Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix I
Response to Community Input

FINAL

Table of Contents

Responses to Public Input

This appendix presents responses to comments received from members of the public on the various work plans, data submittals, and technical reports produced for the Lora Lake Apartments Site (Site) Remedial Investigation/Feasibility Study (RI/FS), and in other communications with the Port of Seattle (Port) and the Washington State Department of Ecology (WSDOE) prior to submittal of the Draft RI/FS. The following documents are those that received public input:

- Stormwater Interim Action (SWIA) Report 1 (March 19, 2010)
- SWIA Report 2 (March 19, 2010)
- Lora Lake Apartments Parcel (LL Apartments Parcel) RI/FS Work Plan (July 30, 2010)
- Lora Lake Parcel (LL Parcel) RI/FS Work Plan (February 11, 2011)
- Additional Shallow Dioxin Soil Sampling Memorandum—LL Apartments Parcel (February 16, 2011)
- Other email communication between the Port, WSDOE, and the public received between July 2010 and February 2011

This appendix consists of public comments, and/or summaries of multiple similar public comments, organized by subject matter. Each comment is numbered, and indicates the document or RI/FS period commented on. Each comment is followed by a response statement that describes how the comment and/or concern was addressed as part of the Lora Lake Apartments Site RI/FS document and/or remedial investigation activities and interim actions.

COMMENTS RECEIVED REGARDING DATA QUALITY AND SAMPLING

Comment 1 [SWIA Report 1]*—The Port claims that a source of pollutants in the stormwater system is from upstream or off-site, but the Port has yet to take any stormwater or sediment samples from upstream.*

Response to Comment 1: The Port has collected sediment and stormwater samples at the upstream boundary of the LL Apartments Parcel. The purpose of the SWIA was to identify contributions to stormwater from the Lora Lake Apartments Site. That purpose has been accomplished by the remedial investigation. The Port did not generate remedial investigation data to identify specific upgradient and off-site sources of dioxins/furans to stormwater that are not associated with the LL Apartments Site.

To determine the stormwater quality entering the LL Apartments Parcel, the Port collected and submitted for laboratory analysis catch basin sediment samples, stormwater solids samples, and 10 rounds of stormwater samples, and conducted storm flow monitoring upstream of any areas of the LL Apartments Parcel that could provide significant contributions to stormwater. As reported in the SWIA Data Report

(Appendix E of the RI/FS), the results of the analyses and flow monitoring determined that the stormwater quality entering the LL Apartments Parcel and discharging from the LL Apartments Parcel is not statistically different.

The comment appears to question the validity of the location of upgradient sample collection. Upstream sample collection and storm flow monitoring were completed at Catch Basin CB-31A (referred to as the Main Line Inlet Catch Basin) because this location represents the inlet of all of the upgradient piped stormwater conveyance from the City of Burien onto the LL Apartments Parcel, including upgradient contributions from 8th Avenue South that runs along the western boundary of the LL Apartments Parcel. Because the Main Line Inlet Catch Basin data collection point is located approximately 8 feet inside of the LL Apartments Parcel property boundary, the Port performed an assessment of the potential that dioxins/furans could be contributed to this catch basin from LL Apartments Parcel soil that drains to it. The assessment quantitatively demonstrates that the soil concentrations on the western portion of the Site in the vicinity of the upgradient catch basin could not be the main contribution of dioxin/furan concentrations detected in the Main Line Inlet stormwater (Appendix J of the RI/FS). Refer to the SWIA Data Report (Appendix E of the RI/FS) for further details on the upgradient and LL Apartments Parcel stormwater drainage systems and the results from the Main Line Inlet Catch Basin sampling and flow monitoring.

Comment 2 [SWIA Report 1]*—There is a sediment basin that the main line portion of the storm drain system discharges to that is not proposed for sampling and it seems like this location would be a sampling priority.*

Response to Comment 2: The comment refers to a sediment settling basin located in the northwestern corner of Lora Lake. As part of the LL Parcel data collection activities, a surface sediment sample (LL-SED5) was collected from this location. Refer to the LL Parcel Remedial Investigation Data Report (Appendix G of the RI/FS) for further information about the sample collected at this location and the results of the chemical analyses performed on this sample.

Comment 3 [SWIA Report 1]*—It is important to have reference upstream and downstream sediment samples for the main line portion of the storm drain system.*

Response to Comment 3: Upstream and downstream sediment samples were collected. The Response to Comment 1 summarizes collecting upstream stormwater, catch basin sediment, and stormwater solids samples from the main line portion of the storm drain system as part of the SWIA. Downstream storm flow monitoring and stormwater, catch basin sediment, and stormwater solids sampling were also performed as part of the SWIA at a location on the main line portion of the storm drain system. This sampling was performed at Catch Basin 4857 (referred to as the Main Line Outlet Catch Basin), because this location represents the outlet of the Main Line Drainage from the LL Apartments Parcel. The samples collected at this downstream location included only the contributions from the main line exiting the LL Apartments Parcel, excluding off-site drainage and sediment (primarily road runoff from Des Moines Memorial Drive) that comingles with this main line flow. Refer to the SWIA Data Report (Appendix E of the

RI/FS) for further details on the stormwater drainage system and the results from the upstream and downstream main line sampling and flow monitoring.

Comment 4 [SWIA Report 2]*—Catch basin sediment data are not representative of the stated minimum time of accumulation (at least 12 years since the last catch basin cleanout) because less than two-thirds of the vertical profile was sampled.*

Response to Comment 4: SWIA catch basin sediment samples represent more recently deposited sediment in the catch basin, rather than all of the material that has accumulated since the last catch basin cleanout. While the samples are not fully representative in time, there is no reason to conclude that these samples are not fully representative of sediment quality, at least with respect to LL Apartments Parcel input. Since the previous catch basin cleanout, there have been no substantial changes in LL Apartments Parcel land use that would have changed the nature of the sediment accumulating in the catch basins. Neither the reduction in on-site activity due to the closure of the apartments, nor on-site demolition, which was conducted as a no-discharge construction project with completely sealed stormwater drainage features, would have altered the catch basin sediment characteristics. Refer to the SWIA Data Report (Appendix E of the RI/FS) for further details.

Comment 5 [SWIA Report 2]—*Catch basin sediment data from the downstream sampling location came from a different month than the rest of the dataset. This makes comparison of the data problematic.*

Response to Comment 5: The catch basin sediment sample from the downstream sampling location (or Main Line Outlet), collected on December 10, 2009 was collected approximately 1 month earlier than the remaining catch basin sediment samples, collected between January 7 and 11, 2010. This Main Line Outlet sample was collected at this earlier date to take advantage of the access to this sampling location provided during a TV in-line inspection of this portion of the main line.

Accumulated sediment depths measured in the catch basins ranged from 1.0 to 1.5 feet thick. Since the stormwater conveyance system at the LL Apartments Parcel had not been cleaned or otherwise altered since the Port's initial acquisition of the property in 1998, this thickness of sediment represented at least 12 years of accumulation or approximately 1 to 1.5 inches of accumulated sediment per year. The catch basin sediment samples collected from the top 3 to 4 inches of accumulated sediment likely represent between 2 and 4 years of accumulated material. It is unlikely that a difference of 1 month in sample collection dates would have a significant impact in the comparison of the downstream catch basin sample to the other catch basin samples collected.

Comment 6 [LL Apartments Parcel RI/FS Work Plan]*—If there is an "off-site source" contributing to stormwater pollution moving through the LL Apartments Site, then the preliminary information from the draft RI/FS work plan is lacking in source identification/source control effort, related sampling, and off-property data collection to identify this source. Additionally, no sampling of any kind has been proposed to the west* *of the existing LL Apartments Parcel property boundary, though assumptions have been made that there are sources of dioxins to the west.*

Response to Comment 6: The objective of this remedial investigation is to characterize the nature and extent of contamination associated with the Lora Lake Apartments Site for the purposes of assessing remedial alternatives and conducting a cleanup of the Site. Remedial investigation sampling efforts have delineated the extent of site contamination exceeding cleanup levels at the western (upgradient) property boundary. Remedial investigation sampling downgradient of the LL Apartments Parcel core source area was also conducted and has defined the extent of downgradient contamination at concentrations greater than cleanup levels. The Port did not conduct remedial investigation sampling to identify upgradient off-site sources of dioxins/furans that are not associated with the Site. There are numerous sources of dioxins/furans in the urban environment, as described in further detail in the Review of Regional, National, and International Background Studies for Dioxin/Furans in Soils (Appendix M of the RI/FS).

Comment 7 [LL Apartments Parcel RI/FS Work Plan]*—There is no discussion or proposal to collect data to describe the uppermost geological and hydrological units at the site. There is no information available on the extent of vertical contamination in groundwater.*

Response to Comment 7: In response to input received by the public and WSDOE during the public comment period for the Draft LL Apartments Parcel RI/FS Work Plan, three deep monitoring wells were installed on the LL Apartments Parcel in August 2010. The wells were installed to provide further information regarding subsurface geologic and hydrogeologic conditions at the LL Apartments Parcel and to investigate if dense non-aqueous phase liquid (DNAPL) contamination was present at depths below the vertical extent of previous investigations on this parcel. Well locations were selected based on a LL Apartments Parcel Hydrogeologic Evaluation provided as Attachment 1 to the Deep Monitoring Well Installation Technical Memorandum and Sampling and Analysis Plan (SAP; Floyd|Snider 2010b). Results of the Deep Groundwater Quality Investigation are included in the LL Apartments Parcel Remedial Investigation Data Report (Appendix F of the RI/FS). An updated description of the site geological and hydrogeologic units is presented in Section 2.0 of the RI/FS.

Comment 8 [LL Apartments Parcel RI/FS Work Plan]*—The discussion of preferential flow pathways fails to consider or provide sampling of utilities or related bedding materials.*

Response to Comment 8: Contaminated groundwater at the Site is limited to the Central Source Area, as discussed in Section 7.3.3 and shown in Figure 7.2 of the RI/FS. Current groundwater monitoring results indicate that groundwater concentrations are in compliance with cleanup levels downgradient of the Central Source Area, showing no evidence of contaminated groundwater migration away from the Central Source Area. Monitoring Well MW-1 is located within the Central Source Area, and seasonal groundwater table elevations fluctuate in this well between 285—290 feet

(North American Vertical Datum [NAVD] 88). The storm drain system main line running from west to east across the property crosses through this area of contaminated groundwater. The storm drain system elevations (approximated from the TV In-Line Inspection discussed in Appendix E of the RI/FS) range from 288—291 feet (NAVD88) in this area. This approximate comparison indicates the storm drain system may be in contact with the groundwater table during portions of the year. The presence of other utilities in this area is unknown; however typical utilities such as electric, gas, and water supply lines are placed between 5 to 8 feet below ground surface. These utilities would not be expected to be placed deep enough to come in contact with groundwater at the Site. The remedial alternative proposed in Section 14.0 of the RI/FS includes source area soil excavation in the area of groundwater contamination at MW-1. This excavation will extend to approximately 20 feet below ground surface, or elevation 284 feet (NAVD88). The proposed excavation will extend past the storm drain system in this area, and will encounter all of the storm line segments in the vicinity of MW-1 and the site groundwater contamination. Any indications of preferential flow along utility bedding will be identified during the remedial action. With removal of the soil source contamination to groundwater, groundwater is expected to be in compliance with cleanup standards throughout the Site, which will in turn eliminate the potential for preferential contaminant migration along utility bedding in the future.

Comment 9 [LL Apartments Parcel RI/FS Work Plan]*—The proposal to only analyze bioassay samples from Lora Lake provides no point of comparison with other data collected from the site. Need to collect data from Lora Lake that can be compared to the contamination profile of the site.*

Response to Comment 9: Based on public input received on the LL Apartments Parcel RI/FS Work Plan and discussions with WSDOE, the LL Parcel sediment sampling effort was expanded, as described in the Final LL Parcel RI/FS Work Plan (Floyd|Snider 2010a). The expanded scope included the collection of seven surface sediment samples from Lora Lake and Miller Creek for chemical and biological testing, the collection of a surface sediment sample from the sediment settling basin for chemical testing, and the collection of three sediment cores from Lora Lake for chemical testing. Further details on the sediment sampling performed on Lora Lake and Miller Creek and the chemical and biological testing results are included in the Lora Lake Remedial Investigation Data Report (Appendix G of the RI/FS).

Comment 10 [LL Apartments Parcel RI/FS Work Plan]*—A single sample on the horizontal plane between site and off-site is not enough to prove that contamination is bounded.*

Response to Comment 10: The Shallow Soil Dioxin/Furan Investigation was performed as part of the Remedial Investigation on the LL Apartments Parcel property and adjacent off-property areas to help delineate the horizontal and vertical extent of the Site’s shallow soil dioxin/furan contamination. Samples with dioxin/furan concentrations that fell less than the site screening level for dioxins/furans of 5 pg/g were used to define the perimeter of the Site. After analysis of the initial and archived samples collected during this investigation, however, data gaps remained in four areas where the horizontal extent of dioxin/furan contamination had not been fully defined using the site screening level. In the Southeast Corner and the Eastern Property Line areas of the Site additional shallow dioxin/furan soil sampling was performed in April 2011. Three additional hand auger borings were installed near the southeast corner of the LL Apartments Parcel and six hand auger soil borings were completed as part of the LL Parcel investigation to help delineate the horizontal extent of dioxins/furans in these two areas. The results from these additional soil sampling efforts are included in the LL Apartments Parcel Remedial Investigation Data Report (Appendix F of the RI/FS) and in the LL Parcel Remedial Investigation Data Report (Appendix G of the RI/FS). The dioxin/furan concentrations observed along the Western Property Line and in the Northeast Corner of the Site fell within the range of typical urban background concentrations (refer to Appendix M of the RI/FS). Consequently, no additional data collection will be performed as part of the remedial investigation; rather, any additional data required for implementation of the remedy in these areas of the Site would be collected during remedial design as necessary.

Comment 11 [LL Apartments Parcel RI/FS Work Plan]*—Separating the LL Apartments Parcel sampling from off-LL Apartment Parcel sampling (or the rest of the site) by a year increases the potential for introducing factors that will degrade the ability to compare the data sets.*

Response to Comment 11: Remedial investigations often require multiple sampling events, which can span years. All of the remedial investigation field work that was outlined in the LL Apartments Parcel Work Plan, the LL Parcel Work Plan, and the Dredged Material Containment Area (DMCA) Characterization Technical Memorandum was completed within an approximate 9-month period within the LL Apartments Parcel and the LL Parcel Work Plan remedial investigation schedules approved by WSDOE. Refer to the data reports for these three areas of the Site (Appendices F though H of the RI/FS) for additional details of these field efforts.

Comment 12 [LL Parcel RI/FS Work Plan]*—The existing Conceptual Site Model (CSM) should not have influence on the sampling design.*

Response to Comment 12: The LL Parcel remedial investigation was developed to determine whether contamination from the LL Apartments Parcel has come to be located at the LL Parcel. In addition to an understanding of migration pathways from the LL Apartments Parcel, the LL Parcel sampling design was based on existing environmental data, historical documentation, the physical site conditions of the LL Parcel, including Lora Lake sediment conditions, and the relationship between Lora Lake and Miller Creek.

Comment 13 [LL Parcel RI/FS Work Plan]*—Surface water and groundwater sampling need to be added to the LL Parcel Work Plan, including surface water sampling of Lora Lake and Miller Creek and groundwater connecting Lora Lake to Miller Creek. A sediment evaluation cannot serve as a substitute pathway for sampling and analysis of the surface water to surface water pathway (Lora Lake Outfall to Lora Lake and Lora Lake to Miller Creek). Additionally, looking at sediment in Miller Creek is not an* *adequate measure of the potential for the stormwater discharges from the LLA facility and discharges from Lora Lake to Miller Creek to impact the water quality of Miller Creek.*

Response to Comment 13: The purpose of this remedial investigation is to investigate the nature and extent of the contamination resulting from historical operations at the LL Apartments Parcel. To evaluate the potential for historical inputs of site contamination to Lora Lake sediments, the LL Parcel investigation was conducted and is discussed in Section 4.2 of the RI/FS. The evaluation of historical sediment leaching to surface water is evaluated in Appendix O of the RI/FS to determine the potential for historical sediments in Lora Lake to be causing surface water quality impacts in Lora Lake and Miller Creek.

The collection of surface water samples in Lora Lake would provide information about the current water quality conditions in the lake. Surface water samples would not be representative of the LL Apartments Parcel inputs to surface water, which have been shown by the SWIA not to be degrading stormwater quality prior to discharging into Lora Lake (refer to Appendix E of the RI/FS). Surface water in the lake is composed of stormwater discharges from over 83 acres of residential Burien (refer to Figure 3.3 of the RI/FS), stormwater discharges from the LL Apartments Parcel, and stormwater runoff from Des Moines Memorial Drive. The SWIA demonstrated that contamination from the LL Apartments Parcel is not contributing to contamination in stormwater runoff reaching Lora Lake; therefore sampling of Lora Lake surface water is not an appropriate part of this RI/FS process, since water quality conditions in the lake that are not associated with the Site are not within the scope of this investigation.

Comment 14 [LL Parcel RI/FS Work Plan]*—The assumption of a sedimentation rate of 2.4 cm/yr for Lora Lake may not be conservative due to substantial algal blooms and die off events.*

Response to Comment 14: Our assumption is that the intent of Comment 14 was to question the sufficiency of sediment sampling depths. Remedial investigation historical research of the LL Parcel discovered that Lora Lake was dredged in 1982. It is likely that most of the sediment that had accumulated in the lake was removed during this dredging. The originally proposed core sampling depth interval of 0 to 5.5 feet was retained in the final version of the work plan to assure collection of sediment deposited in Lora Lake following the 1982 dredge event, as well as any of the underlying sediment that was not dredged. Use of the 5.5-foot sample interval obviates the previously estimated sedimentation rate.

Comment 15 [LL Parcel RI/FS Work Plan]*—The LL Parcel Work Plan must consider the nature and extent of contamination associated with sediment/soil from the outfall structure to the waterline of Lora Lake.*

Response to Comment 15: Refer to Response to Comment 2, above.

Comment 16 [LL Parcel RI/FS Work Plan]*—The LL Parcel RI/FS Work Plan appears to disregard the requirements of the Clean Water Act, which at a minimum should be addressed as an Applicable or Relevant and Appropriate Requirement (ARAR) for the Site. The LL Parcel Work Plan fails to consider point source discharges to Lora Lake, by not collecting any samples of discharged stormwater at the outfall to Lora Lake or at the point of discharge to the receiving water. It also fails to take any sediment samples from below the outfall, but prior to the ordinary high water mark of the lake, fails to take any surface water samples of the receiving water, fails to take any samples of surface water discharge from Lora Lake to Miller Creek, fails to take any groundwater samples of discharge from Lora Lake to Miller Creek, and fails to include any provision for surface water sampling of Miller Creek.*

Response to Comment 16: Refer to Responses to Comments 13 and 2, above. With respect to Lora Lake, the scope of this site remedial investigation is to determine whether contamination from the LL Apartments Parcel has come to be located at Lora Lake. This objective was accomplished by the stormwater and in-line solids sampling conducted as part of the SWIA. Sampling surface water at the outfall to Lora Lake is not representative of contaminant discharges to the lake from the LL Apartments Parcel because the water at the point of discharge to the lake is comingled stormwater runoff from more than 83 acres of residential Burien, stormwater runoff from Des Moines Memorial Drive, and stormwater runoff from the LL Apartments Parcel. Assuming that the comment means the point where Lora Lake enters Miller Creek as “the receiving water,” the same is true. Stormwater from these runoff sources is combined in the main line system prior to discharge to Lora Lake; therefore, the surface water in the lake is comingled water from multiple sources, and sampling this surface water does not provide data on the contribution of contaminants from the LL Apartments Parcel to the lake or creek surface water.

Sediment Sample LL-SED5 was collected from below the outfall to Lora Lake. Refer to Appendix E of the RI/FS for sediment sampling information.

In regards to the comment on groundwater sampling between Lora Lake and Miller Creek, refer to the Response to Comment 17 below.

Comment 17 [LL Parcel RI/FS Work Plan]*—Groundwater monitoring locations are limited to extreme eastern and western portions of the LL Parcel and are not adequate to assess water quality on this parcel.*

Response to Comment 17: A remedial investigation of the LL Parcel was conducted to determine if contamination originating from the LL Apartments Parcel had come to be located on the LL Parcel and, based on these findings, if the LL Parcel should be included as part of the Lora Lake Apartments Site.

Groundwater samples were collected from four monitoring wells (MW-8 through MW-11) located along the stretch of Des Moines Memorial Drive that runs between the LL Apartments Parcel and the downgradient LL Parcel (i.e., downgradient of the LL Apartments Parcel, but upgradient of the LL Parcel). Three rounds of groundwater monitoring data reported no exceedances of the groundwater cleanup levels established for the Site's groundwater contaminants of concern (COCs; refer to Section 6.0 of the RI/FS). Refer to the LL Apartments Parcel Data Report (Appendix F of the RI/FS) for a summary of the analytical results from these monitoring wells. Groundwater samples were also collected from three wells located northeast of the LL Parcel and downgradient of the DMCA, to investigate groundwater quality downgradient of the DMCA source area. Monitoring data reported no exceedances of the groundwater cleanup levels established for the Site's groundwater COCs in the downgradient DMCA wells. Refer to the DMCA Data Report (Appendix H of the RI/FS) for a summary of the analytical results from these three monitoring wells.

No additional groundwater monitoring locations are needed, as current groundwater data adequately define the limit of contamination in groundwater downgradient of both the LL Apartments Parcel and DMCA areas.

Comment 18 [LL Parcel RI/FS Work Plan]*—The proposed additional sampling for shallow soil dioxin contamination on the LL Parcel is inadequate based on existing information supplied in the LL Parcel RI/FS Work Plan. The dredge disposal site should be sampled as part of the LL Parcel Work Plan at the very least.*

Response to Comment 18: Based on public input received and discussions with WSDOE regarding the Draft LL Parcel RI/FS Work Plan, the LL Parcel shallow soil investigation sampling effort between Des Moines Memorial Drive and Lora Lake was expanded. Details and the analytical results of this LL Parcel shallow soil investigation are included in the LL Parcel Remedial Investigation Data Report (Appendix G of the RI/FS).

Remedial investigation historical research of the LL Parcel discovered that Lora Lake was dredged in 1982, and that the dredged material was placed in a bermed area on Port property, located approximately 400 feet northeast of Lora Lake. The Port prepared a 1982 DMCA Characterization Technical Memorandum (Floyd|Snider 2011b). With WSDOE approval of this memorandum, the Port conducted a soil and groundwater investigation on the DMCA in April 2011 to assess the chemical characteristics and potential environmental impacts of this dredged material. Further details on the sampling performed in the DMCA and the analytical results are provided in the DMCA Data Report (Appendix H of the RI/FS).

