2011 Interim Action Work Plan
NuStar Vancouver Facility
Vancouver, Washington

Prepared for:
NuStar Terminals Services, Inc

March 25, 2011
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1.0 Introduction

This work plan presents the design for additional interim action at the NuStar Terminals Services, Inc. (NuStar) bulk storage terminal at the Port of Vancouver Terminal No. 2, located at 2565 NW Harborside Drive in Vancouver, Washington (the Property). A Property location map is provided as Figure 1. The Property is defined as the area within the 2006 NuStar leasehold boundary. Work was performed pursuant to Agreed Order (AO) No. 07-TC-S DE3938 between the Washington State Department of Ecology (Ecology) and NuStar.

A Remedial Investigation (RI) and Feasibility Study (FS) were conducted to collect, develop, and evaluate information sufficient for selecting a cleanup action. The RI report was submitted to Ecology in September 2008. Based on comments received from Ecology in July 2009, a revised RI report was submitted in October 2009 (Ash Creek, 2009a). A Baseline Risk Assessment (RiA) is documented in the *Baseline Risk Assessment Report* submitted to Ecology in September 2008 that provides quantitative potential risk to human health and the environment (Ash Creek, 2008). A draft FS was submitted to Ecology in January 2010 and is currently under review. Ecology has requested additional work prior to approval of the RI/FS.

In 2008, NuStar initiated interim action activities in the primary release area at the Property. The interim action activities included enhanced bioremediation injections and installation and operation of a soil vapor extraction (SVE) system. These activities have successfully reduced the concentrations of chemicals of concern (COC) in the release area and treatment is continuing.

Given that RI/FS work is continuing, the draft FS identified area beyond the current interim action to target for remediation, and interim actions have been successful in the release area, NuStar has elected to complete additional interim action at the Property. The proposed additional interim action includes expansion of the existing SVE system, additional bioremediation injections in the current interim action area, and bioremediation injections in an expanded interim action area.

1.1 Definition of Property

As discussed in the section above, the “Property” refers to the NuStar 2006 leasehold area. Features in this report may be referred to as “off-Property” or “on-Property” when describing physical location relative to the 2006 leasehold boundary. The 2006 leasehold boundary is shown on Figure 2. In 2009, NuStar leased additional property to the north, outside of the 2006 leasehold boundary. The additional property is not located in the area of historical activities relevant to the RI/FS (i.e., solvent handling, etc.), thus is not included in the Property.

1.2 Purpose

The purpose of this interim action work plan is to define the scope and schedule for implementation of interim actions in the target remediation area defined in the draft FS.

1.3 Work Plan Organization

Background information, the RI, RiA, and FS are summarized in Section 2. The locations of the proposed interim actions are discussed in Section 3. The basis for the design of the interim actions is presented in Sections 4 and 5. A project schedule is presented in Section 6. Supporting information, including detailed design drawings for the interim actions, are included in Appendices.

2.0 Background

2.1 Property Location, Description, and History

Location. The Property is located at the Port of Vancouver Terminal No. 2 in Vancouver, Washington (as shown on Figure 1). The Property address is 2565 NW Harborside Drive, Port of Vancouver, Vancouver, Washington 98660 (Latitude: N45º 38.26', Longitude: W122º 42.20'). The Property is owned by the Port of Vancouver (Port) and leased by NuStar.

Physical Features. Figure 2 is a Property Plan. The Property is roughly rectangular with nominal dimensions of 600 by 1,300 feet and a total area of approximately 17 acres. The Property is on the north shore of the Columbia River. Land on the other sides is industrial land also owned by the Port. The Property is located on Clark County Tax Lot (TL) Nos. 151979-000, 502010-002, 502010-000, and a portion of 502020-000, as well as a portion of the Washington Department of Natural Resources tideland area managed by the Port.

The Property includes five buildings (Warehouses 9, 13, 14, 15, and 17), a loading dock, three aboveground storage tank (AST) farms, two tank truck loading/unloading racks, a rail tank car loading/unloading area, marine vessel dock and piping, and an office. The ground surface is nearly flat at an elevation typically between 32 and 34 feet above mean sea level (MSL). The majority of product piping is aboveground.

The Property includes extensive underground utilities. Utilities are within about 10 feet of the ground surface, above the groundwater table.

The Property ground surface coverage consists of the following (with approximate aerial extent):

- Buildings (35 percent);
- Paved areas (45 percent);

- Tanks (5 percent); and
- Gravel/bare ground (15 percent).

Property History. Historical aerial photographs were reviewed to identify the developmental history of the Property and were presented in the RI report (Ash Creek, 2009a). In summary, the Property was undeveloped into the 1940s. Filling occurred throughout the 1940s and 1950s, and development began about 1960 with Warehouse 9 and several ASTs. Expansion of facilities on the Property occurred periodically between the 1960s and 2000.

2.2 Property Operations

In general, the Property was developed to receive, store, and handle bulk fuel and chemicals. Typically, these chemicals were not owned by the terminal operator. Rather, the terminal operator entered into agreements as a wholesale distributor to handle chemicals for owners. The terminal was owned/operated by GATX from the early 1960s through 1998 (GATX has since been acquired by Kinder Morgan). The terminal was acquired in 1998 by ST Services, a subsidiary of Kaneb Pipeline Partners L.P. (Kaneb). Kaneb was acquired in 2005 by Valero L.P. Valero L.P. changed its name to NuStar Energy L.P. in 2007.

Although a variety of products have been handled at the Property over the years, the historical sampling has identified chlorinated solvents as the chemicals of interest. Historical company records suggest that handling of chlorinated solvents may have ended as early as 1990, but the end date is uncertain. Currently, products such as fertilizer, jet fuel, biodiesel, methanol, and wood preservative are received and transported via ship, pipeline, railcar, and trucks at the Property. Products are also blended, packaged, and stored on the Property.

