human health and the environment.* The completed cleanup action MTCA must ensure that both human health and the environment are protected.
- *Comply with cleanup standards.* Compliance with cleanup standards requires that cleanup levels are met at the applicable points of compliance. Where a cleanup action involves containment of soil with hazardous substance concentrations exceeding cleanup levels at the point of compliance, the cleanup action may be determined to comply with cleanup standards, provided the requirements specified in WAC 173-340-740(6)(f) are met.

- *Comply with applicable state and federal laws.* The term "applicable state and federal laws" includes legally applicable requirements and those requirements that Ecology determines to be relevant and appropriate as described in WAC 173-340-710.
- *Provide compliance monitoring*. Compliance monitoring for a cleanup action includes the following elements:
  - Protection monitoring confirms that human health and the environment are adequately protected during the cleanup action.
  - Performance monitoring confirms that the cleanup levels have been achieved.
  - Confirmation monitoring confirms the long-term effectiveness of the cleanup action once cleanup levels and other performance standards have been reached.

5.1.2. Other MTCA Requirements

Under MTCA, alternatives that fulfill the threshold requirements described in Section 5.1.1 shall be evaluated against the following additional criteria (WAC 173-340-360[2][b]):

- Use permanent solutions to the maximum extent practicable – MTCA specifies that the permanence of qualifying alternatives be evaluated by balancing the costs and benefits using a "DCA" in accordance with WAC 173-340-360(3)(e). The criteria for conducting this analysis are described in Section 5.1.4.
- Provide a reasonable restoration timeframe – MTCA requires that several factors be considered when evaluating whether a remedial alternative provides a reasonable restoration timeframe (WAC 173-340-360[4]). Collectively, these factors characterize how an alternative is anticipated to perform over the long term, particularly for alternatives that leave hazardous substances in place at concentrations greater than cleanup levels. MTCA expresses a preference for alternatives that, although equivalent in other respects, can be implemented in a shorter period of time.
- Reflect consideration of public concerns – MTCA requires that the cleanup action planning process allow public participation and consideration of public concerns associated with the proposed cleanup action. Typically, Ecology requires that responsible parties seek public comment (including concerns from affected landowners) on the alternative selection process before identifying a preferred cleanup action alternative. This preliminary selection of a preferred alternative is subject to further public review and comment when the proposed remedy is published in the draft CAP.

5.1.3. SMS Minimum Requirements

Additional requirements specific to sediment cleanup actions are evaluated based on the minimum requirements in SMS (WAC 173-204-570[3]). Although structured differently than MTCA, the SMS evaluation criteria are similar to, and intended to be compatible with, MTCA criteria discussed in Sections 5.1.1 and 5.1.2.

SMS requires evaluation of sediment cleanup alternatives relative to improvement in overall environmental quality, known as net environmental benefit, and for adverse environmental impacts. Net environmental benefit includes restoration of water quality, sediment quality, habitat and fisheries, public access and recreation aesthetics. Environmental impacts to be considered include construction-related water and sediment quality degradation, habitat value or acreage loss, and land use or access restrictions. The evaluation of alternatives for net environmental benefit and for adverse environmental impacts is addressed through the following SMS evaluation criteria (minimum requirements):

- Protect human health and the environment.
- Comply with ARARs.
- Comply with sediment cleanup standards specified in WAC 173-204-560 through 173-204-564.
- Implement effective source controls, where needed.
- Meet the requirements for implementation of a sediment recovery zone (WAC 173-204-590) if cleanup standards cannot be achieved within 10 years.
- Provide for permanent cleanup action where technically feasible instead of relying exclusively on MNR or ICs and monitoring. Where ICs are used, they must comply with WAC 173-340-440 to include measures that control exposures and ensure the integrity of the cleanup action.
- Provide an opportunity for review and comment by affected landowners and the general public consistent with the public participation plan, and consider concerns identified in these comments.
- Include long-term monitoring to ensure remedy effectiveness.
- Provide periodic review of remedy effectiveness where elements of a cleanup action include containment, enhanced or natural recovery, ICs, sediment cleanup levels based on practical quantitation limits, or sediment recovery zones.

The alternatives are also evaluated relative to the following:

- Use permanent solutions to the maximum extent practicable: The permanence of the cleanup action is established on the basis of the DCA.
- Provide a reasonable restoration timeframe: Preference is given to alternatives that provide for a shorter restoration timeframe. The reasonable restoration timeframe is evaluated considering the following:
    - Length of time to achieve site-specific cleanup standards
    - Potential risks posed by the site or cleanup units to people and ecological resources
    - Practicability of achieving the cleanup standards in less than 10 years
    - Current and potential future use of the site (or cleanup units), surrounding areas and associated resources that may be adversely affected by residual contamination
    - State aquatic land use classification of the site (or units)
    - Likely effectiveness of source control measures to reduce the time to achieve site-specific cleanup standards
    - Likely effectiveness and reliability of ICs
    - Degree of, and ability to control and monitor migration of, residual contamination
    - Degree to which natural recovery is expected to reduce contamination

In addition to the above minimum requirements, SMS stipulates that the evaluation of sediment cleanup actions shall provide sufficient information to fulfill the State Environmental Policy Act (SEPA) requirements (Chapter 43.21C Revised Code of Washington [RCW]) for the proposed preferred remedy. This information includes discussions of significant short- and long-term environmental impacts; significant irrevocable commitments of natural resources; significant alternatives, including mitigation measures; and significant environmental impacts that cannot be mitigated. A SEPA analysis of environmental impacts was not completed for this FS, but is likely to be undertaken during development of the CAP.

5.1.4. Disproportionate Cost Analysis

The DCA is used to evaluate cleanup action alternatives that meet the MTCA and SMS minimum requirements. Consistent with MTCA and SMS, the DCA process for this FS compares the benefits and costs of the alternatives to identify which alternative has incremental costs that are not disproportionate to its incremental benefits, thereby defining the alternative that is permanent to the maximum extent practicable.

As described in Section 4.2, upland and sediment technologies were combined to develop holistic alternatives for the entire Site (upland and marine units combined). Each of the holistic alternatives were evaluated using the DCA process described below, considering the degree to which each criterion is addressed by the site-wide cleanup action. This approach was used rather than conducting separate DCAs for the upland versus marine units because the primary goal of each alternative is to reduce the risk of exposures to Site contaminants in the marine unit. All upland and nearshore sediment components of each remedial alternative contribute to this goal by reducing to the risk of contaminant migration and associated exposures in marine sediment and surface water.

5.1.4.1. Disproportionate Cost Analysis Benefit Criteria

Environmental benefits for the alternatives are evaluated based on the six criteria in WAC 173-340-360(3)(f):

- Protectiveness
- Permanence
- Long-term effectiveness
- Management of short-term risks
- Technical and administrative implementability
- Consideration of public concerns

The DCA process is also applicable for in-water cleanup actions. The evaluation criteria under SMS [WAC 173-204-570(4)] are identical to the MTCA evaluation criteria for protectiveness, permanence, management of short-term risks, technical and administrative implementability, and consideration of public concerns. The long-term effectiveness criterion differs slightly between MTCA and SMS.

These criteria form the basis of the DCA evaluation, which is used to compare alternatives and determine which cleanup action is permanent to the maximum extent practicable. The individual criteria are described below.

- Protectiveness – Considers the overall protection of human health and the environment. This evaluation criterion accounts for the degree of risk reduction, both on-site and off-site, and the time required to achieve risk reduction and attain cleanup standards,
- Permanence – Addresses the extent to which permanent reductions in contaminant toxicity, mobility or volume are achieved. The adequacy of destroying, reducing or eliminating hazardous substance releases and sources is considered, along with the degree of irreversibility of waste treatment and the characteristics and quantity of treatment residuals generated.

- Long-term effectiveness – Assesses the certainty that an alternative will be successful, as well as reliable over the period that contaminants are expected to remain on-site at concentrations that exceed cleanup levels. Effectiveness further considers the magnitude of residual risk after implementing the alternative, and the effectiveness of controls required to manage treatment residues or remaining wastes. The MTCA and SMS evaluation criteria for long-term effectiveness differ slightly.
    - Under MTCA for upland remedies, the following types of cleanup action components, in descending order, are used as a guide in assessing the relative degree of long-term effectiveness (WAC 173-340-360[3][f][iv]):
        - Reuse or recycling
        - 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 ECs
        - ICs and monitoring
    - Under SMS for sediment cleanup alternatives (WAC 173-204-570[4]), the following remedial technologies, in descending order, are used as a guide for assessing the relative degree of long-term effectiveness:
        - Source control (e.g., cleanup of upland facilities, regulation of wastewater discharges, implementation of stormwater pretreatment requirements, removal of creosoted pilings) in combination with other cleanup technologies
        - Beneficial reuse of dredged sediment
        - Treatment to immobilize, destroy or detoxify contaminants
        - Dredging and disposal in an upland engineered facility that minimizes subsequent releases and exposures to contaminants
        - Dredging and disposal in a nearshore, in-water confined aquatic disposal facility
        - Containment in-place with an engineered cap
        - Dredging and disposal at an open-water disposal site approved by applicable state and federal agencies
        - ENR
        - MNR (in areas of relatively low levels of contamination with sufficient rates of clean sedimentation)
        - ICs (e.g., site use restrictions, environmental covenants) and monitoring
- Management of short-term risks – Considers the human health and environmental risks during construction and implementation, and the effectiveness of measures taken to manage such risks. Risks can occur from worker or public exposure to contaminants, other releases of contaminants to the environment, and physical hazards created by construction and related materials management. Risks associated with invasive technologies such as dredging can include localized recontamination and potential off-site migration of contaminants (dredge residuals).
- Technical and administrative implementability – Addresses the technical likelihood that an alternative can be implemented; availability of facilities, services and materials to support the work; and administrative and regulatory requirements. Other factors affecting implementability are scheduling,

project size and complexity, monitoring requirements and site access. Integration of the work with existing activities at and near the site, including other remedial actions, must also be evaluated.

- Consideration of public concerns – As required by MTCA, assesses community input regarding the alternatives and the ways in which the alternatives address those public concerns. Affected parties include the general public (individuals), community groups, local governmental jurisdictions, Tribes, regulatory agencies and other interested parties.

5.1.4.2. DCA Scoring and Cost/Benefit Comparison

Following the MTCA procedures described above, the DCA compares the relative overall benefit and cost of the cleanup alternatives to identify which alternative is permanent to the maximum extent practicable; this alternative is selected as the preferred remedy.

The benefits of an alternative were evaluated based on the six MTCA DCA criteria. For each criterion, this FS assigned alternatives a score between 1 and 10: a score of 1 indicates the alternative is considered to satisfy the elements of the criterion to a very low degree and a score of 10 indicates the alternative is considered to satisfy the elements of the criterion to a very high degree. For each alternative, the individual criterion scores were then weighted as follows:

DCA EVALUATION CRITERIA WEIGHTING FACTORS

DCA Criteria	Weighting Factor (%)
Protectiveness	30
Permanence	20
Long-term effectiveness	20
Management of short-term risks	10
Technical and administrative implementability	10
Consideration of public concerns	10

These DCA weighting factors are consistent with those used for other MTCA sediment remediation projects, including Ecology-led cleanups at other complex Bellingham Bay sites. At these sites, criteria most directly associated with the primary goals and objectives of the cleanup (e.g., protectiveness, permanence, long-term effectiveness) were more heavily weighted than the others. The weighted benefit scores for each alternative are summed to create a total weighted benefit score for each alternative.

The total weighted benefit scores are compared to the estimated cost to implement the alternative, including the cost of construction, the net present value of any long-term expenses, and agency oversight costs that are recoverable from the responsible parties. Long-term costs cover operation and maintenance, monitoring, equipment replacement and ICs. Detailed FS-level cost estimates for each alternative are provided in Appendix B; the estimated total costs for the cleanup alternatives are included in Tables B-3 to B-7.

A final benefit-to-cost ratio was calculated for each alternative by dividing its total weighted benefit score by its total cost.

5.1.4.3. Determination of Permanent to the Maximum Extent Practicable

Under MTCA, preference is given to cleanup actions that use permanent solutions to the maximum extent practicable. By definition (WAC 173-340-200), permanent remedies, once implemented, require no additional action to meet cleanup standards. A practicable cleanup action is designed, constructed and implemented in a reliable, cost-effective manner. A cleanup action is not considered practicable if the incremental costs are disproportionate to the incremental benefits when compared to lower-cost alternatives.

The MTCA DCA analysis for the Site FS uses a relative benefit-to-cost ratio to compare the alternatives and determine whether costs are disproportionate to benefits. To calculate the relative benefit-to-cost ratio for each alternative, the total weighted benefit score was divided by the total cost. Alternatives were then compared from least cost to highest cost. Alternatives with incremental benefits that are disproportionately small in comparison to the incremental cost produce lower relative benefit/cost ratios.

5.2. Evaluation of Individual Cleanup Action Alternatives

This section describes how cleanup actions for the five alternatives meet MTCA threshold requirements and minimum SMS criteria. Table 5-1 summarizes the alternatives relative to MTCA and SMS evaluation criteria.

5.2.1. Threshold Requirements

MTCA threshold requirements include protection of human health and the environment, compliance with cleanup standards and ARARs, and provisions for compliance monitoring. Table 5-1 provides a description of how each alternative meets the respective MTCA threshold requirement.

5.2.1.1. Protection of Human Health and the Environment

The alternatives were developed using a combination of treatment, removal, and containment technologies to prevent human and ecological exposures to Site contaminants. All alternatives incorporate containment measures for impacted media in the upland and marine units, designed to prevent exposure to contaminants by human and ecological receptors. All alternatives also incorporate natural recovery methods relying on existing processes to decrease concentrations of constituents in sediment over time. Collectively, the remedial elements for each alternative were selected to reduce potential exposures and contaminant migration, and are considered protective of human health and the environment under MTCA.

5.2.1.2. Compliance with Cleanup Standards

The treatment, containment, removal, and natural recovery elements as well as ICs of all alternatives are expected to lead to compliance with cleanup standards. Although most alternatives include treatment and/or removal technologies, compliance with cleanup standards still requires containment features. A conditional point of compliance would likely be required for groundwater for most, or all, alternatives. Compliance would rely on long-term operation and maintenance of containment systems and ICs. The use of the Site as a public park facilitates the effectiveness of ICs and the implementability of long-term monitoring.

5.2.1.3. Compliance with Applicable State and Federal Regulations

All alternatives are required to meet other applicable state and federal regulations, as described in Section 2. The alternatives in this FS were developed on the assumption that they would meet permitting requirements for upland and marine cleanup actions.

5.2.1.4. Provision for Compliance Monitoring

Monitoring of both short-term performance and long-term effectiveness is anticipated for each alternative. The monitoring will focus on components of both the upland and sediment cleanups, and costs for these actions are included in the estimated costs to implement each alternative. Monitoring methods and schedules will be developed during subsequent cleanup planning phases, such as in the Engineering Design Report.

5.2.2. Other MTCA Requirements

5.2.2.1. Use of Permanent Solutions to the Maximum Extent Practicable

MTCA requires that cleanup actions be permanent to the maximum extent practicable. It specifies that the most practicable permanent alternative be selected using a DCA to identify the alternative whose incremental costs are not disproportionate to the incremental benefit (see Section 5.3).

5.2.2.2. Requirement for Reasonable Restoration Timeframe

MTCA requires consideration of several factors in determining whether a remedial alternative provides a reasonable restoration timeframe. In areas where containment measures (capping) are utilized, the restoration timeframe is assumed to be equivalent to the period required to complete design, permitting and construction of the cleanup action. In active remediation areas, restoration is estimated to require up to about five years, including construction. For some alternatives that rely on natural recovery methods for sediment, cleanup standard for cPAHs are expected to be achieved within 10 years of construction on a SWAC basis.

5.2.2.3. Consideration of Public Concerns

Ecology will issue the draft FS for public comment as part of the standard MTCA review process. The review process includes the general public, affected landowners, regulatory agencies, affected stakeholders and other interested parties. The reviewing parties have opportunity for input prior to preliminary selection of a preferred alternative. This alternative will be subject to further public review and comment when the proposed remedy is published in the draft CAP.

5.2.3. SMS Minimum Requirements

This section evaluates elements of the alternatives for the marine unit relative to SMS minimum requirements identified in WAC 173-204-570(3) and summarized in Section 5.1.3. Table 5-1 presents the results of this evaluation. Although the structure and terminology differ slightly, MTCA and SMS evaluation criteria are similar in intent. As for MTCA, all alternatives achieve compliance with SMS minimum requirements for protection of human health and the environment, applicable regulations and cleanup standards, and use of permanent solutions to the maximum extent practicable. These entries in Table 5-1 are therefore noted as "yes," and carried forward into Table 5-2.

5.2.3.1. Protection of Human Health and the Environment

This SMS minimum requirement is considered equivalent to the similarly named MTCA threshold requirement described in Section 5.2.1.1.

5.2.3.2. Compliance with ARARs

This SMS minimum requirement is considered equivalent to the "Compliance with Applicable State and Federal Regulations" MTCA threshold requirement described in Section 5.2.1.3. All alternatives were developed with the expectation that compliance with ARARs can be achieved.

5.2.3.3. Compliance with Cleanup Standards

This SMS minimum requirement is considered equivalent to the similarly named MTCA threshold requirement described in Section 5.2.1.2. Alternatives achieve compliance with cleanup standards for benthic risks and human health (direct contact) on a point-by-point basis, while achieving cleanup standards for risks associated with bioaccumulative compounds (cPAHs) on an area-weighted average basis.

5.2.3.4. Use of Permanent Solutions

This SMS minimum requirement is considered equivalent to the MTCA minimum criterion of using permanent solutions to the maximum extent practicable, described in Section 5.2.2.1. The DCA identifies the most practicable permanent alternative (Section 5.3).

5.2.3.5. Reasonable Restoration Timeframe

This SMS minimum requirement is considered equivalent to the similarly named MTCA threshold requirement described in Section 5.2.2.2. The restoration timeframe for Alternatives 1, 2 and 4 is anticipated to be 10 years (or less) due to some reliance on natural recover processes to achieve compliance with the bioaccumulative cleanup level for cPAHs. Alternatives 3 and 5 are anticipated to achieve compliance with all cleanup standards at the time construction is completed.

5.2.3.6. Use of Sediment Recovery Zone

The expectation is that each of the alternatives evaluated in this FS will achieve cleanup standards within 10 years, precluding the need for sediment recovery zones. The potential use of a sediment recovery zone, however, would be further evaluated during the design, construction and post-construction monitoring phases of cleanup, if needed.

5.2.3.7. Compliance with Institutional Controls

ICs are a component of each sediment alternative, and may include limitations such as no-anchor zones, aquatic land use restrictions and other measures to maintain the integrity of capping areas. Monitoring and contingency plans would be included to ensure that ICs sufficiently protect the cleanup action.

5.2.3.8. Public Review

This SMS minimum requirement is considered equivalent to the “Consideration of Public Concerns” MTCA threshold requirement. As described in Section 5.2.2.3, Ecology will issue the draft FS for public comment as part of the standard MTCA review process.

5.2.3.9. Compliance Monitoring

This SMS minimum requirement is considered equivalent to the similarly named MTCA threshold requirement described in Section 5.2.1.4. Monitoring of both short-term performance and long-term effectiveness of the sediment remediation elements is anticipated for each alternative. Monitoring for these actions are included in the estimated costs to implement each alternative.

5.2.3.10. Provision for Periodic Review

Periodic reviews will be conducted as part of the MTCA process and as a component of compliance monitoring. Details will be developed during later cleanup planning phases.

5.3. MTCA Disproportionate Cost Analysis

As discussed in Section 5.2, the DCA process evaluates the benefits and costs of alternatives as the basis of comparison to select the alternative that is permanent to the maximum extent practicable. Under MTCA, permanent cleanup actions are those in which cleanup standards can be met without further action.

The relative environmental benefits of each alternative are compared against the most permanent alternative. The DCA evaluates whether costs are disproportionate to benefits by determining if the incremental costs of the more permanent alternative exceed the incremental benefits achieved by the other lower-cost alternatives being compared (WAC 173-340-360[3][e][i]). Alternatives are impracticable when their costs are disproportionate to the incremental benefit achieved. MTCA further requires selection of the less costly alternative when multiple alternatives have equal benefits (WAC 173-340-360[3][e][ii][C]).

5.3.1. Costs for FS Alternatives

Costs for implementing FS alternatives were developed consistent with requirements of WAC 173-340-360(3)(f)(iii) for DCA analysis. EPA feasibility study cost estimating guidance (EPA 2000b) was also considered at a general level for development of cost categories and assumptions. Detailed cost breakdowns for the alternatives are presented in Appendix B, including direct capital costs for construction and OMM. Indirect costs cover design, management, regulatory oversight and tax. The cost estimates include appropriate contingencies and discount rates for net present value calculations. Long-term costs include OMM, equipment replacement and maintenance of ICs. Cost estimates are for a 30-year period and are conceptually accurate within a range of -30 percent to +50 percent.

Estimated net present worth costs range from $7,950,000 for Alternative 1 to $20,400,000 for Alternative 5.

5.3.2. DCA Evaluation

Section 5.1.4 summarizes the DCA scoring approach and weighting for the six DCA criteria. These criteria were evaluated for each of the five alternatives in accordance with the MTCA procedural requirements of WAC 173-340-360(3)(e). Each alternative was evaluated against the criteria described in Section 5.1.4, with each criterion scored on a scale from 1 (low) to 10 (high). These raw scores and the rationale for the scores for each criterion are presented in Table 5-1. For each alternative, scores for the individual DCA criteria were weighted according to the factors described in Section 5.1.4.2, and then summed to develop a weighted overall score representative of the benefits of each alternative. The resulting weighted scores and scoring totals for each alternative are summarized in Table 5-2 and discussed below.

5.3.3. Protectiveness

All five alternatives are expected to protect human health and the environment as a result of the immediate reduction of risk following capping of soil and sediment with the highest concentrations of contaminants and in areas more susceptible to exposure. The raw scores for protectiveness range from 4 (Alternative 1) to 9 (Alternative 5). Alternative 1 achieves a moderately low level of overall protectiveness (score of 4) as a result of the limited extent of soil and sediment capping and the heavy reliance of natural processes to achieve cleanup. Alternatives 2 and 3 achieve progressively higher scores (6 and 7, respectively) for protectiveness due to the addition of groundwater treatment (Alternative 2) and a larger and more robust cap (Alternatives 2 and 3) in the upland, and more extensive sediment caps in the marine unit that decrease the reliance on natural recovery processes. Alternative 3 is anticipated to achieve compliance with cleanup levels at the time construction is completed as opposed to the 10-year restoration timeframe for Alternatives 1 and 2. Alternative 4 (score of 6) benefits from the addition of significant soil and groundwater treatment in the upland and nearshore sediment removal, but these benefits are offset by risks associated with sediment excavation and off-site disposal, and the widespread reliance on natural recovery processes in the marine unit. Similar to Alternatives 1 and 2, the restoration timeframe for Alternative 4 is estimated to be 10 years. Alternative 5 achieves the highest score for protectiveness (score of 9) as a result of the extensive use of sediment capping and aggressive upland soil and groundwater treatment technologies.

5.3.4. Permanence

The raw scores for permanence range from 4 (Alternative 1) to 8.5 (Alternative 5). Alternative 1 receives a moderately low score (score of 4) for this criterion because the remedy does not include active treatment technologies and relies heavily on natural recovery processes in sediment, which would not prevent hazardous substance releases with as much certainty (or as quickly) as more aggressive (capping) approaches. Alternative 2 receives a higher score (score of 6) due to the addition of bioremediation in the upland, which would reduce the mass of some contaminants, and the expansion of the area of upland capping. Alternative 2 also incorporates more extensive sediment capping that would reduce potential releases of hazardous substances compared to Alternative 1. The score for Alternative 3 (score of 7) is higher than Alternative 2 because the more widespread and robust capping in the upland and marine units would be expected to significantly reduce contaminant mobility and releases (exposures) in a much shorter timeframe. The score for Alternative 4 (score of 7) is the same as Alternative 3 because the benefit of contaminant destruction related to upland treatment technologies is offset by the increased reliance on natural recovery in the marine unit. Alternative 5 receives the highest score for permanence (score of 8.5) due to the effects of upland treatment technologies (reduced volume and mobility of contaminants) and the very robust sediment capping scheme.

5.3.5. Long-term Effectiveness

The raw scores for long-term effectiveness range from 4 (Alternative 1) to 8 (Alternative 5). Alternative 1 receives the lowest score (score of 4) because its success relies on natural attenuation processes in the upland and natural recovery processes in widespread portions of the marine unit. These processes and the capping technologies included in Alternative 1 are proven technologies, but the active treatment and more widespread capping approaches of other alternatives provide a greater certainty of success. Alternative 2 receives a higher score (score of 6) because of the addition of groundwater treatment and a broader footprint of soil and sediment capping. The combined effects of more widespread (and more robust) upland and sediment capping in Alternative 3 yields a score of 6.5 for this criterion. Alternative 4 (score of 7) benefits from the increased use of treatment technologies and an expanded cap in the upland, and nearshore source (sediment) removal, but this benefit is somewhat offset by the reduced scope of sediment capping. The highest score is assigned to Alternative 5 (score of 8) as a result of extensive upland soil and groundwater treatment, nearshore sediment removal, and widespread capping in the upland and sediment units.

5.3.6. Management of Short-term Risks

The scores for management of short-term risks range from 5 (Alternative 5) to 8 (Alternatives 1 and 2). The lower scores for Alternatives 5 and 6 result from short-term impacts to park usage associated with the more comprehensive upland treatment technologies, and the risks associated with excavation and off-site disposal of significantly contaminated nearshore sediment. ISS, in particular, would require the handling of large volumes of cement-based material in the upper park.

5.3.7. Technical and Administrative Implementability

All alternatives are technically and administratively implementable and involve comparable logistical, regulatory and land use challenges. Alternatives 1 and 2 have the same score (score of 7) for this criterion, utilizing common upland and marine capping methods and implementing deed restrictions and other administrative controls. Alternatives 3, 4, and 5 have progressively lower levels of implementability (scores decline from 6.5 to 5) as a result of progressively higher degrees of upland remediation, capping, and nearshore sediment removal.

5.3.8. Consideration of Public Concern

All alternatives would be subject to public review and comment at the draft FS and alternative selection phases, with further review opportunities during the design phase. In addition, all alternatives would be expected to require an extensive state and federal permitting process. Key parties expected to comment on cleanup alternatives include members of the local community, community groups, government agencies including those with regulatory authority over cleanups, and tribes.

The scores for this criterion range from 5 (Alternatives 1 and 5) to 7.5 (Alternative 3). In general, alternatives that provide the greatest level of protectiveness with the least short-term and long-term disruption (or changes) to the park receive the highest scores. These scores (ranging from 7 to 7.5) are assigned to Alternatives 2, 3 and 4 because of the reasonably good balance between the level of protectiveness and disruption (or long-term changes) to the park. Alternatives 1 and 5 receive the lowest scores because of anticipated concerns about the level of protectiveness (Alternative 1) and extensive disruption (and long-term change) to the park (Alternative 5).

5.3.9. DCA Conclusions

The goal of the DCA is to identify the alternative that is permanent to the maximum extent practicable. To accomplish this, a benefit-per-unit-cost score was developed for each alternative and the alternatives were ranked by score. Table 5-2 presents the overall benefit score for each alternative derived from the raw scores and respective weighting factors for each criterion. Also presented in Table 5-2, and on Figure 5-1, are the total costs for each alternative used to calculate the benefit-per-unit cost, as well as the calculated benefit-to-cost ratio.

Without consideration of cost, the overall weighted benefit scores for the alternatives range from 4.8 (Alternative 1) to 7.5 (Alternative 5), as shown on Table 5-2 and Figure 5-1. Alternatives 3 and 4 have overall benefit scores slightly less than that of Alternative 5, and Alternative 2 has an overall benefit score slightly less than that of Alternatives 3 and 4. However, under MTCA and SMS, costs must be considered when selecting the most practicable permanent alternative. As described in Section 5.3.1, the estimated costs for the five alternatives range from $7,950,000 (Alternative 1) to $20,400,000 (Alternative 5). Under MTCA, "costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of lower cost alternative" (WAC 173-340-360[3][e][i]). Graphically, this concept is illustrated on Figure 5-1 by comparing the relative benefit-to-cost ratios, as expressed by the formula:

$$Benefit/cost\ ratio = Benefit\ \div (Cost \div \$10{,}000{,}000)$$

The cost for each alternative was normalized to increments of $10,000,000 to generate a range of values similar to the range of overall benefit values; $10,000,000 represents the order of magnitude of the total cost for the highest-cost alternative.

The resulting benefit-to-cost ratio scores for each of the five alternatives are noted in Table 5-2 and plotted on Figure 5-1 with the corresponding values for the overall benefit score and the normalized alternative cost.

Alternative 2 has the highest benefit-to-cost ratio (6.9) and Alternative 5 has the lowest (3.7). Although the overall benefit scores for Alternatives 3 through 5 were higher than that for Alternative 2, the incremental cost required to achieve the higher benefits for these higher-cost alternatives is disproportionate, as represented by the respective benefit-to-cost ratios of 5.7, 4.8, and 3.7, compared to the 6.9 benefit-to-cost ratio for Alternative 2. Therefore, Alternatives 3 through 5 are determined to be disproportionately costly relative to Alternative 2 and are not considered to be practicable. Alternative 1 provides lower benefits than Alternative 2, but also has a lower benefit-to-cost ratio (6.0), indicating that Alternative 2 is not disproportionately costly relative to Alternative 1.

Based on this analysis, Alternative 2 has the highest benefit per unit cost and is determined to be permanent to the maximum extent practicable.

6.0 PREFERRED CLEANUP ACTION ALTERNATIVE

The preferred alternative is that which has the highest benefit per unit cost and is determined to be permanent to the maximum extent practicable in accordance with MTCA (Section 5.3). Alternative 2 achieved the highest benefit-to-cost ratio and is permanent to the maximum extent practicable and was therefore selected as the preferred alternative for the Site. Details regarding the preferred alternative are presented in this section. The final cleanup action for the Site will be presented in the CAP and developed in more detail in the Engineering Design Report.