Comment 19 [following RI/FS data collection]*—The collection of only a single sample located in the sediment settling basin is inadequate to characterize the sediment settling basin soils/sediment.*

Response to Comment 19: The settling basin surface area is approximately 2,600 square feet, or approximately 2 percent of the Lora Lake surface area. The Port, in consultation with WSDOE, determined that one sample within the sediment settling basin provided adequate coverage.

COMMENTS RECEIVED REGARDING DIOXINS/FURANS

Comment 20 [SWIA Report 2]*—Does the concentration of dioxin measured in the catch basin sediment qualify this material as a dangerous or hazardous waste? As this catch basin sediment and/or filter socks and material on these filter socks were removed from the catch basins, how was it handled and disposed of?*

Response to Comment 20: The catch basin sediment was profiled for disposal using the sediment sample data collected as part of the SWIA, as well as site soil data. Based on these data, the catch basin sediment did not classify as either a federal hazardous waste or a state dangerous waste, nor did it meet the toxicity criteria to define it as a dangerous waste using the book designation in accordance with WAC 173-303-100(5)(b). The sediment was disposed of at the LRI Municipal Solid Waste Landfill in Pierce County, which is a lined municipal solid waste handling facility fully permitted to accept non-hazardous industrial wastes under 40 Code of Federal Regulations (CFR) Part 258 (Subtitle D). Any filter socks and sediment contained in these filter socks removed were also placed in this landfill. Appendix E of the RI/FS contains a waste designation memorandum prepared by the Port on June 15, 2010.

Comment 21 [LL Parcel RI/FS Work Plan]*—According to the RI/FS data, there is clear evidence that dioxin contamination has migrated outside the secure area of the LL Apartments Parcel and there are no warnings of contamination or measures to prevent erosion and spread of this contamination.*

Response to Comment 21: Detectable concentrations of dioxin/furans are present in soil outside both the LL Apartments Parcel and the LL Parcel secure areas. It is probable that these dioxin/furan concentrations are at least partially associated with the LL Apartments Parcel. The majority of the dioxin/furan concentrations measured outside of these secure areas are within the range of dioxin/furan urban background soil concentrations (refer to the Review of Regional, National, and International Background Studies for Dioxin/Furans in Soils, Appendix M of the RI/FS, and the LL Apartments Parcel Data Report, Appendix F of the RI/FS). Dioxin/furan concentrations that exceed the urban dioxin/furan concentration range from the WSDOE Concise Explanatory Statement (CES) of 0.33 pg/g to 19.5 pg/g are found in only three areas of the Site outside of the LL Apartments Parcel, LL Parcel, or DMCA area fencing. Of these locations, two are located north of the LL Apartments Parcel in the State Route 518 shoulder abutment area. These are densely vegetated locations with non-native blackberries, weeds and grasses. The other location at the north end of the LL Parcel is also in a flat roadway shoulder area, and is completely covered with grasses and vegetation. Under typical conditions, these areas are not subject to erosion or ground disturbance due to the dense vegetation, topography, and location. There are also no visible signs of erosion in any of these areas. All areas where contaminant concentrations exceed cleanup levels will be addressed as part of the RI/FS, including these areas outside of the LL Apartments Parcel and LL Parcel property fences. Refer to Section 14.0 of the RI/FS.

Comment 22 [LL Parcel RI/FS Work Plan]*—Interpretation of LL Apartments Parcel data indicates that the proposed shallow soil investigation program at the LL Parcel is not adequate, due to the failure to bound the extent of dioxin/furan contamination at the LL Apartments Parcel. The extent of dioxin/furan contamination at the eastern and southern boundaries of the LL Apartments Parcel does not agree with the CSM presented in the LL Parcel RI/FS Work Plan.*

Response to Comment 22: Refer to Responses to Comments 10 and 18, above. An updated Conceptual Site Model (CSM) for the Site is presented in Section 8.0 of the RI/FS.

Comment 23 [Additional Shallow Dioxin Soil Sampling Memorandum]*—A dioxin/furan concentration of 19.5 pg/g is well outside the range of anything that could be considered an urban background concentration.*

Response to Comment 23: The Additional Shallow Dioxin Soil Sampling Memorandum for the LL Apartments Parcel (Floyd|Snider 2011a) incorporates the 19.5 pg/g value that is presented as the upper range of dioxin/furan urban background toxic equivalency quotient (TEQ) concentrations on Page 83 of the CES for the 2007 Model Toxics Control Act (MTCA) rule revision.

WSDOE also recently published results of a study of dioxin/furan levels in six Seattle neighborhoods. The range of dioxin/furan TEQ concentrations reported in the study is 1.7 to 114.65 pg/g. The neighborhoods included in the study that are the closest in proximity to the Site include the South Park and West Seattle neighborhoods. Measured soil dioxin/furan concentrations in South Park ranged from 3.5 to 23 pg/g, with an average concentration of 12 pg/g. Measured soil dioxin/furan concentrations in West Seattle ranged from 1.7 to 32.9 pg/g, with an average concentration of 7.5 pg/g.

For additional information regarding dioxin/furan concentrations representative of urban background refer to the Review of Regional, National, and International Background Studies for Dioxin/Furans in Soils (Appendix M of the RI/FS).

Comment 24 [following RI/FS data collection]*—Shallow sediment data from Lora Lake strongly indicates that the shallow sediment is contaminated with dioxin at a couple of orders of magnitude above dioxin background levels.*

Response to Comment 24: Surface sediment samples collected from Lora Lake report dioxin/furan TEQ concentrations ranging from 7.5 pg/g to 217 pg/g. Refer to Appendix G and Section 4.3 of the RI/FS for the analytical results. The sampled sediments, and therefore the reported data, are representative of multiple input sources active, in major part, from 1982 to the present. Background dioxin/furan levels have not been defined for freshwater sediments in an urban setting and there are no draft or promulgated freshwater sediment quality standards for dioxin/furans. For a discussion of surface sediment dioxin/furan cleanup levels, refer to Section 5.2.3 of the RI/FS.

COMMENTS RECEIVED REGARDING STORMWATER

Comment 25 [SWIA Report 1]—*The data collected indicate that the storm drain continues to discharge dioxin through a point source to water of the state. Ecology's answer to this discharge was to informally "assign" this polluted facility and stormwater discharge to MS4 permit coverage for the cities of Burien and SeaTac. This approach is inconsistent with Ecology's obligations under the Clean Water Act, and related to state law, to address point source pollution in such a manner as to protect waters of the state from sources that cause or contribute to the violation of water quality standards or sediment standards.*

Response to Comment 25: It is the Port's understanding that WSDOE has previously responded to this comment as follows:

> "You are correct that there are no current plans to attempt to identify offsite sources not associated with the Lora Lake Apartments site, particularly sources to the west of the Lora Lake Apartments site that are not associated with the site. We would most probably institute such investigations only if there were a clear need for the information in order to select a remedy. Most likely, if investigation of offsite sources not associated with the Lora Lake Apartments site is needed, that would be done as a separate project. It is not clear whether the Port would be involved in such an effort." (South 2010).

Comment 26 [SWIA Report 1]—*The draft stormwater report is not what the community requested. The request was that Ecology require the Port to apply for a NPDES permit for its point source discharges to Lora Lake/Miller Creek and that relevant monitoring and treatment be implemented at the Site.*

Response to Comment 26: Refer to Response to Comment 25, above.

Comment 27 [LL Apartments Parcel RI/FS Work Plan]—*It is unreasonable to assume that a one time cleaning of the stormwater system means that it is going to stay clean or that such an action removes the need to continue to sample the sediments in this system if the system continues to discharge.*

Response to Comment 27: Refer to Response to Comment 1, above.

Comment 28 [LL Apartments Parcel RI/FS Work Plan]—*In-line sediment traps have some use as a screening tool, but are not adequate to determine the nature, extent, and risks posed by contaminated sediment in a stormwater system.*

Response to Comment 28: Sediment traps capture in-line solids that are being transported in stormwater flow and, therefore, collect samples that are representative of particulates and associated COCs that may be transported downgradient of a site or facility. For the SWIA, sediment traps were used for this purpose. In addition to sediment trap samples, stormwater flow samples, and catch basin sediment samples were all collected and analyzed for site COCs to provide data on the quality of the

LL Apartments Parcel input to stormwater as part of the SWIA (Appendix E of the RI/FS).

Comment 29 [LL Parcel RI/FS Work Plan]—*This document fails to consider the potential for the stormwater outfall discharge at Lora Lake to scour sediments during high flow conditions, which could result in the direct discharge of both LLA site sediments and Lora Lake sediments directly to Miller Creek in surface water discharge. This is particularly true for the finer particulates, which are known to contain greater percentages of contamination than the larger fractions and would not likely be subject to local deposition.*

Response to Comment 29: Refer to Response to Comment 2, above. The stormwater outfall does not discharge stormwater directly into Lora Lake, but rather into a sediment settling basin located in the northwest corner of the lake. This sediment settling basin functions to dissipate the energy of high flow from the outfall, thereby allowing the settling of finer particulates into the basin prior to the discharge into Lora Lake.

Comment 30 [following RI/FS data collection]—*In previous stormwater sampling, the level of dioxin in the stormwater dropped after contaminated sediments were removed from the system; however, the dioxin levels quickly rebounded and the last stormwater sample taken shows a dioxin level similar to what it was prior to sediment cleanout. The more recent in-line sediment trap data confirms what the stormwater data showed, that dioxin is again accumulating in and being transported through the stormwater system sediments.*

Response to Comment 30: The SWIA data do not suggest that dioxin/furans are rebounding, or accumulating in the LL Apartments Parcel stormwater system, but rather that consistent dioxin/furan concentrations continue to enter the stormwater system at the inlet to the Site. The SWIA stormwater sampling results showed that the dioxin/furan TEQ concentrations both increased and decreased relative to pre-line cleaning concentrations in both the main line inlet and main line outlet sampling locations (refer to Figures 7.1 and 7.2 of the Final SWIA Report, Appendix E of the RI/FS). Additionally, the statistical evaluation of the stormwater data conducted in the SWIA Report shows that for all sampling events, both prior to and post system cleanout, the LL Apartments Parcel was not contributing to the degradation of stormwater quality.

Comment 31 [following RI/FS data collection]—*The Port has yet to start to implement a source identification/source control program. This program to identify and control source should start at the earliest stages of contaminated site work, and be fully integrated into the site data evaluation and remedy selection. The dioxin discharge to waters of the state is continuing with no best management practices, or best available technology, being applied to minimize and control the problem.*

Response to Comment 31: The Port is responsible for identification and control of sources of contamination to surface water resulting from contamination at the Lora Lake Apartments Site. The SWIA, one element of the remedial investigation, showed that the LL Apartments Parcel is currently not degrading the quality of surface water via inputs from this parcel (refer to the SWIA Report in Appendix E of the RI/FS). For this RI/FS, the Port is not responsible for identifying or controlling upgradient or off-site sources of contamination to the stormwater system, which collects runoff from an approximate 83-acre drainage basin.

COMMENTS RECEIVED REGARDING HISTORY, LAND USE, AND INPUTS

Comment 32 [LL Parcel RI/FS Work Plan]*—Anecdotal accounts from the community indicate that there is a cement pipe coming into the southwestern end of Lora Lake.*

Response to Comment 32: In accordance with the LL Parcel RI/FS Work Plan, two visual inspections were performed along the shoreline of Lora Lake to identify any unknown current and/or historical input sources to Lora Lake. During the March 2011 visual inspection, a cement outfall pipe was observed in the sediment settling basin area, near the northwest corner of Lora Lake. No additional outfall pipes were observed, near the southwestern corner of the lake or elsewhere. For further details on observations made during these two visual inspections refer to the LL Parcel Remedial Investigation Data Report (Appendix G of the RI/FS).

Comment 33 [LL Parcel RI/FS Work Plan]*—The account of the historic discharge of stormwater to Lora Lake is inadequate, as the only identified stormwater discharge structure to Lora Lake was apparently constructed at the same time the apartments were constructed.*

Response to Comment 33: Additional historical research regarding the LL Parcel, including past land use, historical inputs to Lora Lake, and any associated environmental concerns, was performed as part of the LL Parcel RI/FS Work Plan. These historical materials are summarized and provided in the Historic Uses of the Port of Seattle Lora Lake Parcel Report (Appendix B of the RI/FS). Section 4.0 of this report specifically discusses the known drainage history of Lora Lake.

Comment 34 [LL Parcel RI/FS Work Plan]*—It is likely that the COCs are the same for the LL Apartments Parcel and the LL Parcel; however, there have been specific practices on the LL Parcel that differ from the LL Apartments Parcel and those inputs or other sources, and possibly additional COCs, should also be considered. Additionally, given the substantial residential development activity historically on and near the LL Parcel, this information needs to be taken into consideration in developing the sampling plan.*

Response to Comment 34: The specific purpose of the LL Parcel investigation was to determine if contamination associated with the LL Apartments Parcel had come to be located at the LL Parcel, and to determine whether the LL Parcel should be included as part of the Lora Lake Apartments Site in accordance with the Agreed Order. The requested additional investigation elements are beyond the scope of this RI/FS.

Comment 35 [LL Parcel RI/FS Work Plan]*—Due to the past industrial operations and construction on the LL Apartments Parcel, there is high potential for leaks, spills, or* *other releases to have occurred outside the facility property boundaries. These potential off-property pathways should be considered.*

Response to Comment 35: Areas immediately outside of the LL Apartments Parcel property boundary have been evaluated as part of the site remedial investigation. Concentrations of contaminants observed immediately off-property are considered to be a continuous extension of on-property contaminants from activities conducted within the property boundary. These select areas are discussed in the Responses to Comments 10 and 21, and are described in Section 7.0 of the RI/FS.

Comment 36 [LL Parcel RI/FS Work Plan]*—The Port carried out extensive activities on the LL Parcel, including the removal of heating oil tanks and impervious surfaces, and other activities that would have disturbed soils, which potentially substantially modified any previous deposition of contaminants. Any records the Port has on its activities at the LL Parcel should be reviewed to help determine the areas and extent of disturbance on this parcel. Additionally, subsurface conditions should be known on the LL Parcel based on geotechnical work done during construction efforts for the Third Runway. Port technical data collected during the Third Runway investigation and construction should be reviewed as well.*

Response to Comment 36: Applicable reports from the Port regarding the LL Parcel were reviewed, including a report regarding heating oil tank decommissioning on the LL Parcel, a hydrologic studies report regarding construction of the STIA 3rd Runway, the STIA Natural Resources Mitigation Plan, and various documents related to the monitoring of the STIA mitigation areas. Useful information obtained from these documents was incorporated into Section 2.0 of the RI/FS.

Comment 37 [LL Parcel RI/FS Work Plan]*—The Port has done some specific water quality investigations based on complaints received on Lora Lake.*

Response to Comment 37: Water quality sampling has been performed by the Port to assess physical parameters (e.g., temperature and dissolved oxygen) in Miller Creek and Lora Lake. These sampling activities were performed as a requirement of the STIA Natural Resources Mitigation Plan (Parametrix 2001). Water quality sampling under this program was not performed to assess the chemical quality of these water bodies, and did not include chemical analyses.

MISCELLANEOUS COMMENTS

Comment 38 [LL Parcel RI/FS Work Plan]*—A specific terrestrial ecological evaluation (TEE) is necessary for this site, in particular due to its status as a habitat mitigation area.*

Response to Comment 38: As part of the RI/FS, the MTCA procedure for completion of a terrestrial ecological evaluation (TEE) was conducted for the Site, including the LL Apartments Parcel, the LL Parcel, and the DMCA. The TEE evaluation and conclusions are included as Appendix K of the RI/FS.

Comment 39 [LL Parcel RI/FS Work Plan]*—There is substantial direct human interaction with Miller Creek and its sediments downstream of the LL Parcel. This work plan fails to describe that, or to consider related exposure pathways. This would include dermal exposure, and potentially in the case of young children the direct ingestion of sediments.*

Response to Comment 39: Sediment samples were collected from both Lora Lake and Miller Creek for both chemical and biological toxicity testing in order to determine if contamination associated with the LL Apartments Parcel had come to be located within Lora Lake and/or Miller Creek. Sediment sample results indicate sediment concentrations in Miller Creek immediately downgradient of the discharge point from Lora Lake are not impacted to concentrations greater than cleanup levels for the Lora Lake Apartments Site COCs. Sediment sample results are discussed in Appendix G and Section 4.3 of the RI/FS. Pathway evaluations are conducted as part of the CSM and are discussed in Section 8.0 of the RI/FS.

The protectiveness of sediment concentrations for human health is assessed in the RI/FS through the CSM pathway identification in Section 8.0 and through sediment modeling included in Appendix O of the RI/FS.

REFERENCES

Floyd|Snider. 2010a. *Lora Lake Apartments Final Remedial Investigation/Feasibility Study Work Plan*. Prepared for Port of Seattle. 30 July.

_____. 2010b. Deep Monitoring Well Installation and Sampling and Analysis Plan for the Lora Lake Apartments Parcel Phase of the Site Remedial Investigation. Prepared for Port of Seattle. 6 August.

_____.2011a. Additional Shallow Dioxin Soil Sampling – Lora Lake Apartments Parcel. Prepared for Port of Seattle. 14 February.

_____. 2011b. Technical Memorandum re: Dredged Material Disposal Area Characterization-Lora Lake Parcel. Prepared for Port of Seattle. April.

Parametrix, Inc. (Parametrix) 2001. Natural Resource Mitigation Plan Seattle-Tacoma International Airport Master Plan Update Improvements. Prepared for the Port of Seattle. November.

South, D. 2010. Email from D. South, Washington State Department of Ecology, to Greg Wingard Re: Lora Lake Apartments—need comments by Dec. 10th. 10 December.

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix J
Dioxins/Furans in Stormwater Equilibrium Calculation Evaluation Technical Memorandum

FINAL

Table of Contents

List of Figures

List of Attachments

List of Abbreviations/Acronyms

Abbreviation/ Acronym	Definition
foc	Fraction organic carbon
Koc	Organic carbon partitioning coefficient
LL Apartments Parcel	Lora Lake Apartments Parcel
MTCA	Model Toxics Control Act
Port	Port of Seattle
RI/FS	Remedial Investigation/Feasibility Study
SWIA	Stormwater Interim Action
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEQ	Toxic equivalency quotient
TSS	Total suspended solids

1.0 Introduction

This document presents the results of the Lora Lake Apartments stormwater dioxins/furans contribution evaluation conducted as part of the Lora Lake Apartments Parcel (LL Apartments Parcel) Remedial Investigation/Feasibility Study (RI/FS). This dioxins/furans stormwater evaluation assesses the potential contribution of dioxins/furans from the LL Apartments Parcel soils to the stormwater sampled in Catch Basin CB-31A.

The Port of Seattle (Port) conducted a Stormwater Interim Action (SWIA) that consisted of 10 rounds of stormwater sampling, cleaning of catch basins on-site, collecting catch basin sediment samples, conducting a TV-type line inspection of the entire LL Apartments Parcel stormwater drainage system, and collecting one round of stormwater solids samples using in-line solids “sediment traps.” SWIA field work and results are presented in the SWIA Data Report (Appendix E of the RI/FS).

The SWIA Work Plan and Data Report identified Main Line Inlet Catch Basin CB-31A (Figure J.1) as a stormwater sampling location representative of stormwater quality influent to the LL Apartments Parcel (Floyd|Snider and Taylor Associates, Inc. 2009; Appendix E of the RI/FS). Dioxins/furans were detected in stormwater samples obtained from CB-31A. Public comments expressed concern that Catch Basin CB-31A was not an accurate upgradient stormwater sampling location because the catch basin, located approximately 8 feet inside the LL Apartments Parcel property boundary, could receive inputs of dioxins/furans from the LL Apartments Parcel. This evaluation was conducted in response to the public concern.

An overview of the LL Apartments Parcel stormwater drainage system and upgradient and downgradient drainage networks is provided in the SWIA Work Plan and the SWIA Data Report (Floyd|Snider and Taylor Associates, Inc. 2009; Appendix E of the RI/FS).

The LL Apartments Parcel stormwater drainage system is owned and maintained by the Port. The system consists of catch basins and other features that are connected to a Main Line owned by the City of Burien. The Main Line enters the LL Apartments Parcel from the west, along 8th Avenue South, at the paired catch basin location CB4505/CB-31A (also known as the Main Line Inlet Catch Basin) and runs along a west-to-east alignment below the LL Apartments Parcel (Figure J.1). Stormwater from the LL Apartments Parcel enters the drainage system catch basins and flows into the Main Line at various points along its alignment. The Main Line, however, receives flow from a larger upgradient stormwater drainage network (Figure J.2). City of Burien stormwater drainage network plans indicate that, at the LL Apartment Parcel upgradient boundary, the Main Line carries stormwater from an upgradient area of approximately 83 acres (as shown on Figure J.2), before on-site stormwater drainage is introduced to the system. In contrast, the LL Apartments Parcel contributes stormwater drainage to the system from an approximate 8-acre area. The combined LL Apartments Parcel and City of Burien stormwater drainage then exits the LL Apartments Parcel in two locations near Des Moines Memorial Drive. Additional City of Burien stormwater drainage is introduced to the system downgradient from the LL Apartments Parcel via catch basins located along Des Moines Memorial Drive (Figure J.1). The Main Line and Secondary Line catch basins and on-site and off-site contributions and flow are described in more detail in the SWIA Data Report (Appendix E of the RI/FS).

2.0 Stormwater Contribution Evaluation Approach

2.1 OVERVIEW

Several elements were integrated into the effort to determine the maximum potential contribution of LL Apartment Parcel dioxins/furans to stormwater in CB-31A:

- Identification of the portion of the LL Apartments Parcel that has the potential to drain stormwater to CB-31A as opposed to any other catch basin or drainage point.
- Calculation of the amount of dioxins/furans that could be introduced from that area to CB-31A by migration via overland flow of dissolved-phase dioxins/furans leached from LL Apartments Parcel soil.
- Calculation of the amount of dioxins/furans that could be introduced from that area to CB-31A by migration of dioxins/furans-impacted suspended solids from LL Apartments Parcel soil.
- Comparison of the total calculated dioxins/furans contribution to actual CB-31A dioxins/furans stormwater sample concentration(s) to determine the percentage of the detected dioxins/furans concentrations that could potentially be attributable to the LL Apartments Parcel drainage.
- As a quality assurance check, calculation of site soil dioxins/furans concentrations necessary to produce actual CB-31A dioxins/furans stormwater sample concentration(s).