2.3 Geology and Hydrogeology

This section presents the understanding of the geology and hydrogeology as discussed in the RI (Ash Creek, 2009a).

2.3.1 Geology

The vicinity of the Property is dominated by two primary units: unconsolidated alluvial and catastrophic flood deposits and the Troutdale Formation. Information on the regional geology is summarized below based on SECOR (2001) and AMEC (2005). Information on the Property's geology and hydrogeology was obtained during the remedial investigations (Ash Creek, 2009).

The alluvial and flood deposits are the upper unit and comprise the USA hydrogeologic unit. For consistency with previous reports, this unit is referred to as the USA herein. The thickness of the USA varies, observed to range from 125 to 200 feet thick within the areas investigated at and near the Port. The

unit consists of alluvial deposits of the Columbia River and the catastrophic Missoula Floods. The upper portion contains unconsolidated silt and sand. The lower portion generally consists of sand or sand and gravel.

The Troutdale Formation underlies the USA and can be in excess of 1,000 feet thick. The base of the USA is typically identified by the transition to an underlying conglomerate or consolidated/unconsolidated silty, sandy gravel of the Pleistocene Troutdale Formation.

Figure 3 presents a geologic cross-section through the Property. The upper part of the USA that underlies the Property consists of fine to coarse sand with variable layers of silt or silty sand. The upper sandy zone extends from the ground surface to a depth of up to 50 feet beneath the western and central portions of the Property and extending south to the Columbia River. Within the upper USA, a silt layer is present on the north and east parts of the Property. At the northern Property boundary, the silt is encountered at depths as shallow as 9 to 10 feet below the ground surface (bgs) and extends to depths of approximately 40 feet bgs. This layer is continuous along the north and east of the Property, forming a low-permeability ridge at the Property boundary. The upper contact of the silt appears to coincide with the historical riverbank. The sand lying above the silt corresponds to the fill observed being placed in aerial photographs from 1948 through 1961.

A silty gravel layer underlies the sandy/silty layers of the upper USA beneath the Property. The silty gravel grades into the coarse sand and/or gravel of the lower portion of the USA. The depth to the top of the silty gravel varies from 39 (north) to 50 (south) feet bgs beneath the Property. North of the northern Property boundary (i.e., north of the silt ridge), the shallow geology is predominantly silt. The silty gravel is not observed and a sand layer is found between the silt and underlying sand and gravel. The Troutdale Formation underlies the sand and gravel unit; however, borings installed to depths of up to 140 feet bgs at the Property have not encountered the Troutdale Formation.

2.3.2 Hydrogeology

The regional aquifers follow the regional geology discussed above. The alluvial and catastrophic flood deposits comprise the USA. The USA is unconfined and receives recharge directly from the land surface and/or surface water features. Based on numerous studies conducted in the Port area, the following aquifer terminology has been adopted:

- Shallow Zone – The Shallow Zone corresponds to first encountered groundwater, generally the upper 20 to 30 feet of the saturated zone. At the Facility, depth to first encountered groundwater is generally 21 to 33 feet below grade (elevation of 5 to 12 feet). The bottom of the Shallow Zone is about elevation -10 to -20 feet, or a depth of about 40 to 50 feet.
- Intermediate Zone – The Intermediate Zone generally corresponds to the middle of the USA. This zone is most directly influenced by pumping wells in the USA. The Intermediate Zone lies between

approximate elevations -15 and -100 feet. At the Facility, the Intermediate Zone is between the depths of about 55 and 130 feet.

- Deep USA Zone – The Deep Zone includes the lower part of the USA and in some areas, the reworked gravel at the top of the Troutdale Formation.
- TGA – The TGA corresponds to the Troutdale Formation and underlies the USA in the project area. Flow in the TGA is less influenced by regional groundwater pumping and more by regional recharge and discharge influences.

Figure 3 shows an interpretation of the hydrogeologic units at the Property. Beneath most of the Property, the Shallow Zone lies within the sand layer overlying the silty gravel. Along the northern Property boundary and continuing to the north, the Shallow Zone lies entirely within the silt layer. As a result, the silt layer forms a low-permeability zone that greatly impedes hydrogeologic communication between the Shallow and Intermediate Zones on the Property, and effectively isolates the Shallow Zone on-Property from the Shallow Zone off-Property. Off-Property to the north, the sand layer beneath the silt layer is hydrogeologically connected to the underlying sand and gravel, so is therefore effectively part of the Intermediate Zone.

A groundwater divide, approximately parallel to the river bank is present in the central portion of the Property within the Shallow Zone, generally corresponding to the southern edge of the "silt ridge" at the Property. Groundwater south of the groundwater divide is more sensitive to tidal variations. Shallow groundwater to the north of the divide appears to be less tidally influenced and generally flows away from the river. The presence of the silt ridge, coupled with the groundwater divide, effectively isolates the most impacted Shallow Zone groundwater at the Property from the influences of pumping from the Shallow or Intermediate Zones north and east of the Property. Furthermore, given that the geologic source of the silt ridge is the former natural river bank, this feature is believed to be continuous well beyond the Property boundaries to the east and west.

Intermediate Zone groundwater flow is currently being evaluated. Transducers were installed in five site Intermediate Zone wells in December 2010. Water elevation data collected from these transducers will be combined with transducer data from other regional wells screened in the Intermediate Zone to prepare regional groundwater flow maps.

The lower reaches of the Columbia River – where the Property is located – are subject to tidal variations as well as seasonal and stage variations due to precipitation and regulation of river flow by dams.