6.1. Basis for Selection of the Preferred Alternative

The preferred alternative for the Site was selected based on results of the DCA, which comparatively evaluates the relative benefit and cost of each alternative. Alternative 2 has the highest relative benefit/cost and is considered permanent to the maximum extent practicable. Alternative 2 provides the optimum balance between cost, benefit and certainty of long-term performance while meeting the threshold and other requirements for cleanup actions set forth in MTCA and in SMS. The preferred alternative will:

- Protect human health and the environment using capping and targeted treatment technologies. Potential exposures to park users would be addressed using common soil capping methods. Bioremediation would target the location where groundwater impacts are greatest, upgradient of the pocket beach. A conventional cap would be used in intertidal and shallow subtidal areas. This cap would be thicker or contain amendments in the pocket beach area if needed to enhance attenuation of contaminants in underlying sediment and pore water. The conventional cap would transition into a thin cap and ENR in deeper subtidal areas, surrounded by MNR in areas where contaminant concentrations are lower. The effects of natural recovery would achieve compliance with the bioaccumulation cleanup level within a reasonable timeframe on an area-weighted average basis.
- Provide long-term effectiveness through source controls and active remediation. Actions would include:
    - Removing the remaining gas holder structure and contaminated media within the gas holder;
    - Capping soil in the upper and lower parks where contaminant concentrations exceed MTCA cleanup levels;
    - Utilizing in-situ bioremediation and natural attenuation technologies to address groundwater impacts in the upland unit;

  - Capping all sediment exceeding cleanup levels based on human health (direct contact) and benthic toxicity criteria;
  - Utilizing capping and natural recovery technologies to achieve compliance with the bioaccumulation cleanup level on an area-weighted average basis within a reasonable timeframe, and;
  - Monitoring performance of the remedy over time and maintaining the long-term performance of the remedy using ICs.
- Manage short-term risks and reduce potential public concerns by the following actions:
  - Utilizing robust capping methods rather than extensive removal to prevent impacts associated with dredging contaminated sediment,
  - Utilizing upland soil and groundwater remediation methods that will reduce short-term impacts to park use and preserve the current park use upon completion of the cleanup action, and
  - Using construction BMPs for upland and in-water work activities to reduce the risk of impacting surface water during construction.

6.2. Description of the Preferred Alternative

Alternative 2 ("Soil and Sediment Capping with Bioremediation") was identified as the alternative that is permanent to the maximum extent practicable for the Site. The components of Alternative 2 are shown on Figures 4-3 and 4-4 and are described below:

- The concrete cylindrical wall of the only remaining gas holder in the upper park and MGP residuals inside this structure would be removed and disposed of off-site. Underground portions of the base of the gas holder would be removed, to the extent practicable, to observe whether a NAPL source is present and warrants removal. Remnant subgrade components of the former gas holder, to the extent they exist, would be covered by the soil cap as described below, similar to the present-day landscape cover above the former northern gas holder.
- A permeable soil cap would be constructed throughout most of the upper and lower park where contaminants in soil exceed MTCA cleanup levels. The lower park cap would reduce the risk of upland soil erosion and increased contaminant leaching to groundwater as a result of future sea level rise. The cap would include a separation layer (geotextile) and an overlying clean soil horizon, the surface of which would be vegetated. The cap surface would primarily consist of turf grass, but final cap design would be coordinated with the City to incorporate other types of vegetation to the extent feasible. An irrigation system would be incorporated in the cap.

  The cap would reduce human health (direct contact) risks and provide a clean soil horizon in which park workers could conduct routine maintenance activities without encountering deeper contaminated soil. Once the cleanup is implemented, routine park maintenance activities (e.g. irrigation system repairs) could occur in the clean soil horizon without additional requirements. Future maintenance needs would be facilitated, to the extent practicable, by the cap design and provisions in an environmental covenant.
- The portion of the upland where groundwater impacts are greatest, upgradient of the pocket beach, would be addressed using enhanced bioremediation. This in-situ treatment technology would target lighter organic contaminants (primarily benzene and naphthalene). Bioremediation would be implemented by injecting oxygen, nutrients, or other amendments into the saturated zone to generate conditions that stimulate microbes capable of degrading organic contaminants.

- Groundwater in other portions of the upland unit would be addressed using MNA. cPAHs are expected to attenuate prior to reaching a conditional point of compliance as a result of adsorption to the soil matrix, while lighter organic contaminants are expected to degrade biologically, as well as adsorb. Cyanide in groundwater may also be capable of attenuating by adsorption to the upland soil matrix. Additional data collection will be necessary to evaluate these processes.
- A conventional sand cap would be constructed at (and slightly beyond) all locations where surface sediment concentrations exceed the upper remediation level for cPAHs in the intertidal and shallow subtidal zones (above -10 feet MLLW). This cap also would encompass all locations exceeding human health (direct contact) and benthic toxicity cleanup levels. The cap would have a nominal thickness of 2 feet excluding armoring; cap thickness could be increased, or amendments added, in the pocket beach area to enhance attenuation of contaminants in underlying sediment and pore water, if needed. Structures and debris, including piling, would be removed to the extent feasible prior to capping. Piling within the cap area would likely be removed by cutting the piles at the existing mudline prior to cap placement, consistent with BMPs published by regulatory agencies.

  A significant portion of the conventional sand cap would overlap eelgrass beds in lower intertidal portions of the Site, as shown on Figure 4-4. Surf smelt spawning habitat also is present in the pocket beach area. Potential impacts to eel grass beds, surf smelt spawning habitat and other habitat considerations, would be addressed during design and permitting phases of the cleanup action.
- A thin sand cap (1-foot-thick) would be constructed in deeper subtidal (below -10 feet MLLW) areas where surface sediment exceeds the upper remediation level for cPAHs. This cap is not expected to require armoring because it is in a lower energy, depositional environment.
- Natural recovery technologies (ENR and MNR) would be utilized in portions of the marine unit where surface sediment concentrations are below the upper remediation level for cPAHs and where natural recovery mechanisms such as deposition of clean sediment appear to be occurring and would be expected to achieve cleanup levels on a SWAC basis within a reasonable timeframe. Generally, the natural recovery area would be in deeper off-shore areas where lower energy conditions allow net deposition of clean sediment, and where periodic high-energy events (e.g. storms) would not affect recovery on a large scale.
  - ENR would be used in areas surrounding the thin cap where surface sediment concentrations are between the lower and upper remediation levels for cPAHs. ENR would involve the placement of approximately 6 inches of clean sand; this area would be subject to ongoing natural recovery processes.
  - MNR would be utilized in remaining portions of the marine unit, where surface sediment concentrations are less than the lower remediation level for cPAHs and greater than the bioaccumulation cleanup level, and where net deposition is expected to occur. The effect of natural recovery would be expected to achieve compliance with the bioaccumulation cleanup level for cPAHs on a SWAC basis within 10 years.
- ICs would be employed to ensure the long-term protectiveness of the remedy in the upland and marine units. The ICs would be documented in an operations, maintenance, and monitoring plan, and described in a restrictive covenant that is recorded with Whatcom County. ICs on state-owned aquatic lands will require coordination with DNR and implementation via a separate legal mechanism.
  - In the upland, ICs would prohibit activities that may compromise the integrity of the soil cap or result in the extraction of groundwater. This would include restrictions such as digging by park users or park maintenance activities that might damage the cap. Existing fencing that

separates the railroad track from the park would likely be expanded to prevent access to the slope between the upper and lower park. ICs also would prohibit the addition of any structures with indoor airspace without prior evaluation of potential vapor intrusion risks, or mitigation of those risks based on the structure design.

- ICs also would be utilized to protect the sediment remedy. The specific nature of these ICs will depend on details developed during the remedial design and permitting process. As an example, if habitat considerations lead to a less robust remedial design, additional restrictions on vessel uses may be needed to protect the sediment cap. Potential activities that will be considered include beaching or anchoring vessels of a certain size. The potential effect of prop wash also will be evaluated. Due to the shallow water depths in the Site vicinity, navigation restrictions on large vessels may not be necessary. Although the details of ICs in the marine unit cannot be specified at this time, the goal of the ICs will be to protect the integrity of the sediment cap, and ENR and MNR areas.

- Long-term monitoring and maintenance of the upland and sediment caps and natural recovery areas would be required. Groundwater monitoring also would be required. Periodic review of remedy performance and effectiveness would be conducted in conjunction with the monitoring program.

Shoreline erosion would be addressed by integrating the upper part of the nearshore sediment cap with the adjacent upland soil cap. In areas where there is no active nearshore sediment remedy, a permanent shoreline stabilization revetment would be integrated with the adjacent upland soil cap. These shoreline components of the remedy would be designed to resist coastal erosion. Remedy design would account for the effects of sea level rise. For the purpose of this FS, a 100-year sea level rise value of 2.4 feet was used, consistent with values used for planning other Bellingham Bay cleanup projects, based on analyses completed for the Port of Bellingham (Blumen 2010). Nearshore components of the remedy would incorporate shoreline stabilization materials placed during the 2017 Interim Action (Section 1.6.2) to the extent practicable.

The estimated cost for the preferred alternative is $9,330,000. The estimated timeframe to finalize design (including pre-remedial design sampling) and obtain permits is approximately 3 years after issuance of the CAP, with construction of the preferred alternative completed 2 years after issuance of final project permits.

6.3. Compatibility of the Preferred Alternative with Land Use

The City plans to continue using the Site as a public park. Upland capping will generally increase the elevation of the upper and lower park areas by 2 feet or more but will not detract from the aesthetics or public use of the park. The cap would be designed with input from the City regarding goals for preserving existing vegetation and maintaining flexibility for planting new vegetation in the future, to the extent practicable. The soil cap would be designed to surround existing park structures without disturbing them.

Plans for future development within the Site boundary include shoreline restoration, construction of a new stairway from the upper to lower park, maintenance and replacement of underground utilities, safety improvements at the railroad crossing, removal of the public restroom, and construction of a new over-water walkway. These development activities would be compatible with the preferred alternative, particularly if constructed prior to, or during, remedy implementation.

Current land uses in the marine unit include transit and transient moorage by recreational vessels (e.g., kayak use of the pocket beach). Deep-water navigation is restricted in this area due to the proximity of natural shallow-water obstructions (e.g., Starr Rock), and by the lack of adjacent upland navigation support facilities (RETEC 2006). Aquatic uses would be considered during remedial design and permitting.

6.4. Compatibility with Other Cleanup Actions

The majority of the Site marine unit overlaps with Unit 9 and a portion of Unit 7 of the Whatcom Waterway Site as described in the Final Engineering Design Report, Whatcom Waterway Phase 1 Site Areas (Anchor 2015). Whatcom Waterway Unit 7 (Starr Rock) and Unit 9 (remaining areas of the site) are planned to be addressed using MNR, primarily as a tool to evaluate continued recovery of sediment historically impacted by Whatcom Waterway Site contaminants. The preferred alternative for the Site includes capping, ENR and MNR within the footprint of these Whatcom Waterway units. These elements are not expected to impact the Whatcom Waterway cleanup action, but coordination will be required to ensure that the monitoring requirements for both cleanup actions will be met.

7.0 REFERENCES

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TABLES

Table 2-1

Potential Applicable Laws and Relevant and Appropriate Requirements (ARARs) Governing Cleanup

South State Street MGP Site
Bellingham, Washington

Subject Regulated	State/Local Statutes and Implementing Regulations	Federal Statutes and Implementing Regulations	Notes
Hazardous waste cleanup	Model Toxics Control Act (MTCA) Cleanup Regulation (RCW 70.105D; Chapter 173-340 WAC)	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC Chapter 103; 40 CFR Chapter I, Subchapter J)	State law has precedence; primary regulations governing upland cleanup actions at the Site. Most state and local permits are waived because the work is being conducted under an Agreed Order, but MTCA requires that permit substantive requirements must be met. All federal permits governing the remedial action are still required.
Sediment quality, investigation and cleanup	Sediment Management Standards (RCW 90.48 and 70.105D; Chapter 173-204 WAC)	No Federal equivalent	Primary regulations governing sediment cleanup actions at the Site. MTCA is one of the authorities defining the SMS; thus, waivers of state and local permits also apply to sediment cleanups.
Environmental impact review	State Environmental Policy Act (SEPA) (RCW 43.21C, Chapters 197-11 and 173-802 WAC)	National Environmental Policy Act (NEPA) (42 USC Chapter 55 § 4321 et seq.; 40 CFR Chapter V, Parts 1500-1508)	The City would likely be the lead agency and make the determination of compliance with SEPA.
Water quality			
General	Water Pollution Control Act (RCW 90.48); Water Quality Standards for Surface Waters of Washington (Chapter 173-201A WAC)	Federal Water Pollution Control Act (aka Clean Water Act [CWA]) (33 USC Chapter 26 §1251 et seq.; 40 CFR Chapter 1, Subchapter D)	State implements most components of the CWA. Water quality is considered in the development of cleanup objectives, short-term performance during construction, and long-term performance of the remedy.
Discharge of dredge, excavated or fill materials	No State equivalent	CWA Section 404	Applies to waters of the US; affects sediment remedies that have a removal or capping component. Requires a US Army Corps of Engineers (USACE) Nationwide 38 or Section 404 individual permit, which will be part of the Joint Aquatic Resources Application (JARPA) Permit.
Discharge of return water from dredged material	Water Pollution Control Act (RCW 90.48); Water Quality Standards for Surface Waters of Washington (Chapter 173-201A WAC)	CWA Section 401	State certifies consistency with CWA. Applies to sediment remedies; any requirements are typically specified in a Consent Decree or Cleanup Action Plan.
Discharge of stormwater	Water Pollution Control Act (RCW 90.48); National Pollution Discharge Elimination System Program (NPDES) (Chapter 173-220 WAC)	CWA Section 402	Applies to both sediment and upland remedies. Dewatering of sediment may, and upland construction will, require an NPDES permit which is administered by the State. Local NPDES requirements for stormwater may also apply.
Disposal of contaminated material			
Management, transport and disposal of hazardous wastes	Solid and Hazardous Waste Management Act (RCW 70.105); Dangerous Waste Regulations (Chapter 173-303 WAC)	Resource Conservation and Recovery Act (RCRA) (40 CFR 260 and 261); 49 USC Chapter 51 Transportation of Hazardous Material; 40 CFR 171-180	Federal regulations are implemented by the State. Pertains to soil, sediment, water, and debris waste handling and landfill disposal. Management and disposal process is administered by the State and all substantive requirements must be met. Transportation is regulated by the US Department of Transportation.
Management, transport and disposal of solid wastes	Solid and Hazardous Waste Management Act (RCW 70.95; Chapters 173-305, 173-350 WAC and others)	RCRA (40 CFR 257 Subpart A)	Affects land disposal and transportation of dredged or excavated material and debris from the Site; process is administered by the State and all substantive requirements must be met.
Impacts to navigation	Hydraulic Code Rules (Chapter 77.55.100; Chapter 220-110 WAC)	Rivers and Harbors Act (Section 10)	Rules designed to protect navigation; applies to sediment remedy. Addressed as part of the JARPA permit process.
Shoreline construction or development	Shoreline Management Act (RCW 90.48; Chapter 173-16 WAC); City of Bellingham Shoreline Master Program	Coastal Zone Management Act (Public Law 92-583; 16 USC Chapter 33)	Regulation is implemented by state and local agencies; substantive requirements apply to both upland and sediment remedies that extend out to the jurisdictional boundaries of the implementing government.
Air quality	Clean Air Act (RCW 70.94); Ambient Air Quality Standards (Chapter 173-746 WAC)	Clean Air Act (42 USC, Chapter 85 Air Pollution, Prevention and Control)	Administered by the State and local authorities; substantive requirements apply to construction activities during implementation of the remedy.

Table 2-1

Potential Applicable Laws and Relevant and Appropriate Requirements (ARARs) Governing Cleanup

South State Street MGP Site
Bellingham, Washington

Subject Regulated	State/Local Statutes and Implementing Regulations	Federal Statutes and Implementing Regulations	Notes
Protection of species and habitats			
Protection/restoration of endangered or threatened species and critical habitats	Fish and Wildlife or Natural Resource Conservation Areas (Various RCW Titles 77 and 79; Chapter 232-12 WAC)	Endangered Species Act (16 USC §1361 et seq. 50 CFR 216)	State rules primarily address salmon and their recovery along with general conservation strategies for state lands/state resources. Bellingham Bay is used by species protected under ESA. Consultation with natural resource trustees will take place as part of the USACE Section 404 permit.
Protection of essential fish habitat	No State equivalent	Magnuson-Stevens Fishery Conservation and Management Act (50 CFR Part 600.920)	Essential fish habitat has a specific definition under the Magnuson-Stevens Act. In practice, the State's HPA addresses similar issues. Requirements for protection of essential fish habitat will be part of the USACE Section 404 permit.
Protection of marine mammals	No State equivalent	Marine Mammal Protection Act (16 USC §1531 et seq. 50 CFR 17)	Not likely to be applicable; however, if necessary, would be addressed as part of USACE Section 404 permit.
Protection of migratory birds	No State equivalent	Migratory Bird Treaty Act (16 USC §703 50 CFR §10.12)	Species protected by this Act use Bellingham Bay on a seasonal basis; potential impacts will be addressed as part of USACE Section 404 permit.
Protection of fish and fish habitat	Hydraulic Code Rules (Chapter 77.55.100; Chapter 220-110 WAC)	No Federal equivalent	Rules designed to protect fish; substantive requirements apply to sediment remedy.
Critical areas	Bellingham Municipal Code Chapter 16.55 Critical Areas; Growth Management Act (GMA) (RCW 36.70A)	No Federal equivalent	City ordinance implementing State's GMA requirements for identifying and restoring sensitive habitats and other natural resources that provide critical services (water quality, habitat, erosion protection, etc.). May affect habitat goals in relation to portions of final remedy.
Health and safety	Washington Industrial Safety and Health Act (RCW 49.17; Chapters 296-62, 296-843 WAC and others)	Occupational Safety and Health Act (OSHA) (29 USC Chapter 15; 29 CFR 1910, 1926)	Applicable to investigation and construction phases of a cleanup.
Objects, landscapes or structures of historical or archaeological significance	Regulations addressing these resources include SEPA, the Governor's Executive Order 05-05, and SMA (i.e., no one single regulation or authority). RCW's 27.44, 27.53, 68; WAC's 25-48, 365-196-450 and others also apply.	National Historic Preservation Act (NHPA) (16 USC 470 et seq. Section 106), Archeologic Resources Protection Act (ARPA) (16 USC 470aa-470mm)	State laws govern local projects; federal law governs those requiring federal permits or funds. Protection of significant historic, archaeological and traditional cultural sites from damage or loss during development is coordinated by the State's Department of Archaeological and Historic Preservation (State Historic Preservation Office), and includes evaluating compliance with Section 106 of the federal law.

Table 2-2
Summary of Preliminary Cleanup Levels
South State Street MGP Site
Bellingham, Washington

Indicator Hazardous Substance	Soil		Groundwater	Sediment	Indoor Air	Basis for Cleanup Level
	Vadose	Saturated				
Metals						
Selenium	7.4 mg/kg	0.5 mg/kg	71 µg/L	na	na	**Soil**: Protection of groundwater as surface water (based on toxicity to aquatic organisms), adjusted up to the PQL only for saturated soil. **GW**: Protection of surface water (based on toxicity to aquatic organisms).
Lead	250 mg/kg	250 mg/kg	na	na	na	**Soil**: Human health - based on direct contact.
VOCs						
Benzene	0.2 mg/kg	0.2 mg/kg	1.6 µg/L	na	0.32 µg/m^3	**Soil:** Protection of groundwater as surface water (based on fish consumption by people), adjusted up to the PQL. **GW:** Protection of surface water (based on fish consumption by people). **Air:** Human health - based on inhalation of indoor air.
PAHs						
Naphthalene	2.3 mg/kg	0.12 mg/kg	83 µg/L	na	0.074 µg/m^3	**Soil:** Protection of benthic organisms in sediment via the groundwater pathway. **GW:** Protection of benthic organisms in sediment. **Air:** Human health - based on inhalation of indoor air.
cPAH TEQ	6.6 µg/kg	6.6 µg/kg	0.02 µg/L	86 µg/kg dw	na	**Soil**: Protection of groundwater as surface water (based on fish consumption by people), adjusted up to the derived PQL. **GW**: Protection of surface water (based on fish consumption by people); adjusted up to the derived PQL. **Sed**: Regional background (SMS CSL equivalent based on bioaccumulative risks to people and ecological receptors).
Other						
Cyanide	1 mg/kg[a]	0.05 mg/kg[a]	0.005 mg/L	na	na	**Soil**: Protection of groundwater as surface water (based on toxicity to aquatic organisms), adjusted up to the PQL only for saturated soil. **GW**: Protection of surface water (based on toxicity to aquatic organisms), adjusted up to the PQL.

Notes:

a Cyanide soil CULs based on the protection of groundwater were calculated using a Kd of 9.9 L/kg (U.S. Environmental Protection Agency's "Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites dated December 2002) and MTCA Equation 747-1.

cPAH = carcinogenic polycyclic aromatic hydrocarbon
CSL = cleanup screening level
dw = dry weight
GW = groundwater
mg/kg = milligram per kilogram
na = compound is not an indicator hazardous substance for this medium, therefore, no cleanup level is needed.
PAH = polycyclic aromatic hydrocarbons
PQL = practical quantitation limit
SMS = Sediment Management Standards
TEQ = toxic equivalent concentration
µg/kg = microgram per kilogram
µg/L = microgram per liter
µg/m^3 = microgram per cubic meter
VOC = volatile organic compound

Table 2-3

Sediment Risk-Based Sediment Concentrations - Direct Contact Pathway

South State Street MGP Site

Bellingham, Washington

Analyte	Human Health Risk-Based Sediment Concentrations	
	SCUM II - Table 9-2 Values	Revised SCUM II Values[a]
	µg/kg	µg/kg
cPAH TEQ		
Beach Play	850 (child)	800 (adult and child)
Subsistence Clam Digging (Adult)	75	540
Subsistence Net Fishing (Adult)	580	4,200

Notes:

[a] See Appendix A, Tables A-1 and A-2 for calculations.

cPAH = carcinogenic polycyclic aromatic hydrocarbon

TEQ = toxic equivalent concentration

µg/kg = microgram per kilogram

Table 2-4

Preliminary Soil Remediation Level Summary - Direct Contact Pathway

South State Street MGP Site

Bellingham, Washington

Analyte	MTCA Method B Cleanup Levels	Preliminary Remediation Levels
	Unrestricted Land Use	Park User (Child/Adult)[a]
	0-15 feet	0-2 feet
	mg/kg	mg/kg
Metals		
Selenium	400	1,300
Lead	250	250
VOCs		
Benzene	18	52
PAHs		
Naphthalene	1,600	5,200
cPAH TEQ	0.14	0.39
Other		
Cyanide	48	120

Notes:

[a] See Appendix A, Tables A-3 and A-4 for calculations.

cPAH = carcinogenic polycyclic aromatic hydrocarbon

mg/kg = milligram per kilogram

MTCA = Model Toxics Control Act

PAH = polycyclic aromatic hydrocarbons

TEQ = toxic equivalent concentration

VOC = volatile organic compound

Table 3-1

Remediation Technology Screening – Soil

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
In-situ Soil Treatment	**Biological Treatment**	**Bioventing**	**Oxygen is supplied through passive venting of contaminated vadose zone soil to enhance biological degradation of contaminants. Effective treatment method for vadose zone soil with contaminants that degrade aerobically. Can be implemented in cooperation with active SVE to promote lateral flow of ambient air through vadose zone soil.**	**Effective at accelerating biological degradation of benzene in higher permeability soil. Not significantly effective on cPAHs, which resist biological degradation.**	**Technically implementable. Passive implementation may require a large number of vent wells, requiring completion above ground. Passive venting eliminates the need for infrastructure associated with air injection and soil vapor extraction. Monitoring of off-gasses at ground surface may be required.**	**Low capital and O&M cost relative to other in situ options.**	**Slow technology if applied alone. Would be an effective add-on in areas where SVE is applied for VOCs. Retained.**
		Enhanced Bioremediation	Controlled biological process by which amendments are injected into contaminated soils to enhance microorganism conversion of organic contaminants to innocuous, stabilized by-products.	Enhanced aerobic bioremediation would be effective for benzene and some lower molecular weight PAHs. However, significant mass reduction would not be expected if applied in vadose zone soil alone.	Difficult to implement due to slow degradation and potential need for multiple processes, particularly for vadose zone soil. Site contaminants would require different processes, and multiple implementations.	High capital cost. Moderate to High O&M cost. Cost increases due to uncertainty of process and expected need to repeat treatment.	Difficult to implement. Not cost effective relative to methods that can physically remove VOCs. Not Retained for vadose zone soil.
	Chemical Treatment	Chemical Oxidation	Injection of a dilute oxidant solution (i.e., hydrogen peroxide, ozone, potassium permanganate, sodium persulfate, ferric chloride, etc.) into the contaminated zone to convert hazardous compounds to nonhazardous or less toxic compounds that are more stable, less mobile, or inert.	Chemical oxidation has been demonstrated to effectively treat benzene and PAHs. In-situ application for vadose zone soil would require inducing saturation to sustain treatment. Deeper, saturated soil at the Site consists of high fractions of wood waste which is expected to place significant oxidant demand on the treatment, reducing effectiveness.	Implementable using standard injection or subsurface mixing processes, but difficulties would be expected due to heterogeneity, large obstructions and debris in subsurface, and risk associated with potential migration of the injected oxidant.	High capital and low O&M costs. Moderate treatability testing cost.	High organic fraction of saturated soil, particularly in lower Park, reduces the expected effectiveness. Not retained.
		Chemical Reduction	Injection or placement of reactive material that generates reducing conditions within the saturated environment. Chemical reduction, particularly in the presence of iron, has been demonstrated to promote the sequestration of cyanide.	Chemical reduction has been demonstrated to reduce mobility of cyanide, but is not a destructive process. Generally, more applicable as a way to promote adsorption of dissolved cyanide rather than treating cyanide within the soil matrix of saturated or vadose zone soil.	Implementable using standard injection or subsurface mixing processes, but difficulties would be expected if applied in a large-scale soil treatment application due to heterogeneity, large obstructions and debris in the subsurface.	High capital and low O&M costs. Moderate treatability testing cost.	Not expected to be cost effective as a soil technology. Not retained.
	Physical Treatment	**In-situ Solidification**	**Contaminants are physically and/or chemically bound within a solidified mass, resulting in reduced leachability of contaminants and reduced groundwater flow through the treated soil.**	**In-situ solidification of organic and inorganic contaminants in soil and NAPL has been demonstrated to effectively reduce the leachability of contaminants in soil. The solidification process can be designed to be effective for all Site contaminants.**	**Technically implementable. In-situ mixing process has been demonstrated at similar sites. Debris and other obstructions in the treatment area may inhibit some mixing technologies and require use of more expensive processes or removing debris. Treatability testing is required.**	**High capital cost and no O&M cost. Moderate cost relative to other in-situ physical/chemical options.**	**Applicable for Site conditions and contaminants, but requires treatability testing. Retained.**

Table 3-1

Remediation Technology Screening – Soil

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Removal	Soil Removal	Excavation	Excavation of contaminated upland soil using common excavation methods. Shoring and/or dewatering is sometimes needed to stabilize excavation sidewalls depending on excavation depth and Site conditions.	Generally effective for all Site contaminants. Excavation depths required to achieve greater effectiveness than other technologies, such as capping, would be significant, reducing cost-effectiveness.	Technically implementable. Shoring and dewatering may be required at the Site.	Moderate to high capital cost. Negligible O&M cost.	Applicable and common method for soil removal, but expected to be less effective than containment technologies. Not retained.
	Soil Vapor Extraction	**Soil Vapor Extraction Wells**	**Vacuum is applied at vertically installed soil vapor extraction wells to create a pressure/concentration gradient in impacted areas, which induces transport of gas-phase volatiles to extraction wells. Primarily used for volatile contaminants (e.g. benzene). The process includes a system for treating off-gas. Induced subsurface air flow has a secondary effect of inducing aerobic bioremediation of amenable organic contaminants, particularly when paired with passive bioventing to promote flow of ambient air through the treated soil .**	**Common method for reducing mass of volatile contaminants from vadose zone soil and managing soil vapors. Effective for VOCs in higher permeability granular soils. Less effective in clay and silt where SVE is diffusion limited. Not effective on cPAHs in Site soil.**	**Technically implementable at the Site using readily available equipment.**	**Moderate to high capital cost. High O&M cost.**	**Applicable for removal of benzene from soil in areas with high soil vapor concentrations. Retained.**
Off-site Management	Off-site Disposal	Landfill	Transport and disposal of contaminated soil at a permitted, off-site landfill.	Common and effective method of disposal for contaminated soil.	Technically implementable. Impacted soil must be profiled and meet land disposal requirements. Pre-treatment may be required if material does not meet requirements.	Moderate to high capital cost depending on types of waste present and type and location of landfill. Negligible O&M cost.	Only applicable in conjunction with excavation. Not retained.
Ex-situ Soil Treatment	Chemical Treatment	Chemical Oxidation	A dilute oxidant solution is mixed ex-situ with excavated soils, chemically destroying contaminants for the purpose of reusing soil onsite or reducing off-site disposal costs. The specific oxidant used is selected based on contaminant oxidation/reduction chemistry.	Chemical oxidation has been proven effective at treating some of the organic Site contaminants, such as benzene and lighter PAHs. Treatability testing would be required to determine effectiveness.	Challenging to implement at Site due to limited space for equipment (e.g. pug-mill) or land-based (e.g. wind-row) applications. Park disruption/closure and uncontrollable odors would likely be unacceptable to public and adjacent residents.	Moderate capital cost. No O&M cost. Treatability testing would be required to determine performance as well as implementation costs.	Not retained because of implementability challenges.
Soil Containment	**Capping**	**Permeable Vegetated Soil Cap**	**Placement of a layer of clean, permeable soil over contaminated soil to isolate contaminants while allowing stormwater to infiltrate.**	**Effective for preventing direct contact exposures (i.e. dermal contact or ingestion) to contaminated soil and controlling erosion of potentially contaminated material.**	**Technically implementable except on steeply sloping portion of Site. Compatible with current and planned future land use (City Park).**	**Low capital cost relative to other cap methods. Low O&M cost.**	**Retained for use where prevention of direct contact is the primary RAO.**
		Low-permeability Cap with Drainage Controls, Vegetated Surface	**A low-permeability cap material (clay soil, HDPE liner material, etc.) would be placed over contaminated soil, overlain by a vegetated soil surface. Surface water collection and discharge would be designed to reduce infiltration of stormwater at the Site.**	**Effective for preventing direct contact exposure, erosion of source material, reducing stormwater infiltration, and reducing contaminant transport in groundwater.**	**Technically implementable. The City's long-term plans for Site use as a park is generally compatible with a low-permeability/vegetated soil cap. Additional considerations for stormwater collection, treatment, and discharge will be needed.**	**Moderate capital cost. Low O&M cost. Stormwater management requirements may affect capital and O&M cost.**	**Applicable for preventing direct contact as well as reducing storm water infiltration and groundwater flow through contaminated soil. Retained.**

Table 3-1

Remediation Technology Screening – Soil

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Engineering Controls	Physical Vapor Barrier	Synthetic Membrane Beneath Future Buildings	Installation of membrane vapor barrier below building foundations to prevent soil vapor intrusion into indoor air.	Effective for preventing migration of VOCs into indoor air spaces.	Technically implementable using standard methods if structures are built on-site in future.	Low additional capital cost. Negligible O&M cost.	Applicable for future on-site buildings, if constructed. Retained.
Institutional Controls	Land Use Restrictions	Environmental Covenant	Record an environmental covenant to restrict land use, inform property owners of the presence of potentially hazardous substances and assure the integrity of the remedy (e.g. maintenance of an engineered cap).	Effectiveness would depend on compliance with conditions of the environmental covenant.	Technically implementable. Specific legal requirements and authority would need to be met.	Low capital cost. Low O&M cost.	Applicable in combination with containment technologies. Retained.
	Access Control	Fencing and Warning Signage	Construct Site fencing and signage to control Site access by the general public thereby reducing potential exposure to contaminants.	Fencing and signage can help reduce potential exposures, but by themselves, are not typically effective.	Fencing is not generally compatible with Site use as a City Park, but would be applicable to prevent access to the slope between the upper and lower park areas.	Low capital cost. Low O&M cost.	Fencing and signage retained for potential use.