These steps are described in detail below, along with conservative assumptions used in this evaluation where site-specific data were not available. In addition to the step-specific assumptions, note that the various contribution calculations do not include adjustments for physical attenuation due to vegetation or organics that may be present in the subject area and the CB-31A catch basin.

During this evaluation, dioxin/furan toxic equivalency quotient (TEQ) concentrations are used in all calculations and are referred to as “dioxin/furan TEQs.” The CB-31A stormwater dioxin/furan TEQ and individual congener concentrations used in this evaluation were taken from the SWIA Data Report (Appendix E of the RI/FS). The LL Apartments Parcel surface soil dioxin/furan TEQ and individual congener concentrations are taken from the LL Apartments Remedial Investigation Data Report (Appendix F of the RI/FS) and are also presented in Table 4.1 of the RI/FS.

The calculations and results for the dissolved-phase contribution and suspended solids contribution are provided in Worksheets 1 and 2, respectively (Attachment J.1). Worksheet 2 also provides the calculation of site soil dioxin/furan TEQs necessary to produce the actual CB-31A dioxin/furan TEQ.

2.2 AREA OF LL APARTMENTS PARCEL WITH POTENTIAL TO CONTRIBUTE STORMWATER TO CB-31A

As shown on Figure J.1, Main Line Catch Basin CB-31A is located along the western, upgradient side of the LL Apartments Parcel, approximately 8 feet inside the LL Apartments Parcel property boundary. Figures J.1 and J.2 both show the extent of the LL Apartments Parcel area that is both adjacent to CB-31A and higher in elevation than CB-31A. This is the area from which water on the LL Apartments Parcel surface could flow into the catch basin. This area measures approximately 22,864 square feet, or 0.52 acres, which is approximately 0.7 percent of the total area from which upgradient stormwater drainage is received by CB-31A (Figure J.2). Approximately 46 percent of the 0.52-acre LL Apartments Parcel drainage area is impervious surface that would potentially drain to CB-31A, but for the purposes of this evaluation, 100 percent of this area is assumed to drain into CB-31A.

In the sections that follow, the potential LL Apartments Parcel dissolved-phase and suspended-solids-phase dioxins/furans contributions relative to the CB-31A stormwater dioxin/furan TEQ are initially presented at a one-to-one ratio (i.e., an assumption that *equal* flow volumes are contributed to CB-31A by both the LL Apartments Parcel area that could drain to that catch basin [0.52 acres] and the upgradient City of Burien drainage area [approximately 83 acres]). This ratio is extremely conservative because the LL Apartments Parcel potential drainage area is approximately 0.7 percent of the upgradient drainage that is entering CB-31A. Drainage-area-weighted results are also presented in Worksheet 2 in Attachment J.1.

2.3 POTENTIAL DISSOLVED-PHASE DIOXINS/FURANS CONTRIBUTION

Equilibrium partitioning calculations (using dioxin/furan organic carbon partitioning coefficients) were used to quantify the potential dissolved dioxin/furan TEQ associated with overland flow from actual LL Apartments Parcel surface soil dioxins/furans. Equilibrium partitioning assumes instantaneous chemical equilibrium between the contaminants in the water (dissolved phase) and the soil particles. The dioxin/furan source TEQs used in this evaluation were the LL Apartments Parcel surface soil TEQs reported from remedial investigation samples collected from locations within the site area identified to have potential to drain to CB-31A (Samples SSB-02 and PSB-01; Figure J.1). Both samples were collected from the 0- to 0.5–foot soil interval.

Equilibrium partitioning was calculated with the following equation:

$$Csoil = Cdissolved \times Kd$$

Where: Csoil = equilibrium soil concentration (TEQ)
Cdissolved = dissolved water concentration (TEQ)
Kd = dioxins/furans partitioning coefficient

The dioxins/furans Kd value was calculated using the Model Toxics Control Act (MTCA) default fraction organic carbon (foc) content (0.001 g/g or 0.01 percent; Washington Administrative Code [WAC] 173-340-747) and an average organic carbon partitioning coefficient (Koc) for the dioxin congener 2,3,7,8-tetrachlorodibenzo-p-dioxin

(2,3,7,8-TCDD; refer to Worksheet 1 in Attachment J.1). The only congener with multiple peer-reviewed and published Koc values is 2,3,7,8-TCDD, the most toxic and well-studied dioxin/furan congener (USEPA 2003). The dioxins/furans Kd value was calculated using the following equation:

$$Kd = Koc \times foc$$

Where: Kd = dioxin/furan 2,3,7,8-TCDD partitioning coefficient
Koc = organic carbon partitioning coefficient
foc = fraction of organic carbon

An average Koc value for 2,3,7,8-TCDD was used in the equilibrium partitioning calculation of the dissolved-phase LL Apartments Parcel dioxins/furans contribution. The dioxin/furan 2,3,7,8-TCDD congener consists of four chlorine atoms, while all of the other dioxin and furan congeners consist of five, six, seven, or eight chlorine atoms. Dioxins/furans migration and transport calculations are very sensitive to the Koc value used as the additional chlorine atoms significantly reduce the liberation of dioxins/furans congeners into the dissolved phase. Therefore, the use of the lower chlorinated Koc value is conservative and substantially overestimates the amount of dioxins/furans that would be in the dissolved phase.

In addition, the MTCA default soil fraction of organic carbon content of 0.001 was used for the calculation of the LL Apartments Parcel dissolved-phase dioxins/furans contribution. This is often considered a conservative value because the foc value for site soil with vegetation and organics is generally greater than 0.001. Therefore, the use of the default MTCA foc value likely overestimates the amount of dioxins/furans that would be in the dissolved phase.

The parameter values, calculation equations, and results are presented in Worksheet 1 (Attachment J.1). The results are discussed below in Section 3.0.

2.4 POTENTIAL SUSPENDED-SOLIDS-PHASE DIOXINS/FURANS CONTRIBUTION

This element of the evaluation quantifies the potential suspended–solids-phase dioxin/furan TEQs associated with overland flow from actual LL Apartments Parcel Remedial Investigation surface soil dioxin/furan TEQs and the total suspended solids (TSS) concentrations measured in stormwater samples collected from CB-31A as part of the SWIA. Consistent with the quantification of the dioxins/furans dissolved-phase contribution, the LL Apartments Parcel surface soil TEQs from remedial investigation samples collected from locations within the potential CB-31A drainage area were considered the dioxin/furan source TEQs in this evaluation. This calculation incorporates several conservative assumptions:

- The calculation assumes that all of the TSS measured in CB-31A stormwater originated from the LL Apartments Parcel surface soil and that no suspended solids came from upgradient stormwater flow; this conservative assumption overestimates the potential LL Apartments Parcel contribution.

- The calculation assumes that all surface soil transported to CB-31A as suspended solids (a) had dioxins/furans compounds attached to particle surfaces, and (b) had a dioxin/furan TEQ equal to the maximum dioxin/furan TEQ reported for the area that drains to that catch basin (Sample SSB-02, 11.5 pg/g); these assumptions likely overestimate the actual dioxin/furan TEQs that could be transported to the stormwater in CB-31A.

Therefore, the TSS concentrations measured in stormwater samples collected from CB-31A during the SWIA were assigned dioxin/furan TEQs representing maximum area-specific surface soil TEQs to calculate the potential suspended-solids-phase dioxins/furans contribution to CB-31A, assuming the transport of surface soil particles to CB-31A via overland flow.

The parameter values, calculation equations, and results are presented in Worksheet 2 (Attachment J.1). The results are discussed below in Section 3.0.

2.5 TOTAL CALCULATED DIOXINS/FURANS CONTRIBUTION AND COMPARISON TO REPORTED DATA

To determine the potential contribution of the LL Apartment Parcel to the dioxin/furan TEQs reported in samples collected from the intended upgradient/influent stormwater data collection point, CB-31A, the calculated dissolved-phase dioxins/furans potential contribution was added to the suspended-solids-phase dioxins/furans potential contribution to quantify the total dioxins/furans potential contribution to CB-31A stormwater. This calculation and comparison are presented in Worksheet 2 (Attachment J.1). The results are discussed below in Section 3.0.

2.6 LL APARTMENTS PARCEL DIOXIN/FURAN SOIL TEQ NECESSARY TO RESULT IN MEASURED STORMWATER DIOXIN/FURAN TEQ

In addition to the quantification of the potential LL Apartments Parcel surface soil dioxins/furans contribution to CB-31A stormwater, the question was asked: “What LL Apartments Parcel surface soil dioxin/furan TEQs would be necessary to result in 100 percent of the dioxin/furan TEQ measured in CB-31A?” To answer this question, an equilibrium partitioning calculation was performed, back-calculating to the required LL Apartments Parcel total dioxin/furan TEQ contribution from the actual site stormwater data. For this equation the LL Apartments Parcel total dioxin/furan TEQ potential contribution was set equal to the mean dioxin/furan TEQ measured in CB-31A during the SWIA of 19.8 pg/L. Then the LL Apartments Parcel dioxin/furan surface soil TEQ was calculated in the equation, as shown on Worksheet 2 (Attachment J.1). The required LL Apartments Parcel dioxin/furan soil TEQ necessary to result in 100 percent of the dioxin/furan TEQ measured in CB-31A was calculated using the following equation:

$$Csoil = (Csw \times Kd)/(1 + TSS \times Kd)$$

Where: Csoil = required LL Apartments Parcel surface soil dioxin/furan TEQ necessary to result in 100 percent of the CB-31A dioxin/furan stormwater TEQ measured during the SWIA
Csw = mean dioxin/furan TEQ measured in CB-31A stormwater
TSS = mean total Suspended Solids measured in CB-31A stormwater
Kd = dioxin/furan 2,3,7,8-TCDD partitioning coefficient

Worksheet 2 details the parameters, input values, and data used in the equation (Attachment J.1). The results are discussed below in Section 3.0.

This page intentionally left blank.

3.0 Stormwater Evaluation Results

3.1 LORA LAKE APARTMENTS PARCEL DIOXINS/FURANS POTENTIAL CONTRIBUTION RESULTS

Based on the LL Apartments Parcel surface soil dioxin/furan TEQs, as detected in remedial investigation Soil Samples PSB-01 and SSB-02 and an average 2,3,78,8-TCDD Koc value, results of the equilibrium partitioning equation predict that the LL Apartments Parcel dioxins/furans dissolved-phase potential contribution to stormwater in CB-31A is 0.89 pg/L (refer to Worksheet 1 in Attachment J.1).

Based on the mean TSS concentration measured in CB-31A stormwater during the SWIA (35.5 mg/L) and the highest LL Apartments Parcel surface soil dioxin/furan TEQ adjacent to CB-31A detected in Sample SSB-02 (11.5 pg/g), the LL Apartments Parcel dioxins/furans suspended-solids-phase potential contribution to CB-31A stormwater via soil particle migration in overland flow was calculated to be 0.41 pg/L (refer to Worksheet 2 in Attachment J.1).

The sum of the potential LL Apartments Parcel dissolved-phase and suspended-solids-phase dioxins/furans contributions to CB-31A was calculated to be 1.3 pg/L based on the conservative assumptions noted above.

When comparing the total dioxins/furans LL Apartments Parcel potential contribution to the dioxin/furan TEQ detected in CB-31A during the SWIA, with no weighting of the LL Apartments Parcel contribution to account for the difference in drainage areas (and, therefore, volumes) from the two sources of stormwater flow influent to the LL Apartments Parcel (refer to Section 2.2), the calculated LL Apartments Parcel contribution represents 3.5 percent to 17.6 percent of the maximum and minimum detected dioxin/furan stormwater TEQ in CB-31A, respectively.

A far more appropriate evaluation, however, requires factoring in relative flow volume contributions. When the LL Apartments Parcel total dioxins/furans potential contribution is weighted by the relative drainage area and associated flow, it potentially represents 0.02 percent to 0.12 percent of the maximum and minimum detected dioxin/furan stormwater TEQ in CB-31A, respectively (refer to Worksheet 2 in Attachment J.1).

3.2 LL APARTMENTS PARCEL DIOXIN/FURAN SOIL TEQ NECESSARY TO RESULT IN MEASURED STORMWATER DIOXIN/FURAN TEQ

The “back-calculation” to determine the LL Apartments Parcel surface soil dioxin/furan TEQ that would be required to account for 100 percent of the mean dioxin/furan TEQ detected in CB-31A stormwater sampled during the SWIA resulted in a predicted soil concentration of 171.4 pg/g. The highest dioxin/furan TEQ detected in LL Apartments Parcel surface soils (0- to 0.5-foot) adjacent to CB-31A was from Sample SSB-02 with a TEQ concentration of 11.5 pg/g. The SSB-02 detected TEQ concentration is approximately 1/15th (less than 7 percent) of that required to account for the dioxin/furan TEQ measured in CB-31A.

4.0 Conclusions

The potential for LL Apartments Parcel surface soil dioxin/furan TEQs to contribute to the CB-31A detected dioxin/furan TEQ via overland flow and drainage was evaluated using equilibrium partitioning calculations. The evaluation calculations were structured to use site-specific data as the LL Apartments Parcel dioxin/furan soil source TEQs and represent actual dioxin/furan TEQ and TSS concentrations measured in stormwater from CB-31A. Additionally, the actual upgradient and LL Apartments Parcel drainage areas were used. The use of empirical data coupled with multiple conservative assumptions make the evaluation an overestimation of the potential dioxin/furan contribution, but provide a prudent representation of actual site conditions.

The results of the LL Apartments Parcel stormwater dioxins/furans contribution weighted to accurately reflect the relative difference in stormwater volumes influent to CB-31A[1] indicate that the LL Apartments Parcel surface soils contribute less than 0.2 percent of the dioxin/furan TEQ detected in that catch basin. Therefore, the use of CB-31A as the Main Line upgradient stormwater sampling location to represent stormwater quality as it is entering the LL Apartments Parcel is appropriate.

Additionally, the LL Apartments Parcel surface soil dioxin/furan TEQ that would be required to result in 100 percent of the dioxin/furan TEQ detected in CB-31A stormwater, with the conservative assumption that all TSS originates from the LL Apartments Parcel and not from upgradient drainage, was predicted to be 15 times greater than the dioxin/furan TEQ detected in adjacent site surface soils.

CB-31A provides the most appropriate and representative available sampling location to assess the quality of stormwater entering the LL Apartments Parcel. CB-31A is the only sampling access point close to the site upgradient boundary; because of this location it captures all of the stormwater influent to the Lora Lake Apartments Site, including sources associated with 8th Avenue South along the western property boundary. At the same time, it is located only approximately 8 feet inside the property boundary, and has only a minor amount of surface area that could contribute to drainage into the catch basin. Moreover, as demonstrated in this report, there is little, if any, LL Apartments Parcel contribution to the CB-31A dioxin/furan content. Conversely, sampling of a different catch basin further upgradient to characterize Main Line stormwater quality as it enters the LL Apartments Parcel would not capture all of the 8th Avenue South inputs and, therefore, would not be representative of LL Apartments Parcel influent drainage.

[1] The LL Apartment Parcel surface area that potentially contributes dioxins/furans is less than 0.7 percent of the upgradient City of Burien surface area.

This page intentionally left blank.

5.0 References

Floyd|Snider and Taylor Associates, Inc. 2009. *Port of Seattle Lora Lake Apartments Final Stormwater Interim Action Work Plan*. Prepared for Port of Seattle. 17 November.

Jackson, D.R., M.H. Roulier, H.M. Grotta, S.W. Rust, and J.S. Warner. 1986. "Solubility of 2,3,7,8-TCDD in Contaminated Soils." pp. 185-200 in *Chlorinated Dioxins and Dibenzofurans in Perspective*, ed. C. Rappe, G. Choudhary, and L.H. Keith. Lewis Publishers, Inc.

Schroy, J.M., F. D. Hileman, and S. C. Cheng. 1985 "Physical/chemical properties of 2,3,7,8-TCDD." *Chemosphere* 14:877–880.

U. S. Environmental Protection Agency (USEPA). 2003. *Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds.* National Academy Sciences (NAS) Review Draft, Part I: Estimating Exposure to Dioxin-Like Compounds, vol 3: Site-Specific Assessment Procedures. Office of Research and Development. Washington, District of Columbia.

Port of Seattle
Lora Lake Apartments Site

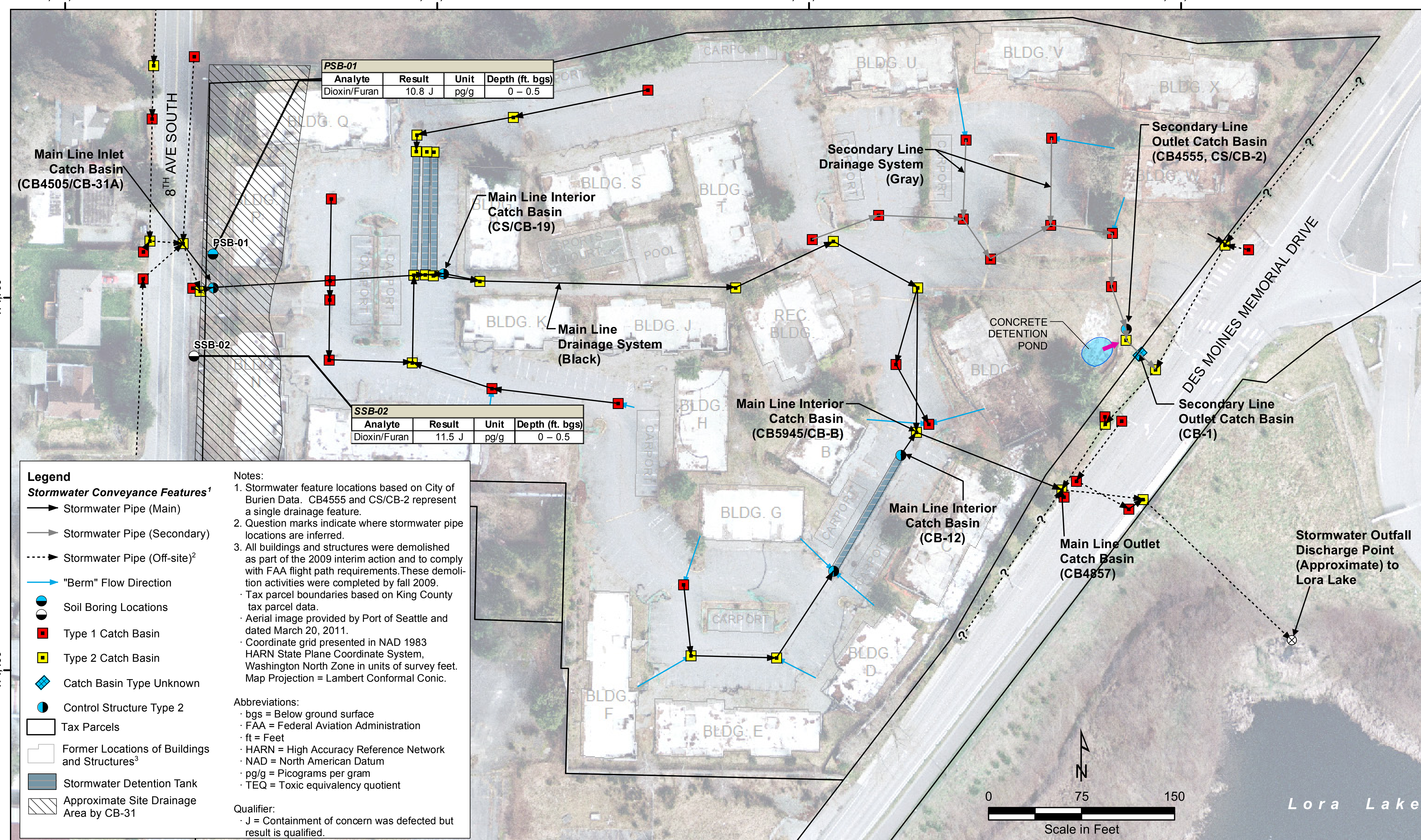
Remedial Investigation/ Feasibility Study

Volume II

Appendix J
Dioxins/Furans in Stormwater Equilibrium Calculation Evaluation Technical Memorandum

Figures

FINAL



PSB-01

Analyte	Result	Unit	Depth (ft. bgs)
Dioxin/Furan	10.8 J	pg/g	0 – 0.5

SSB-02

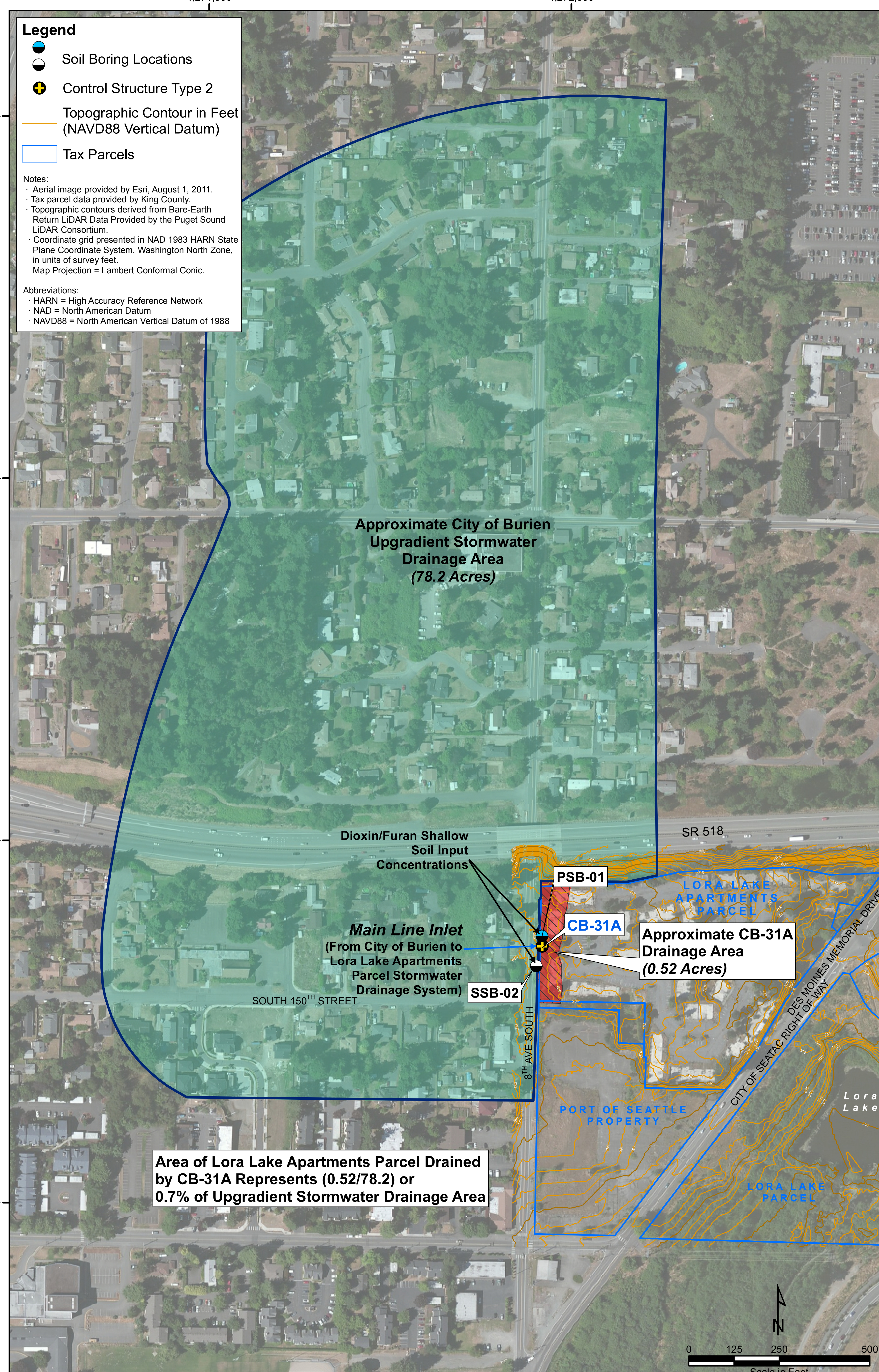
Analyte	Result	Unit	Depth (ft. bgs)
Dioxin/Furan	11.5 J	pg/g	0 – 0.5

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure J.1
Lora Lake Apartments Parcel Stormwater Drainage System and Dioxin/Furan Shallow Soil Input TEQ Concentrations

Path: I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix J\Figure J.1 Lora Lake Apartments Parcel SW Drainage System and Dioxin Furan Conc.mxd
Date: 9/15/2014



FLOYD | SNIDER
strategy · science · engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure J.2
CB-31A Drainage

Path: I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix J\Figure J.2 CB-31A Drainage.mxd
Date: 9/15/2014

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix J
Dioxins/Furans in Stormwater Equilibrium Calculation Evaluation Technical Memorandum

Attachment J.1
Lora Lake Apartments Parcel Stormwater Dioxin/Furan Contribution Evaluation

FINAL

Lora Lake (LL) Apartments Parcel Stormwater Dioxin/Furan Contribution Evaluation

Worksheet No. 1: Dioxin/Furan Soil to Groundwater/Overland Flow Evaluation—Equilibrium Calculation of the LL Apartments Parcel Dissolved Phase Dioxins/Furans Potential Contribution

Method: Equilibrium Partitioning Equation

$C_{Dissolved} = C_{Soil} / K_d$ $K_d = K_{oc} * foc$

Indicates a cell with an input parameter from site data, technical reference, and/or guidance document. (blue)
Indicates a value calculated from the input parameters as shown in blue shaded cells. (yellow)
Values and text in red indicate the results of the evaluation.