In 1999, an aquifer test was conducted to evaluate hydraulic properties of the Shallow Zone on the Property (SECOR, 1999a). The analysis of data collected during aquifer pumping in the central area of the Property resulted in an estimated Shallow Zone aquifer transmissivity of 0.82 square feet per minute (ft^2/min) to 6.4 ft^2/min and an aquifer storativity of 0.002 to 0.005. The transmissivity of the Intermediate Zone has been estimated by others to range from 200 to 1,250 ft^2/min (Parametrix, 2008).

Deep groundwater is found in the Troutdale Formation which underlies the catastrophic flood deposits and alluvial deposits that make up the USA in the project area. The depth to the top of the Troutdale Formation varies significantly in the project area, and has been encountered at a depth of 98 feet directly north of the Property but is below a depth of 140 feet beneath the Property. The Troutdale Formation contains more fines than the USA and ranges from consolidated to semi-consolidated due to cementation. The differing lithology of the Troutdale Formation results in a transmissivity of the TGA at least an order of magnitude lower than the USA (Parametrix, 2008).

2.3.3 Surface Water and Surface Water Drainage

The Columbia River bounds the Property to the southwest. The Property is situated on the Columbia River flood plain. As described in Section 2.1, the majority of the Property is covered with an impermeable surface (i.e., buildings, asphalt, concrete). Surface water in the terminal area is directed to a permitted stormwater system that is maintained by the Port.

2.3.4 Aquatic and Terrestrial Habitat

The Columbia River is located along the southwest boundary of the Property. Aquatic organisms including anadromous and resident fish species, some of which are threatened or endangered, use parts of the river during various stages in their life cycles. As discussed in Section 2.1, the Property and surrounding area are covered with impermeable surfaces and provide no terrestrial habitat.

2.4 Remedial Investigation

Since 1980, numerous investigations have been conducted by various parties. These investigations identified the presence of chlorinated solvents and associated breakdown products, primarily tetrachloroethene (PCE), trichloroethene (TCE), and cis-1,2-dichloroethene (DCE) in soil, groundwater, and soil vapor. Most of the planned investigation activities were completed between 1980 and 2009. Together, these activities comprise the RI (Ash Creek, 2009a) findings to date summarized in this section.

Land Use. The RI report presents supporting documentation indicating the site is an industrial property as defined by WAC 173-340-200.

Groundwater Use. Groundwater at the Property is not currently used for any purpose. As discussed in Section 2.3.2, a groundwater divide is present in the Shallow Zone groundwater. Groundwater south of the divide has a southerly gradient on much of the Property, is tidally influenced, and discharges to the Columbia River. Groundwater north of the ridge is less tidally influenced and generally flows away from the river. The Intermediate Zone beneath the Property is a productive aquifer that is used regionally for municipal and industrial water supply.

Surface Water. There are no surface waters on the Property. The Columbia River is located adjacent to the Property, to the south. The Columbia River has a variety of uses including serving as an active channel for large commercial ships. The river is not currently used for drinking water in Vancouver or within several miles of the Property and is not likely to be used for drinking water within the foreseeable future. Anadromous and resident fish species use parts of the river during various stages in their life cycles. A number of local American Indian tribes have fishing rights on the Columbia River. The Columbia River is also used for fishing for sport and consumption and for recreational boating.

Chemicals of Potential Concern. A screening of chemical data identified the chemicals of potential concern (COPCs) in soil and groundwater to be chlorinated solvents and associated degradation products. Three COPCs (PCE, TCE, and vinyl chloride [VC]) account for greater than 99.9 percent of potential human health risk based on comparison to screening levels (Ash Creek, 2008). Cis-1,2-DCE is a breakdown product of PCE and TCE and will break down into VC. These four compounds represent the primary human health COPCs. In addition, PCE, TCE, cis-1,2-DCE, 1,1-dichloroethene, 1,1,1-trichloroethane, and 1,1-dichloroethane were identified as COPCs based on screening levels for aquatic organisms.

Extent of COPCs in Soil. A review of soil analytical data indicate that the relatively highest molar concentrations of COPCs in vadose zone soil (<25 feet bgs) are present near location AGP-22 and locations AGP-28/AGP-29. The COPCs in vadose zone soil are predominantly PCE, with lesser concentrations of TCE and cis-1,2-DCE. The extent of total molar chloroethenes in soil is shown on Figure 4.

Extent of COPCs in Shallow Zone Groundwater. Figure 5 shows the extent of COPCs in Shallow Zone groundwater. Shallow-zone COPCs emanating from source areas within the NuStar facility property are limited to within about 100 feet of the Property boundary to the north and up to 300 feet of the Property to the west and east in the Shallow Zone. The river defines the extent of halogenated volatile organic compounds (HVOCs) to the south. It is anticipated that there will be net discharge from the Shallow Zone groundwater to the river.

2.5 Risk Assessment

A baseline RiA was completed in accordance with the requirements for determining cleanup standards under MTCA (Ash Creek, 2008).

Human Health. The baseline human health risk assessment indicated that the potential hazards associated with non-carcinogens or the estimated excess lifetime cancer risks associated with carcinogens were acceptable with the exception of the vapor intrusion pathway and a hypothetical (future) drinking water pathway.

Ecological. The Property is within an industrial area, is generally covered with buildings and pavement, and has little or no habitat, so terrestrial ecological risk is acceptable. Several COPCs are estimated to potentially exceed conservative effects-based concentrations in surface water or sediment at the groundwater/surface water interface.

2.6 Feasibility Study

Based on the results of the RI and risk assessment, an FS was completed in accordance with MTCA. The draft FS report was submitted to Ecology in January 2010 (Ash Creek, 2010b).

Cleanup standards were developed for soil and groundwater as follows.