Notes:

cPAH = carcinogenic polycyclic aromatic hydrocarbons
HDPE = high-density polyethylene
NAPL = nonaqueous phase liquid
O&M = operation and maintenance
PAH = polycyclic aromatic hydrocarbons
RAO = remedial action objective
SVE = soil vapor extraction
VOC = volatile organic compounds

Table 3-2

Remediation Technology Screening – Groundwater

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
In-situ Groundwater Treatment	Passive Groundwater Treatment	Permeable Reactive Barrier Wall	Permeable reactive barrier (PRB) walls utilize in-situ treatment methods in a passive configuration, treating groundwater as it passes through the reactive material. PRBs can effectively prevent groundwater contaminants from migrating to downgradient receptors by applying treatment technologies, potentially including natural attenuation, in a passive manner that doesn't require constant operation.	Primary applicability would be to treat groundwater at the farthest downgradient location in the upland to prevent contaminants from migrating from the upland to marine environment. Treatment capabilities rely on the availability of effective in situ technologies that can be applied as a barrier wall and would need to address multiple contaminants. A PRB constructed on the upland side of the shoreline bank would have limited overall effectiveness if contaminants being treated are also present in marine sediment.	Common PRB installation methods would be difficult and potentially infeasible along a significant portion of the shoreline due to obstructions. Subsurface obstructions can impact implementability and/or cost.	Moderate to High capital costs. Moderate O&M cost. O&M costs increase dramatically for treatment methods that require frequent replenishment or to address multiple contaminant groups.	High expected capital and O&M costs due to implementation difficulties and the need to address multiple contaminant groups. Not retained.
	Chemical Treatment	In-situ Chemical Oxidation	Injection of reagent in groundwater that provides treatment through direct destruction by oxidation. Organic contaminants such as benzene and some PAHs can be treated by oxidants through destructive oxidation processes (i.e., hydrogen peroxide, ozone, potassium permanganate, sodium persulfate, ferric chloride, etc.).	Chemical oxidation has been demonstrated to effectively treat benzene and PAHs. Extensive wood debris within the expected treatment zone, particularly across the lower Park, would likely reduce the effectiveness of oxidation technologies. Broad plume-wide application would be inhibited by subsurface heterogeneity, underground obstructions, and high levels of non-target organics (i.e., natural organics, other organic contaminants) in the subsurface.	Implementable using standard injection or subsurface mixing processes, but difficulties would be expected due to heterogeneity, large obstructions and debris in subsurface, and risk associated with potential migration of the injected oxidant in a shoreline environment.	Moderate to high capital cost. Negligible O&M cost. Cost highly dependent on non-target organics, and application methods.	High capital cost but proven in-situ treatment method. Limited expected effectiveness due to high organic content of target saturated soil. Not Retained.
		In-situ Chemical Reduction	Injection or placement of reactive material that generates reducing conditions within the saturated environment. Cyanide has been shown to be capable of immobilization by the reducing conditions produced by zero-valent iron (ZVI).	Chemical reduction has been demonstrated to reduce mobility of cyanide, but is not a destructive process. Not effective on most prevalent Site contaminants and the resulting reducing conditions may adversely affect geochemistry for organic contaminants.	Implementable using standard injection or subsurface mixing processes, but difficulties would be expected due to heterogeneity, large obstructions and debris in the subsurface. Potentially implementable in a PRB configuration	High capital and low O&M costs. Moderate treatability testing cost.	High capital cost, not applicable for most prevalent Site contaminants, and difficult application using PRB. Not retained.

Table 3-2

Remediation Technology Screening – Groundwater

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
In Situ Groundwater Treatment (continued)	Physical Treatment	Air Sparging/SVE	Air is injected into the saturated zone to induce mechanical stripping and volatilization of contaminants. Introduction of oxygen also enhances biodegradation. SVE is required to capture vapor phase contaminants.	Would be effective for volatile COCs like benzene, but ineffective for cPAHs, metals, and cyanide. The limited saturated thickness and seasonal disappearance of perched groundwater in areas of VOC exceedances significantly reduces effectiveness.	Technically implementable using commonly available equipment. Requires use of SVE to remove sparged air and volatilized contaminants, including effluent treatment. Limited footprint and presence of groundwater in upper park reduces implementability by limiting operation periods.	Moderate capital and O&M costs.	Not expected to be cost effective due to limited periods of operation. Not Retained.
	Biological Treatment	**Enhanced Bioremediation**	**Stimulating biological activity in groundwater by adding oxygen, nutrients, and/or amendments. The primary degradable site contaminants, benzene and naphthalene, can be degraded aerobically or anaerobically.**	**Common method for treating benzene in groundwater but has limited effect on heavier molecular weight PAHs. Treatability testing will be required to determine most effective degradation mechanism. Limited thickness, extent and seasonal presence of saturated horizon in upper Park reduces effectiveness. Slow acting relative to other technologies.**	**Technically implementable using commonly available technologies. Passive treatment by injection of bioremediation amendments would be easily implementable.**	**Moderate capital cost. Low to moderate O&M cost.**	**Enhanced bioremediation would be a cost-effective method to treat light molecular weight organic contaminants in groundwater. Retained.**
	Monitored Natural Attenuation	**Intrinsic Bioremediation, Adsorption**	**Reduction of dissolved concentrations through naturally occurring biodegradation processes, as well as other attenuation processes such as dispersion, volatilization, or adsorption. Involves groundwater sampling and monitoring to identify indicators of natural attenuation.**	**Commonly effective where conditions are amenable for natural degradation of VOCs in groundwater. Adsorption by the large quantities of organics (wood debris) in saturated zone soil would be expected to effectively attenuate PAHs. Natural attenuation of cyanide is less understood, but has been demonstrated.**	**Technically implementable. Further data needed to demonstrate attenuation. Monitoring well network already established at the Site, and can be easily enhanced to improve MNA data collection.**	**Negligible to low capital cost. Moderate O&M cost. Low overall cost relative to active remediation options.**	**Applicable to benzene and PAHs in groundwater. Potentially applicable to cyanide. Retained.**
Groundwater Collection	Groundwater Extraction	Extraction Wells	Groundwater extraction using common vertical extraction wells. Objectives of groundwater extraction include removal of dissolved contaminants from the subsurface and containment of contaminated groundwater to prevent migration.	Potentially effective for plume containment but Site conditions limit effectiveness due to limited saturated thickness and intermittent presence of perched groundwater horizon in upper park as well as the influence of adjacent surface water on groundwater in the lower park.	Groundwater extraction is technically implementable using standard methods. However, limited groundwater volume in the upper park limits the potential extraction volume and the proximity to surface water of the lower park would require extraction of high volumes of groundwater for effective containment, reducing implementability.	Moderate capital cost. Moderate to high O&M cost assuming need for long-term operation and water treatment.	Not applicable or cost effective for limited footprint and volume of impacted groundwater at the Site. Groundwater extraction and treatment technologies are Not Retained.

Table 3-2

Remediation Technology Screening – Groundwater

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Containment	Physical Groundwater Barrier	Low Permeability Sheet Pile Wall	Construction of a low-permeability vertical barrier to alter groundwater flow path away from contaminated soil (or sediment), or contain a contaminant plume. Long-term monitoring of the barrier would be required for either application.	Can be effective for containing impacted groundwater or directing groundwater away from a source or receptor, or providing a barrier to direct groundwater toward a collection and treatment system. Barrier installation requires the ability to predict groundwater flow and address increased discharge in a localized area in intertidal sediment.	Technically implementable using common barrier methods, but installation difficulties are expected along the shoreline at the Site due to buried piles and riprap. Installation along shoreline near railroad track carries additional difficulties. Configurations requiring groundwater extraction would be significantly less implementable due to the long-term operation necessary.	Moderate to high capital and low O&M cost assuming implemented without long-term groundwater extraction and treatment.	Implementation issues and high cost relative to benefit. Creates uncertainty of groundwater flow and need for enhanced sediment remedy at predicted point of discharge. Not retained.
Institutional Controls	**Groundwater Use Restrictions**	**Environmental Covenants**	**Covenant attached to deed would restrict installation of water supply wells and water usage.**	**Effectiveness at preventing exposure to impacted groundwater would depend on enforcement of and compliance with environmental covenants and conditions of well permits.**	**Technically implementable. Specific legal requirements and authority would need to be met.**	**Low capital cost. Negligible O&M cost.**	**Potentially applicable in combination with other technologies. Retained.**

Notes:

COC = contaminant of concern
cPAH = carcinogenic polycyclic aromatic hydrocarbons
MNA = Monitored Natural Attenuation
O&M = operation and maintenance
PAH = polycyclic aromatic hydrocarbons
SVE = soil vapor extraction
VOC = volatile organic compound

Table 3-3

Remediation Technology Screening – Sediment

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Sediment Containment	**Permeable Isolation Cap**	**Conventional Sand Cap**	**Installation of a clean sand cap over contaminated sediment to isolate contaminants. Armoring and habitat substrate would be included, as needed, to resist erosion and satisfy permit requirements.**	**Effective for physical and chemical containment of contaminated sediment. Engineered sand caps are designed using methods developed by the U.S. Army Corps of Engineers (USACE).**	**Technically implementable using standard cap placement methods. Conventional sand caps have been successfully constructed at multiple Puget Sound locations, and other cleanup sites across the country.**	**Moderate capital cost. Potentially low to moderate O&M cost depending on cap maintenance requirements.**	**Common method used to contain contaminated sediment. Retained.**
		Thin Sand Cap	**Installation of a clean sand cap over contaminated sediment to isolate contaminants, using a thinner cap profile than conventional sand caps. Primarily reserved for sediment with lower contaminant concentrations and migration potential.**	**Effective for physical and chemical containment of contaminated sediment. Engineered sand caps are designed using methods developed by the U.S. Army Corps of Engineers (USACE).**	**Technically implementable using standard cap placement methods.**	**Low capital cost. Potentially low to moderate O&M cost depending on cap maintenance requirements.**	**Common method to contain contaminated sediment. Retained.**
	Low-permeability Cap	Engineered Multi-layer Cap with Geomembrane or Clay Liner	Installation of a low-permeability cap over contaminated sediment to isolate contaminants and redirect the point of groundwater discharge to off-shore areas of cleaner sediment. Hydrogeologic conditions would need to be considered. This technology can be implemented using low-permeability clay or bentonite aggregate or a low-permeability synthetic membrane liner. Armoring and habitat substrate would be included, as needed, to resist erosion and satisfy permit requirements.	Effective for physical and chemical containment of contaminated sediment. Can be difficult to predict the altered groundwater flow paths and requires addressing groundwater discharge at the off-shore point of discharge.	Technically implementable, but creates implementability issues for addressing point of discharge farther off-shore. Clay or bentonite can be placed as aggregate farther off-shore, but liner placement may be cost effective in shallower water environments. Would allow total cap thickness to be reduced relative to a conventional sand cap.	Moderate capital cost. Potentially moderate O&M cost depending on cap maintenance requirements	Unpredictable groundwater flow and discharge location reduces overall effectiveness and may result in groundwater discharging through higher concentration sediment. Not retained.
In-situ Sediment Treatment	**Amended/ Reactive Cap**	**Engineered Amended/Reactive Sand Cap**	**Installation of a cap consisting of clean sand mixed with an amendment that is capable of sequestering Site contaminants. Cap amendment materials such as granular organoclay, activated carbon, or granular iron would treat Site contaminants.**	**Effective for treating contaminants in Site sediment. Amendment material would be selected to treat contaminants present in sediment pore water.**	**Technically implementable using standard cap placement methods. Amendment may allow reduced cap thickness and enhance chemical containment where contaminant concentrations are higher.**	**Moderate to high capital cost. Potentially moderate O&M cost depending on cap maintenance requirements.**	**Effective, implementable and has been successfully used at Puget Sound locations. Retained.**
Sediment Removal	**Dredging and Excavation**	**Land-based Excavation**	**Removal of sediment performed from the land at low tide using land-based earthwork equipment such as an excavator. This technology also may be used in conjunction with shoring/sheet pile walls and dewatering techniques to excavate sediment below ordinary high water.**	**Commonly used and effective for removing sediments from nearshore areas.**	**Technically implementable for sediment areas exposed during low tide or using cofferdam type methods to expand the excavation area. Nearshore excavation of sediment is common, but subject to significant administrative constraints.**	**Moderate to high capital cost. Negligible O&M cost.**	**Expected to be effective removal method for nearshore sediments. Retained.**
	Dredging and Excavation	Mechanical Dredging / Barge-based Excavation	Conventional dredging techniques using a barge-mounted crane and bucket or excavator to remove contaminated sediment in submerged areas.	Commonly used and effective at removing sediment in lower intertidal and subtidal areas not reachable from land. Elevated contaminant concentrations in deeper Site sediment increase the risk of mobilizing contaminants (dredge residuals) during construction, thereby reducing the overall effectiveness of this technology.	Technically implementable, but the need to isolate the dredging area to contain mobilized contaminants reduces implementability.	High capital cost. Negligible O&M cost.	Dredging not justified because of the high potential for mobilizing contaminants in deeper sediment, the extensive depth of contamination and the high cost of dredging and disposing a thick sediment profile. Not retained.

Table 3-3

Remediation Technology Screening – Sediment

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Sediment Removal	Dredging and Excavation	Hydraulic Dredging	Pumps are used to remove a mixture of water and sediment.	Effective at removing impacted sediments in locations and conditions in which excavation or dredging methods are ineffective due to obstructions. Generally, not effective if sediment contains larger debris, such as the wood waste .	Technically implementable, although difficult considering the large quantity of wood debris present in sediment. Hydraulic dredging produces a large volume of water.	Moderate to high capital cost. Negligible O&M cost.	Slow process and large volume of water result in reduced implementability and high cost compared to more effective methods applicable to the Site. Not retained.
On-site Management	On-site Reuse	Upland Consolidation under Cap	Sediment would be consolidated within the upland portion of the Site under a cap.	May be effective if sediment is managed to be protective of upland exposure scenarios. Sediment would likely require strengthening to be geotechnically suitable for use as fill.	Technically implementable. Administrative approvals required to consolidate sediment in the upland cap. Would need to consider the effect upland management of sediment would have on park grades/topography.	Low capital cost. Negligible O&M cost. May offset cost for imported fill if park grade needs to be raised.	Marine sediment may be acceptable for consolidation within upland areas of the Site, but suitability is uncertain. Potentially applicable, but not retained for consideration in the FS alternatives.
Off-site Management	**Off-site Disposal**	**Upland RCRA Landfill Disposal**	**Disposal of contaminated sediment at an upland permitted Subtitle D landfill. Sediment may require dewatering and/or stabilization before transport and disposal.**	**This is an effective disposal technology; Site sediment would likely be accepted for disposal at a Subtitle D landfill facility.**	**Technically implementable. Impacted sediment would need to be profiled to receive disposal authorization.**	**Moderate to high capital cost. Negligible O&M cost.**	**Common disposal option for excavated and/or dredged sediments. Retained.**
	Off-site Reuse	Beneficial Reuse	Dredged/excavated materials are recycled and reused as capping material or for other applications. Sediments targeted for reuse would be required to meet applicable standards identified for the proposed reuse.	Treatment would be required to reduce contaminant concentrations to levels compatible with reuse. Effective if treated concentrations meet reuse criteria.	Treatment requirements and other administrative restrictions would likely limit potential reuse.	High capital cost. Negligible O&M cost. Capital cost depends on pre-treatment requirements, but would be expected to exceed cost of Subtitle D disposal.	Treatment requirements and other administrative restrictions significantly increase cost and would likely limit potential reuse. Not retained.
Natural Recovery Processes	**Monitored Natural Recovery (MNR)**	**MNR**	**Reduction of toxicity and bioavailability of contaminants through natural processes such as deposition of clean sediment and biodegradation. Monitoring in the form of periodic sediment sampling is performed to verify natural recovery.**	**Can effectively recover contaminated sediment as a result of natural processes. Generally effective in low-energy depositional setting.**	**Technically implementable. Monitoring would be required to confirm recovery. May require institutional controls during recovery period.**	**Negligible capital cost. Moderate O&M cost.**	**Common technology for sediment with low contaminant concentrations in low energy environments where natural processes can isolate contaminants. Retained.**
		Enhanced Monitored Natural Recovery (EMNR)	**Natural recovery is enhanced by placement of a thin layer of sand. Similar to MNR, monitoring is performed to confirm performance.**	**Can effectively recover contaminated sediment in settings where natural recovery processes act too slowly to achieve cleanup levels within restoration time frame.**	**Technically implementable using standard cap placement methods. Monitoring would be required to confirm recovery rate. May require institutional controls during recovery period.**	**Moderate capital and O&M costs.**	**Common technology for sediment with low contaminant concentrations in low energy environments where natural processes can isolate contaminants. Retained.**

Table 3-3

Remediation Technology Screening – Sediment

South State Street MGP Site
Bellingham, Washington

General Response Action	Type of Remediation Technology	Process Option	Description of Remediation Technology	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Institutional Controls	**Land Use Restrictions**	**Waterway Use Restrictions**	**Restrictions on activities such as dredging, boat anchoring and other activities to prevent contaminant releases and protect capped surfaces.**	**Would be implemented with remedy components that require protection for long-term performance. Enforcement would be required for restrictions to be effective.**	**Technically implementable. Restrictions would need to be compatible with land use.**	**Low capital cost. Negligible O&M cost.**	**Some restrictions are potentially applicable in combination with other technologies. Retained.**
	Access Restrictions	Fencing and Warning Signage	Placement of fencing and warning signs to prevent access and inform the public regarding health risks.	Not effective for remediating contaminants. Enforcement would be required for restrictions to be effective.	Fencing and restricting access is incompatible with current and future use as a public park.	Low capital cost. Negligible O&M cost.	Not consistent with land use. Not Retained.

Notes:

AOC = area of concern

O&M = operation and maintenance

RCRA = Resource Conservation and Recovery Act

Table 3-4

Remediation Technology Screening – Summary of Retained Technologies

South State Street MGP Site
Bellingham, Washington

Technology Type	Process Option/Specific Technology	General Applicability
UPLAND REMEDIATION TECHNOLOGIES		
In-situ Soil Treatment		
Biological Treatment	Bioventing	Effective treatment method for vadose zone soil with contaminants that degrade aerobically. Oxygen is supplied through passive venting of contaminated vadose zone soil to enhance biological degradation of contaminants. Retained for implementation as an add-on element of soil vapor extraction.
Physical Treatment	In-situ Solidification	Contaminants are physically and/or chemically bound within a solidified mass, resulting in reduced leachability of contaminants and reduced groundwater flow through the treated soil.
In-situ Groundwater Treatment		
Biological Treatment	Enhanced Bioremediation	Injection of oxygen, nutrients, or other amendments into groundwater to stimulate microbial activity, resulting in degradation of organic compounds.
Monitored Natural Attenuation	Intrinsic Bioremediation, Adsorption	Reduction of dissolved concentrations through naturally occurring biodegradation processes, as well as other attenuation processes such as dispersion, volatilization, or adsorption.
Removal		
Soil Vapor Extraction	Vertical Soil Vapor Extraction Wells	Extraction of vadose zone soil vapor to remove volatile contaminant mass.
Soil Containment		
Capping	Permeable Vegetated Soil Cap	Placement of a layer of clean, permeable soil over contaminated soil to isolate contaminants while allowing stormwater to infiltrate.
	Low-permeability Cap with Drainage Controls, Vegetated Surface	A low-permeability cap with stormwater collection system would be constructed to contain soil and reduce infiltration of stormwater.
Engineering Controls		
Physical Vapor Barrier	Synthetic Membrane Beneath Buildings	Installation of membrane vapor barrier below building foundations, if constructed in the future, to prevent soil vapor intrusion into indoor air space.

Table 3-4

Remediation Technology Screening – Summary of Retained Technologies

South State Street MGP Site
Bellingham, Washington

Technology Type	Process Option/Specific Technology	General Applicability
Institutional Controls		
Land Use Restrictions	Environmental Covenant	Record an environmental covenant to restrict land use, inform property owners of the presence of potentially hazardous substances and assure the integrity of the remedy (e.g., maintenance of an engineered cap).
Groundwater Use Restrictions	Environmental Covenants	Covenant attached to deed would restrict groundwater extraction and usage.
Access Control	Fencing and Warning Signage	Construct new or maintain existing site fencing and signage to inform public of acceptable activities and control site access by the general public thereby reducing potential exposure to contaminants.
SEDIMENT REMEDIATION TECHNOLOGIES		
In-situ Sediment Treatment		
Amended/Reactive Cap	Engineered Amended/Reactive Sand Cap	Use of amendment(s) in a sediment cap to enhance attenuation of contaminants in underlying contaminated sediment.
Sediment Containment		
Permeable Isolation Cap	Conventional Sand Cap	Placement of a clean sand cap at least 2-feet-thick in areas of contaminated sediment. Cap construction would include armoring as needed to prevent erosion of cap material.
	Thin Sand Cap	Placement of a thin sand cap (approximately 1-foot thick) in areas where chemical containment can be achieved with this capping thickness (typically areas with lower contaminant concentrations and/or less mobile contaminants).
Sediment and Debris Removal		
Sediment Removal	Land-based Excavation	Excavation of nearshore sediment, primarily in the intertidal zone, during low tides using equipment such as an excavator. Use of cofferdam-like structures can extend the work window and footprint of nearshore sediment excavation.
Upland Disposal	Off-site Landfill Disposal	Disposal of excavated sediment at a RCRA facility. Dewatering likely required prior to transport off-site for disposal.

Table 3-4

Remediation Technology Screening – Summary of Retained Technologies

South State Street MGP Site
Bellingham, Washington

Technology Type	Process Option/Specific Technology	General Applicability
Natural Recovery Processes		
Natural Recovery	Monitored Natural Recovery	Reduction of toxicity and bioavailability of contaminants through natural processes such as deposition of clean sediment and biodegradation.
Natural Recovery (Continued)	Enhanced Natural Recovery	The rate of natural recovery is enhanced by placement of a thin layer of sand.
Institutional Controls		
Land Use Restrictions	Waterway Use Restrictions	Regulations on activities such as dredging, boat anchoring and other activities to prevent exposure and contaminant mobility and protect capped surfaces.

Notes:

RCRA = Resource Conservation and Recovery Act

Table 4-1

Common Element Evaluation

South State Street MGP Site
Bellingham, Washington

Common Element	Alternative	Description of Common Element Option	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Remaining Gas Holder Structure	Leave in place	Leave the gas holder in place, remove residual tar from the exterior, and remove and dispose of contaminated material from inside the gas holder. Close the top of the gas holder to prevent access. Implement selected cleanup action as close to gas holder as practical while maintaining integrity of foundation.	This option would be effective at preventing park user exposures to contaminated media on the exterior of the gas holder, and prevent future releases of contaminated material that is in the gas holder.	Implementable using common construction methods. Would need to consider approaches to safely implement selected cleanup action close to gas holder foundation. Leaving gas holder in place would limit the footprint of other upper park cleanup components.	Moderate cost relative to other options, primarily associated with removal and disposal of gas holder contents.	Presence of gas holder would limit footprint of other upper park cleanup components. Not selected.
	Remove Gas Holder and Contents	**Remove and dispose of contaminated material inside the gas holder and demolish the remaining above-ground gas holder structure. Implement selected cleanup action across the footprint of the removed gas holder.**	**Removing the remaining above-ground gas holder structure would reduce the risk of potential exposures to chemicals on and in the gas holder and enable the expansion of other remedy components throughout the gas holder footprint.**	**Implementable using common demolition and backfilling methods.**	**Moderate cost relative to other options, but at higher certainty that additional action will not be required.**	**Compatible with park use and facilitates implementation of other remedy components. Selected option.**
Steep Slope Between Upper and Lower Park	**Monitoring and Institutional Controls**	**Cover limited areas of bare soil with clean soil and/or vegetation to the extent practicable. Remove and/or cap loose MGP-related debris, if present. Limit access to the slope using fencing. Monitor the slope for continued stability, vegetated cover, lack of soil erosion and access limitations.**	**The steep, heavily vegetated slope currently inhibits soil erosion and access by park users. Long-term effectiveness would be enhanced by monitoring and additional planting if needed, all of which would be memorialized in an institutional control.**	**Easily implemented.**	**Low cost associated with additional fencing, periodic monitoring and limited planting, if needed.**	**This option maintains the current low risk of exposure to contamination on the slope without removing mature vegetation that enhances the park experience and slope stability. This option is selected over more aggressive approaches that would require removal of mature vegetation and construction of an engineered slope.**
	Excavate and Reconstruct South Portion of Slope	The south half of the slope, where vegetation is limited to shrubs and blackberries, would be grubbed and some or all of the soil above bedrock would be excavated and disposed off-site. The excavated slope would be reconstructed and likely include engineered features (e.g. retaining wall) for slope stability. Revegetation options would be constrained by the nature of the engineered slope.	Removal of contaminated soil would mitigate potential exposures with greater certainty.	Excavating soil on the slope would be difficult due to limited space for equipment and the proximity of active railroad tracks at the toe of the slope. Reconstructed slope would require engineering features to address slope stability.	Higher cost relative to the monitoring option. Construction methods would cost more than performing similar work in relatively level portions of the upper and lower park.	The reduction in exposure potential relative to current conditions does not offset the risk of destabilizing the slope, anticipated higher cost, park disruption and decrease in park aesthetics (e.g. retaining wall, and limited vegetation options). Not selected.

Table 4-1

Common Element Evaluation

South State Street MGP Site
Bellingham, Washington

Common Element	Alternative	Description of Common Element Option	Effectiveness of Remediation Technology	Implementability of Remediation Technology	Relative Cost of Remediation Technology	Screening Results
Steep Slope Between Upper and Lower Park	Excavate and Reconstruct Entire Slope	The full extent of the slope between the upper and lower park would be grubbed and some or all of the contaminated soil above bedrock would be excavated and disposed off-site. The excavated slope would be reconstructed as described above, but more aggressive geotechnical engineering solutions would be required because the north part of the slope is steeper.	Removal of contaminated soil would mitigate potential exposures with greater certainty.	Excavating soil on the slope would be difficult due to the limited space for equipment and the proximity of active railroad tracks at the toe of the slope. Reconstructed slope would require engineering features to address slope stability. Due to slope geometry, reconstruction of the northern part of the slope would require engineered solutions that are less desirable than the existing mature vegetation (including large trees).	Highest of the slope remedy options to overcome implementability issues and to ensure long term slope stability.	The reduction in exposure potential relative to current conditions does not offset the risk of destabilizing the slope, anticipated higher cost, park disruption and decrease in park aesthetics (e.g. retaining wall, and limited vegetation options). Not selected.
Railroad Right-of-Way	**Institutional Controls or Administrative Mechanisms**	**Institutional controls or administrative mechanisms would be implemented to address subsurface contaminated media likely present within the footprint of the BNSF railroad right-of-way.**	**Current railroad ballast, active operations and access controls provide a significant barrier to exposures. Institutional controls or administrative mechanisms would be used to ensure these controls remain in place.**	**Easily implemented.**	**Limited costs compared to the overall cleanup action.**	**Selected option for addressing contamination likely present within railroad right-of-way.**
Remnant Piling in Marine Unit	**Remove Remnant Piling**	**Remaining piling within the area of the cleanup action would be removed and disposed off-site, prior to sediment cap placement. Specific pile removal methods will be determined during remedy design and permitting.**	**Removing piling eliminates an ongoing source of contamination to the marine environment and facilitates efficient capping of contaminated sediment.**	**Implementable using common pile removal and disposal methods.**	**Moderate direct costs relative to cost of overall cleanup action.**	**Compatible with park use and facilitates implementation of other remedy components. Selected option.**

Note:

Bold indicates the selected option.