Dioxin/furan soil TEQs closest to CB-31A

Soil Sample	Sample Depth	Reported Units		Units used in Calculations	
PSB-01	0–0.5 ft	10.8	pg/g	10,800	pg/kg
SSB-02	0–0.5 ft	11.5	pg/g	11,500	pg/kg

Assumed total organic carbon value

	Reported Units		Units used in Calculations	
MTCA Default Soil Fraction of Organic Carbon (f_{oc})	0.001	g/g	0.1	%

Dioxin (2,3,7,8-TCDD) K_{oc} value

K_{oc} Reference[1]		K_{oc}	Units
Schroy et al., 1985		1.0E+06	L/kg
Jackson et al., 1986		2.4E+07	L/kg
	Average K_{oc}	1.3E+07	L/kg

Dioxin (2,3,7,8-TCDD) calculated K_d value

Equation	K_d	Units
$K_d = K_{oc} * f_{oc}$	12,500	L/kg

Potential dioxins/furans dissolved concentration contribution

Equation	$C_{dissolved}$	Units	Associated Soil Samples	
$C_{Dissolved} = C_{Soil} / K_d$	**0.86**	pg/L	PSB-01	*(10,800 pg/kg / 12,500 L/kg))*
	0.92	pg/L	SSB-02	*(11,500 pg/kg / 12,500 L/kg))*
Average:	**0.89**	pg/L		

Range of Dioxin/Furan TEQ values in stormwater detected in Upgradient CB-31A (with 1/2DL=ND): 7.4 to 37.2 pg/L

Minimum detected dioxin/furan TEQ	7.4	pg/L
Maximum detected dioxin/furan TEQ	37.2	pg/L
Mean detected dioxin/furan TEQ	19.8	pg/L

Note:
1. Full references for K_{oc} values included in appendix text references. The Schroy et al., 1985 and Jackson et al., 1986 references were obtained from USEPA 2003, Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds National Academy Sciences (NAS) Review Draft, Part I: Estimating Exposure to Dioxin-Like Compounds, vol 3: Site-Specific Assessment Procedures.

Lora Lake (LL) Apartments Parcel Stormwater Dioxin/Furan Contribution Evaluation

Worksheet No. 2: Dioxin/Furan Soil to Groundwater/Overland Flow Evaluation—LL Apartments Parcel Suspended Solids Phase and Total Dioxin/Furan Potential Contribu

Range of Total Suspended Solids (TSS) concentrations in stormwater measured in Upgradient CB-31A (from SWIA with 1/2DL=ND)

Minimum measured TSS:	11.2	mg/L
Maximum measured TSS:	59	mg/L
Mean measured TSS:	35.5	mg/L

(blue) Indicates a cell with an input parameter from site data, technical reference, and/or guidance document.
(yellow) Indicates a value calculated from the input parameters as shown in blue shaded cells.
Values and text in red indicate the results of the evaluation.

Dioxin/furan soil TEQs closest to CB-31A

Soil Sample	Sample Depth	Reported Units		Units used in Calculations	
PSB-01	0–0.5 ft	10.8	pg/g	10,800	pg/kg
SSB-02	0–0.5 ft	11.5	pg/g	11,500	pg/kg

Dioxins/furans dissolved potential concentration contribution (refer to Worksheet No. 1)

Equation	$C_{dissolved}$	Units	Associated Soil Samples
$C_{Dissolved} = C_{Soil} / K_d$	**0.86**	pg/L	PSB-01
	0.92	pg/L	SSB-02
Average:	**0.89**	pg/L	

Dioxins/furans suspended solids potential concentration contribution

Equation	$C_{dissolved}$	Units	
$C_{Suspsolid} = C_{Soil} \times TSS$	**0.41**	pg/L	*Highest Surface Csoil (SSB-02) x mean CB-31A measured TSS (11.5 pg/g x 35.5 mg/L x 1g/1000mg)*

Range of dioxin/furan TEQ values in stormwater detected in Upgradient CB-31A (with 1/2DL=ND): 7.4 to 37.2 pg/L

Minimum detected dioxin/furan TEQ	7.4	pg/L
Maximum detected dioxin/furan TEQ	37.2	pg/L
Mean detected dioxin/furan TEQ	19.8	pg/L

Total LL Apartments Parcel Dioxins/Furans Potential Contribution to CB-31A Stormwater

Equation	C_{total}	Units	
$C_{Total} = C_{Dissolved} + C_{Suspsolid}$	**1.30**	pg/L	*(0.89 pg/L + 0.41 pg/L)*

Percentage of the total dioxin/furan potential concentrations in stormwater at CB-31A contributed from dissolved and solids phase transport from surrounding LL Apartments Parcel surface soils with equal weight to upgradient/influent stormwater flow and on-site LL Apartments overland flow)			*(CTotal/Dioxin TEQ Concentrations from CB-31A) x 100*
Percent total dioxin/furan TEQs from LL Apartments Parcel dissolved and suspended solids phases based on minimum detected dioxin/furan TEQ in CB-31A	**17.6**	%	*(1.3 pg/L / 7.4 pg/L) x 100*
Percent total dioxin/furan TEQs from LL Apartments Parcel dissolved and suspended solids phases based on maximum detected dioxin/furan TEQ in CB-31A	**3.5**	%	*(1.3 pg/L / 37.2 pg/L) x 100*
Drainage Area Weighted—Percentage of the total dioxin/furan potential concentrations in stormwater at CB-31A contributed from dissolved and solids phase transport from surrounding LL Apartments Parcel surface soils			
Area of the LL Apartments Parcel that is potentially drained by CB-31A relative to the upgradient stormwater drainage area received by CB-31A (see Figure 1.2)	0.67	%	*((CTotal x 0.0067 LLA drainage area)/Dioxin TEQ Concentrations from CB-31A) x 100*
Drainage Area Weighted—Percent total dioxin/furan TEQs from LL Apartments Parcel dissolved and suspended solids phases based on minimum detected dioxin/furan TEQ in CB-31A	**0.12**	%	*((1.3 pg/L x 0.0067)/ 7.4 pg/L) x 100*
Drainage Area Weighted—Percent total dioxins/furans concentrations from LL Apartments Parcel dissolved and suspended solids phases based on maximum detected dioxin/furan TEQ in CB-31A	**0.02**	%	*((1.3 pg/L x 0.0067)/ 37.2 pg/L) x 100*

Summary: The total dioxin/furan potential contribution from the LL Apartments Parcel soils via dissolved-phase concentrations leaching from adjacent surface soils, and contribution of the soil particles themselves to the stormwater sampled in CB31A via suspended solids is estimated to be an average of 1.3 pg/L, ranging from **3.5 to 17.6% of the CB-31A stormwater dioxin/furan TEQ concentrations**—when the drainage area and associated flow of the adjacent LL Apartments Parcel surface soils at a higher elevation than CB-31A are assumed equal to the drainage area and flow from the upgradient City of Burien stormwater.

However, the drainage area and associated flow of the adjacent LL Apartments Parcel surface soils at a higher elevation than CB-31A is approximatley 0.7% of that of the upgradient City of Burien drainage area entering CB-31A (refer to Figure I.2). Therefore, when the potential total dioxin/furan contribution from the LL Apartments Parcel surface soils is drainage area weighted—the potential total dioxin/furan contribution ranges from **0.02% to 0.12%** of the dioxin/furan TEQ detected in CB-31A stormwater during the SWIA.

Required LL Apartments Parcel surface soil dioxin/furan TEQ necessary to result in 100% of the detected mean stormwater dioxin/furan TEQ in CB-31A			
Equation	Value	Units	
$C_{dissolved} = C_{soil} / K_d$	**0.89**	pg/L	*(See Worksheet No. 1)*
$C_{suspsolid} = C_{soil} \times TSS$	**0.41**	pg/L	*(See calculations above)*
$C_{Total} = C_{dissolved} + C_{suspsolid}$	**1.30**	pg/L	*(See calculations above)*
$C_{soil} = (C_{sw} \times K_d)/(1 + TSS \times K_d)$	**171.4**	pg/g	*(19.8 pg/L x 12,500 L/kg x (1kg/1000g)) / (1 + 35.5 mg/L x 12,500 L/kg x (1g/1000mg x 1 kg/1000g))*

Note: The LL Apartments Parcel dioxin/furan surface soil sample that is closest to CB-31A is SSB-02 with a dioxin/furan TEQ concentration of 11.5 pg/g, or ***approximately 1/15th of the concentration needed to result in mean dioxin/furan stormwater TEQs observed in CB-31A during the SWIA 10 sampling events****.*

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix K
Terrestrial Ecological Evaluation

FINAL

TERRESTRIAL ECOLOGICAL EVALUATION FOR THE LORA LAKE APARTMENTS SITE

Prepared for
FLOYD|SNIDER
Two Union Square
601 Union Street, Suite 600
Seattle, WA 98101

Prepared by

integral consulting inc.

411 1st Avenue S.
Suite 550
Seattle, WA 98104

August 2012

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

CDD	chlorinated dibenzo-*p*-dioxin
CDF	chlorinated dibenzofurans
COC	chemical of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
DMCA	1982 Dredged Material Containment Area
EIC	ecological indicator concentration
FAA	Federal Aviation Administration
LL Apartments Parcel	Lora Lake Apartments Parcel
LL Parcel	Lora Lake Parcel
MTCA	Model Toxics Control Act
RI/FS	remedial investigation and feasibility study
RPZ	runway protection and approach transition zones
Site	Lora Lake Apartments Site
STIA	Seattle-Tacoma International Airport
TEE	terrestrial ecological evaluation
TEF	toxicity equivalency factor
TEQ	toxic equivalent concentration
WAC	Washington Administrative Code
WHMP	Wildlife Hazard Management Plan

1 INTRODUCTION

This document was prepared to determine whether the Lora Lake Apartments Site (the Site) located in Burien, WA, adjacent to the Seattle-Tacoma International Airport (STIA) qualifies for a terrestrial ecological evaluation (TEE) consistent with the Model Toxics Control Act (MTCA) Cleanup Regulation (WAC 173-900). In addition, this report was prepared to determine whether hazardous chemicals are present in soils at levels that may present a threat to the terrestrial environment for those portions of the Site for which a TEE was found to be appropriate.

In support of the TEE, documents relevant to ecological conditions at the Site were reviewed, including the remedial investigation and feasibility study (RI/FS) work plans (Floyd Snider 2010, 2011) and Port of Seattle documents that are relevant to Site conditions and management objectives (Parametrix 2001, Port of Seattle 2005 and 2011). Additional reviewed information, including maps of data and sampling areas, were also provided by Floyd Snider. A Site visit was conducted in August 2011 by Integral Consulting Inc. scientists to better understand Site ecological conditions.

The remainder of this document describes the process for evaluating whether a TEE is appropriate for the three parcels comprising the Site and for conducting the TEE for those portions of the site for which it was found to be appropriate, consistent with WAC 173-340-7490 through WAC 173-340-7494, including:

- Section 2, Problem Formulation—1) Describes the Site, 2) evaluates whether Site parcels qualify for a TEE, and 3) describes the chemicals of concern (COCs), exposure pathways, relevant ecological receptors, and toxicological assessment for those portions of the Site for which a site-specific TEE is appropriate. In addition, the toxicological assessment identifies those chemicals that are below ecological criteria and can be removed from further evaluation of risk.
- Section 3, Ecological Evaluation—Addresses those COCs that are retained in the toxicological assessment because they cannot be ruled out as indicating negligible risk and discusses applying appropriate cleanup values in the context of MTCA guidance.
- Section 4, Conclusions—Summarizes the findings, including outlining the decisions regarding which portions of the Site qualify for a TEE, COCs retained in the evaluation and their associated criteria and recommended cleanup values consistent with MTCA guidance.

2 PROBLEM FORMULATION

The Site is located in the Puget Sound Lowlands within the Miller Creek Watershed and is just northwest of the STIA. The Site consists of the Lora Lake Apartments Parcel (LL Apartments Parcel), the Lora Lake Parcel (LL Parcel), and the 1982 Dredged Material Containment Area (DMCA) (Figure 1).

2.1 LL APARTMENTS PARCEL

The LL Apartments Parcel is a former apartment building complex with soil and groundwater contamination due to prior historical activities as described in Section 2.0 of the RI/FS. All buildings were removed from this parcel between 2007 and 2009, leaving building foundations and a parking lot as the primary cover material. Swimming pools have been closed or filled with gravel and the southeast perimeter has been covered with plastic sheeting to reduce the potential for soil erosion. Currently, the only natural areas at this parcel are: 1) the parcel margins, which contain ruderal groundcover including grasses, blackberries, scotch broom, and a mixture of ornamental and native trees; 2) ornamental plantings located on median strips and dividers in the parking lots; and 3) forbs and grasses that have opportunistically colonized breaks in the pavement. The future intended use of the LL Apartments Parcel is for light industrial or commercial use, and therefore is expected to be fully paved. Given that impervious surfaces comprise the vast majority of the LL Apartments Parcel and that the future use of the parcel is expected to be commercial or light industrial, this parcel was excluded from further consideration in the TEE (see Appendix A-1 for the checklist for LL Apartments Parcel exclusion).

2.2 DMCA PARCEL

The DMCA is comprised of material that was dredged from Lora Lake by King County in 1982 in response to homeowner (then living adjacent to the lake) concerns regarding the accumulation of sediment within Lora Lake. King County reportedly removed approximately 16,000 yd^3 of sediment, which was placed in a bermed area on Port of Seattle property, located approximately 400 ft northeast of Lora Lake (i.e., the DMCA, Figure 1). The western half of the DMCA lies underneath the approach lighting system for the STIA third runway, is covered in gravel, and is maintained by the Port of Seattle to be free of vegetation. The remainder of the DMCA is covered by a mix of grasses and invasive and pioneering plant species including scotch broom, alder saplings, Himalayan blackberry, and butterfly bush.

The DMCA is located within the extended object free area of the runway protection and approach transition zones (RPZ) for STIA (Figure 2.5 of the RI/FS) that have been established by the Federal Aviation Administration (FAA). The object free area is not allowed for uses that interfere with navigational aids or that attract wildlife. The DMCA is also commercially zoned as an area of aviation operations by the City of SeaTac. The DMCA will support continued Port of Seattle commercial use, consistent with FAA requirements and security zone use. Consistent with this zoning and intended use, the future conditions of the DMCA post-remedial action will include an engineered compacted gravel or paved surface that will eliminate wildlife habitat, prevent plant re-establishment, and therefore prevent plants or wildlife from being exposed to any soil contamination present in this parcel. Based on this expected future use, this parcel was excluded from further consideration in the TEE (see Appendix A-2 for the checklist for DMCA exclusion).

2.3 LL PARCEL

The LL Parcel is located across Des Moines Memorial Drive from the LL Apartments Parcel (Figure 1) and contains Lora Lake, a man-made surface water feature that was constructed as a result of peat mining sometime after 1936. The LL Parcel is located within both the controlled activity area and the extended object free area of the RPZ (Figure 2.5 of the RI/FS). The LL Parcel is zoned by the City of SeaTac as a mix of "Aviation Operations" and "Aviation Commercial".

Lora Lake is located down-gradient of the LL Apartments Parcel and receives stormwater runoff from the LL Apartments Parcel, City of Burien residential and commercial areas up-gradient of the LL Apartments Parcel, and surrounding roadways down-gradient of the LL Apartments Parcel via a single outfall located at the northwestern edge of the lake. Miller Creek runs past the southeast margin of Lora Lake and is connected to the lake via two surface water channels, an outfall, and a low point in the berm at the southeast edge of the lake. The LL Parcel is densely vegetated and contains a mixture of grasses, forbs, emergent wetland plants, and a canopy of mixed deciduous trees.

The LL Parcel and other adjacent areas have recently been enhanced to support aquatic, amphibian, and wetland habitat as part of the mitigation requirements associated with development of the STIA third runway (Port of Seattle 2011). The mitigation plan requirements support specific ecological functions managed within the context of the Port's Wildlife Hazard Management Plan (WHMP; Port of Seattle 2005), which is the controlling requirement for this special use area. These ecological functions include, "providing aquatic habitat enhancements for fish, amphibians, and invertebrates when such can be accomplished without increasing waterfowl use. On-site mitigation also replaces flood storage functions impacted and enhances the biological and physical functions of riparian areas near Miller and Des Moines Creeks. These areas will provide small mammal and song bird habitat, though this is not their primary purpose" (Section 4.1, Parametrix 2001). Consistent with the WHMP, specific wildlife taxa are potential nuisance species and will be monitored and controlled so that they do not interfere with airport operations or safety, including flocking birds (e.g., pigeons, starlings, and waterfowl) and large mammals (e.g., coyotes and deer). The WHMP also identifies small mammals (e.g., rodents) as prey and therefore primary attractant of hawks and coyotes, and directs control of prey species to reduce such attractants for nuisance species (Port of Seattle 2005). The Port actively manages the LL Parcel, including replacing and enhancing vegetation as necessary, and actively controlling or eliminating birds and mammals as necessary, so as not to increase use of the Site by prey species or nuisance taxa that may attract wildlife that pose a hazard to aviation activities.

Although the LL Parcel is being managed to minimize or control terrestrial wildlife under the WHMP, Lora Lake does not qualify for either an exclusion from the TEE process or a simplified TEE because Lora Lake is managed as a wetland area where semi-native[1] vegetation has been restored and because there are more than 10 acres of contiguous vegetated habitat within 500 ft of the area within and surrounding Lora Lake (Figure 2 and as consistent with the conditions outlined in the evaluation checklist, Appendix A-3). Consequently, as required by WAC 173-340-7493, a site-specific TEE is appropriate to evaluate the potential for ecological risks for these areas (Appendix A-3).

2.4 CHEMICALS OF CONCERN

The remedial investigation has identified soil COCs for the Site, which include two metals, petroleum hydrocarbons, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), semivolatile and volatile organic compounds, and chlorinated dibenzo-*p*-dioxins (CDDs) and dibenzofurans (CDFs) (Table 1). This list of COCs is evaluated in the TEE. Chemicals that do not exceed ecological indicator concentrations (EICs) as described in Model Toxics Control Act (MTCA) Table 749-3 may be removed from further consideration of risk to ecological receptors at the Site, consistent with WAC 173-340-7493 2(a)(i).

2.5 EXPOSURE PATHWAYS

The primary transport pathways of COCs to the Lora Lake Parcel include:

- Stormwater, storm drain sediment, and groundwater to LL Parcel soils—Lora Lake receives discharges of groundwater, stormwater, and storm drain sediment from the LL Apartments Parcel as well as from other sources. Particulates transported by stormwater that settle in the upper wetland margins or partition from discharged surface waters to seasonally inundated soils have the potential to contaminate these soils. Such discharges also have the potential to contaminate sediment within the lake.

[1] Semi-native vegetation refers to a plant community that includes at least some vascular plant species native to the state of Washington, consistent with WAC 173-340-7491 2(c)(ii).

- Air deposition to LL Parcel—Airborne transport and deposition of particulates is a potential transport pathway for contaminants, particularly dioxins and furans, to the LL Parcel.
- Soil-to-Soil, via overland sheet flow from the LL Apartments Parcel—Overland sheet flow from the LL Apartments Parcel to the LL Parcel is a potential contaminant transport pathway; however, such flow would have to cross a major street that has curbs and drains to the storm sewer system, and is therefore not considered a likely or significant transport pathway.

Sediment and surface water in Lora Lake are the media where benthic and pelagic organisms would be exposed to possible contamination. These exposure pathways are evaluated for potential risk to aquatic biota in a separate process in the RI/FS, consistent with WAC 173-340-760 for sediments and with WAC 173-340-730 for surface water.