- Soil – Cleanup levels for soil were developed in accordance with MTCA Method C. Each applicable pathway was considered and cleanup levels protective of groundwater (as a drinking water source) were the controlling cleanup levels. The standard point of compliance for soil cleanup levels to protect groundwater is throughout the site.
- Groundwater – Cleanup levels for groundwater were developed in accordance with MTCA Method B. Groundwater cleanup levels were established to be protective of groundwater as a drinking water source. Cleanup levels protective of air, sediment, and surface water were also evaluated in the development of the groundwater cleanup standard. Groundwater cleanup levels protective of drinking water are presumed to be adequate to protect the air pathway. Two cleanup levels were developed for each COC based on the point of compliance. The first is a cleanup level protective of the drinking water pathway. The second represents the pathway protective of surface water/sediment for each COC (whichever is the lower value). The standard groundwater point of compliance is the saturated zone throughout the site and corresponds to the drinking water pathway cleanup level. For the surface water/sediment protective groundwater cleanup level, the point of compliance is the point where groundwater enters the surface water.

Cleanup alternatives were developed and evaluated in accordance with MTCA requirements. To select a cleanup action that uses permanent solutions to the maximum extent practicable, the groundwater cleanup action alternatives were subjected to a disproportionate cost analysis. Based on a comparative analysis, the groundwater cleanup action alternatives were ranked from most to least permanent, as follows: enhanced bioremediation, reactive treatment wall/enhanced bioremediation, and groundwater extraction/treatment.

Based on the results of the FS, the recommended cleanup action alternative for the site is SVE combined with enhanced bioremediation and monitored natural attenuation (MNA). The current interim action SVE system would be expanded to address the soil above cleanup levels. Enhanced bioremediation would be used to treat groundwater and saturated soil corresponding to the majority of site risk. MNA would be used to address residual concentrations of COC in peripheral areas of soil and groundwater. Groundwater use

restrictions, as part of a restrictive covenant or equivalent, would be implemented. Monitoring would be used to evaluate the concentrations of COC in soil, groundwater, and/or vapor to evaluate the effectiveness of the cleanup action.

2.7 Interim Actions

The results of the RI indicate that the primary release area is located between Warehouses 13 and 15, beneath the rail siding north of these warehouses, and extending south toward the sea wall. Rail car off-loading historically occurred at the north end of this area. Soil vapor, vadose zone soil, saturated zone soil, and groundwater data support that releases occurred in this area. Two interim actions have been conducted at this release area. A summary of each is provided below.

2.7.1 Interim Action – 2000 through 2005

Pursuant to a 1998 AO between Ecology and Support Terminals Services, Inc. (a.k.a. ST Services), an interim remedial action system was installed at the Property in 2000. Detailed work scopes, procedures, and methods for these activities were presented in the *Final Interim Action Pilot Study Work Plan*, (SECOR, 1999b), *Response to Ecology's Comments Letter* (SECOR, 1999c), and the *Final Interim Action Work Plan* (SECOR, 2000a). The primary objective of the interim action was to reduce chlorinated volatile organic compound (VOC) concentrations within the areas of greatest impact and to complete cleanup of hazardous substances in these areas. The interim action consisted of two components: (1) a re-circulating system to treat groundwater; and (2) vapor extraction to treat soil. The system was designed to treat shallow groundwater (less than 45 feet deep) with PCE concentrations in excess of 1 milligram per liter (mg/L). The interim action system pumped groundwater from extraction wells installed near the river (EX-3 through EX-5), treated the pumped water with potassium permanganate, and then filtered and pumped the water into a series of injection wells along the railroad tracks (IN-1 through IN-9). For soil, an SVE system withdrew soil vapors from wells IW-1, IN-2, IN-3, IN-4, EX-1, EX-3, EX-4, and EX-5. A detailed description of the installation of the interim action system is provided in the *Final Remedial Investigation Report* (SECOR, 2001). Interim remedial action continued through 2005. The interim action successfully removed HVOC mass at the Property (based on the drop in concentration of HVOCs in some wells), but overall the system was not efficient at addressing the release area.

2.7.2 Interim Action – 2008 through Present: Combined Enhanced Bioremediation and Soil Vapor Extraction

An interim action analysis (Ash Creek, 2006) was completed in accordance with WAC 173-340-430 and WAC 173-340-360 that evaluated a range of potential alternatives for additional interim remedial action. The implemented interim action selected for the release area consisted of SVE in the vadose zone and enhanced anaerobic bioremediation of the saturated zone. The interim action was initiated in April 2008. The interim action activities were conducted in general accordance with the *Release Area Interim Action*

Design (Ash Creek, 2007). The general scope of the interim action consisted of injection of a bioremediation substrate into temporary injection points and installation/operation of an SVE system. The layout of the interim action system is shown on Figure 6, and installation is documented in the *Interim Action Installation Report* (Ash Creek, 2009b). Operation and monitoring of the interim actions is ongoing.

2.7.3 Interim Action Performance Monitoring

Performance monitoring including soil and groundwater sampling was conducted in September and October 2010. These data are reported and evaluated in the *Interim Action Performance Evaluation* report (Ash Creek, 2010c). A copy of the report is included in Appendix A. Based on the performance evaluation, the following conclusions and recommendations have been made regarding the current interim action and anticipated expanded interim action at the Property:

- *Vadose Zone Soil*
  - The interim action SVE system is effectively removing VOC mass from the vadose zone soils. SVE should be effective within the expanded interim action area.
  - NAPL was not observed during the performance evaluation site assessment or during historical site assessment activities. However, elevated VOC concentrations are present in isolated areas of silty vadose zone soil within the existing interim action area. Elevated PCE concentrations exceed the soil saturation limit in some silty soil, indicating that it may be possible that residual NAPL is present in localized areas within the silty soil at the site. The continued operation of the SVE system will address areas of elevated VOC concentrations; however, this will involve operating the SVE system in the 2008 Interim Action area for longer than anticipated at design.
  - The expanded interim action area is not within the former product handling area, so NAPL (or isolated areas of relatively higher VOC concentrations associated with silt layers) is not anticipated to be present in vadose zone soils in the expanded area. Therefore, it is expected that SVE operations in the expanded area will exhibit classic behavior with concentrations that steadily decline to an asymptotically low value within a few years of operation. The duration of required SVE in the expanded area should be less than the current interim action.
- *Groundwater*
  - The 2008 bioremediation injections have effectively decreased VOC concentrations in groundwater. The presence of VOCs in saturated soil within the current interim action area may continue to contribute VOCs to groundwater in the absence of further interim action. Therefore, as part of the expanded interim action, additional treatment should be completed in the source area treated in 2008.