Table 4-2

Summary of Remedial Alternatives

South State Street MGP Site
Bellingham, Washington

AREA		Alternative 1 Soil and Sediment Cap with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Cap and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Cap and Sediment Cap and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
Description of Alternative		Construct a permeable vegetated soil cap in the upland where soil concentrations exceed direct-contact remediation levels for park users. Address groundwater using monitored natural attenuation. Construct a sand cap in the intertidal and shallow subtidal zones; potentially increase cap thickness or use amendments closest to shore, as needed. Utilize natural recovery technologies in deeper subtidal zone.	Construct a permeable vegetated soil cap in the upland to address direct-contact risk. Treat organic contaminants in groundwater between the pocket beach and the slope using enhanced bioremediation, with monitored natural attenuation used elsewhere. Construct a sand cap in the intertidal and shallow subtidal zones; potentially increase cap thickness or use amendments closest to shore, as needed. Utilize a thin sand cap and natural recovery technologies in deeper subtidal zone.	Construct a low permeability cap in the upland to eliminate direct-contact risk, stormwater infiltration and groundwater flux from the upland to marine units. Treat groundwater using monitored natural attenuation. Construct a sand cap in the intertidal zone and an expanded portion of the subtidal zone; potentially increase cap thickness or use amendments closest to shore, as needed. Utilize a thin sand cap and natural recovery technologies in deeper subtidal zone.	Construct a permeable vegetated soil cap in the upland to address direct-contact risk. Treat vadose zone soil with SVE and bioventing (upper park). Treat organic contaminants in groundwater with enhanced bioremediation and monitored natural attenuation (upper and lower park). Excavate and dispose nearshore intertidal sediment. Construct a sand cap in the intertidal and shallow subtidal zones. Utilize natural recovery technologies in deeper subtidal zone.	Utilize in-situ solidification (ISS) in upper park to reduce leaching to seasonal (perched) groundwater and generation of soil vapors. Construct a permeable vegetated soil cap in upper and lower park to address direct-contact risk. Treat groundwater in lower park utilizing enhanced bioremediation (TPH, VOCs and PAHs to a lesser extent). Construct a conventional sand cap in intertidal and broader subtidal areas. Utilize natural recovery technologies in remaining subtidal areas with lower concentrations.
Soil	Upper Park	▪ Permeable vegetated soil cap where shallow soil exceeds park user remediation levels. ▪ Construct a shoreline protection revetment along the marging of the Lower Park that is outside the footprint of sediment capping to prevent coastal erosion of shoreline soil. ▪ Institutional and engineering controls to maintain integrity of the cleanup action and prevent future exposures (e.g. land use restrictions, cap maintenance requirements, vapor intrusion mitigation for future buildings).	▪ Permeable vegetated soil cap to prevent direct contact where soil exceeds MTCA cleanup levels for unrestricted land use (excluding the steep slope).Construct a shoreline protection revetment, as in Alternative 1 ▪ Institutional and engineering controls to maintain integrity of the cleanup action and prevent future exposures.	▪ Low permeability vegetated soil cap to prevent direct contact across entire area where soil exceeds MTCA cleanup levels for unrestricted land use (excluding the steep slope). ▪ Stormwater falling on the cap would be collected and managed. ▪ Construct a shoreline protection revetment, as in Alternative 1 ▪ Institutional and engineering controls to maintain integrity of the cleanup action and prevent future exposures.	▪ SVE and bioventing would target TPH and VOCs (PAHs to lesser degree) in vadose zone soil. ▪ Permeable vegetated soil cap to prevent direct contact where soil exceeds MTCA cleanup levels for unrestricted land use (excluding the steep slope). ▪ Institutional controls to maintain integrity of the cleanup action and prevent future exposures.	▪ ISS treatment of soil in upper park to reduce leaching to seasonal perched groundwater and generation of soil vapors. ▪ Permeable vegetated soil cap to prevent direct contact where soil exceeds MTCA cleanup levels for unrestricted land use (excluding the steep slope). ▪ Institutional controls to maintain integrity of the cleanup action and prevent future exposures.
	Lower Park				▪ Permeable vegetated soil cap and institutional controls (as above). ▪ Construct a shoreline protection revetment, as in Alternative 1	▪ Permeable vegetated soil cap and institutional controls (as above). ▪ Construct a shoreline protection revetment, as in Alternative 1

Table 4-2

Summary of Remedial Alternatives

South State Street MGP Site
Bellingham, Washington

	AREA	Alternative 1 Soil and Sediment Cap with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Cap and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Cap and Sediment Cap and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
Groundwater	Upper Park	▪ Monitored natural attenuation. ▪ Institutional controls (groundwater use restrictions).	▪ Monitored natural attenuation. ▪ Institutional controls (groundwater use restrictions).	▪ Reduce stormwater infiltration, and groundwater flow, using low-permeability upland cap. ▪ Monitored natural attenuation. ▪ Institutional controls (groundwater use restrictions).	▪ Enhanced bioremediation will target TPH and VOCs (PAHs to lesser degree). ▪ Monitored natural attenuation. ▪ Institutional controls (groundwater use restrictions).	▪ ISS to reduce contaminant leaching when groundwater is seasonally present. ▪ Institutional controls (groundwater use restrictions).
	Lower Park		▪ Enhanced bioremediation would target TPH, and VOCs (PAHs to lesser degree) in upland groundwater adjacent to northern shoreline. ▪ Monitored natural attenuation in other portions of upland unit. ▪ Institutional controls (groundwater use restrictions).			▪ Enhanced bioremediation for TPH and VOCs (PAHs to lesser degree). ▪ Institutional controls (groundwater use restrictions).
Sediment	Note: All sediment alternatives would achieve compliance with SMS benthic criteria and human health (direct contact) criteria on a point-by-point basis at the time construction is completed. Alternatives 1,2 and 4 would achieve Site-wide compliance with the human health (bioaccumulation) cleanup level on a SWAC basis within an estimated 10-year (or less) period. Alternatives 3 and 5 would achieve Site-wide compliance with the human health (bioaccumulation) cleanup level on a SWAC basis at the time construction is completed.					
	Intertidal and Shallow Subtidal[1]	▪ Conventional sand cap at (and slightly beyond) locations with cPAH concentrations exceeding the upper remediation level.[2] ▪ Modify cap thickness and/or use amendments in nearshore (pocket beach) area, as needed, to increase contaminant attenuation.	▪ Same as Alternative 1.	▪ Conventional sand cap the same as Alternatives 1 and 2, but with the addition of a thin sand cap in the remaining area with cPAH concentrations between the lower and upper remediation levels.	▪ Same as Alternative 1, but with the addition of nearshore (intertidal) sediment excavation in pocket beach area. Extend the conventional cap into the excavation area. ▪ Off-site transport and disposal of excavated sediment.	▪ Nearshore sediment excavation and off-site disposal as in Alternative 4. ▪ Conventional sand cap in all areas with cPAH concentrations exceeding the lower remediation level (including the nearshore excavation area).
	Deeper Subtidal	▪ ENR in areas with cPAH concentrations exceeding the lower remediation level.[2] ▪ MNR in remaining subtidal areas (cPAHs < lower remediation level).	▪ Thin sand cap in areas with cPAH concentrations exceeding the upper remediation level. ▪ ENR in areas with cPAH concentrations between the lower and upper remediation levels. ▪ MNR in remaining subtidal areas (cPAHs < lower remediation level).	▪ Conventional sand cap in areas with cPAH concentrations exceeding the upper remediation level. ▪ Thin sand cap in areas with cPAH concentrations between the lower and upper remediation levels. ▪ MNR in remaining subtidal areas (cPAHs < lower remediation level).	▪ Same as Alternative 1.	▪ Conventional sand cap in areas with cPAH concentrations exceeding the lower remediation level. ▪ MNR in remaining subtidal areas (cPAHs < lower remediation level).

Notes:

[1]For purposes of this discussion, the boundary between shallow subtidal and deeper subtidal is approximately -10 ft MLLW.

[2]Use of an active remedy in areas exceeding the lower remediation level (345 µg/kg dw) would achieve SWAC-based compliance with the cPAH cleanup level at the time the remedy is completed.
Use of an active remedy in areas exceeding the upper remediation level (965 µg/kg dw) would achieve SWAC-based compliance with the cPAH cleanup level in 10 years.

dw = dry weight
ENR = enhanced natural recovery
MNR = monitored natural recovery
ISS = In-situ solidification
RAL = remedial action level
SVE = soil vapor extraction
PAHs = polycyclic aromatic hydrocarbons
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds

Table 5-1

Summary of MTCA Remedial Alternatives Evaluation

South State Street MGP Site
Bellingham, Washington

Alternative, Description and Evaluation Criteria	Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
1. Meets Cleanup Action Objectives (WAC 173-340-360[2][a]) – MTCA Criteria Specific to Upland Cleanup	Yes	Yes	Yes	Yes	Yes
Protection of Human Health and the Environment	Yes – This alternative would protect human health and the environment using a combination of containment, natural attenuation, and institutional controls. Upland and marine capping methods would reduce the risk of human and ecological exposures to site contaminants. ENR and MNR would reduce the risk of exposures where contaminant concentrations in sediment are lower and natural recovery processes are expected to be effective. Institutional controls and long-term monitoring would help ensure protectiveness of the remedy.	Yes – This alternative would protect human health and the environment using a combination of containment, groundwater treatment, natural attenuation, and institutional controls. The overall protectiveness of this alternative is increased by the more extensive use of upland capping and the use of in situ groundwater treatment in the upland and more extensive capping in portions of the subtidal zone with higher contaminant concentrations. Institutional controls and long-term monitoring would help ensure protectiveness of the remedy.	Yes – This alternative would protect human health and the environment using a combination of containment, reduced groundwater recharge, natural attenuation, and institutional controls. Upland and marine caps would reduce contaminant transport in groundwater, and reduce the risk of human and ecological contaminant exposures. The expanded footprint of subtidal sediment capping eliminates the reliance on natural recovery processes, resulting in compliance at the time construction is completed. Institutional controls and long-term monitoring would help ensure protectiveness of the remedy.	Yes – This alternative would protect human health and the environment using a combination of nearshore sediment removal, containment, soil and groundwater treatment, natural attenuation, and institutional controls. Upland and marine capping technologies would be designed to reduce the risk of human and ecological contaminant exposures. Soil and groundwater treatment and nearshore sediment removal would increase protectiveness by removing and destroying some contaminants. Institutional controls and long-term monitoring would help ensure protectiveness of the remedy.	Yes – This alternative would protect human health and the environment using a combination of nearshore sediment removal, containment, soil and groundwater treatment, natural attenuation, and institutional controls. Upland and marine capping technologies would be designed to reduce the risk of human and ecological contaminant exposures. Soil and groundwater treatment would increase the protectiveness by sequestering or destroying some site contaminants. The extensive intertidal and subtidal sediment cap eliminates reliance on natural recover processes, resulting in compliance at the time construction is completed. Institutional controls and long-term monitoring would help ensure protectiveness of the remedy.
Compliance with Cleanup Standards	Yes - This alternative utilizes containment (capping) to prevent direct exposure to contaminants exceeding cleanup levels. The upland cap footprint is based on a park user exposure scenario. A conditional point of compliance would likely be required for groundwater. Compliance would rely on long-term operation and maintenance of containment systems and institutional controls.	Yes - Although this alternative utilizes in situ treatment, compliance with cleanup standards primarily results from the use of containment (capping). The upland cap footprint is based on MTCA cleanup levels for unrestricted land use. A conditional point of compliance would likely be required for groundwater. Compliance would rely on long-term operation and maintenance of containment systems and institutional controls.	Yes – This alternative utilizes containment (capping) to prevent direct exposure to contaminants exceeding cleanup levels. The upland cap footprint is based on MTCA cleanup levels for unrestricted land use. A conditional point of compliance would likely be required for groundwater. Compliance would rely on long-term operation and maintenance of containment systems and institutional controls.	Yes – Although this alternative utilizes upland in situ treatment and sediment removal, compliance with cleanup standards primarily results from the use of containment (capping). The upland cap footprint is based on MTCA cleanup levels for unrestricted land use. A conditional point of compliance would likely be required for groundwater. Compliance would rely on long-term operation and maintenance of containment systems and institutional controls.	Yes – Although this alternative utilizes upland in situ treatment and sediment removal, compliance with cleanup standards primarily results from the use of containment (capping). The upland cap footprint is based on MTCA cleanup levels for unrestricted land use. A conditional point of compliance would likely be required for groundwater. Compliance would rely on long-term operation and maintenance of containment systems and institutional controls.
Compliance with Applicable State and Federal Regulations	Yes	Yes	Yes	Yes	Yes
Provision for Compliance Monitoring	Yes – Alternative includes provisions for compliance monitoring.	Yes – Alternative includes provisions for compliance monitoring.	Yes – Alternative includes provisions for compliance monitoring.	Yes – Alternative includes provisions for compliance monitoring.	Yes – Alternative includes provisions for compliance monitoring.

Table 5-1

Summary of MTCA Remedial Alternatives Evaluation

South State Street MGP Site
Bellingham, Washington

Alternative, Description and Evaluation Criteria	Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
2. Restoration Timeframe for Upland Cleanup (WAC 173-340-360[4])	Restoration timeframe for the upland unit includes design, permitting and construction of the remedy. Exposure pathways would be eliminated when construction is completed. Future use of upland as a City park would facilitate the maintenance of institutional controls. Estimated 5-year restoration timeframe for this alternative is considered reasonable.	Same as Alternative 1. Restoration timeframe is considered reasonable.	Same as Alternative 1. Restoration timeframe is considered reasonable.	Same as Alternative 1. Restoration timeframe is considered reasonable.	Same as Alternative 1. Restoration timeframe is considered reasonable.
3. Minimum Requirements (WAC 173-204-570[3]) – SMS Criteria Specific to Sediment Cleanup					
Protection of Human Health and the Environment (equivalent to Protection of Human Health and the Environment under MTCA, as described above)	Yes	Yes	Yes	Yes	Yes
Compliance with ARARs (equivalent to Compliance with ARARs under MTCA, as described above)	Yes	Yes	Yes	Yes	Yes
Compliance with Cleanup Standards (equivalent to Compliance with Cleanup Standards under MTCA, as described above)	Yes – benthic risks are addressed on a point-by-point basis and risks associated with bioaccummulative compounds (cPAHs) are addressed on an area-weighted basis.	Yes – Same as Alternative 1	Yes – Same as Alternative 1	Yes – Same as Alternative 1	Yes – Same as Alternative 1
Use of Permanent Solutions	Yes	Yes	Yes	Yes	Yes
Reasonable Restoration Timeframe	Yes – Cleanup standards achieved immediately following construction in the actively remediated area. Design and construction estimated to take 5 years. Cleanup standard for cPAHs are expected to be achieved within 10 years of remedy construction on a SWAC basis as a result of natural recovery processes.	Yes – Cleanup standards achieved immediately following construction in the actively remediated area. Design and construction estimated to take 5 years. Cleanup standard for cPAHs are expected to be achieved within 10 years of remedy construction on a SWAC basis as a result of natural recovery processes.	Yes – Cleanup standards expected to be achieved at the time construction is completed. Design and construction estimated to take 5 years.	Yes – Cleanup standards achieved immediately following construction in the actively remediated area. Design and construction estimated to take 5 years. Cleanup standard for cPAHs are expected to be achieved within 10 years of remedy construction on a SWAC basis as a result of natural recovery processes.	Yes – Cleanup standards expected to be achieved at the time construction is completed. Design and construction estimated to take 5 years.

Table 5-1
Summary of MTCA Remedial Alternatives Evaluation
South State Street MGP Site
Bellingham, Washington

Alternative, Description and Evaluation Criteria	Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
Source Control – Preference for alternatives with source control measures that are more effective at reducing the accumulation of contamination	This alternative would prevent the erosion and transport of contaminated upland soil to the marine unit. Resuspension and deposition of contaminated intertidal sediment would be mitigated using an engineered cap.	This alternative would prevent the erosion and transport of contaminated upland soil to the marine unit. In situ groundwater treatment would marginally increase source control although these contaminants in upland media likely pose little risk to surface water or sediment. Resuspension and deposition of contaminated intertidal sediment would be mitigated using an engineered cap.	This alternative would prevent the erosion and transport of contaminated upland soil to the marine unit and reduce groundwater (and contaminant) flux. Resuspension and deposition of contaminated intertidal sediment would be mitigated using an engineered cap.	This alternative would remove shallower contaminated sediment from nearshore intertidal areas, where groundwater flux is expected to be greatest. The upland treatment components would reduce the potential for contaminant migration. The upland and intertidal sediment caps would reduce the risk of soil erosion, and sediment resuspension and deposition.	This alternative would remove shallower contaminated sediment from nearshore intertidal areas, where groundwater flux is expected to be greatest. The upland treatment components would reduce the potential for contaminant migration. The upland and intertidal sediment caps would reduce the risk of soil erosion, and sediment resuspension and deposition.
Use of Sediment Recovery Zone	No sediment recovery zone will be required for this alternative.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
Compliance with Institutional Controls – Preference for alternatives relying on controls with a demonstrated ability to limit or prevent exposure and ensure integrity of remedy	Institutional controls, such as no-anchor zones, are anticipated components of all alternatives and are implementable and effective. Monitoring requirements and contingency plans will be included as administrative controls in the cleanup action plan to ensure the protectiveness of the sediment cap, ENR and MNR areas.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
Public Review	Public review opportunities will be provided as part of the RI/FS, CAP and permitting processes.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
Compliance Monitoring to Ensure Remedy Effectiveness – Preference for alternatives with greater ability to monitor effectiveness	This alternative would include provisions for compliance monitoring.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
Provision for Periodic Review	This alternative would include a periodic review of the completed remedy.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1

Table 5-1

Summary of MTCA Remedial Alternatives Evaluation

South State Street MGP Site
Bellingham, Washington

Alternative, Description and Evaluation Criteria	Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
4. Disproportionate Cost Analysis – Criteria in MTCA 173-340-360(3)(f) and SMS 173-204-570(4) (Scored from 1 =Low to 10 = High)					
Protectiveness: *"Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternatives and improvement of the overall environmental quality."*	Score = 4 Alternative 1 achieves a moderately low level of overall protectiveness as a result of capping areas that exceed the park user remediation level in the upland, but no other active remedy components. The sediment remedy relies on natural recovery processes in widespread (subtidal) portions of the marine unit. The use of monitored natural attenuation for groundwater treatment would require data collection to confirm its effectiveness.	Score = 6 Alternative 2 achieves a moderate level of overall protectiveness; higher than Alternative 1 because of the expansion of the upland cap area, addition of in situ groundwater treatment and expansion of the sediment capping footprint (thin cap) in the subtidal zone.	Score = 7 Alternative 3 achieves a moderately high level of overall protectiveness; somewhat higher than Alternative 2 as a result of extensive upland capping where soil exceeds unrestricted land use cleanup levels, the reduction of groundwater (and contaminant) flux, and the use of capping rather than ENR in the subtidal zone. As opposed to Alternatives 1 and 2, Alternative 3 would be expected to achieve compliance with cleanup levels at the time construction is completed; there is no reliance on natural recovery processes.	Score = 6 Alternative 4 achieves a moderate level of protectiveness as a result of extensive upland capping where soil exceeds unrestricted land use cleanup levels and the use of in situ treatment technologies that would reduce contaminant concentrations. Removal of intertidal sediment in the pocket beach area increases the protectiveness of this alternative, but excavation of intertidal sediment comes with a risk of mobilizing contaminants to surface water. Overall, the benefit of more aggressive upland actions and nearshore sediment removal are offset by the widespread reliance on natural recovery processes in the subtidal zone (as with Alternative 1).	Score = 9 Alternative 5 achieves a high level of overall protectiveness. This alternative includes in situ treatment technologies in widespread portions of the upland and an extensive conventional sediment cap. Similar to Alternative 3, this sediment remedy would be expected to achieve compliance with cleanup levels at the time construction is completed; there is no reliance on natural recovery processes.
Permanence: *"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 or irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated."*	Score = 4 Achieves a moderately low level of permanence relative to other alternatives, due to the heavy reliance on containment and natural attenuation processes.	Score = 6 Achieves a moderate level of permanence due to the combined effect of upland groundwater treatment and more robust off-shore capping. Expansion of the upland cap across the majority of the lower park reduces the potential for erosion under potential future sea level rise scenarios, increasing permanence over Alternative 1.	Score = 7 Achieves a moderate level of permanence; higher degree of permanence than Alternative 2 because the upland low-permeability cap would be expected to reduce contaminant transport in groundwater and the more robust sediment capping elements would more permanently contain sediment contaminants.	Score = 7 Achieves a moderately high level of permanence by removing contaminants from soil (SVE), removing contaminants from intertidal sediment (excavation of nearshore sediment) and destroying contaminants in groundwater (bioremediation).	Score = 8.5 Achieves a moderately high level of permanence; higher than Alternative 4 as a result of using ISS to reduce the mobility of contaminants in soil and the use of a more robust sediment capping design

Table 5-1

Summary of MTCA Remedial Alternatives Evaluation

South State Street MGP Site
Bellingham, Washington

Alternative, Description and Evaluation Criteria	Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
Long-term Effectiveness: *"Includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes."*	Score = 4 Achieves a moderately low degree of long-term effectiveness because hazardous substances remain on-site and the alternative relies primarily on natural attenuation processes to reduce contaminant concentrations in groundwater. Capping methods included in the alternative are proven and effective methods of containing contaminants.	Score = 6 Achieves a higher degree of long-term effectiveness than Alternative 1 due to the larger scale of upland capping, the use of upland groundwater treatment, and more robust sediment capping.	Score = 6.5 Achieves a higher degree of long-term effectiveness than Alternative 2 due to the use of a low-permeability upland cap that would reduce groundwater and contaminant flux to the marine unit, and the sediment capping rather than ENR.	Score = 7 Alternative 4 achieves a moderately high level of long-term effectiveness as a result of upland contaminant removal and treatment and intertidal sediment removal, but only scores slightly higher than Alternative 3 due to the reduced scope of sediment capping in Alternative 4.	Score = 8 Alternative 5 achieves a moderately high level of long-term effectiveness as a result of upland contaminant treatment, including groundwater bioremediation and ISS, intertidal sediment removal in pocket beach area, and extensive upland and sediment capping.
Management of Short-term Risks: *"The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks."*	Score = 8 Alternative 1 manages short-term risks to a moderately high degree. Short-term risks are primarily related to handling a high volume of imported fill materials to construct the upland and sediment caps. Most short-term construction risks can be effectively managed through conventional construction means and methods.	Score = 8 Alternative 2 manages short-term risks to a moderately high degree, using construction methods similar to Alternative 1.	Score = 7 Short-term risks associated with construction of Alternative 3 are generally similar to Alternatives 1 and 2. However, the significant larger volume of cap materials required to construct Alternative 3 increases risks associated with transport and placement of cap material.	Score = 6 Alternative 4 manages short-term risks to a moderate degree. In addition to construction of the upland and sediment caps, there are short-term risks associated with nearshore sediment excavation and limited soil disturbance for installation of the SVE and bioventing system in the upland. These short-term risks can be mitigated using construction and monitoring techniques established during design and permitting.	Score = 5 Alternative 5 manages short-term risks to a moderate degree. In addition to the short-term risks associated with Alternative 4, Alternative 5 would utilize ISS in most of the upper park. This would require disturbance of contaminated soil and handling large volumes of a cement-based amendment, all of which would pose additional short-term risk to stormwater. These short-term risks would be addressed using construction and monitoring techniques established during design and permitting.

Table 5-1
Summary of MTCA Remedial Alternatives Evaluation
South State Street MGP Site
Bellingham, Washington

Alternative, Description and Evaluation Criteria	Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery	Alternative 2 In Situ Groundwater Treatment with Soil and Sediment Capping and Natural Attenuation and Recovery	Alternative 3 Low Permeability Upland Capping and Sediment Capping and Natural Attenuation and Recovery	Alternative 4 SVE and Bioremediation, Sediment Removal, with Soil and Sediment Capping	Alternative 5 ISS and Bioremediation, Sediment Removal, with Soil and Sediment Capping
Technical and Administrative Implementability: *"Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions."*	Score = 7 Alternative 1 has a moderately high degree of implementability. The upland and marine caps will require availability of appropriate capping materials, stockpile and equipment staging areas, and vessel loading facilities (for sediment cap). Several Issues associated with construction elements and the use of institutional controls are relatively equal across all alternatives.	Score = 7 Alternative 2 has a moderately high degree of implementability, similar to Alternative 1	Score = 6.5 Alternative 3 has a moderate degree of implementability; slightly lower than Alternative 2 due to the extensive use of a low permeability cap in the upland and the need to manage stormwater that would otherwise infiltrate.	Score = 6 Alternative 4 has a moderate degree of implementability. Relative to Alternatives 1 through 3, the addition of nearshore excavation will require protective measures (e.g. temporary coffer dam) that will add complexity to implementation. The need for SVE equipment in the park setting also will add to implementability challenges.	Score = 5 Alternative 5 has a moderate degree of implementability. The implementability challenges are similar to Alternative 4, except for the added complexity of implementing ISS in the upper park which has limited access and available space.
Consideration of Public Concerns: *"Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site."*	Score = 5 It is anticipated the public will have concerns about the overall level of protectiveness because of the lack of upland treatment technologies and widespread reliance on natural recovery processes in the marine unit.	Score = 7 Alternative 2 is expected to address public concerns to a moderately high degree. The in situ treatment components of this alternative would likely be viewed by the public as increasing protectiveness in comparison to Alternative 1 without significantly detracting from the park setting. The more robust upland and sediment capping scheme also would likely be viewed favorably.	Score = 7.5 Alternative 3 is expected to address public concerns to a moderately high degree; slightly higher than Alternative 2 due to use of a low-permeability upland cap that may considered more reliable to the public, and the use of sediment capping instead of ENR in the marine unit.	Score = 6.5 Alternative 4 is expected to address public concerns to a moderately high degree, but slightly lower than Alternative 3. The added protectiveness of in situ treatment and pocket beach excavation would likely be viewed favorably but the need for SVE equipment in the upper park may detract from the park experience. The widespread use of ENR instead of capping in the marine unit also would likely be viewed unfavorably.	Score = 5 Alternative 5 is expected to address public concerns to a moderate degree. The use of ISS in the upper park would significantly disrupt park use and the neighboring residential property, and potentially cause an unrecoverable change to the park setting (e.g. loss of mature trees).

Notes:

ARAR = applicable or relevant and appropriate requirement
CAP = cleanup action plan
ENR = enhanced natural recovery
MNR = monitored natural recovery
MTCA = Model Toxics Control Act
SMS = Sediment Management Standards
WAC = Washington Administrative Code

Table 5-2

Summary of MTCA Evaluation and Ranking of Cleanup Action Alternatives

South State Street MGP Site
Bellingham, Washington

Alternatives	1		2		3		4		5	
	Soil and Sediment Capping with Natural Attenuation and Recovery		Soil and Sediment Capping with Bioremediation and Natural Attenuation and Recovery		Low Permeability Upland Capping and Sediment Capping with Natural Attenuation and Recovery		SVE, Bioremediation, and Nearshore Sediment Removal with Soil and Sediment Capping		ISS, Bioremediation, and Nearshore Sediment Removal with Soil and Sediment Capping	
Minimum Criteria										
Protection of Human Health and the Environment	Yes		Yes		Yes		Yes		Yes	
Compliance with ARARs	Yes		Yes		Yes		Yes		Yes	
Compliance with Sediment Cleanup Standards	Yes		Yes		Yes		Yes		Yes	
Use of Permanent Solutions	Yes		Yes		Yes		Yes		Yes	
Reasonable Restoration Timeframe	Yes		Yes		Yes		Yes		Yes	
Source Control	Yes		Yes		Yes		Yes		Yes	
Use of Sediment Recovery Zone	No[a]		No[a]		No[a]		No[a]		No[a]	
Compliance with Institutional Controls	Yes		Yes		Yes		Yes		Yes	
Public Review	Yes		Yes		Yes		Yes		Yes	
Monitoring to Ensure Remedy Effectiveness	Yes		Yes		Yes		Yes		Yes	
Provision for Periodic Review	Yes		Yes		Yes		Yes		Yes	
Disproportionate Cost Analysis Relative Benefits Score										
Criteria	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Protectiveness (30%)	4	1.2	6	1.8	7	2.1	6	1.8	9	2.7
Permanence (20%)	4	0.8	6	1.2	7	1.4	7	1.4	8.5	1.7
Long-term Effectiveness (20%)	4	0.8	6	1.2	6.5	1.3	7	1.4	8	1.6
Management of Short-term Risks (10%)	8	0.8	8	0.8	7	0.7	6	0.6	5	0.5
Technical and Administrative Implementability (10%)	7	0.7	7	0.7	6.5	0.65	6	0.6	5	0.5
Consideration of Public Concern (10%)	5	0.5	7	0.7	7.5	0.75	6.5	0.65	5	0.5
Total Score	**32.0**	**4.8**	**40.0**	**6.4**	**41.5**	**6.9**	**38.5**	**6.5**	**40.5**	**7.5**
Disproportionate Cost Analysis										
Estimated Cost[b]	$7,950,000		$9,330,000		$12,100,000		$13,300,000		$20,400,000	
Ratio of Cost Compared to Lowest Cost Alternative[c]	1.0		1.2		1.5		1.7		2.6	
Relative Benefit ÷ Cost (Total Weighted Score ÷ (Cost ÷ $10,000,000)	6.0		6.9		5.7		4.8		3.7	
Costs Disproportionate to Incremental Benefits[d]	No		No		Yes		Yes		Yes	
Practicability of Remedy Based on Test of Disproportionate Cost[e]	Practicable		Practicable		Not Practicable		Not Practicable		Not Practicable	
Remedy Permanent to Maximum Extent Practicable[f]	No		Yes							
Overall Alternative Ranking	2		1							
Ratio of Benefit Compared to Most Permanent Practicable Alternative[g]	0.8		1.0							

Notes

[a] Need for sediment recovery zone will be based on monitoring.

[b] Estimated costs are at FS level, with a range of +50% and -30%. See Appendix DD.

[c] Estimated cost of alternative ÷ estimated cost of Alternative 1, the lowest cost alternative.

[d] Disproportionate Cost Analysis test per WAC 173-340-360(3)(i) is defined as follows: "Costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed

[e] An alternative is considered not practicable if it is disproportionately costly relative to the benefit achieved.

[f] The practicable alternatives are compared; the most permanent, practicable remedy is identified as the preferred alternative.

[g] Weighted benefit of practicable alternative ÷ weighted benefit of the preferred alternative, Alternative 2.