Potentially complete and significant exposure pathways relevant to the TEE include exposure to surface soils via direct contact or uptake by plants and invertebrates, ingestion of soils by soil invertebrates and wildlife, trophic transfer of contaminants to wildlife via ingestion of plants and animals containing contaminants, and inhalation of particulates and vapors from surface soils (Figure 3). Exposure via direct (dermal) contact with soil by wildlife is generally considered a minor pathway relative to the ingestion pathway because of the low frequency and duration of exposure and the relative contribution to risk when compared to oral exposures (USEPA 2003). Inhalation is also generally considered to be a relatively minor pathway for exposure relative to direct ingestion of COCs by wildlife for most receptors (USEPA 2003), and potential inhalation exposure is likely to be limited to species that use burrows where vapors could accumulate. U.S. Environmental Protection Agency (USEPA 2003) did not use inhalation of soil particles or dermal contact in deriving the national ecological soil-screening levels because exposure is accounted for by the soil-ingestion route. Therefore, dermal contact and inhalation pathways for wildlife are considered potentially complete but minor pathways of exposure, and quantitative exposure evaluation will focus on the ingestion and trophic transfer pathways of soil exposures to wildlife.

Windblown dust and airborne transport within the Site and from the LL Apartments Parcel is expected to be insignificant, because surface soils at the LL Apartments Parcel are primarily covered with impervious materials. In addition, the LL Parcel is largely covered with dense vegetation, which minimizes wind erosion or volatilization from exposed soils.

For evaluating complete exposure pathways relevant to the TEE, the LL Parcel was evaluated with respect to upland and seasonally inundated soils[2]. The depth of the biologically active

[2] Sample LL-SED 5 was used to represent seasonally inundated soils, as this sample is located near the outfall to Lora Lake and alternates between saturated and dry conditions.

zone (6 ft below ground surface) is established as the conditional point of compliance[3] and all soils sampled within this depth were used to evaluate potential risks to ecological receptors. Soil data used in the TEE for the LL Parcel are presented in Table 2.

2.6 TERRESTRIAL ECOLOGICAL RECEPTORS OF CONCERN

Current or potential future terrestrial species groups that are likely to live on or feed at the LL Parcel include a variety of plants and invertebrates and both avian and mammalian herbivorous, omnivorous, and carnivorous receptors. Consistent with the Port of Seattle's wildlife management plan, some wildlife taxa are potential nuisance species and will be monitored and, if necessary, controlled so that they do not interfere with airport operations or safety. Potential nuisance taxa include flocking birds (e.g., pigeons, geese, and starlings) and large mammals (e.g., coyotes and deer) (Port of Seattle 2005).

This site-specific TEE has adopted Washington State's Department of Ecology wildlife exposure model and surrogate receptors for each of the following trophic guilds:

- Local vascular plants that may be a food source for herbivorous birds and mammals
- Small mammalian herbivores that may forage on local plants—represented by a vole (*Microtus* spp.)
- Soil-dwelling invertebrates—represented by earthworms
- Small mammals that prey on soil invertebrates—represented by a shrew (*Sorex* spp.)
- Small birds that also prey on soil invertebrates–represented by the American robin (*Turdus migratorius*).

All of these taxa are considered to be appropriate for evaluating ecological risk at the LL Parcel because they are consistent with the communities and feeding guilds that may be expected to use the upland components of this area, and they do not represent species that are likely to be controlled by the Port of Seattle for safety reasons. These ecological receptors and their relevant exposure pathways are outlined in the conceptual site model (Figure 3).

2.7 TOXICOLOGICAL ASSESSMENT

2.7.1 Data Treatment

Validated data for COCs from the LL Parcel were received from Floyd Snider (McKay 2011, pers. comm.). The maximum concentration for all samples (detected or not detected) as well as

---

[3] Consistent with WAC 173-340-7490(4)(a) and with the existence of institutional controls to prevent excavation of deeper soil in these areas as described in the RI/FS.

the mean concentration was identified for each analyte (Table 2). Maximum concentrations were used for screening against ecological criteria (discussed in Section 2.7.2), and individual samples were also evaluated to identify spatial distribution of exceedances. When an analyte was not detected in a sample, the following reporting or detection limits were used: 1) for CDDs and CDFs, one-half the detection limit was used for non-detected values; and 2) for all other COCs, one-half the reporting limit was used, consistent with treatment of data outlined in the RI/FS (Section 4.0). Analytes were screened individually with the exception of CDDs and CDFs. For CDDs and CDFs, soil concentrations for the individual congeners were multiplied by toxicity equivalency factors (TEFs) to derive soils concentrations expressed as toxic equivalent concentrations (TEQs) of the 2,3,7,8-TCDD congener. TEQs were calculated for CDDs and CDFs separately following MTCA guidelines. Because the MTCA screening value for CDDs is based on a wildlife exposure model using a mammalian receptor (shrew) the soil concentrations of CDDs were multiplied by their respective mammalian TEFs (Van den Berg et al. 2006) to calculate a mammalian TEQ for comparison to the CDD screening value (Table 3). Because the MTCA screening value for CDFs is based on a wildlife exposure model using an avian receptor (robin) the soil concentrations of CDFs were multiplied by their respective avian TEFs (Van den Berg et al. 1998) to calculate an avian TEQ for comparison to the CDF screening value (Table 3).

2.7.2 Screening Values

EICs provided in Table 749-3 of WAC 173-340-900 are summarized in Table 4 for the Site's soil COCs. The RI/FS expresses cPAHs on the basis of cPAH TEQs as the COC for the Site. Although cPAHs are relevant for assessing human health risks, carcinogenic endpoints are generally not as relevant to ecological receptors, and therefore benzo[a]pyrene concentrations were used for direct comparison to the EIC available for this compound (Table 4). To evaluate uncertainty associated with using a single polycyclic aromatic hydrocarbon compound for comparison, we also screened maximum cPAH TEQs calculated using California Environmental Protection Agency TEFs presented in Table 708-2 of WAC 173-340-900, and identified no exceedances based on these higher concentrations.

MTCA does not identify ethylbenzene or motor oil-range hydrocarbons as priority contaminants for the TEE and no screening values are available for these two compounds. A review of other screening value resources including Oak Ridge National Laboratory (Sample et al. 1996; Efroymson et al. 1997a,b) and RAIS (2011) did not confirm any relevant ecological screening values for these compounds. Other oil range EICs were available (gasoline and diesel), and concentrations of these compounds in soils from the LL Parcel were an order of magnitude or more below screening levels. Concentrations of ethylbenzene were never detected in samples from the LL Parcel and were considered in the evaluation as part of the gasoline range oils.

2.7.3 Assessment Results

Results of comparing LL Parcel soil data to EICs are presented in Table 5. The only chemicals exceeding EICs for one or more ecological receptor groups were CDDs and CDFs, which exceeded wildlife EICs, so these chemicals were retained as COCs for ecological receptors (ecological COCs). All other chemical concentrations were less than the wildlife EICs; in the case of arsenic and lead compared to plant EICs, concentrations were not greater than their EICs based on a comparison using the appropriate level of precision, i.e., 1 significant figure (HQs ≤ 1, Table 5). Sample locations that exceeded EICs[4] are provided in Figure 4. There were no exceedances for any of the other COCs and therefore all other COCs are considered to be unlikely to present a potential risk to ecological receptors and are not considered further in this evaluation.

[4] Tables include all samples, including duplicates, while figures indicate locations of exceedances (duplicates are at the same location and so they are treated as a single exceedance in the figures).

3 ECOLOGICAL EVALUATION

The results of the toxicological assessment (Section 2.7) indicate that CDDs and CDFs are retained as ecological COCs for the LL Parcel. Following the problem formulation stage of the TEE, MTCA guidance provides two options for further evaluation if EIC concentrations are exceeded at the Site:

- Selecting one or more of the following candidate methods for additional risk assessment and characterization:
  - Survey-relevant literature
  - Conduct soil bioassays
  - Revise the wildlife exposure model
  - Measure biomarkers in tissues of receptors of concern
  - Conduct ecological field studies; or
- Cleanup to the soil concentrations listed in Table 749-3 of MTCA.

Based on the results of the problem formulation, additional site-related studies to assess risk in further detail are not recommended by any of the candidate methods. Therefore, it is proposed that further site assessment and evaluation of site remedial alternatives be based on the EIC values provided by MTCA unless alternative cleanup levels are available and consistent with MTCA guidance.

For CDDs and CDFs, the EIC is 2 ng/kg. This value is lower than the WSDOE Washington State natural background soil concentration of 5.2 ng/kg (WSDOE 2010). Consequently, using a dioxin/furan soil background concentration at the LL Parcel, which is located within an urban setting, to set the cleanup level for CDDs and CDFs may not be fully protective of wildlife; however, MTCA guidance supports that background values may be substituted for EICs (WAC 173-340-900 Table 749-3 footnote a) and that cleanup levels should not be set below natural background, consistent with WAC 173-340-700(6)(d).

4 CONCLUSIONS

In conclusion, based on the lack of habitat and exposure pathways that would indicate the potential for risk to ecological receptors, neither the LL Apartments Parcel nor the DMCA qualify for a TEE as directed by MTCA (WAC 173-900). For the LL Parcel, the site-specific TEE indicates that CDDs and CDFs are retained as ecological COCs. The wildlife EIC for CDDs and CDFs is 2.2 ng/kg; however, consistent with MTCA, the selected cleanup level should not be lower than the natural background value of 5.2 ng/kg, or alternative cleanup levels that are available and consistent with MTCA guidance.

5 REFERENCES

Efroymson, R.A., M.E. Will, G.W. Suter, II, and A.C. Wooten. 1997a. Toxicological benchmarks for contaminants of potential concern for effects on soil and litter invertebrates and heterotrophic processes: 1997 revision. ES/ER/TM-126/R2. Oak Ridge National Laboratory, Oak Ridge, TN.

Efroymson, R.A., M.E. Will, G.W. Suter, II, and A.C. Wooten. 1997b. Toxicological benchmarks for screening contaminants of potential concern for effects on terrestrial plants: 1997 revision. ES/ER/TM-85/R3. Oak Ridge National Laboratory, Oak Ridge, TN.

Floyd Snider. 2010. Port of Seattle Lora Lake Apartments remedial investigation/feasibility study work plan. Prepared for Port of Seattle Aviation Environmental Programs. Floyd Snider, Seattle, WA. July 30, 2010.

Floyd Snider. 2011. Port of Seattle Lora Lake Parcel remedial investigation/feasibility study work plan. Prepared for Port of Seattle Aviation Environmental Programs. Floyd Snider Seattle, WA. February 11, 2011.

Foxx, T.S., G.D. Tierney, J.M. Williams. 1983. Rooting depths of plants relative to biological and environmental factors. Report LA-10254-MS. Los Alamos National Laboratory, Los Alamos, NM.

McKay, A. 2011. Personal communication (e-mail communication and ftp transfer transmitting data files from Amanda McKay at Floyd Snider to Deborah Rudnick, Integral Consulting Inc., Seattle, WA on July 25, 2011). Floyd Snider, Seattle, WA.

Parametrix. 2001. Natural resource mitigation plan, Seattle-Tacoma International Airport: master plan update improvements. Prepared for Port of Seattle. Parametrix, Kirkland, WA. November 2001.

Port of Seattle. 2005. Wildlife hazard management plan: Seattle-Tacoma International Airport. unabridged Section 26 of the airport certification manual for SEA. Developed by Port of Seattle in cooperation with U.S. Department of Agriculture Wildlife Services. Port of Seattle, Seattle, WA.

Port of Seattle. 2011. 2010 Port of Seattle wetland mitigation monitoring report. Port of Seattle MPU Natural Resource Mitigation. Prepared by Port of Seattle, Aviation Division, Seattle-Tacoma International Airport, Seattle, WA. April 2010.

RAIS. 2011. Risk Assessment Information System. http://rais.ornl.gov Accessed on August 25, 2011. Oak Ridge National Laboratory, Oak Ridge, TN.

Sample, B.E., D.M. Opresko, and G.W.I. Suter. 1996. Toxicological benchmarks for wildlife: 1996 Revision. ES/ER/TM-86/R3 Contract DE-AC05-84OR21400. Lockheed Martin Energy Systems, Inc., Oak Ridge National Laboratory, Risk Assessment Program, Health Sciences Research Division, Oak Ridge, TN.

USEPA. 2003. Guidance for developing ecological soil screening levels. Attachment 1-3: Evaluation of dermal contact and inhalation exposure pathways for the purpose of setting eco-SSLs. OSWER Directive 9285.7-55. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington D.C.

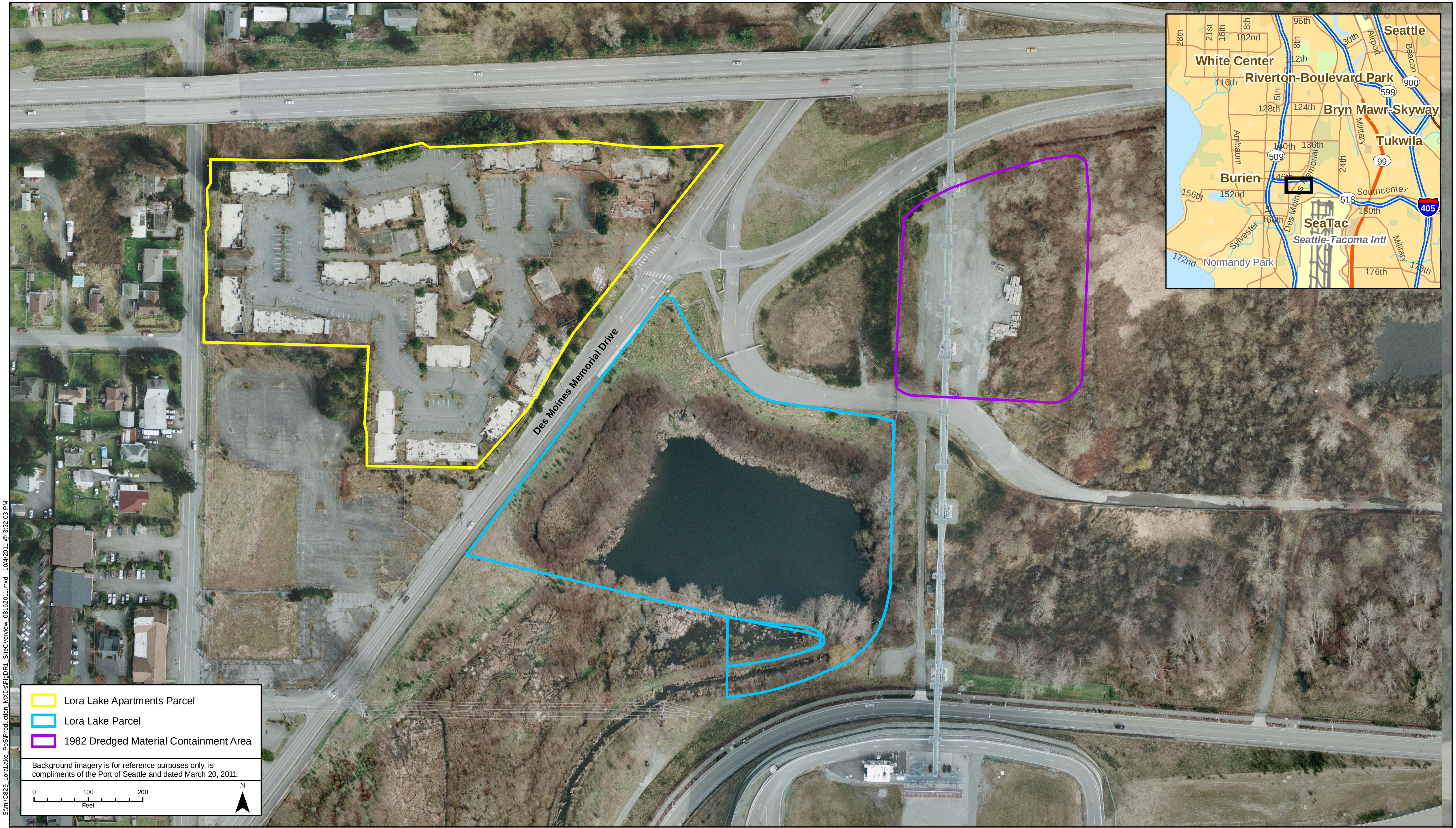
Van den Berg, M, L.S. Birnbaum, M. Denison, M. DeVito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and, R.E. Peterson. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicol. Sci.* 93:223–241.

Van den Berg, M., L. Birnbaum, A.T.C. Bosveld, B. Brunstromm, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, F.X. van Leeuwen, A.K. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Waern, and, T. Zacharewski. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environ. Health Perspect.* 106(12):775–792.

WDOE. 2010. Technical memorandum #8: natural background for dioxins/furans in WA soils. Policy and Information Technology Section. Washington State Department of Ecology, Olympia, WA. April 28, 2010.

WDOE. 2011. Urban Seattle area soil dioxin and PAH concentrations initial summary report. Publication No. 11-09-049. Washington State Department of Ecology, Olympia, WA. September 2011.

FIGURES



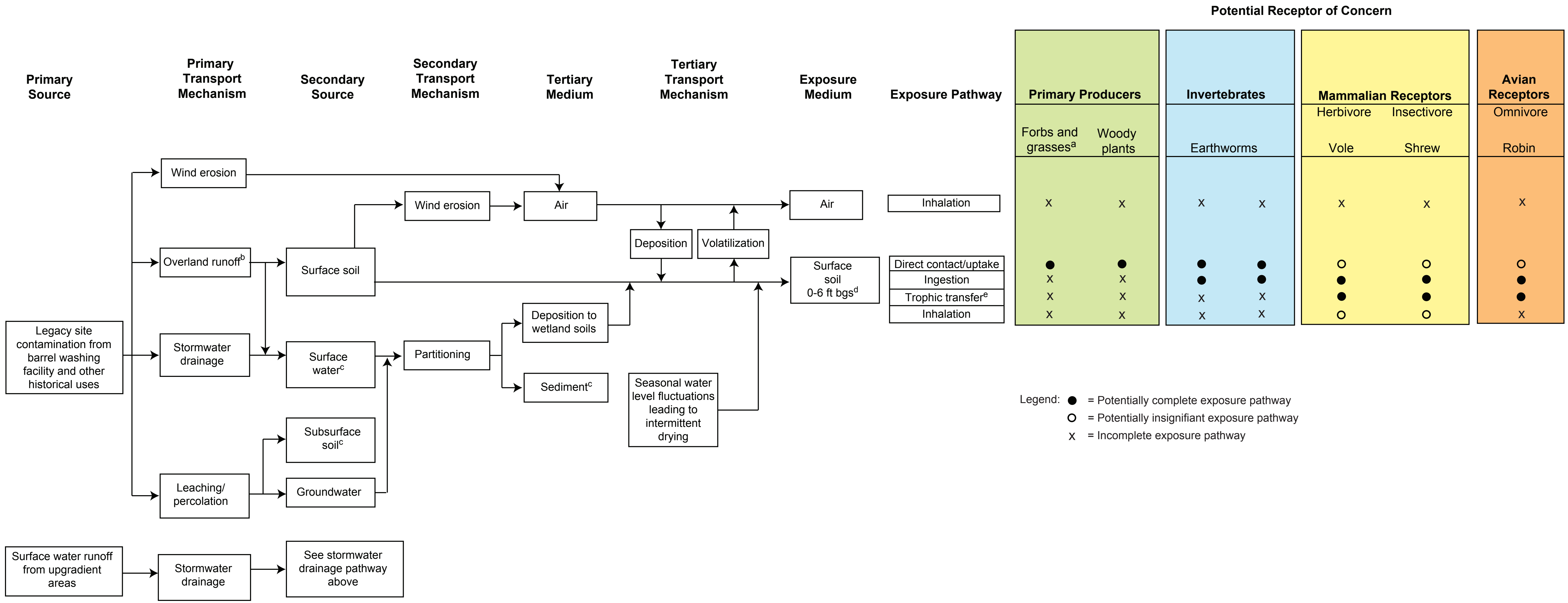
S:\mil\C829_LoraLake_PoSProduction_MXDs\FigDR1_SiteOverview_08162011.mxd - 10/4/2011 @ 3:32:03 PM

integral consulting inc.

Figure 1
The Lora Lake Apartments Site Showing the Three Areas Evaluated for the Terrestrial Ecological Evaluation

integral consulting inc.

Figure 2
Lora Lake Parcel Soil Sampling Locations
and 500-foot Habitat Buffer



Notes:

[a] Root depths, and therefore exposure to soil, of most forbs and grasses are expected to be limited to depths less than 6 ft (Foxx et al. 1983). For this reaon, exposure to groundwater is expected to be limited to areas of the site with groundwater less than 6 ft below ground surface (bgs).

[b] Overland runoff has to cross a major street with curbs and storm drains and is, therefore, not considered a likely or significant tansport pathway.

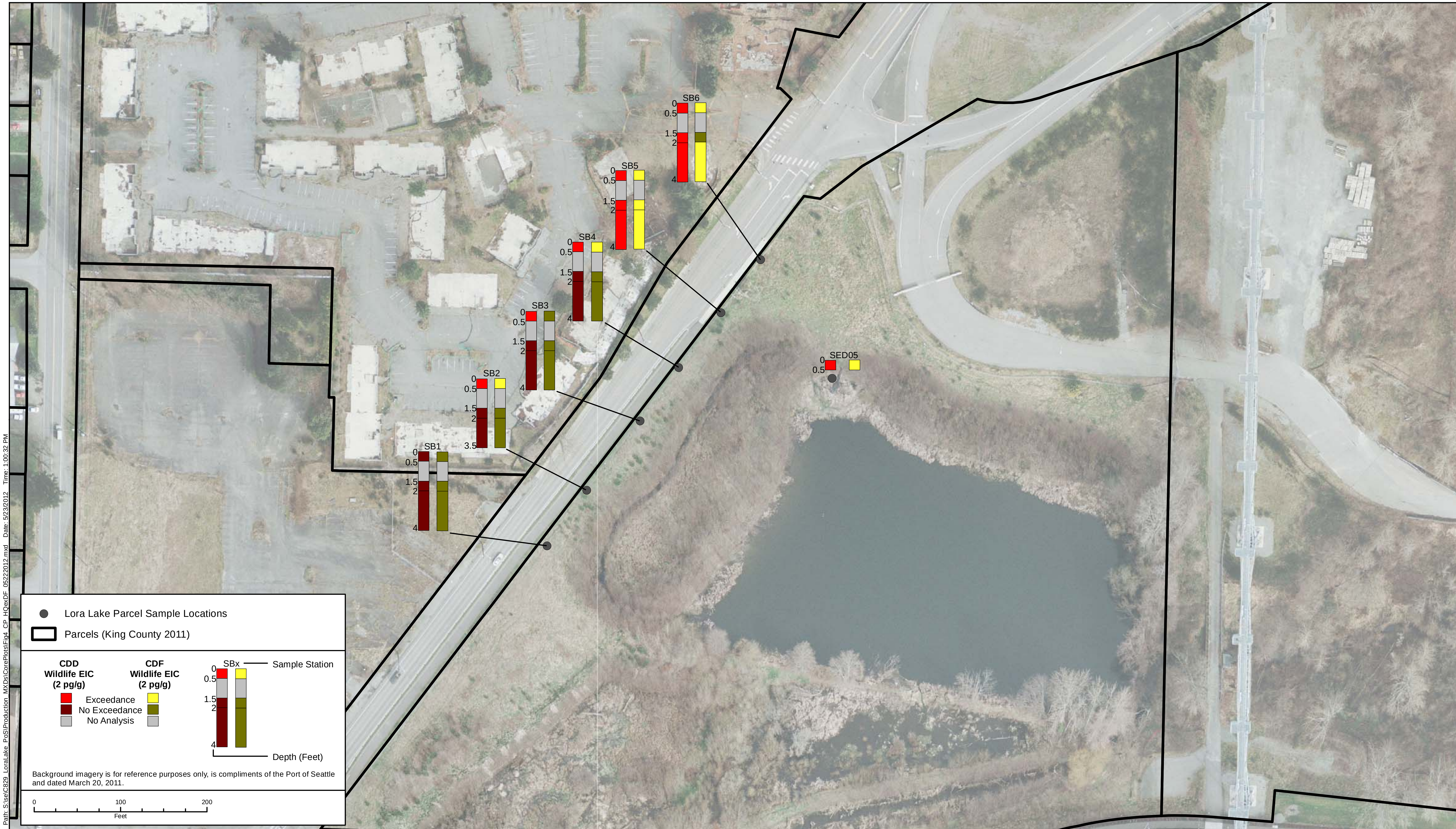
[c] Consistent with WAC 173-340-7490(1)(c), terrestrial ecological evaluation (TEE) procedures are not intended to be used to evaluate potential threats to ecological receptors in sediments, surface water, or wetlands. Procedures for sediment evaluations are described in WAC 173-340-760, and for surface water evaluations in WAC 173-340-730; evaluations of these media are addressed in the remedial investigation and feasibility study (RI/FS).