- Nitrates in the interim action area are interfering with the reductive dechlorination of chlorinated solvents and have likely accelerated the use of the bioinjection substrate. Design of the oil injection volumes should account for the higher nitrate levels.
- As discussed in the vadose zone section above, elevated concentrations of VOCs still remain in the subsurface, particularly in silty soils. However, unlike vadose zone soil being treated by SVE, the presence of relatively elevated VOC concentrations in silty soil within the saturated zone is not anticipated to slow the remediation process via enhanced bioremediation, because injected oil creates an anaerobic environment throughout the saturated zone inducing degradation in both finer and coarser grained soils. This is evidenced by the decreasing groundwater concentration trends for PCE in almost every site well.

3.0 Extent of Interim Action

This section discusses the extent of COC in soil and groundwater at the Property warranting further interim action.

3.1 Soil

The discussion of extent presented in this section focuses on vadose zone soil (generally corresponding to a depth of 25 to 30 feet). Although the standard point of compliance for soil (for protection of groundwater) is throughout the soil column, the concentrations of COC present in groundwater make differentiating between COC in saturated soil and groundwater difficult. Furthermore, actions to clean up groundwater will address saturated soil as well, so saturated soil will be addressed together with groundwater. Finally, for other potential soil cleanup levels (i.e., Method C or vapor intrusion), the point of compliance is entirely within the vadose zone.

In the FS, vadose zone soil data from the RI were compared to the cleanup levels developed in the FS. Only PCE and TCE were detected in vadose zone soil above cleanup levels. The extent of vadose zone soil with concentrations of PCE and TCE detected above cleanup levels is shown on Figure 7. The figure shows that the primary area of impact to soil is around Warehouse 13 and extending in a corridor toward the seawall. Figure 7 also shows the area of current interim action in the vadose zone soil. That portion of the vadose zone above cleanup levels that is not currently within the active or historical interim action areas will be targeted for expanded interim action.

3.2 Groundwater

The FS (Ash Creek, 2010b) presented a detailed evaluation of the extent of groundwater warranting active remedial action. A disproportionate cost analysis was used to evaluate the practicability of active groundwater cleanup. Figure 8 shows the extent of practicable active groundwater cleanup at the site as

determined in the FS. Also shown on the figure is the extent of the current interim action in groundwater. The area of practicable active groundwater cleanup is targeted for treatment in the expanded interim action. The interim action performance evaluation (see Section 2.7.3) indicates that further treatment in the source area would be beneficial. The expanded interim action will include additional injection within the source interim action area.

4.0 Design Analysis – Soil Vapor Extraction

The *Interim Action Analysis* (Ash Creek, 2006) and FS (Ash Creek, 2010b) identified SVE as the technology to address VOCs in the vadose soil at the Property. The layout and size of the SVE components is dependent on the surface cover, soil type, depth to groundwater (the thickness of the vadose zone), and horizontal and vertical extent of the target VOCs. The Interim Action Analysis (Ash Creek, 2006) provided detailed evaluation of the design components of the SVE system. In addition, the source area interim action has been operating since September 2008. As discussed in Section 2.7.3, based on the performance of the current interim action SVE system, SVE should be effective in the expanded interim action area.

Based on the prior design analysis and performance of the existing interim action system, a similar design will be used for the interim action expansion. In summary, the well design parameters are:

- Air flow rate of 25 cubic feet per minute (cfm) per extraction well;
- Well spacing of 30 feet;
- Well screen extending from 5 to 25 feet bgs (two wells each with 10-foot screens at each location to better assure uniform flow over full well depth); and
- Ground surface covered with pavement.

A total of 17 vapor extraction locations are required to cover the expanded treatment area, as shown on Figure 9. The wells will be configured into five groupings with three to four well locations per group. Each group will be connected to a single branch connecting to a header pipe through a valve. Between the existing and new wells, there will be a total of 10 branches (each with three to four well locations) for a total of 34 well locations.

Blower. In general, the existing blower is suitable for operating both the existing and expanded SVE system, although operation would be conducted on a rotating basis with only a portion of the branches operating at any one time. However, the under-rail crossing for the piping is at capacity, so two blowers will be used, one on each side of the railroad. Because eight of the 10 branches are on the south side of the tracks, the existing blower will be relocated to the south side of the tracks and connected to those eight branches. A new, lower-capacity blower will be installed in the existing treatment area.

Piping Selection. Piping has been sized for ease of installation and so that the pressure drop (friction losses) through the pipe is less than one inch of water per 100 feet of pipe. Friction losses were estimated from the friction loss equation for turbulent air flow in a pipe ($\Delta P = 0.109136 Q^{1.9} / d^{5.02}$, where ΔP is the pressure drop over 100 feet of pipe, Q is the flow rate in cubic feet per minute, and d is the pipe diameter in inches). Well diameters were set at not more than 2 inches to allow installation using direct-push techniques. Pipe diameters are maintained over the length of each branch to simplify installation and reduce the potential for vacuum leaks at pipe junctions.