ARAR = applicable or relevant and appropriate requirement

ISS = in situ solidification

MTCA = Model Toxics Control Act

SVE = soil vapor extraction

WAC = Washington Administrative Code

FIGURES

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Legend

South State Street MGP Site

N
W E
S

2,000 0 2,000

Feet

Notes:

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Data Source: Mapbox Open Street Map, 2017

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Vicinity Map

South State Street MGP Site
Bellington, Washington

GEOENGINEERS

Figure 1-1

P:\0\0186890\GIS\MXDs\018689001_F01_VicinityMap_MGP.mxd Date Exported: 08/13/18 by maugust

Legend

- Railroad
- Gravel Path
- Topographic Contours (5ft)
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- Inner Harbor Line
- Site Structures
- Former Gas Holder
- Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Upland Unit Boundary
- Marine Unit Boundary
- Direct Push Soil Boring
- Hand Auger Soil Boring
- Hollow-Stem Auger Soil Boring

Notes:
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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Project North   True North

60   0   60
Feet

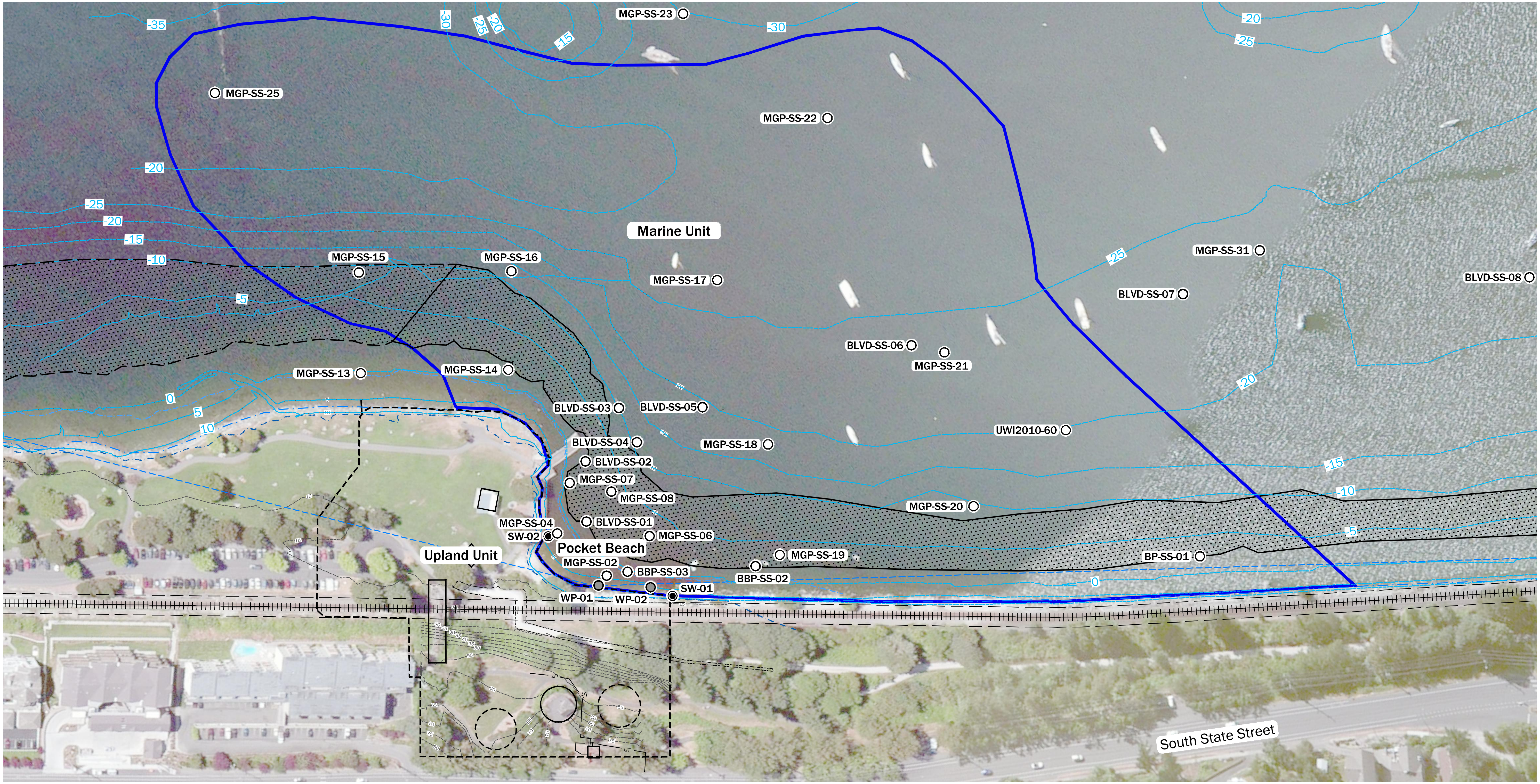
Upland Unit

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 1-2

P:\0\0186890\CAD\01\FS Phase 1\018689001_F01-2_FS Site Units Upland Area.dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 9:23 by tmichaud



Notes:
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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Legend

- Marine Unit Boundary
- Upland Unit Boundary
- Stormwater Sample
- Surface Sediment Sample
- Well Point Sample
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- 15 Bathymetry Contours (5ft)
- 15 Topographic Contours (5ft)
- Surveyed Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Estimated Extent of Eelgrass (Grette and Associates, 2008b)

W S N E Project North

W N S E True North

150 0 150
Feet

Marine Unit

South State Street MGP Site
Bellingham, Washington

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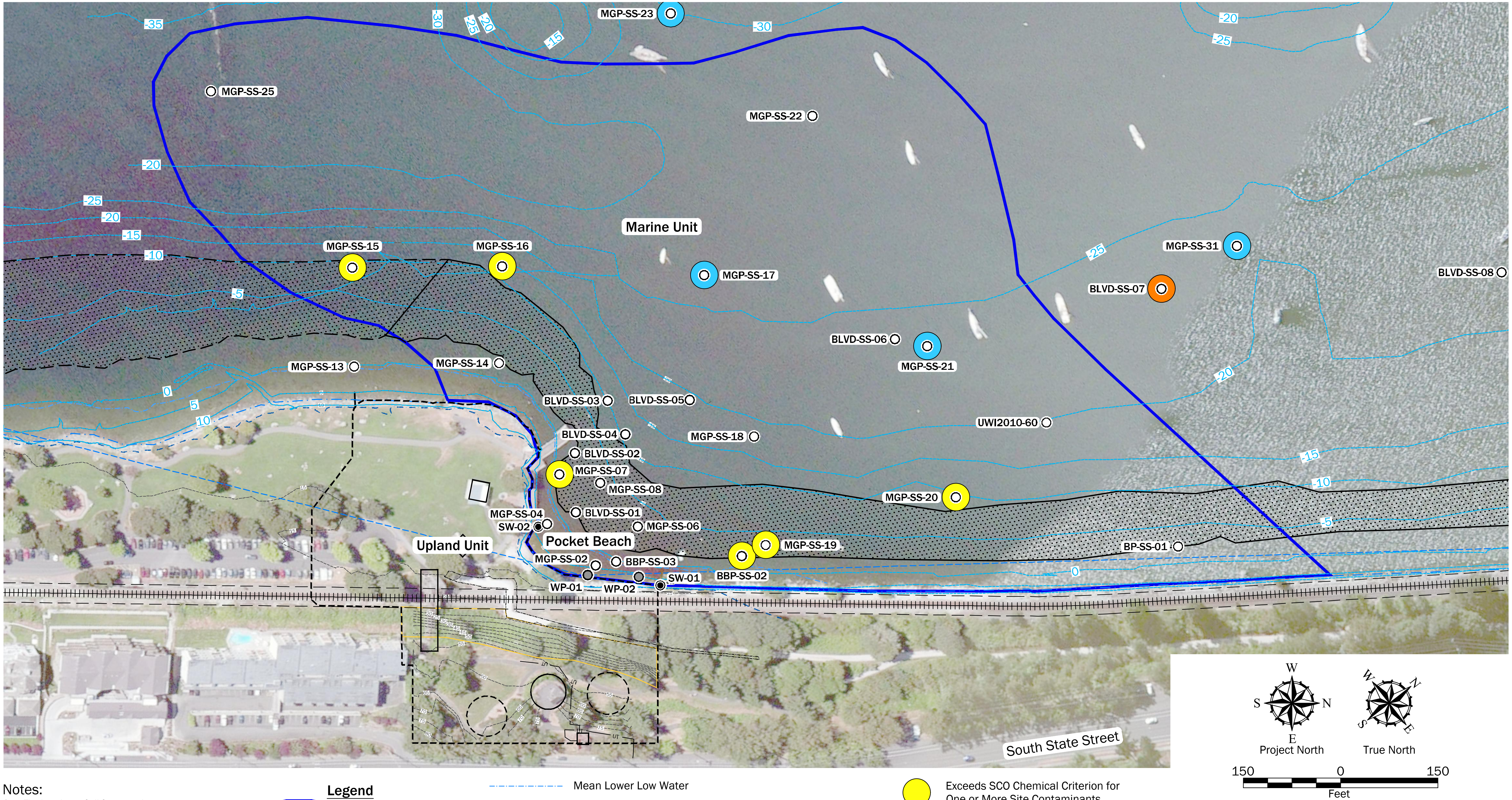
Figure 1-3



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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Legend

- Marine Unit Boundary
- Upland Unit Boundary
- Stormwater Sample
- Surface Sediment Sample
- Well Point Sample
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- Bathymetry Contours (5ft)
- Topographic Contours (5ft)
- Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Approximate Extent of Eelgrass (Grette and Associates, 2008b)
- Exceeds SCO Chemical Criterion for One or More Site Contaminants
- Exceeds SMS Chemical Criterion for Mercury Only (Not Site-Related)
- Exceeds SCO Chemical Criterion for Benzyl Alcohol Only (Not-Site Related)

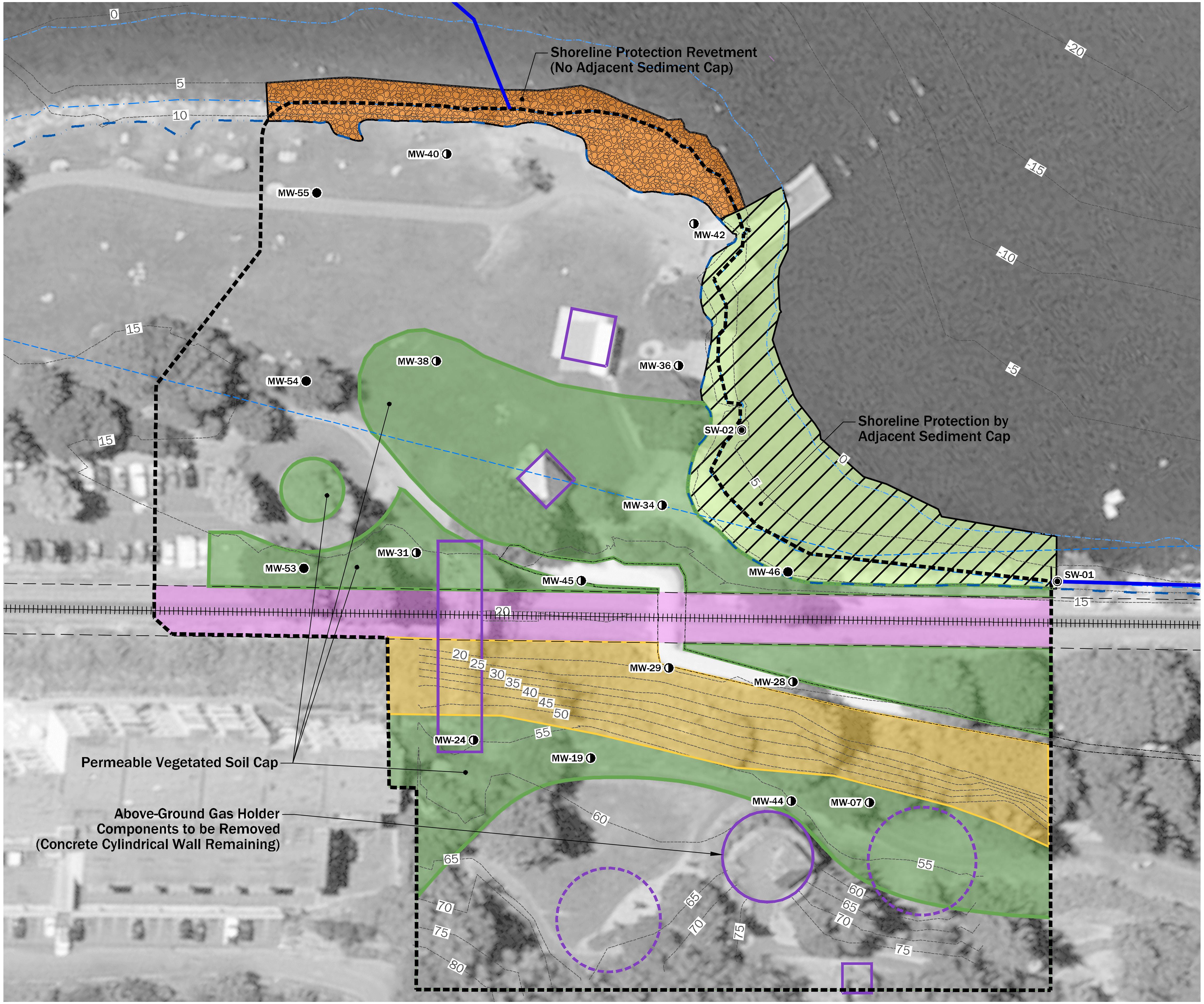
Extent of SMS Benthic Criteria Exceedances in Surface Sediment

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 1-4

P:\0\0186890\CAD\01\FS Phase 1\018689001_F01-4_FS Site Marine Upland Area Extent of SMS Benthic.dwg TAB:F01-4 Date Exported: 08/17/18 - 10:02 by tmichaud



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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

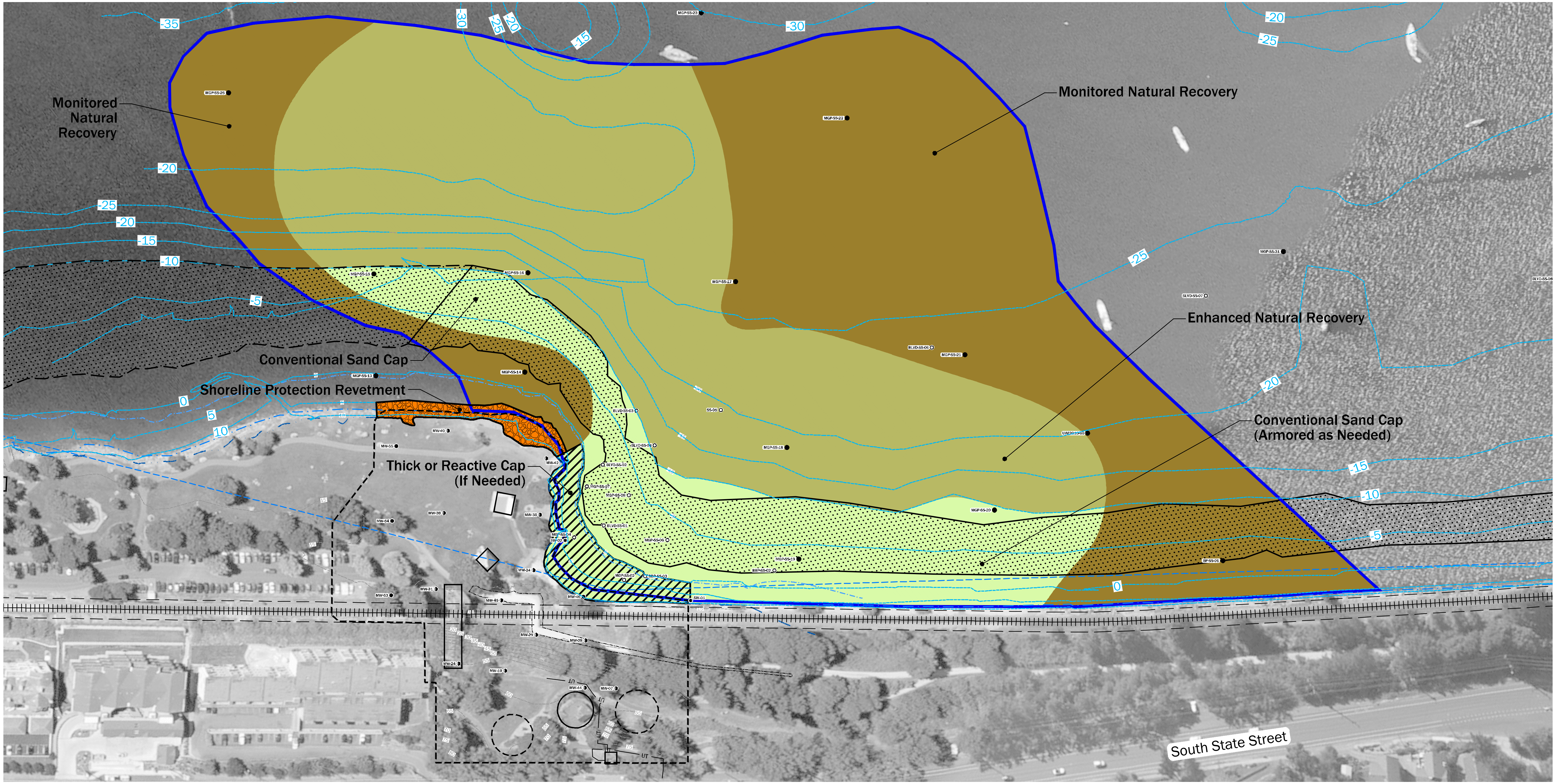
Cleanup Action Alternative 1
Upland Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-1

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-01_Upland Elements (CAA1).dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 9:51 by tmichaud



Notes:

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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Legend

- Conventional Sand Cap (Armored as Needed)
- Cap Modification as Needed (Thick Cap or Reactive Cap)
- Enhanced Natural Recovery
- Monitored Natural Recovery
- Shoreline Protection Revetment
- Marine Unit Boundary
- Upland Unit Boundary
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- 15 Bathymetry Contours (5ft)
- 15 Topographic Contours (5ft)
- Surveyed Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Estimated Extent of Eelgrass (Grette and Associates, 2008b)

W S N E
Project North

W N S E
True North

150 0 150
Feet

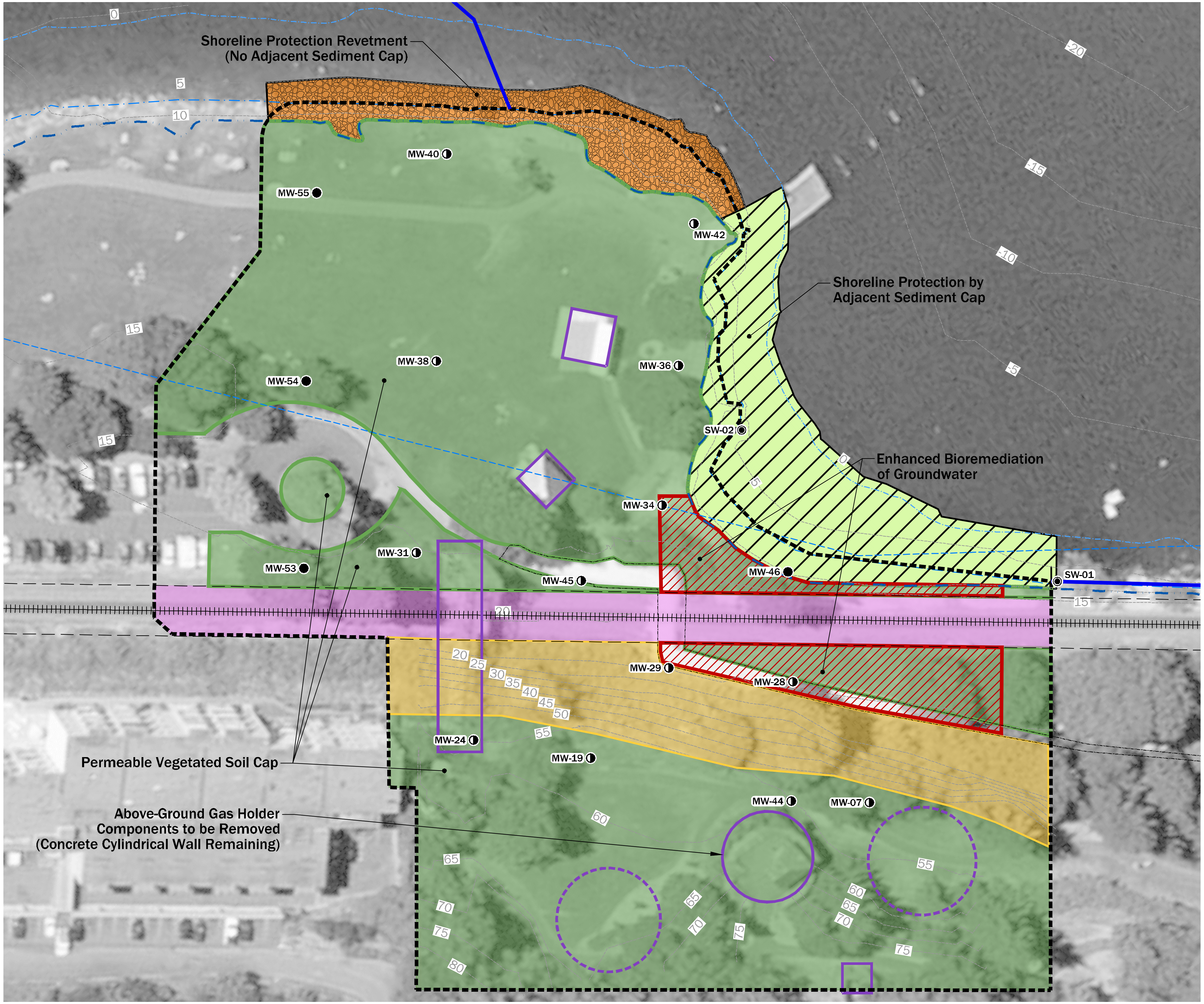
Cleanup Action Alternative 1
Marine Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-2

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-02_Marine Elements [CAA1].dwg TAB:11x17 Landscape Date Exported: 09/11/18 - 11:30 by tmichaud



Legend

- Permeable Vegetated Soil Cap
- Enhanced Bioremediation (Groundwater)
- Shoreline Protection Revetment
- Shoreline Protection Component of Adjacent Sediment Remedy
- Slope Area - Monitor Vegetation and Slope Stability
- Railroad Right-of-Way Institutional Controls
- Site Structures
- Former Gas Holder
- Gravel Path
- Topographic Contours (5ft)
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- Inner Harbor Line
- Upland Unit Boundary
- Marine Unit Boundary

Notes:

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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Project North   True North

60   0   60
Feet

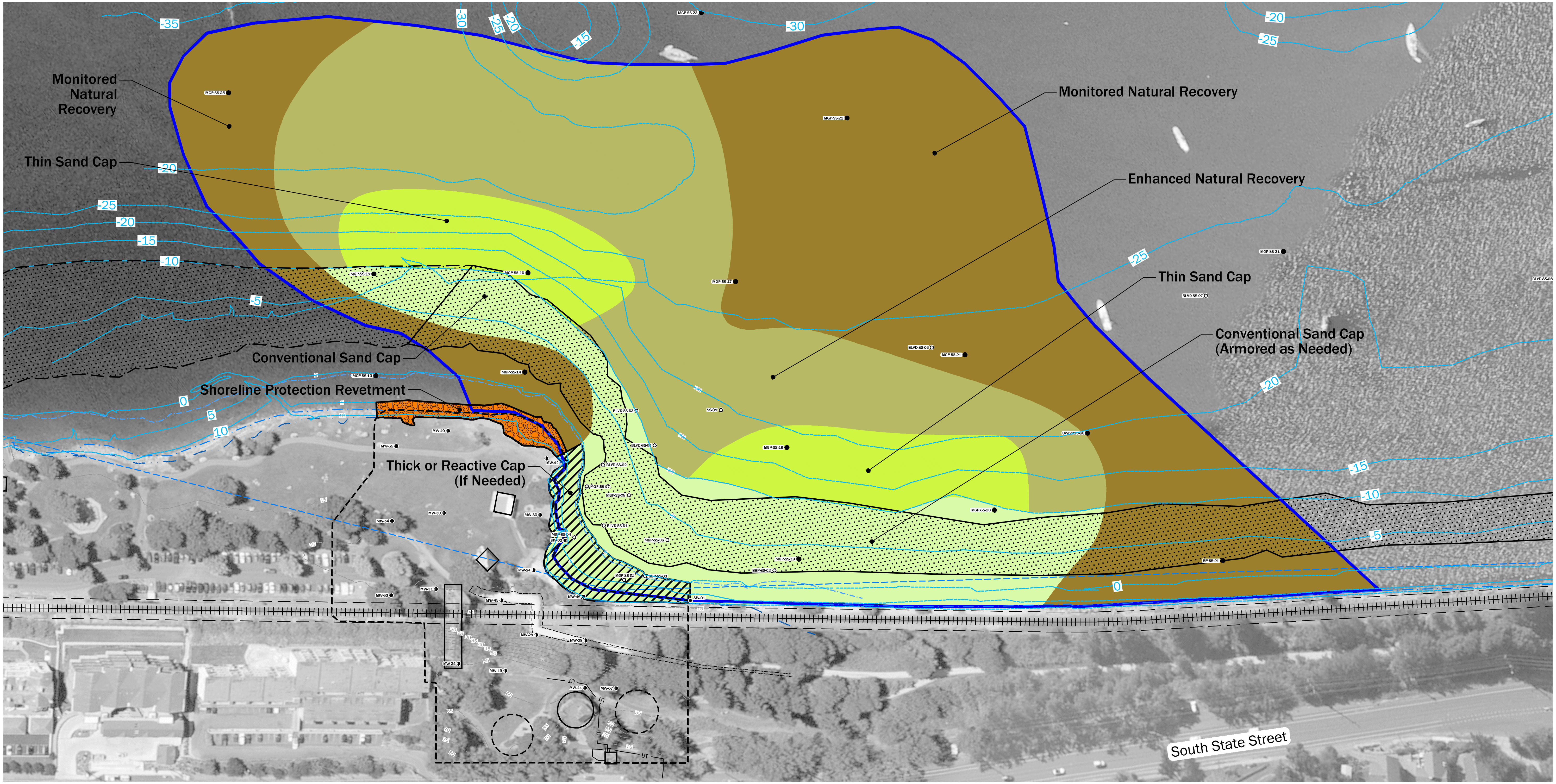
Cleanup Action Alternative 2
Upland Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-3

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-03_Upland Elements (CAA2).dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 9:54 by tmichaud



Legend

- Conventional Sand Cap (Armored as Needed)
- Cap Modification as Needed (Thick Cap or Reactive Cap)
- Thin Sand Cap
- Enhanced Natural Recovery
- Monitored Natural Recovery
- Shoreline Protection Revetment
- Marine Unit Boundary
- Upland Unit Boundary
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- 15 Bathymetry Contours (5ft)
- 15 Topographic Contours (5ft)
- Surveyed Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Estimated Extent of Eelgrass (Grette and Associates, 2008b)

150 0 150
Feet

Project North
True North

Notes:
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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

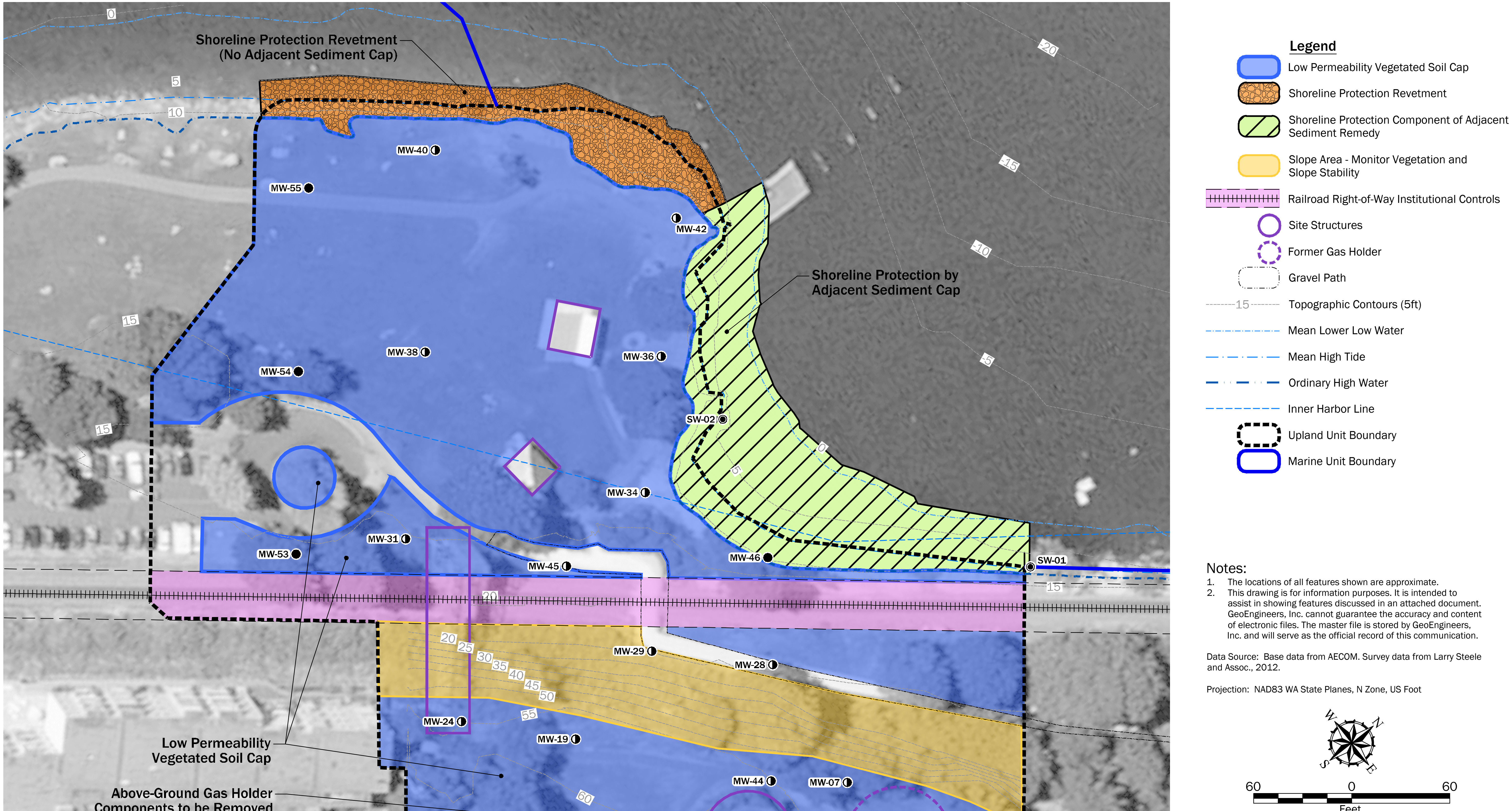
Cleanup Action Alternative 2
Marine Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-4

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-04_Marine Elements (CAA2).dwg TAB:11x17 Landscape Date Exported: 09/11/18 - 11:31 by tmichaud



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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

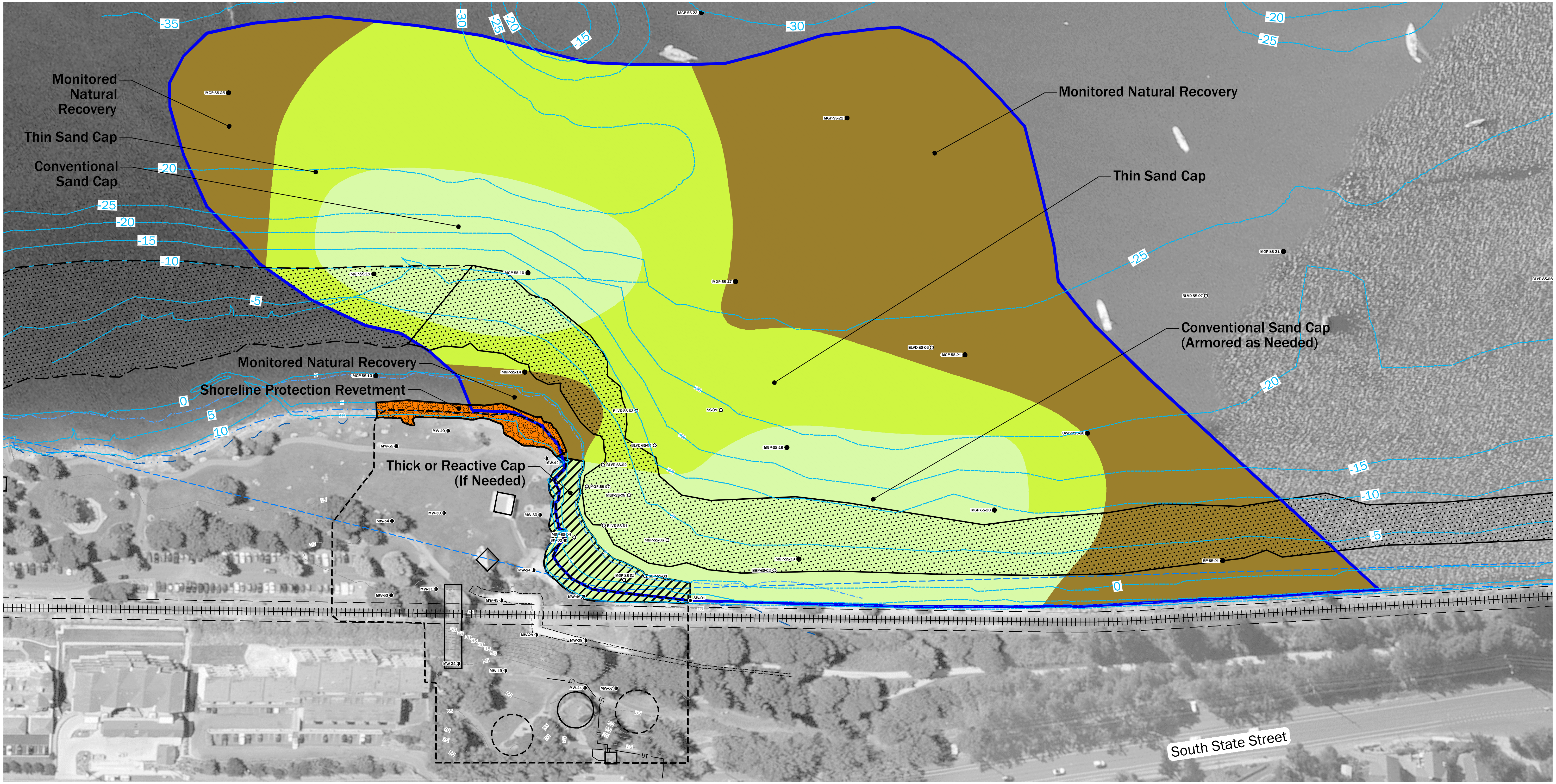
Cleanup Action Alternative 3
Upland Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-5

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-05_Upland Elements (CAA3).dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 9:54 by tmichaud