[d] Six feet bgs is the lowest depth to which biological activity may be expected to extend, consistent with the established point of compliance for the Lora Lake parcel.

[e] "Trophic transfer" refers to exposure by the consumption of lower trophic level species that are exposed to the exposure medium. Trophic transfer is not shown for airborne particulates because this pathway is captured by the surface soil pathway.

integral consulting inc.

Figure 3.
Conceptual Site Model for Terrestrial Ecological Receptors at the Lora Lake Parcel



Path: S:\se\C829_LoraLake_PoS\Production_MXDs\CorePlots\Fig4_CP_HQexDF_05222012.mxd Date: 5/23/2012 Time: 1:00:32 PM

integral consulting inc.

Figure 4
Location of Chlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs) Exceeding Ecological Indicator Concentrations (EICs) in the Lora Lake Parcel

TABLES

Table 1. Chemicals of Concern in Soils of the Lora Lake Parcel

Medium	COC
Soil	**Metals**
	Arsenic
	Lead
	Total Petroleum Hydrocarbons
	Gasoline range
	Diesel range
	Motor oil range
	Semivolatile Organic Compounds
	Pentachlorophenol
	Polycyclic Aromatic Hydrocarbons
	cPAHs TEQ (benzo-*a* -pyrene)[a]
	Volatile Organic Compounds
	Ethylbenzene
	Toluene
	Dioxins and furans
	Chlorinated dibenzo-*p* -dioxins TEQ[b]
	Chlorinated dibenzofurans TEQ[b]

Notes:

cPAH = carcinogenic polycyclic aromatic hydrocarbon
COC = chemical of concern

TEQ = toxicity equivalent concentration (a summed total of chemical concentrations of individual congeners multiplied by congener-specific toxicity equivalency factors [see WAC Table 708-1])

[a]The remedial investigation and feasibility study expresses carcinogenic polycyclic aromatic hydrocarbons (cPAHs) on the basis of cPAH TEQs as the COC for the Site. cPAHs are relevant for assessment of human health risks; carcinogenic endpoints are generally not as relevant to ecological receptors, and therefore benzo-*a* -pyrene concentrations were used for direct comparison to the ecological indicator concentration available for this compound.

[b]The RI/FS expresses dioxins and furans on the basis of the summed dioxin and furan TEQ as the COC for the Site. However, the terrestrial ecological evaluation expresses ecological indicator concentration as separate values for chlorinated dibenzo(p)dioxins and chlorinated dibenzofurans; therefore, separate TEQs were calculated for each of these two sets of congeners.

Table 2. Lora Lake Parcel Chemical of Concern Data Used in the Terrestrial Ecological Evaluation

			Metals				Total Petroleum Hydrocarbons						Semivolatile Organic Compounds				Volatile Organic Compounds				Summed Dioxin TEQ with One-half of the Detection Limits[a]		Summed Furan TEQ with One-half of the Detection Limits[b]	
			Arsenic		Lead		Gasoline Range Hydrocarbons		Diesel Range Hydrocarbons		Motor Oil Range Hydrocarbons		Pentachlorophenol		Benzo(a)pyrene		Ethylbenzene		Toluene					
Sample ID	Sample Date	Sample Depth (ft bgs)	mg/kg	Lab Qualifier	mg/kg	Lab Qualifier	mg/kg	Lab Qualifier	mg/kg	Lab Qualifier	mg/kg	Lab Qualifier	µg/kg	Lab Qualifier	µg/kg	Lab Qualifier	µg/kg	Lab Qualifier	µg/kg	Lab Qualifier	ng/kg	Lab Qualifier	ng/kg	Lab Qualifier
LL-SB1-0-0.5-041911	4/19/2011	0-0.5	5	U	2		5.6	U	5.4	U	11	U	6.6	U	4.7	U	28	U	28	U	0.315	J	0.261	J
LL-SB1-0-0.5-041911-D	4/19/2011	0-0.5	5	U	2	U	5.7	U	5.4	U	11	U	6.7	U	4.7	U	29	U	29	U	0.343	J	0.214	J
LL-SB1-1.5-2-041911	4/19/2011	1.5-2	6		9		6.2	U	5.4	U	18		6.6	U	4.9	U	31	U	31	U	1.170	J	0.410	J
LL-SB1-2-4-041911	4/19/2011	2-4	8		15		5.5	U	5.5	U	11	U	6.7	U	4.7	U	27	U	27	U	1.52	J	1.08	J
LL-SB2-0-0.5-041911	4/19/2011	0-0.5	13		58		5.8	U	5.7	U	17		6.8	U	4.7	U	29	U	29	U	11.5	J	4.40	J
LL-SB2-1.5-2-041911	4/19/2011	1.5-2	5	U	2		12		5.4	U	11	U	6.5	U	4.9	U	31	U	31	U	0.312	J	0.255	J
LL-SB2-2-3.5-041911	4/19/2011	2-3.5	5	U	2		5.1	U	5.6	U	11	U	6.5	U	4.5	U	25	U	25	U	0.247	J	0.202	J
LL-SB3-0-0.5-041911	4/19/2011	0-0.5	8		21		7	U	5.7	U	16		7.2	U	8.7		35	U	35	U	4.42	J	1.94	J
LL-SB3-1.5-2-041911	4/19/2011	1.5-2	6		6		5.2	U	5.6	U	11	U	6.9	U	4.5	UJ	26	U	26	U	1.13	J	0.364	J
LL-SB3-2-4-041911	4/19/2011	2-4	7		8		5.1	U	5.6	U	11	U	6.7	U	4.6	U	26	U	26	U	1.78	J	0.973	J
LL-SB4-0-0.5-041911	4/19/2011	0-0.5	13		26		7.2	U	6.1		28		7.5	U	12		36	U	36	U	4.58	J	2.55	J
LL-SB4-1.5-2-041911	4/19/2011	1.5-2	5	U	2		5.6	U	5.6	U	11	U	7	U	4.6	U	28	U	28	U	0.234	J	0.173	J
LL-SB4-2-4-041911	4/19/2011	2-4	6	U	3		5.9	U	5.8	U	12	U	7.1	U	4.6	U	29	U	29	U	0.235	J	0.182	U
LL-SB5-0-0.5-041811	4/18/2011	0-0.5	12		64		9.5	U	13		150		8.7	U	17	J	47	U	47	U	6.82	J	4.07	J
LL-SB5-1.5-2-041811	4/18/2011	1.5-2	12		14		5.8	U	5.7	U	22		7	U	5.6		29	U	29	U	8.76	J	3.42	J
LL-SB5-2-4-041811	4/18/2011	2-4	10		14		6.9	U	6.1	U	17		7.6	U	4.7	U	35	U	35	U	19.4	J	5.67	J
LL-SB6-0-0.5-041811	4/18/2011	0-0.5	9		17		7.2	U	6	U	49		24		8.9		36	U	36	U	34.7	J	7.59	J
LL-SB6-1.5-2-041811	4/18/2011	1.5-2	10		13		6.5	U	5.7	U	11	U	7.1	U	4.6	U	32	U	32	U	6.10	J	2.60	J
LL-SB6-2-4-041811	4/18/2011	2-4	7		13		6.2	U	5.6	U	11	U	7	U	5.3		31	U	31	U	3.81	J	1.45	J
LL-SED5-0-15-032911	3/29/2011	0-0.5	7		48		NA		NA		NA		33		34		NA		NA		5.38	J	2.89	J

Notes:

bgs = below ground surface

TEQ = toxic equivalent

U = undected

J = estimated value

NA = not applicable (sample not analyzed for this chemical)

[a]Calculated using mammalian toxicity equivalence factors (Van den Berg et al. 2006) and detected dioxin concentrations plus one-half the detection limit for dioxins that were not detected.

[b]Calculated using avian toxicity equivalence factors (Van den Berg et al. 1998) and detected furan concentrations plus one-half the detection limit for furans that were not detected.

Table 3. Toxicity Equivalency Factors for Dioxins and Furans

Compound	TEF-M (WHO 2005)	TEF-Bird (WHO 1998)
Chlorinated Dibenzo-*p*-dioxins		
2,3,7,8-TCDD	1	1
1,2,3,7,8-PeCDD	1	1
1,2,3,4,7,8-HxCDD	0.1	0.05
1,2,3,6,7,8-HxCDD	0.1	0.01
1,2,3,7,8,9-HxCDD	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.001
OCDD	0.0003	0.0001
Chlorinated Dibenzofurans		
2,3,7,8-TCDF	0.1	1
1,2,3,7,8-PeCDF	0.03	0.1
2,3,4,7,8-PeCDF	0.3	1
1,2,3,4,7,8-HxCDF	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01
OCDF	0.0003	0.0001

Sources
WHO (1998) corresponds to Van den Berg et al. (1998)
WHO (2005) corresponds to Van den Berg et al. (2006)

Notes
PCB = polychlorinated biphenyl
TEF-M = mammalian toxicity equivalency factor

Table 4. Soil Screening Levels for the Site-Specific Terrestrial Ecological Evaluation

	Ecological Indicator Concentrations [a]		
Chemicals of Concern	Plants	Soil Biota	Wildlife
Metals (mg/kg)			
Arsenic[b]	10	60	132
Lead	50	500	118
Total Petroleum Hydrocarbons (mg/kg)			
Gasoline range	NV	100	5,000[c]
Diesel range	NV	200	6,000[c]
Motor oil range	NV	NV	NV
Semivolatile Organic Compounds (µg/kg)			
Pentachlorophenol	3,000	6,000	4,500
Benzo(a)pyrene	NV	NV	12,000
Volatile Organic Compounds (µg/kg)			
Ethylbenzene	NV	NV	NV
Toluene	200,000	NV	NV
Dioxins and furans (ng/kg)			
Chlorinated dibenzo-*p*-dioxins	NV	NV	2[d]
Chlorinated dibenzofurans	NV	NV	2[e]

Notes:

EIC = ecological indicator concentration

NV = no value

TEQ = toxic equivalent

[a] Model Toxics Control Act ecological indicator concentrations, or screening levels, were obtained from WAC 173-340-900, Table 749-3.

[b] Total arsenic EICs are not available; EICs are for arsenic V because primarily unsaturated, aerobic soil conditions are assumed.

[c] Except that the concentration shall not exceed residual saturation at the soil surface.

[d] Value is based on exposure of a mammalian receptor (shrew); value is compared to chlorinated dibenzo-*p*-dioxins TEQs.

[e] Value is based on an avian receptor (robin); value is compared to chlorinated dibenzofurans TEQs.

Table 5. Terrestrial Ecological Evaluation Screening Results for Soils of the Lora Lake Parcel

						Plant EIC				Soil Biota EIC				Wildlife EIC			
Chemicals of Concern	Units	N	mean	max	FOD	EIC[a]	FOE	Exceeding Sample Locations	HQ[b]	EIC[a]	FOE	Exceeding Sample Locations	HQ[b]	EIC[a]	FOE	Exceeding Sample Locations	HQ[b]
Arsenic	mg/kg	20	7.2	13	70%	10	0%		1	60	0%		<1	132	0%		<1
Lead	mg/kg	20	17	64	95%	50	0%		1	500	0%		<1	118	0%		<1
Gasoline range hydrocarbons	mg/kg	19	3.6	12	5.3%	NV	--		--	100	0%		<1	5000	0%		<0.01
Diesel range hydrocarbons	mg/kg	19	3.5	13	11%	NV	--		--	200	0%		<0.1	6000	0%		<0.01
Motor oil range hydrocarbons	mg/kg	19	20	150	42%	NV	--		--	NV	--		--	NV	--		--
Pentachlorophenol	µg/kg	20	6.0	33	10%	3000	0%		<0.1	6000	0%		<0.01	4500	0%		<0.01
Benzo(a)pyrene	µg/kg	20	6.1	34	35%	NV	--		--	NV	--		--	12000	0		<0.01
Ethylbenzene	µg/kg	19	16	24	0%	NV	--		--	NV	--		--	NV	--		--
Toluene	µg/kg	19	16	24	0%	200000	0%		<0.001	NV	--		--	NV	--		--
Summed dioxin TEQ with one-half of the detection limits[c]	ng/kg	20	5.63	34.7	100%	NV	--		--	NV	--		--	2	50%	LL-SB2-0-0.5-041911 LL-SB3-0-0.5-041911 LL-SB4-0-0.5-041911 LL-SB5-0-0.5-041811 LL-SB5-1.5-2-041811 LL-SB5-2-4-041811 LL-SB6-0-0.5-041811 LL-SB6-1.5-2-041811 LL-SB6-2-4-041811 LL-SED5-0-15-032911	17
Summed furan TEQ with one-half of the detection limits[d]	ng/kg	20	2.04	7.59	95%	NV	--		--	NV	--		--	2	40%	LL-SB2-0-0.5-041911 LL-SB4-0-0.5-041911 LL-SB5-0-0.5-041811 LL-SB5-1.5-2-041811 LL-SB5-2-4-041811 LL-SB6-0-0.5-041811 LL-SB6-2-4-041811 LL-SED5-0-15-032911	3.8

Notes:

FOD= frequency of detection
EIC = ecological indicator concentration
FOE = frequency of exceedence
HQ = hazard quotient (maximum soil concentration/EIC)
--= not applicable (no criterion available for this calculation)
TRV=toxicity reference value
TEF = toxicity equivalency factor
TEQ = toxic equivalent

[a] Plant and invertebrate criteria are provided at one significant figure, consistent with the signficant figures provided in the source values for EICs (Efroymson et al. 1997a and b); wildlife criteria are provided at two significant figures, consistent with the level of precision provided in Tables 749-4 and 749-5 that define the wildlife parameters and TRVs for estimation of the EIC. Exceedences are based on the number of relevant significant figures (e.g., the arsenic EIC for plants has one signficant figure, so the site maximum concentration is compared at one significant figure, i.e., 1×10^2 compared to 1×10^2.

[b]The specific magnitude of HQs less than and greater than one are not meaningful from a risk perspective because the EIC does not provide information about the toxicity response above or below the criterion.

[c]Calculated using mammalian TEFs (van den Berg 2006) and detected dioxin concentrations plus one-half the detection limit for dioxins that were not detected.

[d]Calculated using avian TEFs (van den Berg 1998) and detected furan concentrations plus one-half the detection limit for furans that were not detected.

APPENDIX A

TERRESTRIAL ECOLOGICAL EVALUATION CHECKLISTS

integral consulting inc.

APPENDIX A-1: TERRESTRIAL ECOLOGICAL EVALUATION CHECKLIST FOR THE LORA LAKE APARTMENTS PARCEL

Step 1. Decision to exclude site from TEE if any of the following apply

	Criteria	Action
☐	All contaminated soil is below the point of compliance (i.e., > 6ft BGS[1]	No further evaluation is needed
☒	All contaminated soil is, or will be, covered by a physical barrier that prevents plants and wildlife from exposure, and a state-accepted development plan and institutional control are established.	No further evaluation is needed
☐	Contiguous undeveloped land on or within 500 ft of site is: < 0.25 acres if any of the COI are: ☐ PCDD/Fs ☐ PCBs ☐ Chlorinated pesticides ☐ Pentachlorophenol ☐ Pentachlorobenzene and < 1.5 acres for all other COI	No further evaluation is needed
☐	Concentrations of all COI are below natural background	No further evaluation is needed
☐	None of the above apply	Go to Step 2 (Site-Specific TEE)

[1] Per WAC 173-340-7490, the point of compliance is assumed to be 6 ft below ground surface (bgs) (or an appropriate depth approved by the department) for sites with institutional controls to prevent excavation of deeper soil; an institutional control is not required for soil contamination that is at least 15 ft bgs.

APPENDIX A-2: TERRESTRIAL ECOLOGICAL EVALUATION CHECKLIST FOR THE 1982 DREDGED MATERIAL CONTAINMENT AREA

Step 1. Decision to exclude site from TEE if any of the following apply

	Criteria	Action
☐	All contaminated soil is below the point of compliance (i.e., > 6ft BGS[1]	No further evaluation is needed
☒	All contaminated soil is, or will be, covered by a physical barrier that prevents plants and wildlife from exposure, and a state-accepted development plan and institutional control are established.	No further evaluation is needed
☐	Contiguous undeveloped land on or within 500 ft of site is: < 0.25 acres if any of the COI are: ☐ PCDD/Fs ☐ PCBs ☐ Chlorinated pesticides ☐ Pentachlorophenol ☐ Pentachlorobenzene and < 1.5 acres for all other COI	No further evaluation is needed
☐	Concentrations of all COI are below natural background	No further evaluation is needed
☐	None of the above apply	Go to Step 2 (Site-Specific TEE)

[1] Per WAC 173-340-7490, the point of compliance is assumed to be 6 ft below ground surface (bgs) (or an appropriate depth approved by the department) for sites with institutional controls to prevent excavation of deeper soil; an institutional control is not required for soil contamination that is at least 15 ft bgs.

APPENDIX A-3: TERRESTRIAL ECOLOGICAL EVALUATION CHECKLIST FOR THE LORA LAKE PARCEL

Step 1. Decision to exclude site from TEE if any of the following apply

	Criteria	Action
☐	All contaminated soil is below the point of compliance (i.e., > 6ft BGS[1]	No further evaluation is needed
☐	All contaminated soil is, or will be, covered by a physical barrier that prevents plants and wildlife from exposure, and a state-accepted development plan and institutional control are established.	No further evaluation is needed
☐	Contiguous undeveloped land on or within 500 ft of site is: < 0.25 acres if any of the COI are: ☐ PCDD/Fs ☐ PCBs ☐ Chlorinated pesticides ☐ Pentachlorophenol ☐ Pentachlorobenzene <u>and</u> < 1.5 acres for all other COI	No further evaluation is needed
☐	Concentrations of all COI are below natural background	No further evaluation is needed
☒	None of the above apply	Go to Step 2 (Site-Specific TEE)

Notes and recommendations: None of the criteria in Step 1 apply. Go to Step 2.

[1] Per WAC 173-340-7490, the point of compliance is assumed to be 6 ft below ground surface (bgs) (or an appropriate depth approved by the department) for sites with institutional controls to prevent excavation of deeper soil; an institutional control is not required for soil contamination that is at least 15 ft bgs.

Step 2. Decision to conduct a site-specific TEE if any of the following apply

	Criteria	Action
☒	Management or land use plans in place to maintain or restore ☒ Native/semi-native vegetation ☒ Protected wetlands ☐ Forest lands ☐Locally designated sensitive areas ☐Open space managed for wildlife	Conduct site-specific terrestrial ecological evaluation (WAC 173-340-7493)
☐	Site used by special status species: ☐ ESA threatened and endangered ☐ WDFW priority or species of concern ☐ WDNR threatened, endangered or sensitive plant species	Conduct site-specific terrestrial ecological evaluation (WAC 173-340-7493)
☒	Spatial extent of native vegetation inside property boundaries is ☒ $\geq$ 10 acres <u>and</u> ☒ <500 ft from the site	Conduct site-specific terrestrial ecological evaluation (WAC 173-340-7493)
☐	Ecology determines that there is significant risk to wildlife	Conduct site-specific terrestrial ecological evaluation (WAC 173-340-7493)
☐	None of the above apply	Go to Step 3 (Simplified TEE)

Notes and recommendations: Lora Lake Parcel qualifies for a site-specific TEE based on the criteria identified in Step 2.

Step 3. Decision to conduct a simplified TEE if both of the following apply

	Criteria	Action
☐	Site does not qualify for exclusion (see Step 1). <u>and</u>	
☐	None of the site-specific inclusionary criteria apply (see Step 2).	Got to Step 4 - Conduct simplified TEE (WAC 173-340-7492)

Notes and recommendation: Site does not qualify for a simplified TEE. Conduct a site-specific TEE (WAC 173-340-7493). Checklist is ended here.

Step 4. Simplified TEE decision points

	Criteria	Action
☐	Exposure Analysis: If the total area of soil contamination at the site is not more than 350 square ft	End evaluation. Conclude site does not pose a substantial risk to terrestrial ecological receptors[2]
☐	Exposure Analysis: If land use at the site and surrounding area makes substantial wildlife exposure unlikely (See Table 1 below).	End site evaluation. Conclude site does not pose a substantial risk to terrestrial ecological receptors[2]
☐	Pathway Analysis: If there are no potential pathways leading to exposure of soil biota, plants or wildlife[3] to the priority chemicals listed in Table 749-2.	End evaluation. Conclude site does not pose a substantial risk to terrestrial ecological receptors[2]
☐	Contaminant Analysis: None of the hazardous substances in Table 749-2 that have listed soil concentrations are, or will be, present in soil above the point of compliance and at concentrations that are higher than[4] their listed values. and None of the hazardous substances in Table 749-2 that do not have a listed soil concentration are , or will be, present in the soil within 6 feet of ground surface at concentrations that are likely to be toxic or to bioaccumulate[5].	End evaluation. Conclude site does not pose a substantial risk to terrestrial ecological receptors[2]
☐	None of the above	Consider options: Cleanup levels (Table 749-2) Site-specific terrestrial ecological evaluation (WAC 173-340-7493).