The selected piping diameters are:

Location	Diameter (inches)
At each vapor extraction well	2
Each manifold zone (3 or 4 wells)	4
Main header	8

The piping will consist of Schedule 80 PVC to resist damage from heavy traffic and during installation. The concentrations of vapors in the operating airflow are not expected to adversely affect the PVC material during the operating life of the system.

Vapor Treatment. Activated carbon will be used to remove VOCs from the air stream prior to discharge into the atmosphere (other removal technologies, such as catalytic or thermal oxidation, are complicated by the concentrations of chlorinated solvent hydrocarbons, which would produce hydrochloric acid as a byproduct of the oxidation). The existing carbon vessels (two 1,500-pound vapor carbon vessels) will be relocated to the south side of the railroad with the existing blower. These vessels are sized to accommodate the required air flow and to reasonably limit the frequency of carbon replacement. Two vapor carbon vessels are present in series to allow full saturation of the lead carbon prior to replacement. Vapor monitoring will continue to be conducted before, between, and after the carbon vessels to verify efficient use of the carbon but also compliance with discharge limitations. The existing carbon vessels accommodate the design flow rate of up to 450 cfm with a head loss of less than 5 inches of water each.

Carbon treatment will not be installed on the new, lower-capacity blower to be installed at the existing treatment system. Based on recent monitoring, concentrations of emissions at potential exposure points are estimated to be at or below acceptable risk-based concentrations for industrial receptors.

Based on the performance of the existing interim action system, the initial carbon usage rate is expected to be not greater than 3,000 pounds of carbon in 60 days (50 pounds per day). This rate is expected to drop to 15 pounds per day (3,000 pounds in six months) within three months of startup, and will likely remain at similar levels until the higher concentrations in the silt lenses are depleted. Usage for vapors extracted from the expanded interim action area is expected to continue to decrease with time.

Expected Operation Period. In general, soil conditions in the vadose zone of the expanded interim action area are similar to the current interim action area and concentrations of VOCs are lower. The soils consist primarily of sand with occasional silt layers. However, the soils in the expanded interim action area also include some gravel and concrete debris, and there appears to be fewer silt layers relative to the existing interim action area. Therefore, the operation period for the SVE system in the expanded interim action area is expected to be shorter than for the existing interim action area. To date, the SVE system in the existing interim action area has operated for approximately 2.5 years, and except for the a few silt layers, cleanup of the vadose zone is essentially complete. It is expected that cleanup of the expanded interim action area should require on the order of 2 years of operational time. Accounting for on/off cycling of various branches, the total operation time in the expanded area is expected to be approximately 3 years.

System Design. The design for the SVE system is included in Appendix B.

5.0 Design Analysis – Enhanced Bioremediation

The *Interim Action Analysis* (Ash Creek, 2006) and FS (Ash Creek, 2010b) identified *in situ* enhanced bioremediation (anaerobic reductive dechlorination) as the technology to address volatile organics in the groundwater and saturated soil of the Shallow Zone treatment area (from the top of the groundwater table to a nominal depth of 45 to 50 feet). The Interim Action Analysis (Ash Creek, 2006) provided detailed evaluation of the design components of the enhanced bioremediation system. In addition, the source area interim action has been operating since May 2008. As discussed in Section 2.7.3, based on the performance of the current interim action system, enhanced bioremediation should be effective in the expanded interim action area, though the presence of nitrate across the treatment area does increase the mass of bioremediation substrate needed to reach the intended effectiveness.

Based on the prior design analysis and performance of the existing interim action system, the same process will be used for the interim action expansion. The following discusses the conditions within the expanded interim action area (see Figure 8) to support the injection strategy.

Soil Profile. The saturated zone soil in the expanded interim action area is generally characterized by a medium sand (with occasional lenses of silty sand or silt) that extends from the top of the water table (a nominal depth of 25 feet) to the bottom of the shallow aquifer. At 40 to 50 feet bgs, a layer of silt and silty gravel separate the overlying medium sand (Shallow Zone) from an underlying gravel unit (Intermediate Zone). Figure 3 shows a cross section through the vicinity of the treatment area. Aquifer testing completed during previous work at the Facility indicates a hydraulic conductivity on the order of 0.01 cm/sec for the shallow aquifer.

Chemical Profile. Within the expanded interim action area, PCE concentrations ranged from non-detect to 4 milligrams per kilogram (mg/kg) in the soil, and 0.01 to 9.8 mg/L in groundwater. TCE concentrations

ranged from non-detect to 0.57 mg/kg in soil, and non-detect to 4.1 mg/L in groundwater. The relatively highest concentrations of PCE and TCE in the saturated zone were found at depths of between 35 and 45 feet bgs.

Selected Injection Substrate and Quantity. The selected injection substrate for the interim action expansion is an emulsified oil substrate manufactured by EOS Remediation, Inc., of Raleigh, North Carolina. The EOS® electron donor consists of a blend of fast- and slow-release electron donors in a micro-emulsion form with uniform droplets significantly smaller than soil pore spaces. EOS® is an emulsified oil product that includes easily biodegradable substrate (e.g., sodium lactate) and slowly degradable substrates (e.g., edible oil). The sodium lactate in the solution stimulates microbial growth and rapidly produces anaerobic conditions in the subsurface. After the lactate has been consumed, the less-soluble vegetable oil portion of the product is retained on the soil surfaces and pore spaces. The vegetable oil slowly ferments to release volatile fatty acids and molecular hydrogen, which support the anaerobic microbial community. The EOS vendor estimates a default lifetime of 5 years for their product. This default value is used to estimate the quantity of product needed, so assuming a longer lifetime is conservative (i.e., results in a greater estimate of product needed). Actual product lifetime is typically less than five years. Based on data collected to evaluate the performance of the injections in the source area interim action (see Appendix A), those initial injections may be nearing completion after approximately 2.5 years, but this may be partially the result of higher than expected nitrate levels. Accounting for these higher nitrate levels, the expected lifetime of the EOS substrate is on the order of 3 years.