Legend

- Conventional Sand Cap (Armored as Needed)
- Cap Modification as Needed (Thick Cap or Reactive Cap)
- Thin Sand Cap
- Monitored Natural Recovery
- Shoreline Protection Revetment
- Marine Unit Boundary
- Upland Unit Boundary
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- 15 Bathymetry Contours (5ft)
- 15 Topographic Contours (5ft)
- Surveyed Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Estimated Extent of Eelgrass (Grette and Associates, 2008b)

W S N E
Project North

W N S E
True North

150 0 150
Feet

Notes:

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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Cleanup Action Alternative 3
Marine Unit

SSS MGP Site
Bellingham, Washington

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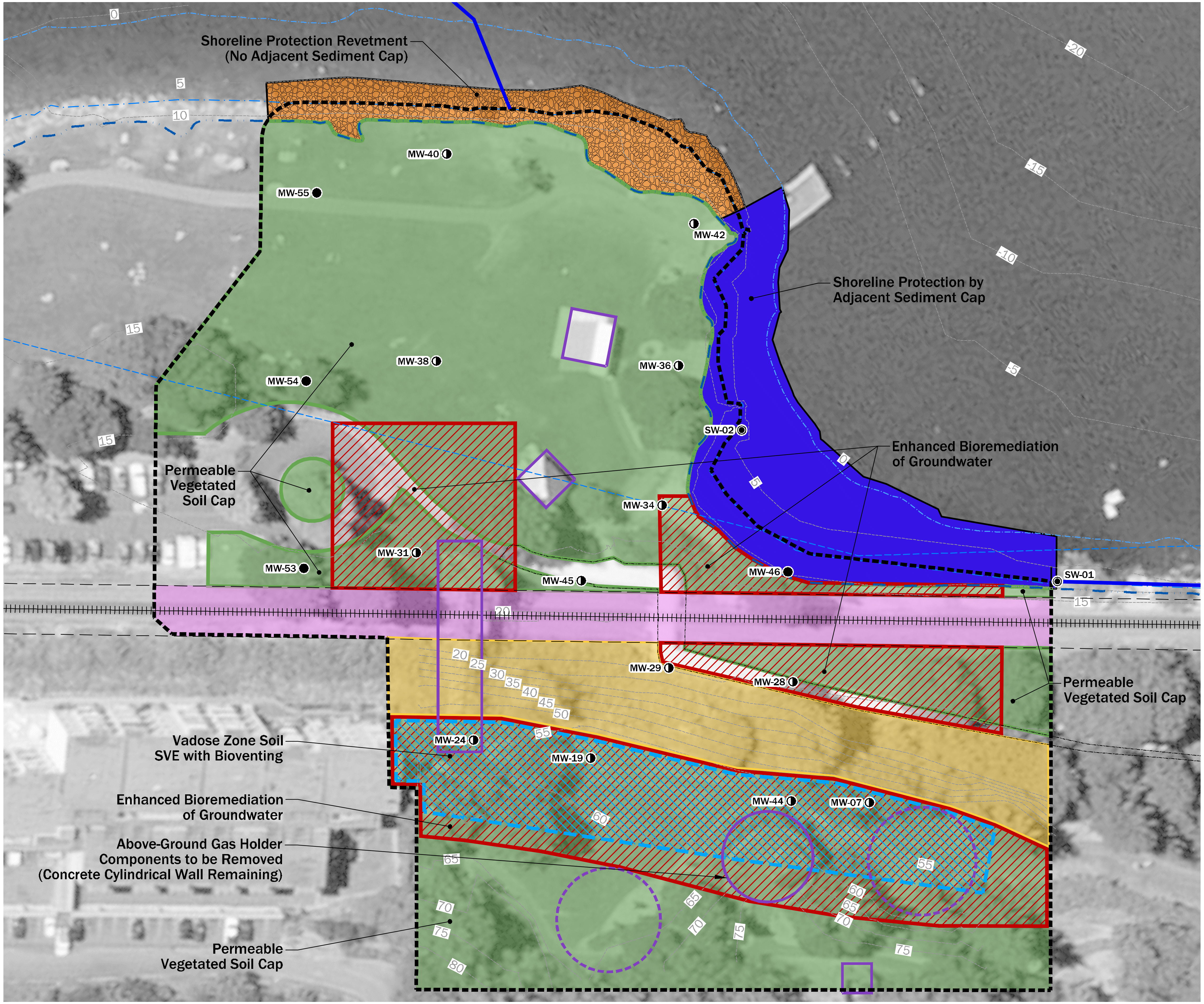
Figure 4-6

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-06_Marine Elements (CAA3).dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 10:05 by tmichaud



Legend

- Permeable Vegetated Soil Cap
- Enhanced Bioremediation (Groundwater)
- Vadose Zone SVE with Bioventing (Soil)
- Excavate Intertidal Sediment and Cap
- Shoreline Protection Revetment
- Slope Area - Monitor Vegetation and Slope Stability
- Railroad Right-of-Way Institutional Controls
- Site Structures
- Former Gas Holder
- Gravel Path
- 15 Topographic Contours (5ft)
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- Inner Harbor Line
- Upland Unit Boundary
- Marine Unit Boundary

Notes:

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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

60 0 60
Feet

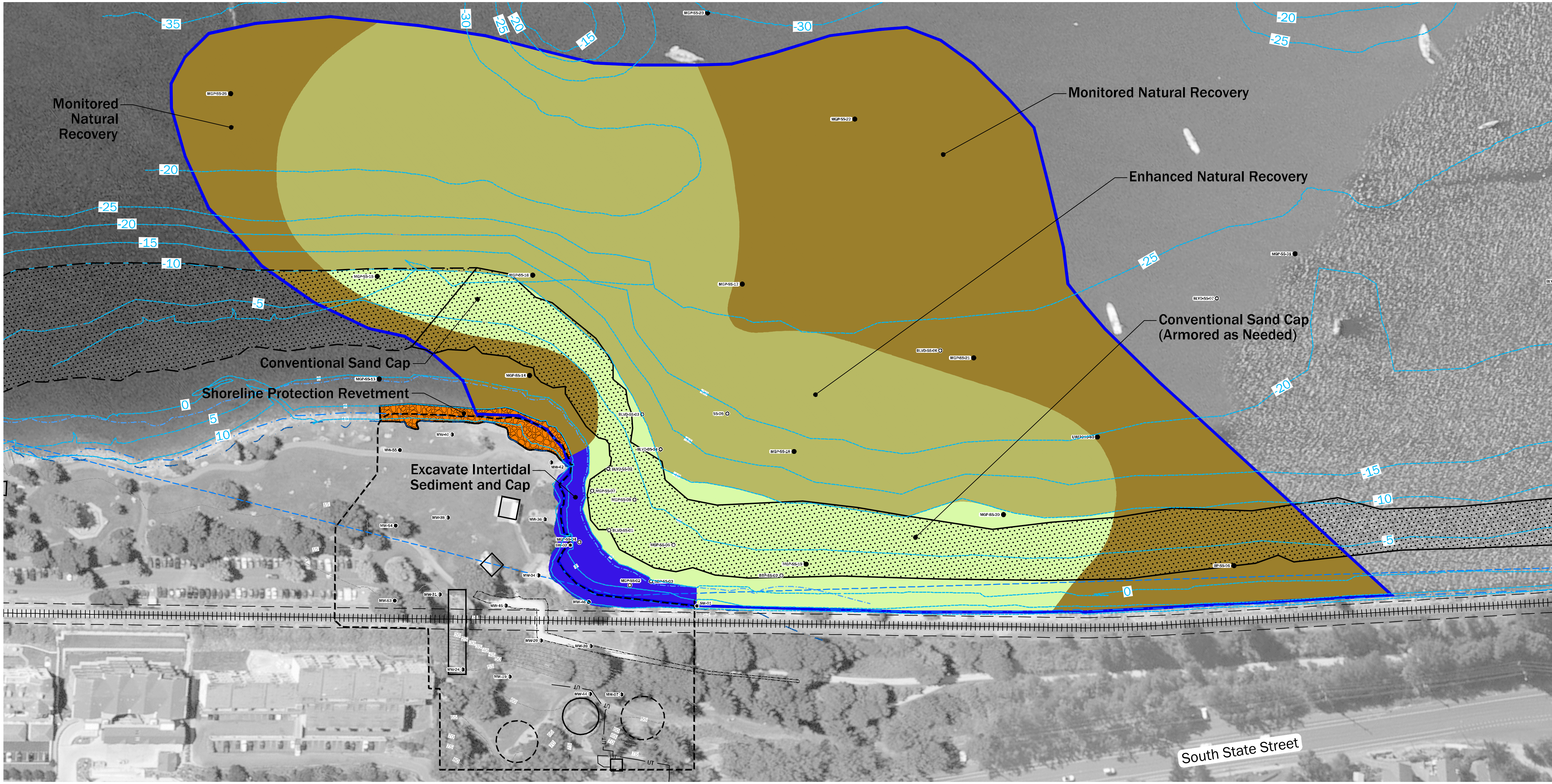
Cleanup Action Alternative 4
Upland Unit

SSS MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 4-7

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-07_Upland Elements [CAA4].dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 9:59 by tmichaud



Notes:

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Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

Legend

- Conventional Sand Cap (Armored as Needed)
- Excavate Intertidal Sediment and Cap
- Enhanced Natural Recovery
- Monitored Natural Recovery
- Shoreline Protection Revetment
- Marine Unit Boundary
- Upland Unit Boundary
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- 15 Bathymetry Contours (5ft)
- 15 Topographic Contours (5ft)
- Surveyed Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Estimated Extent of Eelgrass (Grette and Associates, 2008b)

W S N E Project North

W N S E True North

150 0 150

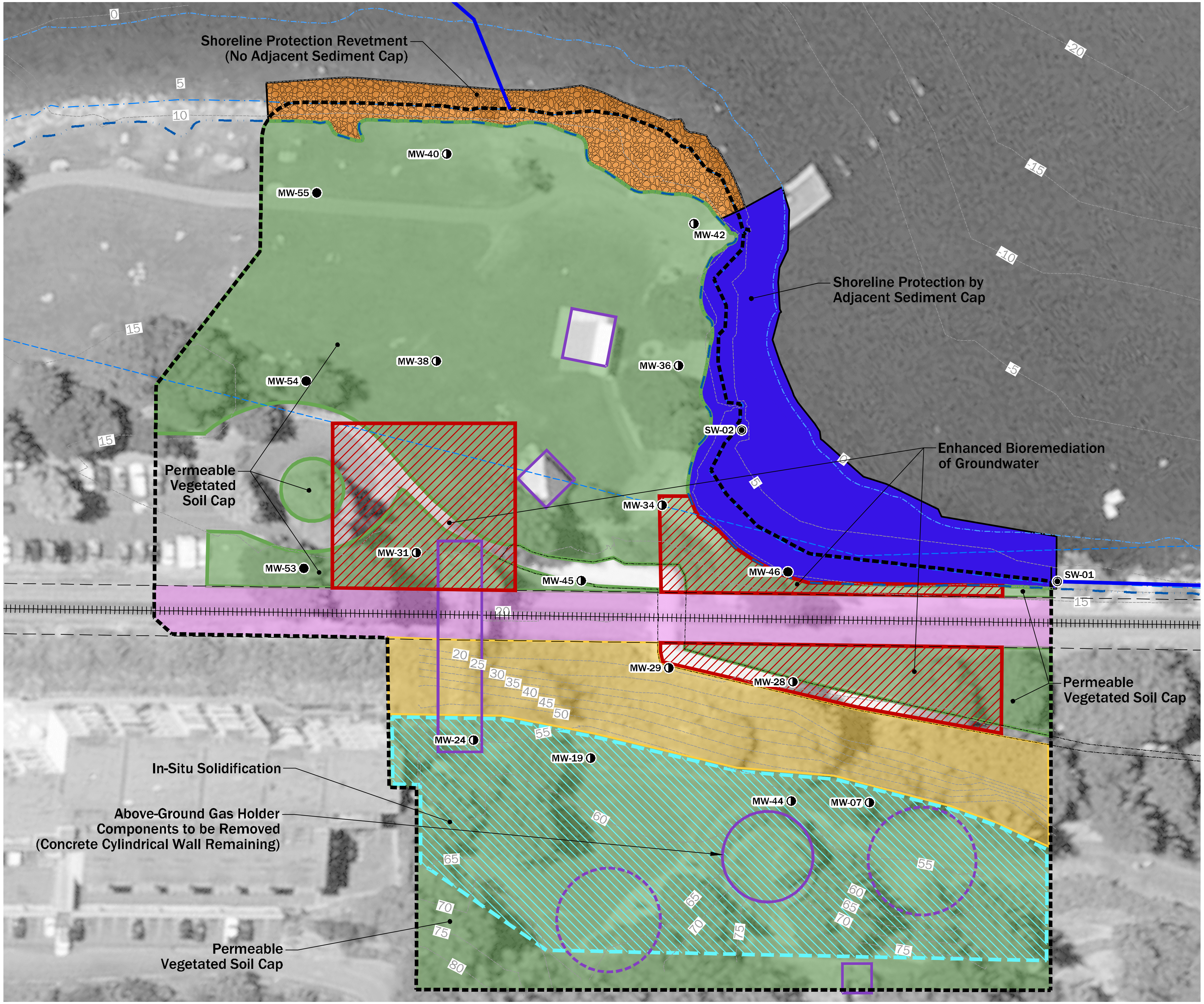
Feet

Cleanup Action Alternative 4
Marine Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-8



Legend

- Permeable Vegetated Soil Cap
- Groundwater Enhanced Bioremediation
- In Situ Soil Solidification
- Excavate Intertidal Sediment and Cap
- Shoreline Protection Revetment
- Slope Area - Monitor Vegetation and Slope Stability
- Railroad Right-of-Way Institutional Controls
- Site Structures
- Former Gas Holder
- Gravel Path
- Topographic Contours (5ft)
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- Inner Harbor Line
- Upland Unit Boundary
- Marine Unit Boundary

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

60 0 60
Feet

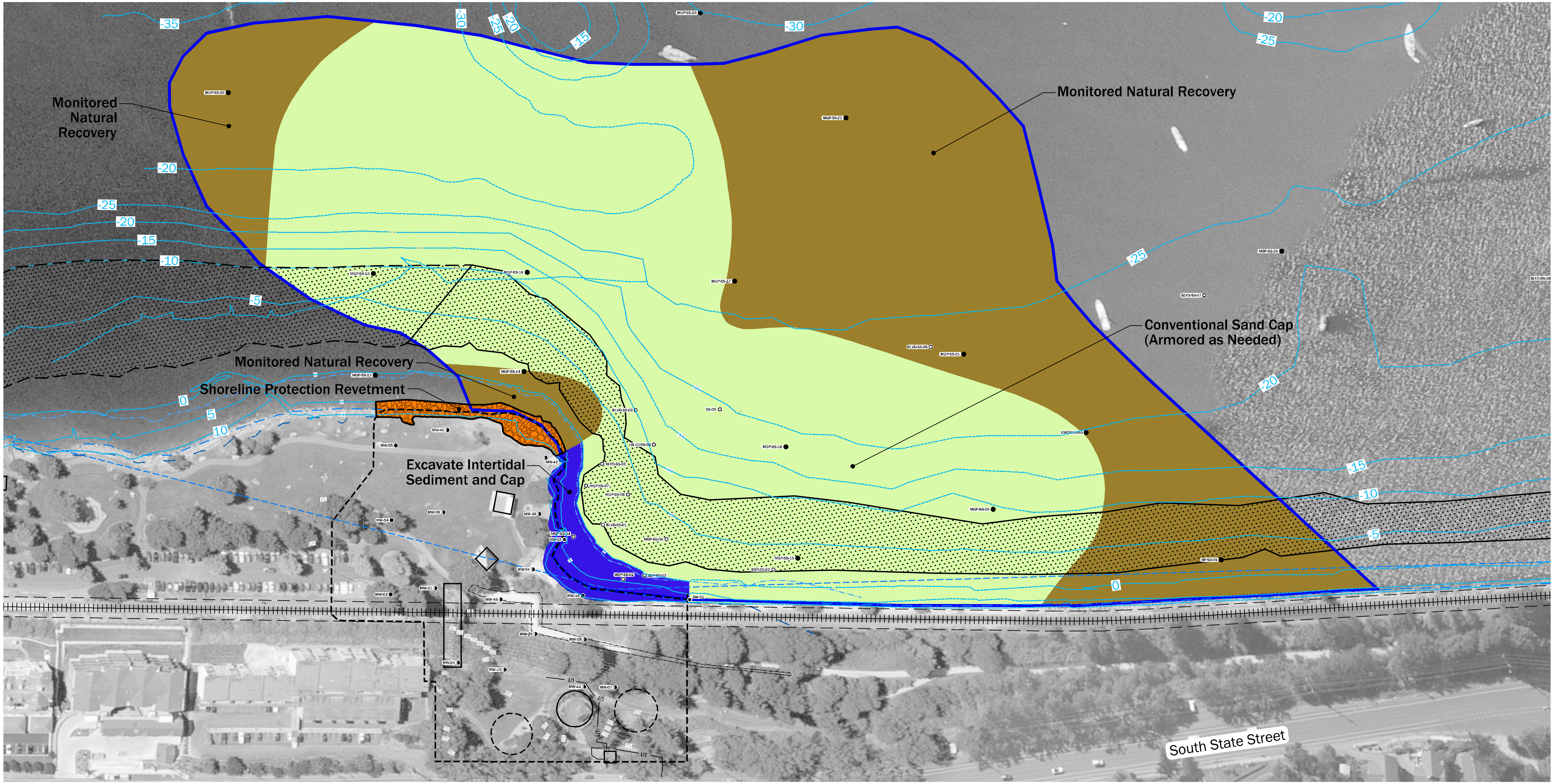
Cleanup Action Alternative 5
Upland Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-9

P:\0\0186890\CAD\01\FS Phase 1\018689001_F04-09_Upland Elements (CAA5).dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 9:59 by tmichaud



Legend

- Excavate Intertidal Sediment and Cap
- Conventional Sand Cap (Armored as Needed)
- Monitored Natural Recovery
- Shoreline Protection Revetment
- Marine Unit Boundary
- Upland Unit Boundary
- Mean Lower Low Water
- Mean High Tide
- Ordinary High Water
- Bathymetry Contours (5ft)
- Topographic Contours (5ft)
- Surveyed Extent of Eelgrass (Grette and Associates, 2008a and 2009)
- Estimated Extent of Eelgrass (Grette and Associates, 2008b)

Project North   True North

150   0   150
Feet

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Base data from AECOM. Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot

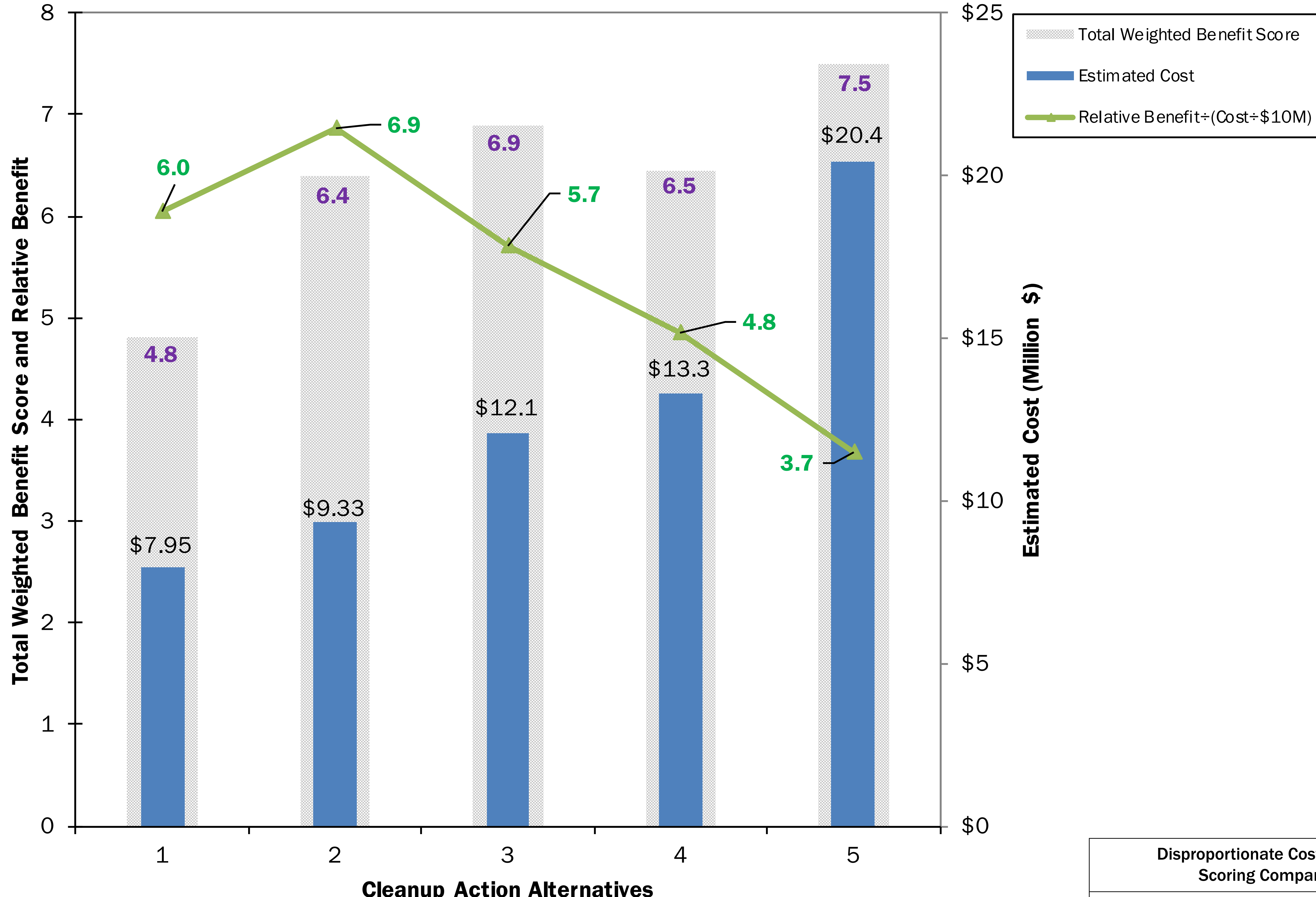
Cleanup Action Alternative 5
Marine Unit

SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 4-10

P:\0\0186890\CAD\01\FS Phase 1\0186890001_F04-10_Marine Elements (CAA5).dwg TAB:11x17 Landscape Date Exported: 08/17/18 - 10:06 by tmichaud



Disproportionate Cost Analysis Scoring Comparison

South State Street Site
Bellingham, Washington

GeoEngineers

Figure 5-1

P:\0\0186890\Graphics_Misc\Figure 5-1 Disproportionate Cost Analysis Scoring Comparison.ai Exported: 03/09/18 by spride

APPENDICES

APPENDIX A
Cleanup Level and Remediation Level Calculations

Table A-1

Sediment Cleanup Level Calculations Based on Direct Contact (Ingestion and Dermal Contact) - Subsistence Clam Digger and Subsistence Net Fisher (Adults)

South State Street MGP Site

Bellingham, Washington

Constants

Parameter	Unit	Scenario			
		Adult Subsistence Clam Digger		Adult Subsistence Net Fisher	
		Cancer	Noncancer	Cancer	Noncancer
Cancer Risk/Hazard Quotient (CR/HQ)	unitless	1E-06	1E+00	1E-06	1E+00
Fractional Intake or Gastrointestinal Absorption Fraction (AB/AB1)	unitless	1	1	1	1
Body Weight (BW)	kg	80	80	80	80
Averaging Time (AT)	days	27,375	25,550	27,375	25,550
Exposure Frequency (EF)	days/year	120	120	119	119
Exposure Duration (ED)	years	70	70	70	70
Sediment Ingestion Rate (SIR/IR)	mg/day	100	100	50	50
Dermal Surface Area (SA)	cm^2	3,160	3,160	3,160	3,160
Adherence Factor (AF)	mg/cm^2-day	0.6	0.6	0.02	0.02
Unit Conversion Factor (UCF)	mg/kg	1.00E+06	1.00E+06	1.00E+06	1.00E+06

Calculated Soil Cleanup Levels

Analyte	Oral Cancer Potency Factor (CPFo)	Oral Reference Dose (RfDo)	Dermal Absorption Factor (ABS)	GI Absorption Factor	Dermal Cancer Potency Factor (CPFd)	Dermal Reference Dose (RfDd)	Sediment Cleanup Level by Scenario					
							Adult Subsistence Clam Digger		Adult Subsistence Net Fisher		Adult Subsistence Clam Digger Cleanup Level	Adult Subsistence Net Fisher Cleanup Level
	$(mg/kg\text{-}day)^{-1}$	mg/kg-day	unitless	unitless	$(mg/kg\text{-}day)^{-1}$	mg/kg-day	Cancer - mg/kg	Noncancer - mg/kg	Cancer - mg/kg	Noncancer - mg/kg	mg/kg	mg/kg
cPAH TEQ (old toxicity value)	7.3	--	0.1	0.5	14.6	--	7.5E-02	--	5.7E-01	--	7.5E-02	5.7E-01
cPAH TEQ (current toxicity value)	1	0.0003	0.1	0.5	2	0.00015	5.4E-01	1.5E+02	4.2E+00	1.2E+03	5.4E-01	4.2E+00

Notes:

cm^2 = square centimeters

kg = kilograms

mg = milligrams

Table A-2

Sediment Cleanup Level Calculations Based on Direct Contact (Ingestion and Dermal Contact) - Beach Play (cPAH TEQ; Adult and Child)

South State Street MGP Site

Bellingham, Washington

Constants[a]

Parameter	Units	Beach Play Adult and Child			
		0-2	2-6	6-16	16-30
		Cancer	Cancer	Cancer	Cancer
Cancer Risk/Hazard Quotient	unitless	1.E-06	1.E-06	1.E-06	1.E-06
Age-Dependent Adjustment Factor[b]	unitless	10	3	3	1
Body Weight	kg	16	16	80	80
Averaging Time	days	27,375	27,375	27,375	27,375
Exposure Frequency	days/year	41	41	41	41
Exposure Duration	years	2	4	10	14
Ingestion Rate	mg/day	200	200	100	100
Fractional Intake	unitless	1	1	1	1
Dermal Surface Area	cm^2	2,200	2,200	3,160	3,160
Sediment to Skin Adherence Factor	mg/cm^2-day	0.2	0.2	0.6	0.6

Sediment Screening Levels

Analytes	Oral Cancer Potency Factor	Dermal Absorption Fraction[a]	Gastrointestinal Absorption Factor[a]	Dermal Cancer Potency Factor	Beach Play Adult and Child				
					0-2	2-6	6-16	16-30	0-30
	mkg-day/mg	unitless	unitless	kg-day/mg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Benzo(a)pyrene	1	0.1	0.5	2	1.9	3.1	3.7	8.0	0.8

Notes:

[a] Values are from Ecology's Sediment Cleanup User's Manual II (SCUM II) revised December 2017, except where noted. Adult values for ingestion rate, dermal surface area, and sediment to skin adherence factor are based on the clam digging adult exposure scenario.