Notes and recommendations: Not applicable to this site.

[2] If any of these criteria are used to end the simplified TEE, institutional controls may be needed to ensure that the condition will continue to be met in the future. Cleanup remedies that rely on chemical concentrations for industrial or commercial sites in Table 749-2 shall include appropriate institutional controls to prevent future exposures to plants or soil biota in the event of a change of land use.

[3] Only wildlife need be considered for a commercial or industrial property.

[4] Determined using statistical compliance methods described in WAC 173-340-740(7)

[5] Based on bioassays using methods approved by the department.

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix L
BIOSCREEN Modeling

FINAL

Table of Contents

List of Tables

List of Figures

List of Attachments

List of Abbreviations/Acronyms

Abbreviation/ Acronym	Definition
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
ARAR	Applicable or relevant and appropriate requirement
K_{oc}	Organic carbon partitioning coefficient
RI/FS	Remedial Investigation/Feasibility Study
Site	Lora Lake Apartments Site
TEQ	Toxic equivalency quotient
USEPA	U. S. Environmental Protection Agency

1.0 Introduction

This appendix presents the results of the numerical modeling process that was used to identify the maximum dioxin/furan concentrations in groundwater that are protective of surface water in Lora Lake. The U.S. Environmental Protection Agency (USEPA)-derived BIOSCREEN model evaluates attenuation and degradation processes of contamination in groundwater between a designated point and the groundwater discharge point to the adjacent surface water (USEPA 1996). The USEPA BIOSCREEN model Version 1.4 utilizes the Domenico solution for solute transport, which incorporates approximations for solute transport parameters such as dispersion. An update to the BIOSCREEN Version 1.4 (BIOSCREEN-AT Version 1.43) has been released by S.S. Papadopulos & Associates. This version of BIOSCREEN performs a more rigorous analytical solution to the transport equations utilized in the model, thereby eliminating the approximations in evaluation introduced by the Domenico solution (Karanovic et al. 2007). For the analysis presented in this appendix, model runs were completed with BIOSCREEN-AT.

The model is designed to use actual on-site concentrations to determine an attenuated concentration at a specified distance. As recommended in the BIOSCREEN guidance (USEPA 1996), the model was run for dioxins/furans at the Lora Lake Apartments Site (Site) to predict concentrations in downgradient groundwater over time that will eventually discharge to surface water and to determine if these groundwater concentrations would meet the most stringent surface water criteria applicable or relevant and appropriate requirement (ARAR) at the point of groundwater discharge to surface water.

The modeling process was conducted as part of the Lora Lake Apartments Site Remedial Investigation and Feasibility Study (RI/FS). As described in Section 5.2.2.2 of the RI/FS text, for all site COCs (except dioxins/furans) groundwater cleanup levels based on drinking water beneficial use are more stringent than surface water ARARs. Therefore, groundwater cleanup levels for all COCs (except dioxins/furans) will be based on beneficial use as drinking water. As part of the evaluation of the groundwater cleanup level for the protection of surface water, per the Washington Administrative Code (WAC) Chapter 173-340-720(4)(b), standard Model Toxics Control Act (MTCA) Method B cleanup levels shall be at least as stringent as concentrations established per the WAC Chapter 173-340-730 for the protection of surface water beneficial uses unless it can be demonstrated that the hazardous substances are not likely to reach surface water. This demonstration must be based on factors other than the implementation of a cleanup action (refer to WAC Chapter 173-340-720(4)(b)(ii)). This modeling evaluation is one line of evidence in the demonstration that dioxins/furans are not likely to reach the surface water of Lora Lake. The most stringent dioxin/furan surface water criterion for the protection of human health via consumption of organisms is 0.0051 pg/L (Federal Clean Water Act Section 304).

This page left intentionally blank.

2.0 BIOSCREEN-AT Model Input Parameters

Figure L.1 provides a conceptual section of the BIOSCREEN-AT model. The application of the model to the Site with associated input parameters is shown in plan view in Figure L.2. Table L.1 summarizes the selected parameters, their source, and the technical rationale behind their selection. The following sections discuss in detail the input parameters that had the greatest influence on the model results and/or that were selected based on site-specific conditions. The model runs were conducted with a simulation time of 100 years.

2.1 GROUNDWATER SOURCE CONCENTRATIONS

The maximum dioxin/furan toxic equivalency quotient (TEQ) concentration detected at the upgradient Lora Lake Apartments Parcel (LL Apartments Parcel) during the 2010/2011 remedial investigation sampling events was 38.3 pg/L, at MW-1 within the Central Source Area. This concentration was used as the model input source concentration to conservatively assess dioxin/furan attenuation in groundwater and the protectiveness of the downgradient Lora Lake surface water. The use of this maximum site dioxin/furan TEQ concentration is particularly conservative because the maximum dioxin/furan TEQ concentrations detected in groundwater samples collected from the monitoring wells located on the Lora Lake Parcel (MW-9, MW-10, and MW-11) ranged from 0.001 pg/L to 3.7 pg/L (refer to the Lora Lake Apartments Parcel Remedial Investigation Data Report, Appendix F of the Lora Lake Apartments Site RI/FS).

2.2 DIOXIN/FURAN PARTITIONING COEFFICIENT (K_{OC})

The organic carbon partitioning coefficient (K_{oc}) represents the ratio of the mass (mg) of chemical adsorbed in the soil per unit mass (kg) of organic carbon in the soil. The K_{oc} is used as a chemical-specific measure of the tendency for an organic compound to be adsorbed by soil. Dioxin congener 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) is the most toxic and well-studied dioxin congener (USEPA 2003); it is the only dioxin congener with multiple peer-reviewed and published K_{oc} values. An average K_{oc} value for 2,3,7,8-TCDD was used in the BIOSCREEN-AT model (Table L.1). The dioxin 2,3,7,8-TCDD congener consists of four chlorine atoms, while all of the other dioxin and furan congeners consist of five, six, seven, or eight chlorine atoms. Dioxin/furan migration and transport calculations are very sensitive to the K_{oc} value used, because the additional chlorine atoms significantly reduce the liberation of dioxin congeners into the dissolved phase. Therefore, the use of the lower chlorinated K_{oc} value for 2,3,7,8-TCDD is conservative and substantially overestimates the amount of dioxin that would exist in the dissolved phase.

2.3 FRACTION OF ORGANIC CARBON (F_{OC})

The MTCA default soil fraction organic carbon (f_{oc}) content (0.001 g/g or 0.1 percent; WAC Chapter 173-340-747) was selected for use in the model in order to conservatively represent the soil organic carbon content along the model source zone and plume length that extends from the groundwater source location of MW-1 within the LL Apartments Parcel Central Source Area to where groundwater discharges to Lora Lake (refer to Figure L.2). The MTCA default soil f_{oc} of 0.1 percent was also used to represent LL Apartment Parcel soils in the Dioxins/Furans in Stormwater Equilibrium Calculation Evaluation (Appendix J of the RI/FS). The fraction of organic carbon selected for use in the BIOSCREEN-AT model is related to the retardation factor, *R*, calculated by the model. The greater the fraction of organic carbon, the greater the retardation factor, and the less the chemical being modeled (in this case, 2,3,7,8-TCDD) will disperse from the source zone.

The MTCA default soil f_{oc} of 0.1 percent is conservative because the f_{oc} value anticipated to be in the wetland-like habitat that surrounds Lora Lake is potentially closer to between 1 and 2 percent (USGS 1997). The total organic carbon measured in a surface sediment grab sample taken from location LL-SED5, within the shallow vegetated sediment settling basin area of the lake edge and approximately 10 to 15 feet from the mouth of the stormwater outfall discharge point, was 0.9 percent. LL-SED5 sediments were predominately sand (greater than 62.5 microns) with some gravel.

As described above, soil near the LL Apartments Parcel MW-1 source zone likely has a lower f_{oc} than observed at the fringe of the lake where groundwater would discharge to lake surface water; therefore, dioxins/furans near the source zone may disperse more readily than near the fringe of Lora Lake. Additionally, the f_{oc} of the saturated zone at the LL Apartments and Lora Lake Parcels may be greater than the MTCA soil default value. Therefore, this f_{oc} variation was further examined in the sensitivity analysis as described below in Section 4.0 where model runs were completed using a soil f_{oc} of 0.005 (0.5 percent), representing the average between a f_{oc} of 0.001 (0.1 percent, MTCA default) and 0.01 (1 percent, as measured in Sample LL-SED5), and using a f_{oc} of 0.01 (1 percent, as detected in LL-SED5).

2.4 HORIZONTAL GRADIENT (I)

Remedial investigation groundwater elevation contour maps were reviewed to determine a conservative but accurate horizontal gradient that could be used as a model input value based on the available site-specific data. Based on the August 2010 and January 2011 groundwater elevation contour maps prepared by Aspect Consulting (Figures 2.14 and 2.15 of the RI/FS), the horizontal gradients within the Lora Lake Parcel range between 0.044 and 0.051 foot/foot. A value of 0.051 foot/foot was used as a model input parameter as a conservative (higher mobility) horizontal gradient, which would also be representative of site-specific conditions.

2.5 HORIZONTAL HYDRAULIC CONDUCTIVITY (K)

A horizontal hydraulic conductivity (K) of 0.11 cm/s was selected as a conservative, but representative, estimate of hydraulic conductivity. Hydraulic conductivity varies from 1×10^{-9} cm/s to 1 cm/s and is dependent on the type of soil on-site. Larger hydraulic conductivities correspond to greater mobility of groundwater in soil, representing more and faster movement of groundwater from the source zone towards Lora Lake.

Well-sorted gravel has the greatest hydraulic conductivity, while clay has the lowest hydraulic conductivity. Hydraulic gradients for peat-containing soil typically fall within the range of 1×10^{-3} to 1×10^{-2} cm/s (Fetter 2001). Hydraulic gradients for silty sand vary between 1×10^{-5} to 1×10^{-1} cm/s (USEPA 1996). A value of 0.11 cm/s, representative of sands with silt, was observed within MW-1 and monitoring wells located on the Lora Lake Parcel (MW-9, MW-10, and MW-11).

This hydraulic conductivity is also consistent with the hydraulic conductivity ranges published by Koloski et al. in the paper "Geotechnical Properties of Geologic Materials" for Washington lacustrine inorganic and organic soils (Koloski et al. 1989). These hydraulic conductivity ranges are shown in Table 1 of the paper as 0.0001 to 0.1 feet per minute (fpm) for inorganic lacustrine soils and 0.0001 to 1.0 fpm for organic lacustrine soils. When these conductivity ranges are converted to centimeters per second for use in the BIOSCREEN-AT model, the corresponding ranges are 5.08×10^{-5} cm/s to 5.08×10^{-2} cm/s and 5.08×10^{-5} cm/s to 5.08×10^{-1} cm/s, respectively. The hydraulic conductivity selected for use in the model (0.11 cm/s) falls between the upper limits (i.e., faster groundwater movement) of the hydraulic conductivity values for inorganic and organic lacustrine soils.

3.0 Model Results

Attachment L.1 presents a BIOSCREEN-AT printout of the model results using the input parameters as discussed above and summarized in Table L.1. Model results are presented in Table L.2 and shown on Figure L.2. Note that the BIOSCREEN-AT results shown in the printout attachments are in the model default concentration units of mg/L and require conversion to pg/L. The BIOSCREEN-AT model results show that the maximum dioxin/furan TEQ concentration detected at the LL Apartments Parcel during the remedial investigation of 38.3 pg/L, at MW-1 within the Central Source Area, attenuates to less than the surface water criterion of 0.0051 pg/L between 150 and 210 feet downgradient of MW-1, even when the model is run for a time period of 100 years (Table L.2). This modeled attenuation occurs well before the point of groundwater discharge to Lora Lake (approximately 425 feet from the location of MW-1). Therefore, this modeling evaluation demonstrates that under current site conditions, prior to any remedial action, dioxins/furans are predicted to attenuate rapidly as the groundwater moves through soil and are not likely to reach the surface water of Lora Lake at concentrations greater than the surface water quality criterion.

This page left intentionally blank.

This page left intentionally blank.

4.0 Sensitivity Analysis

The input parameters discussed above have the greatest influence on model results. These input parameters were further evaluated in a sensitivity analysis, as were additional parameters that have meaningful impact to model results. The sensitivity analysis included model runs that were conducted with varying values of the following parameters to understand how differences in these parameters influence the modeling results:

- Fraction of organic carbon
- Hydraulic conductivity
- Model simulation time
- Source zone length

As described above, the f_{oc} values included in the analysis were 0.005 (0.5 percent), representing the average between a f_{oc} value of 0.001 (0.1 percent, MTCA default) and 0.01 (1 percent, as measured in Sample LL-SED5), and using a f_{oc} value of 0.01 (1 percent, as detected in LL-SED5). Model runs were conducted with a hydraulic conductivity of 0.055, or one-half of the 0.11 cm/s hydraulic conductivity value described above. This hydraulic conductivity still represents a conservative estimate based on site conditions, but is a slightly less conservative value to represent the increased resistance to movement resulting from the presence of silt in the soil. The sensitivity analysis used model simulation times of 50 and 500 years, in addition to the previous target model simulation time of 100 years. Finally, the source zone plume length was amended to 150 feet to increase the soluble mass available in the model, which has the subsequent effect of reducing the estimated plume length prior to reaching Lora Lake from 325 to 275 feet. Amendment of the source zone plume length also results in the assumption that the MW-1 dioxin/furan TEQ concentration of 38.3 pg/L is present from MW-1 to approximately MW-5, the downgradient LL Apartments Parcel well. This is a conservative estimate of the maximum length of the source zone, since the maximum dioxin/furan TEQ concentration detected in MW-5 during the 2010/2011 remedial investigation was 3.72 pg/L.

Table L.3 presents the values of the parameters that were adjusted for the sensitivity analysis model runs and the associated results. Attachment L.2 provides screenshots of the BIOSCREEN-AT model runs edited for sensitivity analysis. The parameter that was changed in each run is indicated in bold text prior to each screenshot pair.

The results of the sensitivity analysis confirm the relationships described previously:

- A higher f_{oc} percentage in soil results in less movement of dioxin/furan in groundwater.
- A lower hydraulic conductivity results in less movement of dioxin/furan in groundwater.
- A longer modeled time results in greater movement of dioxin/furan in groundwater.

- A longer source zone does not impact the modeled results for dioxin/furan movement in groundwater, but does diminish the distance between the modeled source zone and Lora Lake.

The specific results for each of the modeled scenarios indicate that when a single variable is altered, predicted groundwater concentrations are less than the surface water criterion of 0.0051 pg/L prior to reaching the surface waters of Lora Lake for all model runs, except for the model run where elapsed time is equal to 500 years. In this scenario, the model predicts groundwater concentrations to be less than the surface water criterion between 350 and 400 feet downgradient of the modeled source area, or within the surface waters of Lora Lake if the source zone is conservatively estimated to extend 100 feet downgradient of MW-1, which is not supported by site data.

The results of modeling and the sensitivity analysis indicate that dioxins/furans are relatively immobile in groundwater even when the most conservative model input parameters applicable to the Site are used. Given the conservative nature of the assumptions in the model (i.e., low f_{oc}, high horizontal conductivity and high horizontal gradient) it can be reasonably concluded that dioxins/furans present in groundwater at MW-1 will not reach Lora Lake surface water within the conservative time frame of 100 plus years. Additionally, the model results predict, with conservative assumptions, that even without any remedial action, it would potentially take nearly 500 years for the dioxins/furans in groundwater to migrate 350 feet downgradient of the source zone at concentrations greater than the surface water criterion of 0.0051 pg/L.

5.0 References

Fetter, C.W. 2001. *Applied Hydrogeology*. Fourth Edition. New Jersey: Prentice-Hall, Inc.

Jackson, D.R., M.H. Roulier, H.M. Grotta, S.W. Rust, and J.S. Warner. 1986. "Solubility of 2,3,7,8-TCDD in Contaminated Soils." pp. 185-200 in *Chlorinated Dioxins and Dibenzofurans in Perspective*, ed. C. Rappe, G. Choudhary, and L.H. Keith. Lewis Publishers, Inc.

Karanovic, M., C.J. Neville, and C.B. Andrews. 2007. "BIOSCREEN-AT: BIOSCREEN with an Exact Analytical Solution." *Ground Water* 45(2): 242–245.

Koloski, J.W., S.D. Schwarz, and D.W. Tubbs. 1989. "Geotechnical Properties of Geologic Materials." *Engineering Geology in Washington, Volume 1. Washington Division of Geology and Earth Resources Bulletin 78.*

Schroy, J.M., F.D. Hileman, and S.C. Cheng. 1985. "Physical/chemical properties of 2,3,7,8-TCDD." *Chemosphere* 14:877–880.

U.S. Environmental Protection Agency (USEPA). 1996. *BIOSCREEN Natural Attenuation Decision Support System User's Manual, Version 1.3*. EPA/600/R-96/087. Office of Research and Development. Washington, D.C. August.

———. 2003. *Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds National Academy Sciences (NAS) Review Draft, Part I: Estimating Exposure to Dioxin-Like Compounds, vol 3: Site-Specific Assessment Procedures*. Office of Research and Development. Washington, District of Columbia.

U.S. Geological Survey. 1997. Excerpt from *Natural Attenuation of Chlorinated Volatile Organic Compounds in a Freshwater Tidal Wetland, Aberdeen Proving Ground, Maryland.* Water-Resources Investigations Report 97-4171.

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix L
BIOSCREEN Modeling

Tables

FINAL

Table L.1
BIOSCREEN-AT Model Input Parameters

Parameter	Value	Unit	Source/Description and Selection Rationale
Hydrogeology			
Hydraulic Conductivity	1.10E-01	cm/s	Conservative hydraulic gradient representative of well mixed sand with some silt; represents increased permeability compared to peat or silty sand.
Horizontal Hydraulic Gradient	0.051	foot/foot	Site-specific value estimated based on remedial investigation groundwater elevation contour maps.
Porosity	0.3	-	Porosity representative of medium-to-fine sand. MTCA default value for unsaturated zone soil (Eq. 747-1).
Dispersion			
Estimated Plume Length	325	feet	Approximate distance between the leading edge of the modeled source zone and downgradient Lora Lake surface water.
Adsorption			
Soil Bulk Density	1.5	kg/L	MTCA default value (Eq. 747-1).
Partition Coefficient (K_{oc})[1,2]	1.30E+07	L/kg	Schroy et al. 1985, Jackson et al. 1986.
Fraction Organic Carbon	0.001	-	MTCA default value (Eq. 747-1) representative of vadose zone soil (the modeled source zone and downgradient soil that the resultant plume travels through prior to reaching Lora Lake).
General			
Modeled Area Length	300	feet	Approximate distance at which groundwater is not influenced by downgradient dispersion of dioxins/furans for the model input parameters selected.
Modeled Area Width	200	feet	Chosen to allow sufficient horizontal dispersivity in consideration of the source zone and modeled area length.
Simulation Time	100	year	Chosen to allow sufficient time for movement of dioxins/furans in groundwater. Represents conditions decades after the completion of compliance monitoring.
Source Data			
Dioxin/Furan Source Groundwater Concentrations	38.3	pg/L	The greatest concentration detected on the upgradient Lora Lake Apartments Parcel during the remedial investigation (38.3 pg/L in MW-1) was selected to conservatively assess dioxin/furan attenuation in groundwater and the protectiveness of the downgradient surface water based on actual site conditions.
Source Thickness in Saturated Zone	10	feet	Estimated site-specific value based on seasonal variation in the elevation of the shallow groundwater table at the Lora Lake Parcel.
Source Zone Length	100	feet	Used in calculation of soluble source mass available. Source length chosen to provide sufficient source mass for BIOSCREEN-AT mobility modeling.
Source Zone Width	100	feet	Used in calculation of soluble source mass available. Source length chosen to provide sufficient source mass for BIOSCREEN-AT mobility modeling.

Notes:

1 The calculation of an average K_{oc} value for 2,3,7,8-TCDD that was used in the BIOSCREEN-AT model is provided in Appendix J of the Lora Lake Apartments Site Remedial Investigation/Feasibility Study.

2 Full references for K_{oc} values included in Appendix L text references. The Schroy et al. 1985 and Jackson et al. 1986 references were obtained from USEPA 2003, Exposure and Human Health Reassessment of 2,3,7,8-TCDD and Related Compounds National Academy Sciences (NAS) Review Draft, Part I: Estimating Exposure to Dioxin-Like Compounds, vol 3: Site-Specific Assessment Procedures.

Abbreviations:

Eq. Equation
K_{oc} Organic carbon partitioning coefficient
MTCA Model Toxics Control Act
TCDD 2,3,7,8-Tetrachlorodibenzo-p-dioxin

Table L.2
BIOSCREEN Model Dioxin/Furan Results

Modeled Source Dioxin/Furan Groundwater Concentration (pg/L)	Resulting Model-predicted Downgradient Groundwater Concentrations (pg/L)					
	30 Feet Downgradient	90 Feet Downgradient	150 Feet Downgradient	210 Feet Downgradient	270 Feet Downgradient	300 Feet Downgradient
38.3	25	1.2	1.3E-03	2.7E-08	8.7E-15	1.1E-18

Note:

The dioxin/furan surface water criterion for protection of human health via consumption of organisms is 0.0051 pg/L or 5.1E-03 pg/L (Federal Clean Water Act Section 304). The model predicts the dioxin/furan groundwater concentration to be less than this criterion between 150 and 210 feet downgradient of the MW-1 source zone, substantially before the 325 feet distance where groundwater would reach the surface water of Lora Lake.

Table L.3
Sensitivity Analysis Results

Modeled Input Parameters						Resulting Model Predicted Downgradient Groundwater Concentrations (pg/L)							Distance Downgradient Where Model-predicted Concentrations are Less Than Surface Water Criterion[1]
Model Run No.	Source Dioxin/Furan Groundwater Concentrations (pg/L)	Fraction of Organic Carbon (-)	Hydraulic Conductivity (cm/s)	Time (years)	Source Zone Length (feet)	30 Feet Downgradient	90 Feet Downgradient	150 Feet Downgradient	210 Feet Downgradient	270 Feet Downgradient	300 Feet Downgradient	400 Feet Downgradient	
1	38.3	**0.5%**	0.11	100	100	2.2	5.2E-09	0	0	0	0	0	30–90 feet
2	38.3	**1.0%**	0.11	100	100	0.13	2.3E-19	0	0	0	0	0	30–90 feet
3	38.3	0.1%	**0.055**	100	100	14	9.7E-03	2.5E-09	1.7E-19	0	0	0	90–150 feet
4	38.3	0.1%	0.11	**50**	100	14	9.7E-03	2.5E-09	1.7E-19	0	0	0	90–150 feet
5	38.3	0.1%	0.11	**500**	100	38	34	22	8.4	1.6	0.55	3.6E-03	350–400 feet
6	38.3	0.1%	0.11	100	**150**	25	0.95	5.8E-04	4.3E-09	3.6E-16	1.8E-20	0	150–210 feet

Notes:

Bold input parameters indicate the specific parameter and value that was changed for the sensitivity analysis model run.