This product was selected over the previously used whole-oil substrate based on recent groundwater monitoring that has demonstrated nitrate concentrations higher than levels detected prior to the previous interim action. Nitrate concentrations were detected in October 2010 up to 990 mg/L in monitoring well MP-1 with an average of 320 mg/L, compared to an average of 140 mg/L from 2007 data. Based on an evaluation using vendor application models, the EOS product provides overall better results under these changed conditions.

The total volume of substrate to be injected was estimated using the vendor-supplied calculation tool that accounts for both the stoichiometric hydrogen demand of the chemicals (from both the targeted contaminants such as PCE and interfering compounds such as nitrates and sulfates) and the physical limitations of the soil matrix. Appendix C includes the calculation of the amount of substrate to be injected. A total of 92,000 pounds (210 drums) of EOS substrate will be injected for the expanded interim action.

Injection Strategy. To distribute the EOS substrate evenly throughout the proposed treatment area, the injections are generally spaced equidistantly with alternate rows offset by half of the spacing. Outside the source area, the spacing was set at 25 feet (based on an estimated 50-foot zone of potential impact and a factor of safety of two, as described in the Department of Defense ESTCP *Protocol for Enhanced In Situ Bioremediation Using Emulsified Edible Oil;* DOD, 2006). To provide more continuous coverage in the

source area (the area of the current interim action), the spacing between points is reduced by half (to a distance of 12.5 feet). To prevent the substrate injection from potentially impacting the adjacent surface water, injections will not be done within 100 feet of the riverbank (based on the above estimated 50-foot zone of potential impact and a factor of safety of two). The corresponding layout, accommodating obstructions and the overlap between the standard injection spacing and the source area injections, results in a total of 155 injection points. Specifically, there are 46 injection points in the source area and 109 injection points outside of the source area. The layout of the proposed injections is shown on Figure 10 and is presented in the design drawings in Appendix D.

In general, substrate will be injected in the saturated zone over the depth range corresponding to the Shallow Zone. Actual injection depths will be determined at the time of injection. The upper limit will correspond to the top of the water table as determined by the depth to groundwater in monitoring wells within the injection area (generally expected to be on the order of 30 feet). The lower limit is determined by the depth to the silty gravel layer separating the Shallow and Intermediate Zones on the property. Based on prior probe work, the lower limit depth will vary from 42 to 55 feet with most injections being in the 45- to 50-foot depth range. For planning purposes, the injection depths have been assumed to be between 30 to 50 feet, except that injections nearest the river have been assumed to be between 30 to 55 feet.

Delivery Method. The injection points will be completed using direct-push technology. An injection probe tip will be advanced to the pre-designated depth at each injection location, withdrawn in 5-foot intervals, and emulsified oil will be injected through the drill stem via an air diaphragm pump. This process is repeated until the full depth of the injection boring is complete.

Solution Preparation/Injection Volume. The EOS® emulsified oil concentrate will be diluted with water obtained from the municipal water supply and dechlorinated using a purpose-specific commercial additive (such as sodium thiosulfate). Injections outside the source area will be diluted at a ratio of approximately 10 to 1, and injections within the source area will be diluted at a ratio of 20 to 1 (such that at the spacing discussed above, the same mass of substrate will be delivered per unit treated volume). The total solution volume will be approximately 147,000 gallons. Two 1,000-gallon polyethylene tanks will be used to allow mixing and injection to be performed simultaneously. Mixing of the solution will be accomplished by combining the EOS® concentrate with water and stirring with a recirculation pump.

Injection Rate. For the typical injection point outside the source area, approximately 240 gallons of prepared emulsified solution will be injected per 5-foot vertical zone, for a total of approximately 960 gallons of solution injected per location. The source-area injections will receive approximately 230 gallons of solution per 5-foot zone (but at a higher dilution of water to substrate of 20:1), increasing the potential for the solution to directly contact soil with higher relative source area concentrations. For the injection locations nearest the river, the injection thickness is slightly larger (up to about 25 feet) but the lower concentrations of VOCs and nitrates in this area require less substrate mass. Each of these points will receive the same

total volume per injection of 960 gallons (though at 190 gallons per 5-foot zone). In the event that the target depth cannot be achieved because of equipment refusal, the solution will be evenly distributed over the depth range of 25 feet to the actual depth achieved. The initial targeted injection rate is 10 to 20 gallons per minute. The required net injection pressure depends on several factors such as losses in the piping, hydraulic conductivity of the soil, and static water pressure at the injection depth. At the injection depths, the soils consist predominantly of sand so short circuiting along the drill string is anticipated to be minimal.

Abandonment. The injection borings will be abandoned in accordance with OWRD regulations and procedures. The abandonment procedure will consist of pressure-grouting the injection from the bottom up with a high-solids bentonite slurry pumped through a tremie pipe/probe rod set at the bottom of the hole.

Expected Performance Results. The enhanced bioremediation technology is capable of complete destruction of the target compounds (chlorinated VOCs). This has been demonstrated in both laboratory and field applications. The ability to achieve complete destruction depends on a number of factors such as presence of appropriate bacteria, presence of nutrients, ability to achieve and maintain anaerobic conditions, and presence of competing electron acceptors. Usually, the primary factor affecting the ability to achieve complete destruction is the ability to effectively mix the aqueous phase dissolved target compounds with the biosubstrate. Higher concentrations of VOCs in silt layers may not have sufficient contact with the substrate within the effective lifetime of the substrate for complete destruction. These pockets of remaining VOCs can then act as a source for some level of rebound of dissolved phase concentrations of VOCs. For the existing interim action injections in the source area, the average total molar concentration of chlorinated VOCs within the injection area has been reduced by approximately 80 percent (see Appendix A). Complete destruction was not achieved (although further reduction is still possible) likely because of the higher than expected nitrates and because of relatively higher concentrations of VOCs remaining in silt layers within the treatment zone. The presence of higher concentrations in silt zones was anticipated and additional injection within the source area was expected to be required. The proposed injection strategy should be effective in establishing an anaerobic environment in the targeted saturated zone that will be suitable for bioremediating the VOCs present within *both* the finer and courser grained soils in the saturated zone. Given the performance to date, consideration of the higher nitrate levels, and distribution of VOCs, it is expected that average reductions in chlorinated VOCs within the treatment area should be on the order of 90 percent, with nearly complete destruction possible outside of the source area.