[b] Age-Dependent Adjustment Factors from EPA's "Supplemental Guidance for Assessing Susceptibility from Early-Exposures to Carcinogens" dated March 2005.

cm^2 = square centimeters

kg = kilograms

mg = milligrams

Table A-3

Soil Remediation Level Calculations Based on Direct Contact (Ingestion and Dermal Contact)

South State Street MGP Site

Bellingham, Washington

Constants[a]

Parameter	Unit	Scenario			
		Park User Child		Park User Adult	
		Cancer	Noncancer	Cancer	Noncancer
Cancer Risk/Hazard Quotient (CR/HQ)	unitless	1E-06	1E+00	1E-06	1E+00
Fractional Intake or Gastrointestinal Absorption Fraction (AB/AB1)	unitless	1	1	1	1
Body Weight (ABW/BW)	kg	16	16	70	70
Averaging Time (AT)	days	27,375	2,190	27,375	10,950
Exposure Frequency (EF)[a]	days/year	104	104	104	104
Exposure Duration (ED)	years	6	6	24	24
Soil/Sediment Ingestion Rate (SIR/IR)	mg/day	200	200	50	50
Dermal Surface Area (SA)	cm^2	2,200	2,200	2,500	2,500
Adherence Factor (AF)	mg/cm^2-day	0.2	0.2	0.2	0.2
Unit Conversion Factor (UCF)	mg/kg	1.00E+06	1.00E+06	1.00E+06	1.00E+06

Calculated Soil Remediation Levels

Analyte	Oral Cancer Potency Factor (CPFo) [a]	Oral Reference Dose (RfDo) [a]	Dermal Absorption Factor (ABS) [a]	GI Absorption Factor	Dermal Cancer Potency Factor (CPFd) [a]	Dermal Reference Dose (RfDd) [a]	Remediation Level by Scenario				
							Park User Child		Park User Adult		Park User Remediation Level
	$(mg/kg\text{-}day)^{-1}$	mg/kg-day	unitless	unitless	$(mg/kg\text{-}day)^{-1}$	mg/kg-day	Cancer - mg/kg	Noncancer - mg/kg	Cancer - mg/kg	Noncancer - mg/kg	mg/kg
Selenium	--	0.005	0.01	0.2	--	0.001	--	1.3E+03	--	2.0E+04	1.3E+03
Benzene	0.055	0.004	0.0005	0.8	0.06875	0.0032	6.4E+01	1.1E+03	2.8E+02	2.4E+04	5.2E+01
Naphthalene	--	0.02	0.03	0.8	--	0.016	--	5.2E+03	--	8.9E+04	5.2E+03
cPAH TEQ	1	--	0.1	0.5	2	--	see Table A-4	--	see Table A-4	--	see Table A-4
Cyanide	--	0.00063	0.1	0.5	--	0.000315	--	1.2E+02	--	1.3E+03	1.2E+02

Notes:

[a] Values are from Ecology comments on 2014 Draft RI.

cm^2 = square centimeters

kg = kilograms

mg = milligrams

Table A-4

Soil Remediation Level Calculations Based on Direct Contact (Ingestion and Dermal Contact) - cPAHs

South State Street MGP Site

Bellingham, Washington

Analyte	Park User - Remediation Level (mg/kg)		
	Ingestion	Dermal Contact	Combined - Ingestion and Dermal Contact
Benzo(a)pyrene	0.61	1.10	0.39

Cancer - Mutagenic (Ingestion - Child/Adult)

Carcinogenic Formula (Equation 740-2; modified for modified for early life exposure)

$$\text{Soil Cleanup Level (mg/kg)} = \frac{RISK \times AT \times UCF}{CPFo \times AB1 \times EF \times ELESIR_{child/adult\text{-}adj}}$$

Where:

$ELESIR_{child/adult\text{-}adj} = (SIR_{0\text{-}2} \times ADAF_{0\text{-}2} \times ED_{0\text{-}2} \times 1/ABW_{0\text{-}2}) +$
$(SIR_{2\text{-}6} \times ADAF_{2\text{-}6} \times ED_{2\text{-}6} \times 1/ABW_{2\text{-}6}) +$
$(SIR_{6\text{-}16} \times ADAF_{6\text{-}16} \times ED_{6\text{-}16} \times 1/ABW_{6\text{-}16}) +$
$(SIR_{16\text{-}30} \times ADAF_{16\text{-}30} \times ED_{16\text{-}30} \times 1/ABW_{16\text{-}30})$

Method B Cancer Mutagenic (Child/Adult)

Acceptable cancer risk level (RISK) (1 in 1,000,000) untiless =	1.00E-06
Child/Adult Soil Ingestion Early Life Exposure Adjustment Factor ($ELESIR_{child/adult\text{-}adj}$) (mg-year/kg-day) =	431.4
Age-Dependent Adjustment Factor - 0 - 2 years old ($ADAF_{0\text{-}2}$) =	10
Age-Dependent Adjustment Factor - 2 - 6 years old ($ADAF_{2\text{-}6}$) =	3
Age-Dependent Adjustment Factor - 6 - 16 years old ($ADAF_{6\text{-}16}$) =	3
Age-Dependent Adjustment Factor - 16 - 30 years old ($ADAF_{16\text{-}30}$) =	1
Average body weight ($ABW_{0\text{-}2}$) (kg) =	16
Average body weight ($ABW_{2\text{-}6}$) (kg) =	16
Average body weight ($ABW_{6\text{-}16}$) (kg) =	70
Average body weight ($ABW_{16\text{-}30}$) (kg) =	70
Averaging Time (AT) (years) =	75
Unit conversion factor (UCF) (mg/kg) =	1.00E+06
Carcinogenic Potency Factor (CPFo) (kg-day/mg) =	1
Soil ingestion rate - 0 - 2 years ($SIR_{0\text{-}2}$) (mg/day) =	200
Soil ingestion rate - 2 - 6 years ($SIR_{2\text{-}6}$) (mg/day) =	200
Soil ingestion rate - 6 - 16 years ($SIR_{6\text{-}16}$) (mg/day) =	50
Soil ingestion rate - 16 - 30 years ($SIR_{16\text{-}30}$) (mg/day) =	50
Gastrointestinal absorption fraction (AB1) (unitless) =	1
Exposure duration ($ED_{0\text{-}2}$) (years) =	2
Exposure duration ($ED_{2\text{-}6}$) (years) =	4
Exposure duration ($ED_{6\text{-}16}$) (years) =	10
Exposure duration ($ED_{16\text{-}30}$) (years) =	14
Exposure Frequency (EF) (unitless) =	0.28

Cancer - Mutagenic (Dermal Contact - Child/Adult)

Carcinogenic Formula (Equation 740-2; modified for modified for early life exposure)

$$\text{Soil Cleanup Level (mg/kg)} = \frac{RISK \times AT \times UCF}{CPFd \times ABS \times EF \times ELESA_{child/adult\text{-}adj}}$$

Where:

$ELESA_{child/adult\text{-}adj} = (SA_{0\text{-}2} \times ADAF_{0\text{-}2} \times AF_{0\text{-}2} \times ED_{0\text{-}2} \times 1/ABW_{0\text{-}2}) +$
$(SIR_{2\text{-}6} \times ADAF_{2\text{-}6} \times AF_{2\text{-}6} \times ED_{2\text{-}6} \times 1/ABW_{2\text{-}6}) +$
$(SIR_{6\text{-}16} \times ADAF_{6\text{-}16} \times AF_{2\text{-}6} \times ED_{6\text{-}16} \times 1/ABW_{6\text{-}16}) +$
$(SIR_{16\text{-}30} \times ADAF_{16\text{-}30} \times AF_{16\text{-}30} \times ED_{16\text{-}30} \times 1/ABW_{16\text{-}30})$

Method B Cancer Mutagenic (Child/Adult)

Acceptable cancer risk level (RISK) (1 in 1,000,000) untiless =	1.00E-06
Child/Adult Soil Ingestion Early Life Exposure Adjustment Factor ($ELESIR_{child/adult\text{-}adj}$) (mg-year/kg-day) =	1194.3
Age-Dependent Adjustment Factor - 0 - 2 years old ($ADAF_{0\text{-}2}$) =	10
Age-Dependent Adjustment Factor - 2 - 6 years old ($ADAF_{2\text{-}6}$) =	3
Age-Dependent Adjustment Factor - 6 - 16 years old ($ADAF_{6\text{-}16}$) =	3
Age-Dependent Adjustment Factor - 16 - 30 years old ($ADAF_{16\text{-}30}$) =	1
Average body weight ($ABW_{0\text{-}2}$) (kg) =	16
Average body weight ($ABW_{2\text{-}6}$) (kg) =	16
Average body weight ($ABW_{6\text{-}16}$) (kg) =	70
Average body weight ($ABW_{16\text{-}30}$) (kg) =	70
Averaging Time (AT) (years) =	75
Unit conversion factor (UCF) (mg/kg) =	1.00E+06
Carcinogenic Potency Factor (CPFd) (kg-day/mg) =	2
Surface Area - 0 - 2 years ($SA_{0\text{-}2}$) (cm^2) =	2,200
Surface Area - 2 - 6 years ($SA_{2\text{-}6}$) (cm^2) =	2,200
Surface Area - 6 - 16 years ($SA_{6\text{-}16}$) (cm^2) =	2,500
Surface Area - 16 - 30 years ($SA_{16\text{-}30}$) (cm^2) =	2,500
Adherence Factor (AF) (mg/cm^2-day) =	0.2
Dermal absorption fraction (ABS) (unitless) =	0.1
Exposure duration ($ED_{0\text{-}2}$) (years) =	2
Exposure duration ($ED_{2\text{-}6}$) (years) =	4
Exposure duration ($ED_{6\text{-}16}$) (years) =	10
Exposure duration ($ED_{16\text{-}30}$) (years) =	14
Exposure Frequency (EF) (unitless) =	0.28

APPENDIX B
Cleanup Alternatives Cost Estimates

Table B-1

Summary of Cost Estimates for Remedial Alternatives

South State Street MGP Site

Bellingham, Washington

Alternative	Area	Alternative Description	Capital Costs	O&M Costs (NPV)	Contingency (25%)	Sum (Capital, O&M, Contingency)
1	Upland	Vegetated Soil Cap for Remediation Level Area with Natural Attenuation	$ 1,038,542	$ 1,366,990	$ 601,383	$ 3,006,915
	Sediment	Conventional Sand Cap, Enhanced Natural Recovery and Monitored Natural Recovery	$ 2,571,198	$ 1,382,335	$ 988,383	$ 4,941,916
		Totals =	**$ 3,609,739**	**$ 2,749,325**	**$ 1,589,766**	**$ 7,950,000**
2	Upland	Vegetated Soil Cap for Remediation Level Area with Enhanced Bioremediation	$ 1,777,704	$ 1,366,990	$ 786,174	$ 3,930,868
	Sediment	Conventional Sand Cap, Thin Sand Cap, Enhanced Natural Recovery and Monitored Natural Recovery	$ 2,871,582	$ 1,446,003	$ 1,079,396	$ 5,396,982
		Totals =	**$ 4,649,286**	**$ 2,812,994**	**$ 1,865,570**	**$ 9,330,000**
3	Upland	Low Permeability Capping with Natural Attenuation	$ 2,223,985	$ 1,366,990	$ 897,744	$ 4,488,719
	Sediment	Conventional Sand Cap, Thin Sand Cap, and Monitored Natural Recovery	$ 4,334,533	$ 1,739,972	$ 1,518,626	$ 7,593,131
		Totals =	**$ 6,558,517**	**$ 3,106,962**	**$ 2,416,370**	**$ 12,100,000**
4	Upland	Site Wide Vegetated Soil Cap with SVE and Bioremediation	$ 3,035,930	$ 1,796,675	$ 1,208,151	$ 6,040,756
	Sediment	Intertidal Sediment Excavation, Conventional Sand Cap, Enhanced Natural Recovery and Monitored Natural Recovery	$ 4,176,974	$ 1,649,254	$ 1,456,557	$ 7,282,785
		Totals =	**$ 7,212,904**	**$ 3,445,929**	**$ 2,664,708**	**$ 13,300,000**
5	Upland	Site Wide Vegetated Soil Cap with ISS and Bioremediation	$ 5,495,015	$ 1,366,990	$ 1,715,501	$ 8,577,506
	Sediment	Intertidal Sediment Excavation, Conventional Sand Cap and Monitored Natural Recovery	$ 7,243,799	$ 2,194,137	$ 2,359,484	$ 11,797,421
		Totals =	**$ 12,738,814**	**$ 3,561,127**	**$ 4,074,985**	**$ 20,400,000**

Notes:

Estimates represent order-of-magnitude within a range of -30 percent to +50 percent. Costs are in 2017 dollars.

Capital costs include remedial design and permitting, project management, construction management and construction mobilization all as a percentage of the Capital cost. Sales taxes where applicable were not included.

Long-term operation, monitoring, maintenance and inspection (O&M) costs are presented as the Net Present Value (NPV) estimated over a 30 year period using a discount rate of 1.1% as specified by Ecology.
O&M costs include project management and construction management.

The following acronyms are used on Tables B-1 through B-7:

O&M = operations & maintenance
NPV = net present value
TDC = total direct capital cost
CY = cubic yard
SF = square foot
SY = square yard
LS = lump sum
LF = linear feet
LB = pounds
WA = Washington

Table B-2

Unit Costs Used for Detailed Cost Estimates

South State Street MGP Site
Bellingham, Washington

Item	Unit	Unit Cost / Conversion	Source/Assumptions
Direct Capital Costs			
General Site Construction Elements			
Upland earthwork temporary controls (erosion control, temporary facilities, access controls)	lump sum	$ 100,000	Professional judgment and experience on other similar projects.
Stormwater collection, water collection from material stockpile areas, treatment, and discharge system during construction	lump sum	$ 100,000	Professional judgment based on recently completed projects. Costs include mobilization, setup, rental, demobilization, treatment and discharge.
Clearing/Grubbing	acre	$ 7,000	2014 RS Means Heavy Construction Cost Data adjusted for cost escalation. Management of organic waste included.
Post-construction upland survey	each	$ 25,000	Professional judgment and experience on other similar projects.
Post-construction marine survey	each	$ 50,000	Professional judgment and experience on other similar projects.
Air and Dust Monitoring	day	$ 200	Professional judgment and experience on other similar projects.
Demolition of Gas Holder #2, excavate, transport and dispose of debris/impacted materi	lump sum	$ 200,000	Professional judgment and experience on other similar projects.
Monitoring and Institutional Controls			
Install new groundwater monitoring wells	each	$ 5,000	Professional judgment based on recently completed projects.
Institutional Controls/Restrictive Covenants Preparation	lump sum	$ 75,000	Professional judgment based on recently completed projects. Initial costs for activities used to establish or setup institutional controls. Assume annual costs applied Year 1 through Year 30.
Institutional Controls - annual cost	lump sum	$ 25,000	Professional judgment based on recently completed projects. Annual costs for activities performed on a regular basis to monitor and maintain the institutional controls.
Monitored Natural Attenuation - Upland			
Groundwater Sampling Labor	well	$ 500	Professional judgment and experience on other similar projects. Assume 2 field staff for completing the work.
Groundwater Sample Chemical Analysis	well	$ 620	Recent project costs. Includes analysis for BTEX, SIM PAHs, Cyanide, Sulfate, Alakalinity, TDS, Chloride.
Annual reporting	lump sum	$ 25,000	Professional judgment and experience on other similar projects.
Transport/Disposal (Soil/Water)			
Transport (truck/train) and dispose soil to Subtitle D landfill	ton	$ 60	Vendor quote for permitted facility in WA. Includes truck liner and stabilizing wet soil.
Transport (truck/train) and dispose Soil at Subtitle C (hazardous waste) landfill	ton	$ 175	Considered non-hazardous due to TCLP exemption for MGPs. Disposal at permitted Chem WM Subtitle C in Oregon. Per WM 10/30/14 written quote, disposal $90/ton, plus rail-transporation and liner cost to Oregon $800/container. Unit cost ~ $175/ton.
Upland Backfilling and Capping			
Place and Compact Clean Borrow Soil Backfill	cy	$ 10.00	Professional judgment and experience on other similar projects. Assume on-site source or clan borrow from a nearby source.
Rough grading for cap surface preparation	sy	$ 1.00	Professional judgment and experience on other similar projects.
Cap - gas collection layer under geomembrane	sf	$ 1.50	Professional judgment and experience on other similar projects. Includes labor and materials (pea gravel, etc).
Procure and Install Low-Permeability Geomembrane Liner	sf	$ 0.60	Professional judgment and experience on other similar projects.. Assume 40 mil thick PVC geomembrane.
Procure and Install Geotextile Separation Layer	sf	$ 0.25	Professional judgment and experience on other similar projects.. Assume 10 oz. wt, non-woven needle punched fabric.
Cap drainage layer - import, place, compact	cy	$ 45	Recent project experience. Assume Type 17 Bank Run.
Procure and Place Topsoil	cy	$ 40	Recent project experience.
Hydroseeding	sy	$ 2.00	Recent project experience.
Stormwater collection system	lump sum	$ 200,000	Professional judgment. Assume stormwater collection system for both upper and lower Park including discharge via outfall.
Shoreline Restoration	acre	$ 100,000	Professional judgment. Assumes revegetation in lake perimeter areas affected by construction; cost includes restoration design and is based on similar effort scope costs.
Upland Soil Stabilization			
Soil stabilization treatability testing	lump sum	$ 100,000	Vendor quote. Bench testing to evaluate treatability and design factors. Includes cost to develop plan and collect samples.
Soil bulk density	lb/cy	2,800	Assumed average unit weight (in-place volume) of soil.
ISS media cost: Organoclay SS-199	lb	$ 1.50	Vendor quote. ISS media usage ratio for Organoclay SS-199 assumed to be 1 percent organoclay by weight to 8 percent Portland cement by weight. Actual use will depend on treatability tests.
ISS media cost: Portland cement	lb	$ 0.10	Contractor quote. Assumed average bulk density of 94 lb/CF for Portland cement.
ISS media cost: Organoclay PM-199	lb	$ 1.58	Vendor quote. Used for in situ stabilization without solidification. Granular Organoclay PM-199 has larger particle size (coarse sand) than the powdered form and can be used as ISS media without Portland cement. Typical ratio is 1 to 3 percent by weight.
Shallow (less than 15ft) stabilization using an excavator	cy	$ 40	Vendor-provided average cost for stabilization mixing labor and equipment.
Enhanced Aerobic Bioremediation			
Enhanced Aerobic Bioremediation treatability study	lump sum	$ 40,000	Professional judgment and experience on other smilar projects.
Amendment injection - Direct Push	Event-Acre	$ 250,000	Vendor quote. Includes cost for mob/demob, ORC, injection points, equipment, labor and materials per acre based on single event.
Baseline monitoring	lump sum	$ 40,000	Professional judgment and experience on other smilar projects.
Annual reporting	lump sum	$ 25,000	Professional judgment and experience on other smilar projects.
Soil Vapor Extraction and Bioventing			
SVE capital costs	lump sum	$ 250,000	Professional judgment and experience on other similar projects. Includes costs for mobile unit, impermeable surface cover, wells and piping installation.
SVE electrical hookup, startup and testing	lump sum	$ 30,000	Professional judgment and experience on other similar projects.
AS/SVE system operation, maintenance, monitoring and reporting - annual cost	lump sum	$ 75,000	Professional judgment and experience on other similar projects. Includes monthly inspections, repair and maintenance, utility charges and reporting
Passive bioventing well installation	lump sum	$ 25,000	Assume 2-inch diameter direct push passive venting wells.
Sediment Removal			
Sediment excavation using land-based excavation equipment	cy	$ 49	Contractor estimate. Excavate using equipment placed in upland; stockpile in upland. Includes silt curtain for in-water BMP.
Shoring and/or coffer dam install for intertidal excavation	lump sum	$ 325,000	Vendor quote. Based on use of Portadam coffer dam system. Cost includes installation, dismantling, and 2-months rental.
Handling and dewatering of sediment from land-based excavation	cy	$ 15	Professional judgment and experience on other smilar projects.
Handling of water drained from excavated sediment	day	$ 10,000	Professional judgment and experience on other similar projects. Estimate for treatment equipment, collection, treatment, testing, handling, and discharge of water drained from mechanically dredged sediment.
Construction Best Management Practices and Monitoring	day	$ 6,000	Professional judgment and experience on other similar projects. Includes maintenance of BMPs, survey boat, labor and equipment for bathymetric survey and water quality testing during construction.
Soil unit weight conversion (in-place volume)	ton/cy	1.4	Professional judgment. Assumed average unit weight (in-place volume).
Sediment unit weight conversion (in-place volume)	ton/cy	1.3	Professional judgment. Average unit weight (in-place volume).
Transload/Transport/Disposal (Sediment)			
Stockpile and dewatering area setup	lump sum	$ 150,000	Professional judgment and experience on other similar projects.
Handling and loading of excavated material	cy	$ 2	Professional judgment and experience on other similar projects.
Transport (truck) to rail facility	ton	$ 10	Estimate based on professional judgment and experience on similar projects.
Transload, railcar transport to and tipping at Subtitle D landfill	ton	$ 70	Vendor quote for permitted facility in Roosevelt, WA. Cost includes loading dewatered sediment from barge onto truck with container (20-ft container fitted with liner), truck transport to intermodal rail facility and subsequent train transport to Subtitle D landfill.
In-Water Backfilling and Capping			
Sediment debris sweep and disposal	acre	$ 30,000	Professional judgment and experience on other similar projects. Prepares existing surface for cap. Assumes no major obstructions are encountered.
Procure and place Enhanced natural recovery (ENR) layer	cy	$ 44	Contractor estimate. Assume placement of sand in two separate thin lifts with 6-inch final thickness.
Procure and place intertidal sand backfill/cap	cy	$ 43	Contractor estimate.
Procure and place subtidal sand backfill/cap	cy	$ 52	Contractor estimate.
Amended cap media: Organoclay PM-199	lb	$ 1.58	Vendor quote. Application rate varies; determined through cap modeling.
Amended cap media: Activated Carbon	lb	$ 1.20	Vendor quote. Application rate varies; determined through cap modeling.
Amended cap media: Zero-Valent Iron	lb	$ 2.05	Vendor quote. Application rate varies; determined through cap modeling.
Prepare amended cap blend	cy	$ 5	Contractor estimate. Mix sand/amendment blend in upland location to prepare for placement.
Amended Cap placement	cy	$ 43	Estimate based on previous project costs.
Procure and place rock armor	cy	$ 40	Contractor estimate. Assume same unit cost for various armor sizes
Procure and place 6-inch fish mix in-fill on rock armor	cy	$ 27	Estimate based on recent completed project costs.
Net Present Value Multipliers			

Item	Unit	Unit Cost / Conversion	Source/Assumptions
Net Present Value Discount Rate	0.7%		Based on Real 30-year discount rate published in November 2016 Office of Management and Budget Circular No. A-94.
Net Present Value Multipliers for equal payment series	**Years**	**Equal Annual Payment Multiplier**	**Single Payment Multiplier**
	1	0.99	0.99
	2	1.98	0.99
	3	2.96	0.98
	4	3.93	0.97
	5	4.90	0.97
	6	5.86	0.96
	7	6.81	0.95
	8	7.75	0.95
	9	8.69	0.94
	10	9.63	0.93
	15	14.19	0.90
	20	18.60	0.87
	25	22.86	0.84
	30	26.97	0.81
	35	30.95	0.78
	40	34.78	0.76
	45	38.49	0.73
	50	42.06	0.71
Annual Groundwater Monitoring			
Groundwater sampling labor	well	$ 500	Professional judgment and experience on other similar projects. Assume 2 field staff for completing the work.
Groundwater Sample Chemical Analysis	well	$ 620	Recent project costs. Includes analysis for BTEX, SIM PAHs, Cyanide, Sulfate, Alakalinity, TDS, Chloride.
Annual monitoring well repair and replacement	lump sum	$ 10,000	Professional judgment and experience on other similar projects. Cost to repair or replace monitoring wells as needed during monitoring phase.
Annual reporting	lump sum	$ 25,000	Recent project costs.
Upland Cap Monitoring			
Cap monitoring, maintenance, and reporting - annual cost	lump sum	$ 24,000	Professional judgment and experience on other similar projects.
Slope Monitoring			
Slope monitoring, maintenance and reporting - annual cost	lump sum	$ 24,000	Professional judgment and experience on other similar projects. Includes monitoring for slope stability, soil erosion and maintenance to replace damaged vegetation.
Sediment Monitoring and O&M			
Sediment cap operation and maintenance monitoring and reporting	acre	$ 1,800	Professional judgment and experience on other similar projects. Includes labor, equipment, sediment sampling, analytical costs and bathymetric survey for long-term operation and maintenance monitoring. Assume 1 surface sediment grab sample per acre, 8 samples per day, three days total for covering cap, ENR and MNR areas. Vessel and labor - $4,900/day (includes mob/demob), Analytical - $600/sample (TOC, grain size, PAHs), bathymetry - $7,000, and oversight labor - $1,500/day. Total - ($4,900*3+$7,000+$1,500*3)/23 acres = $1,200 plus $600 per sample = $1,800/acre. Assume monitoring in Year 1, 3, 5, 10, 15, 20, 25 and 30 after active remedy construction.
ENR monitoring and reporting	acre	$ 1,800	Professional judgment and experience on other similar projects. Includes labor, equipment, sediment sampling, analytical costs and bathymetric survey for long-term operation and maintenance monitoring. Assume 1 surface sediment grab sample per acre, 8 samples per day, three days total for covering cap, ENR and MNR areas. Vessel and labor - $4,900/day (includes mob/demob), Analytical - $600/sample (TOC, grain size, PAHs), bathymetry - $7,000, and oversight labor - $1,500/day. Total - ($4,900*3+$7,000+$1,500*3)/23 acres = $1,200 plus $600 per sample = $1,800/acre. Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Periodic cap repair event	%	10%	Periodic major repair of cap/ENR areas. Assume repair in Year 5, and 10 after active remedy construction. Based on percent of cap/ENR remedy capital costs.
MNR monitoring and reporting	acre	$ 1,800	Professional judgment and experience on other similar projects. Includes labor, equipment, sediment sampling, analytical costs and bathymetric survey for long-term operation and maintenance monitoring. Assume 1 surface sediment grab sample per acre, 8 samples per day, three days total for covering cap, ENR and MNR areas. Vessel and labor - $4,900/day (includes mob/demob), Analytical - $600/sample (TOC, grain size, PAHs), bathymetry - $7,000, and oversight labor - $1,500/day. Total - ($4,900*3+$7,000+$1,500*3)/23 acres = $1,200 plus $600 per sample = $1,800/acre. Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Indirect Capital Costs			
Mobilization/demobilization	% of TDC	10%	Indirect percentages based on EPA 2000 guidance (EPA, 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. OSWER 9355.0-75) and recent project experience.
Remedial design	% of TDC	10%	
Project management (PM)	% of TDC	8%	
Construction management (CM)	% of TDC	10%	
Ecology Oversight	% of TDC	2%	
Contingency	% of TDC	25%	
Sales Tax	% of TDC	8.7%	
Total Indirect Capital Costs	% of TDC	40%	Apply mob/demob, remedial design, PM, CM, and ecology oversight to sum of capital direct costs.
Indirect Costs - O&M Expenses			
Project management	% of TDC	10%	Indirect percentages based on EPA 2000 guidance (EPA, 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. OSWER 9355.0-75) and recent project experience.
Construction management	% of TDC	5%	
Ecology Oversight	% of TDC	2%	
Contingency	% of TDC	25%	
Sales Tax	% of TDC	8.7%	
Total Indirect O&M Costs	% of TDC	17%	Apply PM, CM and ecology oversight to sum of O&M direct costs.

Notes:

1. Costs shown represent labor, equipment and materials inclusive of overhead and profit.
2. All cost values are estimates, and should not be interpreted as final construction costs.
3. Cost Estimate Guidance: A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. EPA 540-R-00-002. OSWER 9355.0-75, EPA 2000.
4. Estimates represent order-of-magnitude within a range of -30 percent to +50 percent consistent with USEPA Feasibility Study cost estimating guidance. Costs are in 2017 dollars.
5. Cost estimates based on professional judgment, literature reference, RS Means Cost Data, vendor quote and experience on similar projects.
6. The estimated costs include direct costs (construction costs), indirect costs (mobilization/demobilization, remedial design, project management, construction management, ecology oversight, contingency and sales tax), and operation and maintenance costs.
7. Mobilization/demobilization includes contractor submittals, job adminstration/management, mobilizing labor, eqipment and materials, field quality control testing, site preparation and demobilization.
8. Remedial design includes sampling plans, work plans, design support studies (geotechnical/seismic, vessel scour) pre-design sampling, engineering survey, permitting, plans and specifications, engineers estimate, bid documents and contracting support.
9. Project management includes meetings, planning, coordination, cost and performance reporting.
10. Construction management includes field oversight, traffic and vessel navigation control, submittal review, change order review, design modifications, construction schedule tracking and construction completion report.
11. Long-term operation, monitoring, maintenance and inspection (O&M) costs are presented as the Net Present Value (NPV) estimated over a 30 year period using a discount rate of 0.7%. O&M costs include project management and construction management.

Table B-3

Alternative Cost Estimate - Alternative 1 Soil and Sediment Capping with Natural Attenuation and Recovery

South State Street MGP Site

Bellingham, Washington

Description	Quantity: Number	Quantity: Unit	Cost: Unit Cost	Cost: Total Cost	Notes
Capital Costs (Direct and Indirect)					
Upland					
Vegetated Soil Cap for Remediation Level Area with Natural Attenuation					
Mobilization, Environmental and Safety Controls					
Upland earthwork temporary controls (erosion control, temporary facilities, access controls)	1	lump sum	$ 100,000	$ 100,000	Assumed to apply to all upland work.
Air and Dust Monitoring	60	day	$ 200	$ 12,000	Assume perimeter and work area dust monitoring using hand-held real-time dust monitoring equipment. Assume 2 months of upland construction.
Stormwater collection, water collection from material stockpile areas, treatment, and discharge system during construction	1	lump sum	$ 100,000	$ 100,000	
Gas Holder Removal					
Demolition of Gas Holder #2, excavate, transport and dispose of debris/impacted material	1	lump sum	$ 200,000	$ 200,000	
Permeable Vegetated Cap					
Clearing/Grubbing	1	acre	$ 7,000	$ 7,605	
Rough grading for cap surface preparation	5,258	sy	$ 1	$ 5,258	
Procure and Install Geotextile Separation Layer	47,325	sf	$ 0.25	$ 11,831	
Cap drainage layer - import, place, compact	876	cy	$ 45	$ 39,438	Assume 6 inch thick layer of drainage rock (i.e, Type 17)
Procure and Place Topsoil	2,629	cy	$ 40	$ 105,167	Assume 1.5 ft thick layer of topsoil.
Hydroseeding	5,258	sy	$ 2	$ 10,517	
Post-construction upland survey	1	each	$ 25,000	$ 25,000	Final as-built survey for upland construction.
Monitoring and Closure					
Install new groundwater monitoring wells	10	each	$ 5,000	$ 50,000	
Institutional Controls/Restrictive Covenants Preparation	1	lump sum	$ 75,000	$ 75,000	Assumed cost for initial setup of institutional controls for uplands and in-water work.
Direct Capital Cost Subtotal				$ 741,815	
Indirect Capital Cost		% of TDC	40%	$ 296,726	
Total Capital Cost				**$ 1,038,542**	
Sediment					
Conventional Sand Cap, Enhanced Natural Recovery and Monitored Natural Recovery					
Sediment debris sweep and disposal	3.1	acre	$ 30,000	$ 93,384	Assume sweep required for intertidal and subtidal cap areas
Procure and place intertidal sand backfill/cap	1,423	cy	$ 43	$ 61,203	Cap placement above elevation 0
Procure and place subtidal sand backfill/cap	11,132	cy	$ 52	$ 578,847	Cap placement below elevation 0
Procure and place Enhanced natural recovery (ENR) layer	8,834	cy	$ 44	$ 388,686	Asume 0.5 ft thick layer of sand.
Prepare amended cap blend	1,714	cy	$ 5	$ 8,568	Assume 2 ft thick cap.
Amended cap media: Zero-Valent Iron	71,968	lb	$ 2.05	$ 147,534	Assume 3% application of iron amendment by weight.
Amended cap media: Activated Carbon	71,968	lb	$ 1.20	$ 86,361	Assume 3% application of activated carbon amendment by weight.
Amended Cap placement	1,714	cy	$ 43	$ 73,681	
Construction Best Management Practices and Monitoring	28	day	$ 6,000	$ 167,029	Based on an assumed average cap production rate (both cap and ENR) of 1,000 cy/day.
Procure and place rock armor	4,108	cy	$ 40	$ 164,338	Assume a thickness of 1.5 feet in upper intertidal and 0.5 feet in lower intertidal areas above -5 feet.
Procure and place 6-inch fish mix in-fill on rock armor	627	cy	$ 27	$ 16,939	Assume a thickness of 6 inches placed on larger rock armor.
Post-construction marine survey	1	each	$ 50,000	$ 50,000	Assume survey to cover all in-water work areas.
Direct Capital Cost Subtotal				$ 1,836,570	
Indirect Capital Cost		% of TDC	40%	$ 734,628	
Total Capital Cost				**$ 2,571,198**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$ 3,609,739**	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Entire Upland Area - Groundwater Monitoring of shoreline wells quarterly for year 0, annually for 10 years, followed by four 5-year events					
Groundwater sampling labor	10	well	$ 500	$ 5,000	Quantity based on 10 shoreline wells including samples for field qa/qc.
Groundwater sample chemical analysis	10	well	$ 620	$ 6,200	
Annual reporting	1	lump sum	$ 25,000	$ 25,000	
Direct Subtotal				$ 576,600	
Indirect O&M Costs		% of TDC	17%	$ 98,022	
Undiscounted Subtotal (including Indirect Costs)				**$ 674,622**	
Net Present Value Subtotal (including Indirect Costs)				**$ 634,264**	
Slope Monitoring					
Slope monitoring, maintenance and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30. Includes monitoring for slope stability, soil erosion and replacement of vegetation as needed.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		0	17.0%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Upland Cap Monitoring					
Cap monitoring, maintenance, and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		% of TDC	17.0%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Sediment - Capping, ENR, MNR and ICs					
Sediment cap operation and maintenance monitoring and reporting	3.5	acre	$ 1,800	$ 6,368	Assume monitoring in Year 1, 3, 5, 10, 15, 20, 25 and 30 after active remedy construction.
ENR monitoring and reporting	8.8	acre	$ 1,800	$ 15,769	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Periodic cap repair event		%	10%	$ 183,657	Assume repair in Year 5, and 10 after active remedy construction.
MNR monitoring and reporting	7.3	acre	$ 1,800	$ 13,176	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Institutional Controls - annual cost	1	lump sum	$ 25,000	$ 25,000	Assume annual costs for 30 years.
Direct Subtotal				$ 1,284,036.29	
Indirect O&M Costs		% of TDC	17%	$ 218,286	
Undiscounted Subtotal (including Indirect Costs)				**$ 1,502,322**	
Net Present Value Subtotal (including Indirect Costs)				**$ 1,382,335**	
Total Undiscounted O&M Costs (30 Years)				**$ 2,963,184**	
Total Net Present Value of O&M Costs (30 Years)				**$ 2,749,325**	
Contingency (25 Percent of Total Cost)				**$ 1,589,766**	
Total Cost of Alternative (Present Worth)				**$ 7,950,000**	

Notes:

Present worth calculated using equal series present worth analysis where i = 0.7%

Table B-4

Alternative Cost Estimate - Alternative 2 Site Wide Vegetated Upland Soil Capping and Sediment Capping with Natural Attenuation and Recovery

South State Street MGP Site
Bellingham, Washington

Description	Quantity		Cost		Notes
	Number	Unit	Unit Cost	Total Cost	
Capital Costs (Direct and Indirect)					
Upland					
Vegetated Soil Cap for Remediation Level Area with Enhanced Bioremediation					
Mobilization, Environmental and Safety Controls					
Upland earthwork temporary controls (erosion control, temporary facilities, access controls)	1	lump sum	$ 100,000	$ 100,000	Assumed to apply to all upland work.
Air and Dust Monitoring	60	day	$ 200	$ 12,000	Assume perimeter and work area dust monitoring using hand-held real-time dust monitoring equipment. Assume 2 months of upland construction.
Stormwater collection, water collection from material stockpile areas, treatment, and discharge system during construction	1	lump sum	$ 100,000	$ 100,000	
Gas Holder Removal					
Demolition of Gas Holder #2, excavate, transport and dispose of debris/impacted material	1	lump sum	$ 200,000	$ 200,000	
Permeable Vegetated Cap					
Clearing/Grubbing	2.9	acre	$ 7,000	$ 20,465	
Rough grading for cap surface preparation	14,150	sy	$ 1	$ 14,150	
Place and Compact Clean Borrow Soil Backfill	2,852	cy	$ 10	$ 28,519	Assume 1 ft of clean borrow fill over the lower Park footprint to grade the pre-cap surface and raise the pre-cap elevation to account for sea level rise.
Procure and Install Geotextile Separation Layer	127,350	sf	$ 0.25	$ 31,838	
Cap drainage layer - import, place, compact	2,358	cy	$ 45	$ 106,125	Assume 6 inch thick layer of drainage rock (i.e, Type 17)
Procure and Place Topsoil	7,075	cy	$ 40	$ 283,000	Assume 1.5 ft thick layer of topsoil.
Hydroseeding	14,150	sy	$ 2	$ 28,300	
Post-construction upland survey	1	each	$ 25,000	$ 25,000	Final as-built survey for upland construction.
Bioremediation					
Enhanced Aerobic Bioremediation treatability study	1	lump sum	$ 40,000	$ 40,000	
Amendment injection - Direct Push	0.23	Event-Acre	$ 250,000	$ 115,393	Assume 2 events.
Baseline monitoring	1	lump sum	$ 40,000	$ 40,000	
Monitoring and Closure					
Install new groundwater monitoring wells	10	each	$ 5,000	$ 50,000	
Institutional Controls/Restrictive Covenants Preparation	1	lump sum	$ 75,000	$ 75,000	Assumed cost for initial setup of institutional controls for uplands and in-water work.
Direct Capital Cost Subtotal				$ 1,269,788	
Indirect Capital Cost		% of TDC	40%	$ 507,915	
Total Capital Cost				**$ 1,777,704**	
Sediment					
Conventional Sand Cap, Thin Sand Cap, Enhanced Natural Recovery and Monitored Natural Recovery					
Sediment debris sweep and disposal	5.3	acre	$ 30,000	$ 160,052	Assume sweep required for intertidal and subtidal cap areas
Procure and place intertidal sand backfill/cap	1,423	cy	$ 43	$ 61,203	Cap placement above elevation 0
Procure and place subtidal sand backfill/cap	15,613	cy	$ 52	$ 811,889	Cap placement below elevation 0, includes 2-foot conventional cap and thin cap
Procure and place Enhanced natural recovery (ENR) layer	6,593	cy	$ 44	$ 290,091	Asume 0.5 ft thick layer of sand.
Prepare amended cap blend	1,714	cy	$ 5	$ 8,568	Assume 2 ft thick cap.
Amended cap media: Activated Carbon	71,968	lb	$ 1.20	$ 86,361	Assume 3% application of iron amendment by weight.
Amended cap media: Zero-Valent Iron	71,968	lb	$ 2.05	$ 147,534	Assume 3% application of activated carbon amendment by weight.
Amended Cap placement	1,714	cy	$ 43	$ 73,681	
Construction Best Management Practices and Monitoring	30	day	$ 6,000	$ 180,473	Based on an assumed average cap production rate (both cap and ENR) of 1,000 cy/day.
Procure and place rock armor	4,108	cy	$ 40	$ 164,338	Assume a thickness of 1.5 feet in upper intertidal and 0.5 feet in lower intertidal areas above -5 feet.
Procure and place 6-inch fish mix in-fill on rock armor	627	cy	$ 27	$ 16,939	Assume a thickness of 6 inches placed on larger rock armor.
Post-construction marine survey	1	each	$ 50,000	$ 50,000	Assume survey to cover all in-water work areas.
Direct Capital Cost Subtotal				$ 2,051,130	
Indirect Capital Cost		% of TDC	40%	$ 820,452	
Total Capital Cost				**$ 2,871,582**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$ 4,649,286**	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Entire Upland Area - Groundwater Monitoring of shoreline wells quarterly for year 0, annually for 10 years, followed by four 5-year events					
Groundwater sampling labor	10	well	$ 500	$ 5,000	Quantity based on 10 shoreline wells including samples for field qa/qc.
Groundwater sample chemical analysis	10	well	$ 620	$ 6,200	
Annual reporting	1	lump sum	$ 25,000	$ 25,000	
Direct Subtotal				$ 576,600	
Indirect O&M Costs		% of TDC	17%	$ 98,022	
Undiscounted Subtotal (including Indirect Costs)				**$ 674,622**	
Net Present Value Subtotal (including Indirect Costs)				**$ 634,264**	
Slope Monitoring					
Slope monitoring, maintenance and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30. Includes monitoring for slope stability, soil erosion and replacement of vegetation as needed.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		% of TDC	17.0%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Upland Cap Monitoring					
Cap monitoring, maintenance, and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		% of TDC	17%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Sediment - Capping, ENR, MNR and ICs					
Sediment cap operation and maintenance monitoring and reporting	5.8	acre	$ 1,800	$ 10,368	Assume monitoring in Year 1, 3, 5, 10, 15, 20, 25 and 30 after active remedy construction.
ENR monitoring and reporting	6.5	acre	$ 1,800	$ 11,769	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Periodic cap repair event		%	10%	$ 205,113	Assume repair in Year 5, and 10 after active remedy construction.
MNR monitoring and reporting	7.3	acre	$ 1,800	$ 13,176	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Institutional Controls - annual cost	1	lump sum	$ 25,000	$ 25,000	Asssume annual costs for 30 years.
Direct Subtotal				$ 1,342,948.62	
Indirect O&M Costs		% of TDC	17%	$ 228,301	
Undiscounted Subtotal (including Indirect Costs)				**$ 1,571,250**	
Net Present Value Subtotal (including Indirect Costs)				**$ 1,446,003**	
Total Undiscounted O&M Costs (30 Years)				**$ 3,032,112**	
Total Net Present Value of O&M Costs (30 Years)				**$ 2,812,994**	
Contingency (25 Percent of Total Cost)				**$ 1,865,570**	
Total Cost of Alternative (Present Worth)				**$ 9,330,000**	

Notes:

Present worth calculated using equal series present worth analysis where i = 0.7 %

Table B-5

Alternative Cost Estimate - Alternative 3 Low Permeabililty Upland Soil Capping and Sediment Capping

South State Street MGP Site
Bellingham, Washington

	Quantity		Cost		
Description	**Number**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Capital Costs (Direct and Indirect)					
Upland					
Low Permeability Capping with Natural Attenuation					
Mobilization, Environmental and Safety Controls					
Upland earthwork temporary controls (erosion control, temporary facilities, access controls)	1	lump sum	$ 100,000	$ 100,000	Assumed to apply to all upland work.
Air and Dust Monitoring	60	day	$ 200	$ 12,000	Assume perimeter and work area dust monitoring using hand-held real-time dust monitoring equipment. Assume 2 months of upland construction.
Stormwater collection, water collection from material stockpile areas, treatment, and discharge system during construction	1	lump sum	$ 100,000	$ 100,000	
Gas Holder Removal					
Demolition of Gas Holder #2, excavate, transport and dispose of debris/impacted material	1	lump sum	$ 200,000	$ 200,000	
Low Permeability Cap					
Clearing/Grubbing	2.9	acre	$ 7,000	$ 20,465	
Rough grading for cap surface preparation	14,150	sy	$ 1	$ 14,150	
Place and Compact Clean Borrow Soil Backfill	7,525	cy	$ 10	$ 75,248	Assume 2 ft of clean borrow fill over the lower and upper Park footprint to grade the surface to maintain 2% slope for placement of the geomembrane liner and associated stormwater drainage.
Cap - gas collection layer under geomembrane	127,350	sf	$ 2	$ 191,025	
Procure and Install Low-Permeability Geomembrane Liner	127,350	sf	$ 1	$ 76,410	
Procure and Install Geotextile Separation Layer	127,350	sf	$ 0.25	$ 31,838	
Cap drainage layer - import, place, compact	2,358	cy	$ 45	$ 106,125	Assume 6 inch thick layer of drainage rock (i.e, Type 17)
Procure and Place Topsoil	7,075	cy	$ 40	$ 283,000	Assume 1.5 ft thick layer of topsoil.
Hydroseeding	14,150	sy	$ 2	$ 28,300	
Stormwater collection system	1	lump sum	$ 200,000	$ 200,000	Assume stormwater collection system for upper and lower Park areas including discharge via outfalls.
Post-construction upland survey	1	each	$ 25,000	$ 25,000	Final as-built survey for upland construction.
Monitoring and Closure					
Install new groundwater monitoring wells	10	each	$ 5,000	$ 50,000	
Institutional Controls/Restrictive Covenants Preparation	1	lump sum	$ 75,000	$ 75,000	Assumed cost for initial setup of institutional controls for uplands and in-water work.
Direct Capital Cost Subtotal				$ 1,588,561	
Indirect Capital Cost		% of TDC	40%	$ 635,424	
Total Capital Cost				**$ 2,223,985**	
Sediment					
Conventional Sand Cap, Thin Sand Cap, and Monitored Natural Recovery					
Sediment debris sweep and disposal	13	acre	$ 30,000	$ 385,040	Assume sweep required for intertidal and subtidal cap areas
Procure and place intertidal sand backfill/cap	1,423	cy	$ 43	$ 61,203	Cap placement above elevation 0
Procure and place subtidal sand backfill/cap	34,898	cy	$ 52	$ 1,814,701	Cap placement below elevation 0, includes 2-foot conventional cap and thin cap
Prepare amended cap blend	1,714	cy	$ 5	$ 8,568	Assume 2 ft thick cap.
Amended cap media: Zero-Valent Iron	71,968	lb	$ 2.05	$ 147,534	Assume 3% application of iron amendment by weight.
Amended cap media: Activated Carbon	71,968	lb	$ 1.20	$ 86,361	Assume 3% application of activated carbon amendment by weight.
Amended Cap placement	1,714	cy	$ 43	$ 73,681	
Procure and place rock armor	4,785	cy	$ 40	$ 191,385	Assume a thickness of 1.5 feet in upper intertidal and 0.5 feet in lower intertidal areas above -10 feet.
Procure and place 6-inch fish mix in-fill on rock armor	627	cy	$ 27	$ 16,939	Assume a thickness of 6 inches placed on larger rock armor.
Construction Best Management Practices and Monitoring	43	day	$ 6,000	$ 260,682	Based on an assumed average cap production rate (both cap and ENR) of 1,000 cy/day.
Post-construction marine survey	1	each	$ 50,000	$ 50,000	Assume survey to cover all in-water work areas.
Direct Capital Cost Subtotal				$ 3,096,095	
Indirect Capital Cost		% of TDC	40%	$ 1,238,438	
Total Capital Cost				**$ 4,334,533**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$ 6,558,517**	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Entire Upland Area - Groundwater Monitoring of shoreline wells quarterly for year 0, annually for 10 years, followed by four 5-year events					
Groundwater sampling labor	10	well	$ 500	$ 5,000	Quantity based on 10 shoreline wells including samples for field qa/qc.
Groundwater sample chemical analysis	10	well	$ 620	$ 6,200	
Annual reporting	1	lump sum	$ 25,000	$ 25,000	
Direct Subtotal				$ 576,600	
Indirect O&M Costs		% of TDC	17%	$ 98,022	
Undiscounted Subtotal (including Indirect Costs)				**$ 674,622**	
Net Present Value Subtotal (including Indirect Costs)				**$ 634,264**	
Slope Monitoring					
Slope monitoring, maintenance and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30. Includes monitoring for slope stability, soil erosion and replacement of vegetation as needed.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		0	17.0%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Upland Cap Monitoring					
Cap monitoring, maintenance, and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		% of TDC	17%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Sediment - Capping, ENR, MNR and ICs					
Sediment cap operation and maintenance monitoring and reporting	13	acre	$ 1,800	$ 23,867	Assume monitoring in Year 1, 3, 5, 10, 15, 20, 25 and 30 after active remedy construction.
ENR monitoring and reporting	0.0	acre	$ 1,800	$ -	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Periodic cap repair event		%	10.00%	$ 309,609	Assume repair in Year 5, and 10 after active remedy construction.
MNR monitoring and reporting	7.3	acre	$ 1,800	$ 13,176	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Institutional Controls - annual cost	1	lump sum	$ 25,000	$ 25,000	Asssume annual costs for 30 years.
Direct Subtotal				$ 1,612,858.43	
Indirect O&M Costs		% of TDC	17%	$ 274,186	
Undiscounted Subtotal (including Indirect Costs)				**$ 1,887,044**	
Net Present Value Subtotal (including Indirect Costs)				**$ 1,739,972**	
Total Undiscounted O&M Costs (30 Years)				**$ 3,347,906**	
Total Net Present Value of O&M Costs (30 Years)				**$ 3,106,962**	
Contingency (25 Percent of Total Cost)				**$ 2,416,370**	
Total Cost of Alternative (Present Worth)				**$ 12,100,000**	

Notes:

Present worth calculated using equal series present worth analysis where i = 0.7 %

Table B-6

Alternative Cost Estimate - Alternative 4 SVE and Bioremediation with Sediment Capping

South State Street MGP Site
Bellingham, Washington

Description	Quantity		Cost		Notes
	Number	Unit	Unit Cost	Total Cost	
Capital Costs (Direct and Indirect)					
Upland					
Site Wide Vegetated Soil Cap with SVE and Bioremediation					
Mobilization, Environmental and Safety Controls					
Upland earthwork temporary controls (erosion control, temporary facilities, access controls)	1	lump sum	$ 100,000	$ 100,000	Assumed to apply to all upland work.
Air and Dust Monitoring	60	day	$ 200	$ 12,000	Assume perimeter and work area dust monitoring using hand-held real-time dust monitoring equipment. Assume 2 months of upland construction.
Stockpile and dewatering area setup	1	lump sum	$ 150,000	$ 150,000	
Stormwater collection, water collection from material stockpile areas, treatment, and discharge system during construction	1	lump sum	$ 100,000	$ 100,000	
Gas Holder Removal					
Demolition of Gas Holder #2, excavate, transport and dispose of debris/impacted material	1	lump sum	$ 200,000	$ 200,000	
Permeable Vegetated Cap					
Clearing/Grubbing	3	acre	$ 7,000	$ 20,465	
Rough grading for cap surface preparation	14,150	sy	$ 1	$ 14,150	
Place and Compact Clean Borrow Soil Backfill	2,852	cy	$ 10	$ 28,519	Assume 1 ft of clean borrow fill over the lower Park footprint to grade the pre-cap surface and raise the pre-cap elevation to account for sea level rise.
Procure and Install Geotextile Separation Layer	127,350	sf	$ 0.25	$ 31,838	
Cap drainage layer - import, place, compact	2,358	cy	$ 45	$ 106,125	Assume 6 inch thick layer of drainage rock (i.e, Type 17)
Procure and Place Topsoil	7,075	cy	$ 40	$ 283,000	Assume 1.5 ft thick layer of topsoil.
Hydroseeding	14,150	sy	$ 2	$ 28,300	
Post-construction upland survey	1	each	$ 25,000	$ 25,000	Final as-built survey for upland construction.
Bioremediation					
Enhanced Aerobic Bioremediation treatability study	1	lump sum	$ 40,000	$ 40,000	
Amendment injection - Direct Push	1.12	Event-Acre	$ 250,000	$ 559,125	Assume 2 events
Baseline monitoring	1	lump sum	$ 40,000	$ 40,000	
SVE					
Passive bioventing well installation	1	lump sum	$ 25,000	$ 25,000	
SVE capital costs	1	lump sum	$ 250,000	$ 250,000	
SVE electrical hookup, startup and testing	1	lump sum	$ 30,000	$ 30,000	
Monitoring and Closure					
Install new groundwater monitoring wells	10	each	$ 5,000	$ 50,000	
Institutional Controls/Restrictive Covenants Preparation	1	lump sum	$ 75,000	$ 75,000	Assumed cost for initial setup of institutional controls for uplands and in-water work.
Direct Capital Cost Subtotal				$ 2,168,521	
Indirect Capital Cost		% of TDC	40%	$ 867,408	
Total Capital Cost				**$ 3,035,930**	
Sediment					
Intertidal Sediment Excavation, Conventional Sand Cap, Enhanced Natural Recovery and Monitored Natural Recovery					
Sediment debris sweep and disposal	3.1	acre	$ 30,000	$ 93,384	Assume sweep required for intertidal and subtidal cap areas
Shoring and/or coffer dam install for intertidal excavation	1	lump sum	$ 325,000	$ 325,000	Assume cofferdam for excavating nearshore sediment from land.
Sediment excavation using land-based excavation equipment	4,112	cy	$ 49	$ 201,510	Assume average 6 ft for excavation depth.
Handling and dewatering of sediment from land-based excavation	4,112	cy	$ 15	$ 61,687	
Handling of water drained from excavated sediment	5	day	$ 10,000	$ 50,000	
Handling and loading of excavated material	4,112	cy	$ 2	$ 8,225	
Transport (truck) to rail facility	5,655	ton	$ 10	$ 56,546	Includes 10% bulking factor.
Transport (truck/train) and dispose Soil at Subtitle C (hazardous waste) landfill	1,414	ton	$ 175	$ 247,389	Assume 25% of excavated sediment requires disposal at Subtitle C landfill. Assume 10% bulking factor.
Transload, railcar transport to and tipping at Subtitle D landfill	4,241	ton	$ 70	$ 296,867	Assume 75% of excavated sediment can be disposed at Subtitle D landfill. Assume 10% bulking factor.
Procure and place intertidal sand backfill/cap	5,536	cy	$ 43	$ 238,038	Cap placement above elevation 0. Includes backfilling excavated areas.
Procure and place subtidal sand backfill/cap	11,132	cy	$ 52	$ 578,847	Cap placement below elevation 0
Procure and place Enhanced natural recovery (ENR) layer	8,834	cy	$ 44	$ 388,686	
Procure and place rock armor	4,108	cy	$ 40	$ 164,338	Assume a thickness of 1.5 feet in upper intertidal (above el 0) and 0.5 feet in lower intertidal areas above el -10 feet.
Procure and place 6-inch fish mix in-fill on rock armor	627	cy	$ 27	$ 16,939	Assume a thickness of 6 inches placed on larger rock armor.
Construction Best Management Practices and Monitoring	34	day	$ 6,000	$ 206,097	Based on an assumed average cap production rate (both cap and ENR) of 1,000 cy/day.
Post-construction marine survey	1	each	$ 50,000	$ 50,000	Assume survey to cover all in-water work areas.
Direct Capital Cost Subtotal				$ 2,983,553	
Indirect Capital Cost		% of TDC	40%	$ 1,193,421	
Total Capital Cost				**$ 4,176,974**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$ 7,212,904**	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Entire Upland Area - Groundwater Monitoring of shoreline wells quarterly for year 0, annually for 10 years, followed by four 5-year events					
Groundwater sampling labor	10	well	$ 500	$ 5,000	Quantity based on 10 shoreline wells including samples for field qa/qc.
Groundwater sample chemical analysis	10	well	$ 620	$ 6,200	
Annual reporting	1	lump sum	$ 25,000	$ 25,000	
Direct Subtotal				$ 576,600	
Indirect O&M Costs		% of TDC	17%	$ 98,022	
Undiscounted Subtotal (including Indirect Costs)				**$ 674,622**	
Net Present Value Subtotal (including Indirect Costs)				**$ 634,264**	
Slope Monitoring					
Slope monitoring, maintenance and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30. Includes monitoring for slope stability, soil erosion and replacement of vegetation as needed.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		0	17.0%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Upland Cap Monitoring and SVE O&M					
Cap monitoring, maintenance, and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30.
AS/SVE system operation, maintenance, monitoring and reporting - annual cost	1	lump sum	$ 75,000	$ 75,000	Assume annual monitoring for Years 1 to 5.
Direct Subtotal				$ 711,000	
Indirect O&M Costs		% of TDC	17%	$ 120,870	
Undiscounted Subtotal (including Indirect Costs)				**$ 831,870**	
Net Present Value Subtotal (including Indirect Costs)				**$ 796,048**	
Sediment - Capping, ENR, MNR and ICs					
Sediment cap operation and maintenance monitoring and reporting	3.1	acre	$ 1,800	$ 5,603	Assume monitoring in Year 1, 3, 5, 10, 15, 20, 25 and 30 after active remedy construction.
ENR monitoring and reporting	9	acre	$ 1,800	$ 15,769	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Periodic cap repair event		%	10.00%	$ 298,355	Assume repair in Year 5, and 10 after active remedy construction.
MNR monitoring and reporting	10	acre	$ 1,800	$ 17,303	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Institutional Controls - annual cost	1	lump sum	$ 25,000	$ 25,000	Asssume annual costs for 30 years.
Direct Subtotal				$ 1,523,824.28	
Indirect O&M Costs		% of TDC	17%	$ 259,050	
Undiscounted Subtotal (including Indirect Costs)				**$ 1,782,874**	
Net Present Value Subtotal (including Indirect Costs)				**$ 1,649,254**	
Total Undiscounted O&M Costs (30 Years)				**$ 3,682,486**	
Total Net Present Value of O&M Costs (30 Years)				**$ 3,445,929**	
Contingency (25 Percent of Total Cost)				**$ 2,664,708**	
Total Cost of Alternative (Present Worth)				**$ 13,300,000**	

Notes:

Present worth calculated using equal series present worth analysis where i = 0.7 %

Table B-7

Alternative Cost Estimate - Alternative 5 ISS and Bioremediation with Sediment Capping

South State Street MGP Site

Bellingham, Washington

	Quantity		Cost		
Description	**Number**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Capital Costs (Direct and Indirect)					
Upland					
Site Wide Vegetated Soil Cap with ISS and Bioremediation					
Mobilization, Environmental and Safety Controls					
Upland earthwork temporary controls (erosion control, temporary facilities, access controls)	1	lump sum	$ 100,000	$ 100,000	Assumed to apply to all upland work.
Air and Dust Monitoring	60	day	$ 200	$ 12,000	Assume perimeter and work area dust monitoring using hand-held real-time dust monitoring equipment. Assume 2 months of upland construction.
Stockpile and dewatering area setup	1	lump sum	$ 150,000	$ 150,000	
Stormwater collection, water collection from material stockpile areas, treatment, and discharge system during construction	1	lump sum	$ 100,000	$ 100,000	
Gas Holder Removal					
Demolition of Gas Holder #2, excavate, transport and dispose of debris/impacted material	1	lump sum	$ 200,000	$ 200,000	
Permeable Vegetated Cap					
Clearing/Grubbing	2.9	acre	$ 7,000	$ 20,465	
Rough grading for cap surface preparation	14,150	sy	$ 1	$ 14,150	
Place and Compact Clean Borrow Soil Backfill	2,852	cy	$ 10	$ 28,519	Assume 1 ft of clean borrow fill over the lower Park footprint to grade the pre-cap surface and raise the pre-cap elevation to account for sea level rise.
Procure and Install Geotextile Separation Layer	127,350	sf	$ 0.25	$ 31,838	
Cap drainage layer - import, place, compact	2,358	cy	$ 45	$ 106,125	Assume 6 inch thick layer of drainage rock (i.e, Type 17)
Procure and Place Topsoil	7,075	cy	$ 40	$ 283,000	Assume 1.5 ft thick layer of topsoil.
Hydroseeding	14,150	sy	$ 2	$ 28,300	
Post-construction upland survey	1	each	$ 25,000	$ 25,000	Final as-built survey for upland construction.
Shoreline Restoration	1	acre	$ 100,000	$ 100,000	
Bioremediation					
Enhanced Aerobic Bioremediation treatability study	1	lump sum	$ 40,000	$ 40,000	
Amendment injection - Direct Push	0.48	Event-Acre	$ 250,000	$ 239,096	Assume two events.
Baseline monitoring	1	lump sum	$ 40,000	$ 40,000	
ISS					
Soil stabilization treatability testing	1	lump sum	$ 100,000	$ 100,000	
ISS media cost: Organoclay SS-199	585,082	lb	$ 2	$ 877,623	Assume 1 percent application by weight.
ISS media cost: Portland cement	4,680,654	lb	$ 0.10	$ 468,065	Assume 8 percent application by weight.
Shallow (less than 15ft) stabilization using an excavator	20,896	cy	$ 40.00	$ 835,831	Average depth for ISS = 14 feet. Assume solidification is shallow enough to be done by an excavator.
Monitoring and Closure					
Install new groundwater monitoring wells	10	lump sum	$ 5,000	$ 50,000	
Institutional Controls/Restrictive Covenants Preparation	1	lump sum	$ 75,000	$ 75,000	Assumed cost for initial setup of institutional controls for uplands and in-water work.
Direct Capital Cost Subtotal				$ 3,925,011	
Indirect Capital Cost		% of TDC	40%	$ 1,570,004	
Total Capital Cost				**$ 5,495,015**	
Sediment					
Intertidal Sediment Excavation, Conventional Sand Cap and Monitored Natural Recovery					
Sediment debris sweep and disposal	13	acre	$ 30,000	$ 383,364	Assume sweep required for intertidal and subtidal cap areas
Shoring and/or coffer dam install for intertidal excavation	1	lump sum	$ 325,000	$ 325,000	Assume cofferdam for excavating nearshore sediment from land.
Sediment excavation using land-based excavation equipment	4,112	cy	$ 49	$ 201,510	Assume average 6 ft for excavation depth.
Handling and dewatering of sediment from land-based excavation	4,112	cy	$ 15	$ 61,687	
Handling of water drained from excavated sediment	10	day	$ 10,000	$ 100,000	
Handling and loading of excavated material	4,112	cy	$ 2	$ 8,225	
Transport (truck) to rail facility	5,655	ton	$ 10	$ 56,546	Includes 10% bulking factor.
Transport (truck/train) and dispose Soil at Subtitle C (hazardous waste) landfill	1,414	ton	$ 175	$ 247,389	Assume 25% of excavated sediment can be disposed at Subtitle C landfill. Assume 10% bulking factor.
Transload, railcar transport to and tipping at Subtitle D landfill	4,241	ton	$ 70	$ 296,867	Assume 75% of excavated sediment can be disposed at Subtitle D landfill. Assume 10% bulking factor.
Procure and place intertidal sand backfill/cap	5,536	cy	$ 43	$ 238,038	Cap placement above elevation 0. Includes backfilling excavated areas.
Procure and place subtidal sand backfill/cap	50,118	cy	$ 52	$ 2,606,124	Cap placement below elevation 0
Procure and place rock armor	4,785	cy	$ 40	$ 191,385	Assume a thickness of 1.5 feet in upper intertidal and 0.5 feet in lower intertidal areas above -10 feet.
Procure and place 6-inch fish mix in-fill on rock armor	627	cy	$ 27	$ 16,939	Assume a thickness of 6 inches placed on larger rock armor.
Construction Best Management Practices and Monitoring	65	day	$ 6,000	$ 391,068	Based on an assumed average cap production rate of 1,000 cy/day, due to placement in thin lifts over soft sediments.
Post-construction marine survey	1	each	$ 50,000	$ 50,000	Assume survey to cover all in-water work areas.
Direct Capital Cost Subtotal				$ 5,174,142	
Indirect Capital Cost		% of TDC	40%	$ 2,069,657	
Total Capital Cost				**$ 7,243,799**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$ 12,738,814**	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Entire Upland Area - Groundwater Monitoring of shoreline wells quarterly for year 0, annually for 10 years, followed by four 5-year events					
Groundwater sampling labor	10	well	$ 500	$ 5,000	Quantity based on 10 shoreline wells including samples for field qa/qc.
Groundwater sample chemical analysis	10	well	$ 620	$ 6,200	
Annual reporting	1	lump sum	$ 25,000	$ 25,000	
Direct Subtotal				$ 576,600	
Indirect O&M Costs		% of TDC	17%	$ 98,022	
Undiscounted Subtotal (including Indirect Costs)				**$ 674,622**	
Net Present Value Subtotal (including Indirect Costs)				**$ 634,264**	
Slope Monitoring					
Slope monitoring, maintenance and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30. Includes monitoring for slope stability, soil erosion and replacement of vegetation as needed.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		0	17.0%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Upland Cap Monitoring					
Cap monitoring, maintenance, and reporting - annual cost	1	lump sum	$ 24,000	$ 24,000	Assume annual monitoring for Years 1 to 10 followed by monitoring in Years 15, 20, 25 and 30.
Direct Subtotal				$ 336,000	
Indirect O&M Costs		% of TDC	17%	$ 57,120	
Undiscounted Subtotal (including Indirect Costs)				**$ 393,120**	
Net Present Value Subtotal (including Indirect Costs)				**$ 366,363**	
Sediment - Capping, ENR, MNR and ICs					
Sediment cap operation and maintenance monitoring and reporting	13	acre	$ 1,800	$ 23,002	Assume monitoring in Year 1, 3, 5, 10, 15, 20, 25 and 30 after active remedy construction.
ENR monitoring and reporting	0	acre	$ 1,800	$ -	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Periodic cap repair event		%	10.00%	$ 517,414	Assume repair in Year 5, and 10 after active remedy construction.
MNR monitoring and reporting	7.3	acre	$ 1,800	$ 13,176	Assume monitoring in Year 1, 3, 5, and 10 after active remedy construction.
Institutional Controls - annual cost	1	lump sum	$ 25,000	$ 25,000	Asssume annual costs for 30 years.
Direct Subtotal				$ 2,021,545.68	
Indirect O&M Costs		% of TDC	17%	$ 343,663	
Undiscounted Subtotal (including Indirect Costs)				**$ 2,365,208**	
Net Present Value Subtotal (including Indirect Costs)				**$ 2,194,137**	
Total Undiscounted O&M Costs (30 Years)				**$ 3,826,070**	
Total Net Present Value of O&M Costs (30 Years)				**$ 3,561,127**	
Contingency (25 Percent of Total Cost)				**$ 4,074,985**	
Total Cost of Alternative (Present Worth)				**$ 20,400,000**	

Notes:

Present worth calculated using equal series present worth analysis where i = 0.7 %

GeoEngineers