6.0 Schedule

To minimize the interference of the two operations intended for the treatment area (installation of the SVE wells and piping in the vadose zone and the bioremediation injection in the saturated zone), the bioremediation injection effort would be completed first – an effort that is expected to have a duration of 16 to 32 days, depending on the achievable injection rate. These injections could begin within 3 weeks of a notice to proceed (based on the vendor's estimate of needed lead-time to deliver the product). The injection

schedule would need to be coordinated with Facility personnel as the work will be completed within areas of terminal operations and in the vicinity of area roadways and rail spurs.

The installation of the SVE system components would generally follow the bioremediation injections, though the work can overlap with the SVE drilling and pipe installations being done in areas where the bioremediation injections are complete. The SVE system expansion is expected to take two to four weeks to install.

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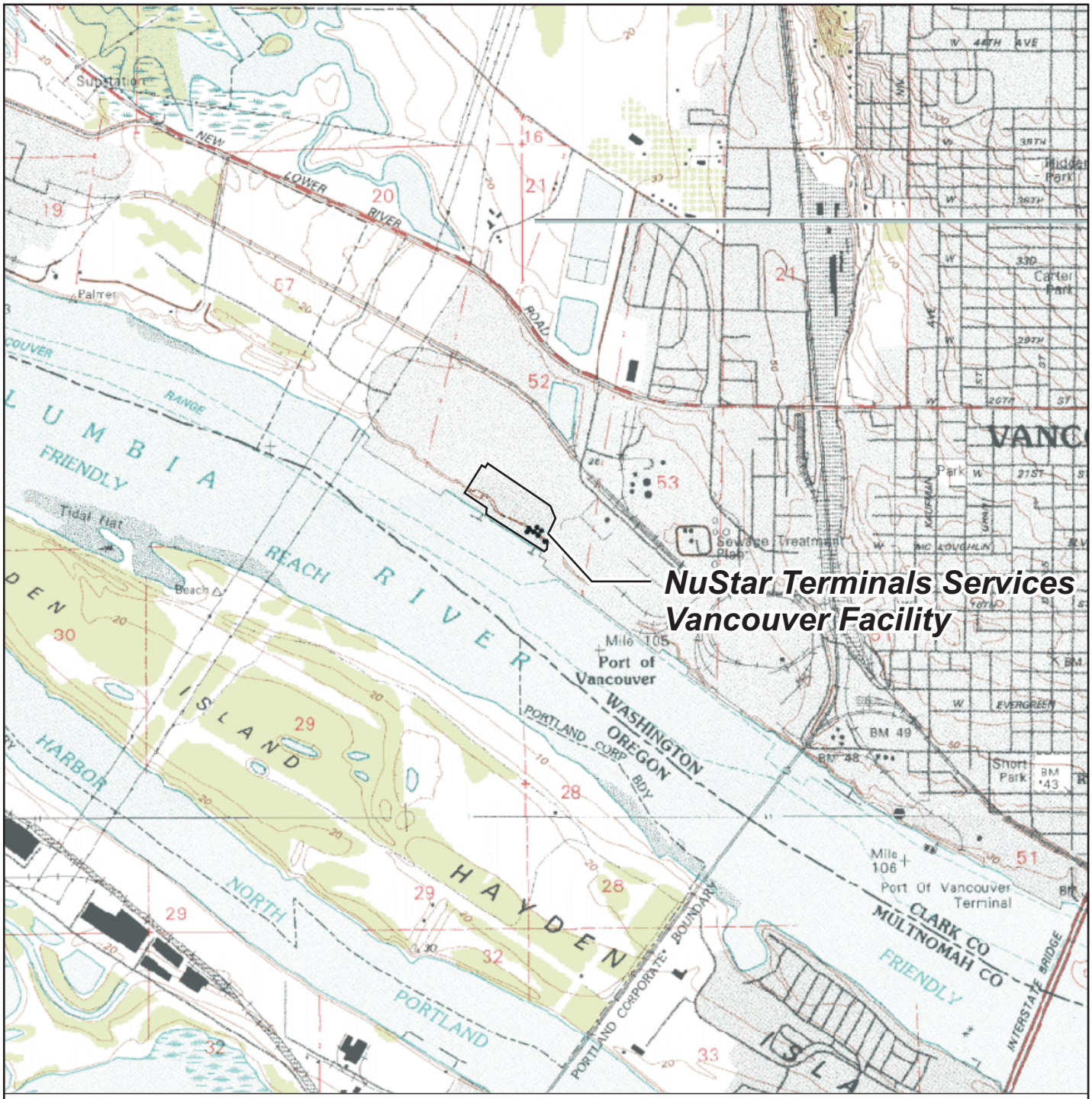

NOTES: 1) Base map prepared from USGS 7.5-minute quadrangles as provided by Topozone.
2) Property defined based on 2006 leasehold boundary.

0 2000 4000
Scale in Feet

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Property Location Map

2010 Interim Action Work Plan
NuStar Terminals Services, Inc. Vancouver Facility
Vancouver, Washington

Ash Creek Associates, Inc.
Environmental and Geotechnical Consultants

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