1 The dioxin/furan surface water criterion for protection of human health via consumption of organisms is 0.0051 pg/L or 5.1E-03 pg/L (Federal Clean Water Act Section 304). The model predicts the dioxin/furan groundwater concentration to be less than this criterion prior to the 325 feet distance downgradient from the modeled MW-1 source zone where groundwater would reach Lora Lake surface water in all model runs EXCEPT for model run No. 5 with a 500-year simulation period.

Port of Seattle
Lora Lake Apartments Site

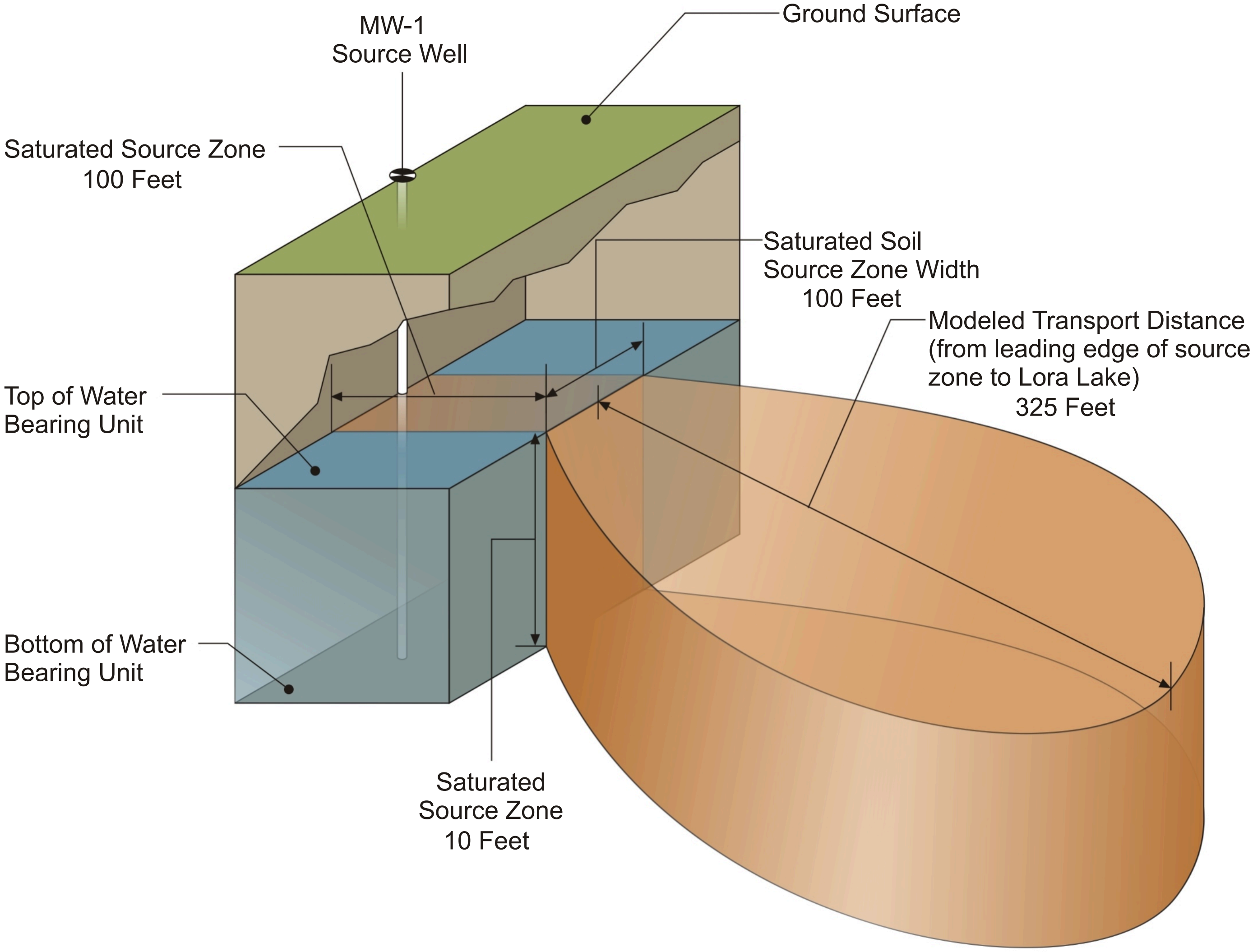
Remedial Investigation/ Feasibility Study

Volume II

Appendix L
BIOSCREEN Modeling

Figures

FINAL

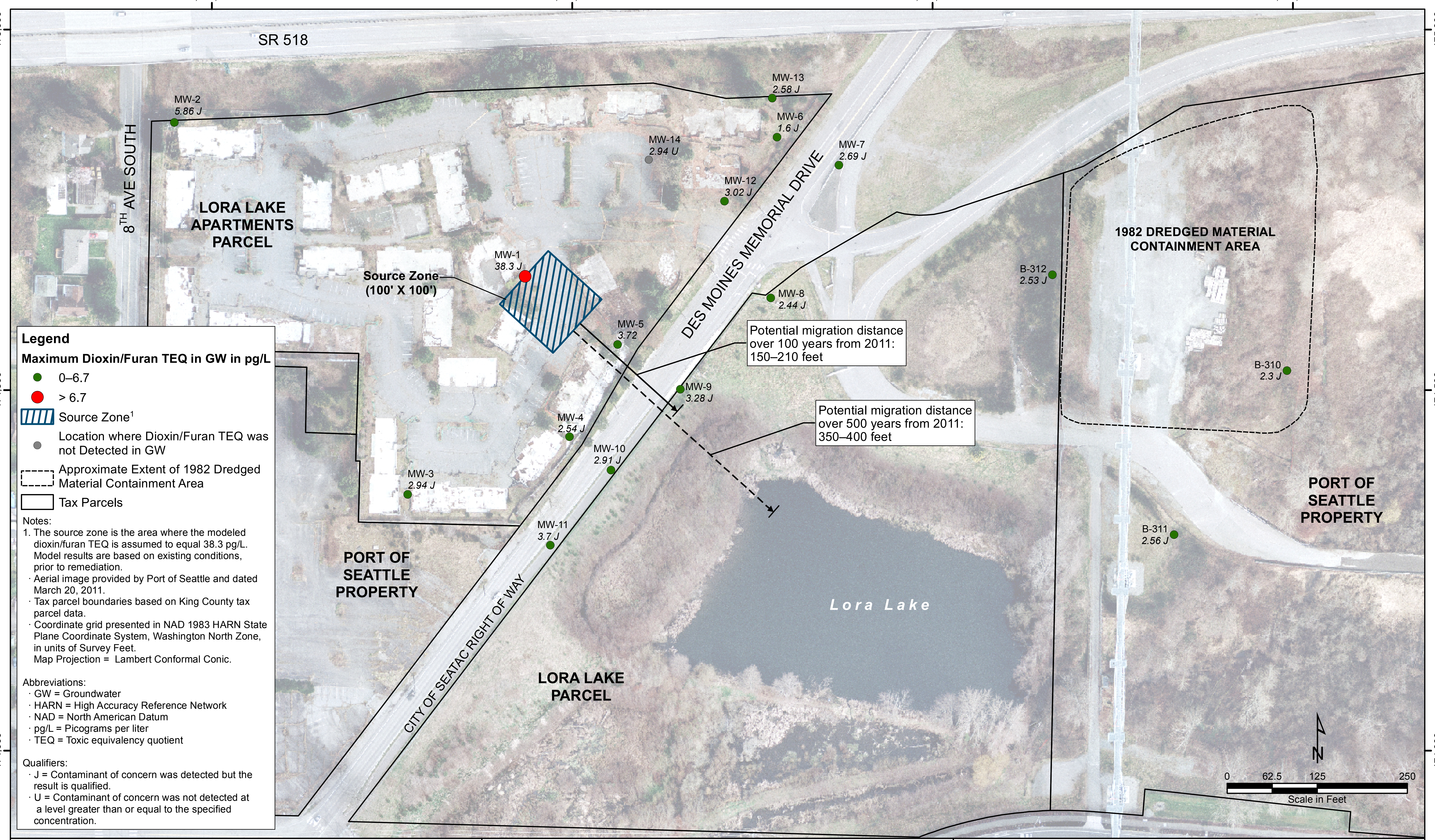


NOT TO SCALE

FLOYD | SNIDER
strategy ▪ science ▪ engineering

**Remedial Investigation/
Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington**

Figure L.1
Conceptual BIOSCREEN-AT
Model Section



FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure L.2
Site Diagram of BIOSCREEN-AT Model and Model Result

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix L\Figure L-2 Site Conceptual Diagram of Model Input Parameters.mxd
12/15/2014

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

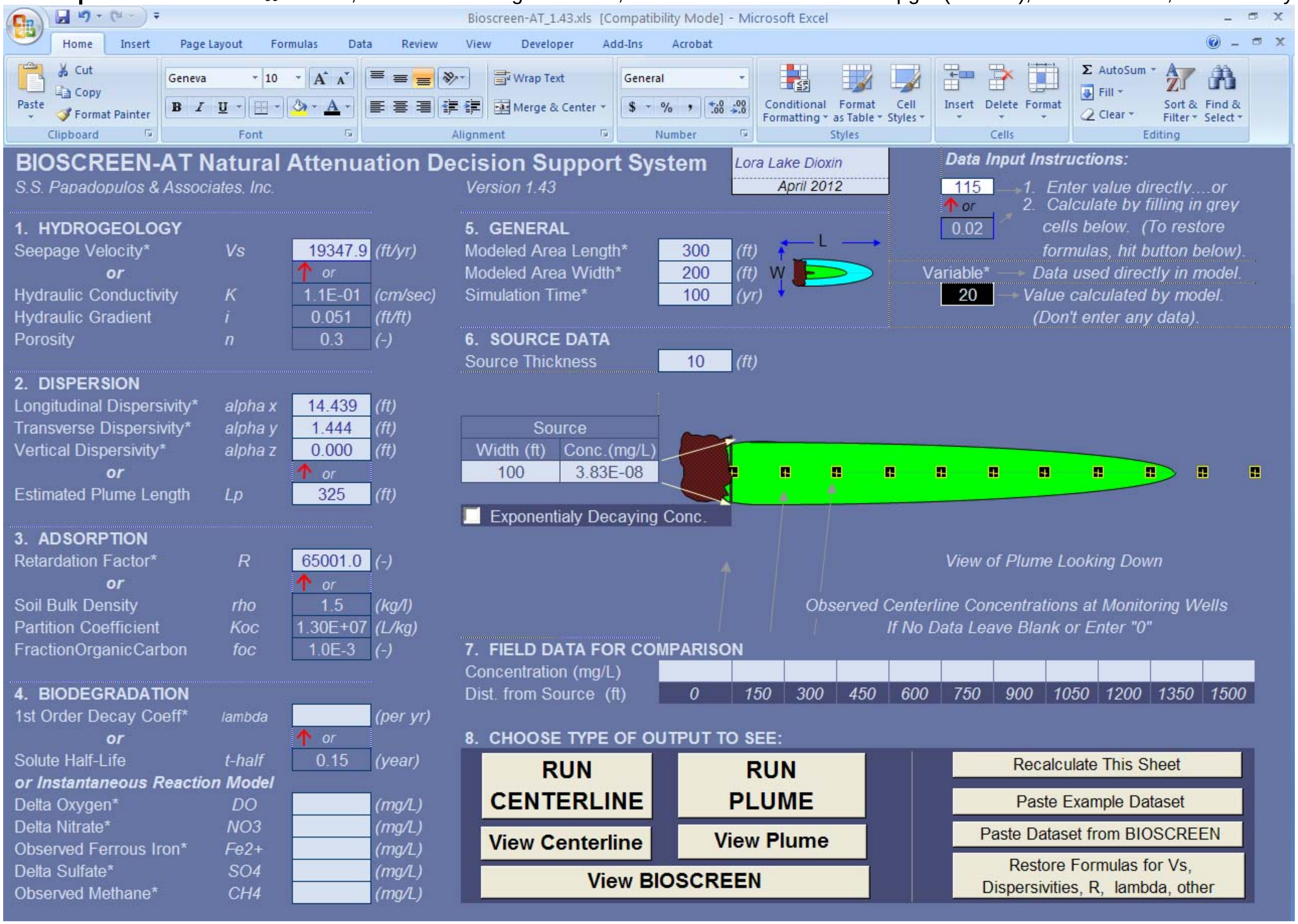
Volume II

Appendix L
BIOSCREEN Modeling

Attachment L.1
BIOSCREEN-AT Model Screenshots

FINAL

Model Input Parameters: f_{oc} = 0.1%, source zone length = 100 ft, source concentration = 38.3 pg/L (MW-01), K = 0.11 cm/s, time = 100 yrs



Bioscreen-AT_1.43.xls [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

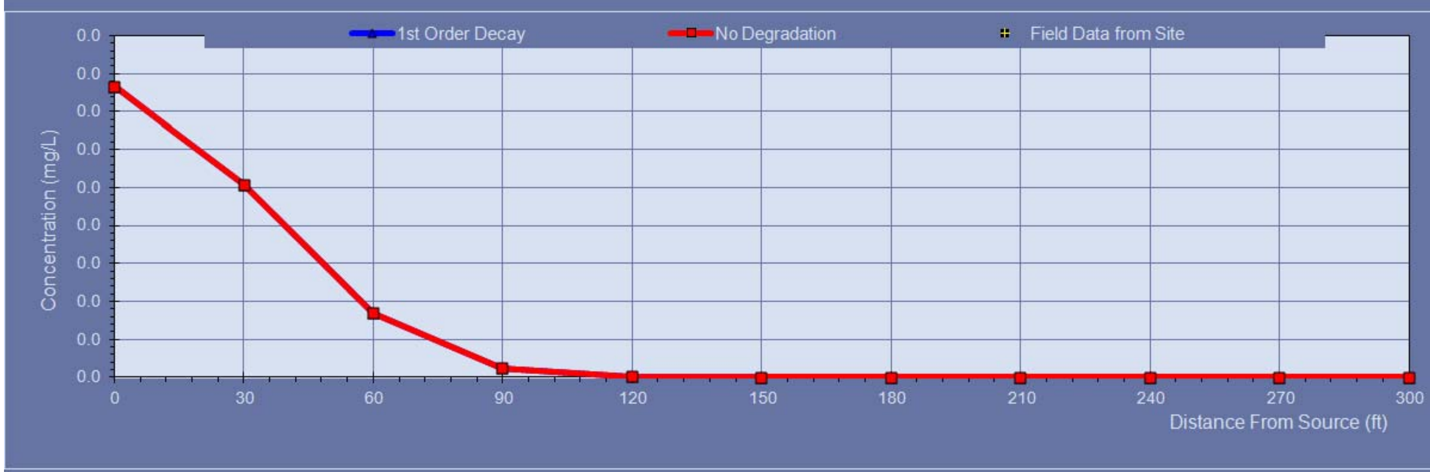
Distance from Source (ft)

	0	30	60	90	120	150	180	210	240	270	300
No Degradation	3.83E-08	2.54E-08	8.48E-09	1.19E-09	6.53E-11	1.33E-12	9.89E-15	2.65E-17	2.55E-20	8.74E-24	1.06E-27
1st Order Decay	3.83E-08	2.54E-08	8.48E-09	1.19E-09	6.53E-11	1.33E-12	9.89E-15	2.65E-17	2.55E-20	8.74E-24	1.06E-27
Field Data from Site											

\# of TimeSteps: 20

Displayed Time=100 years

Return to Input | View Plume Output



Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

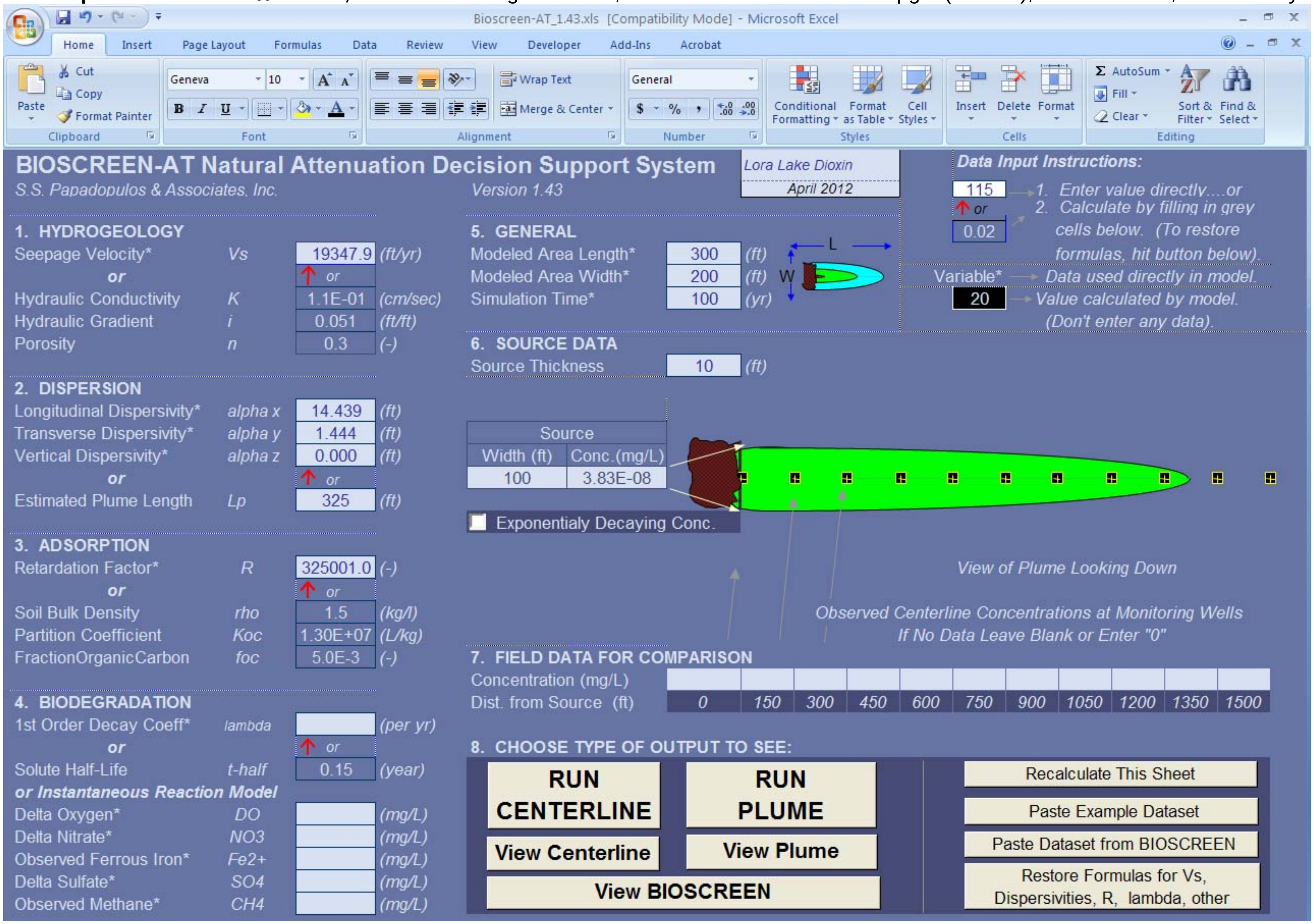
Volume II

Appendix L
BIOSCREEN Modeling

Attachment L.2
BIOSCREEN-AT Model
Sensitivity Analysis Screenshots

FINAL

Model Input Parameters: f_{oc} **= 0.5%,** source zone length = 100 ft, source concentration = 38.3 pg/L (MW-01), K = 0.11 cm/s, time = 100 yrs



Bioscreen-AT_1.43.xls [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

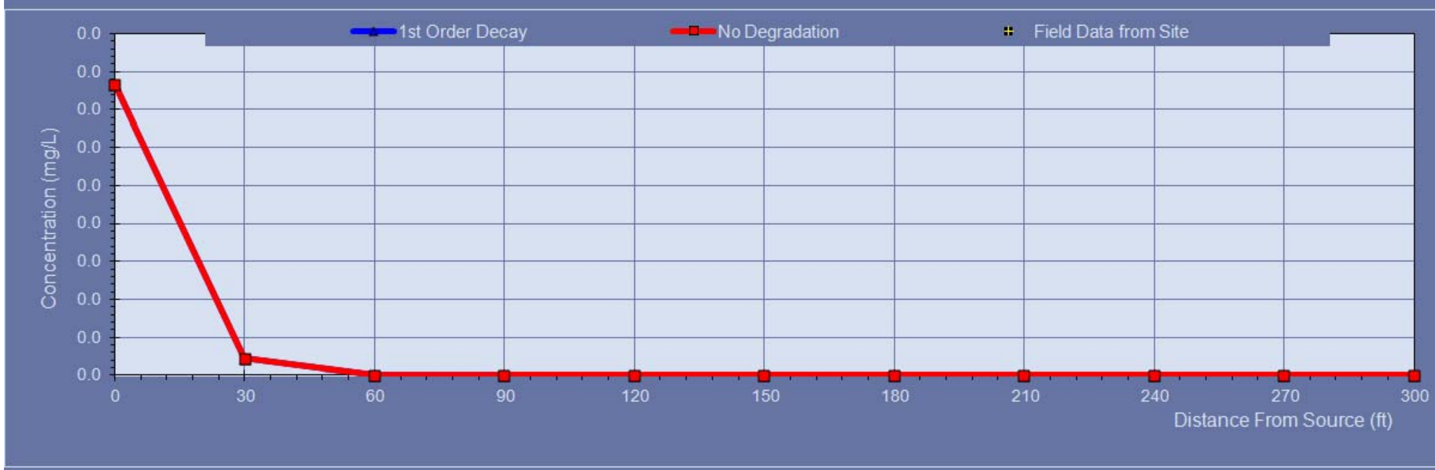
Distance from Source (ft)

	0	30	60	90	120	150	180	210	240	270	300
No Degradation	3.83E-08	2.21E-09	1.32E-12	5.24E-18	1.23E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1st Order Decay	3.83E-08	2.21E-09	1.32E-12	5.24E-18	1.23E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Field Data from Site											

\# of TimeSteps: 20

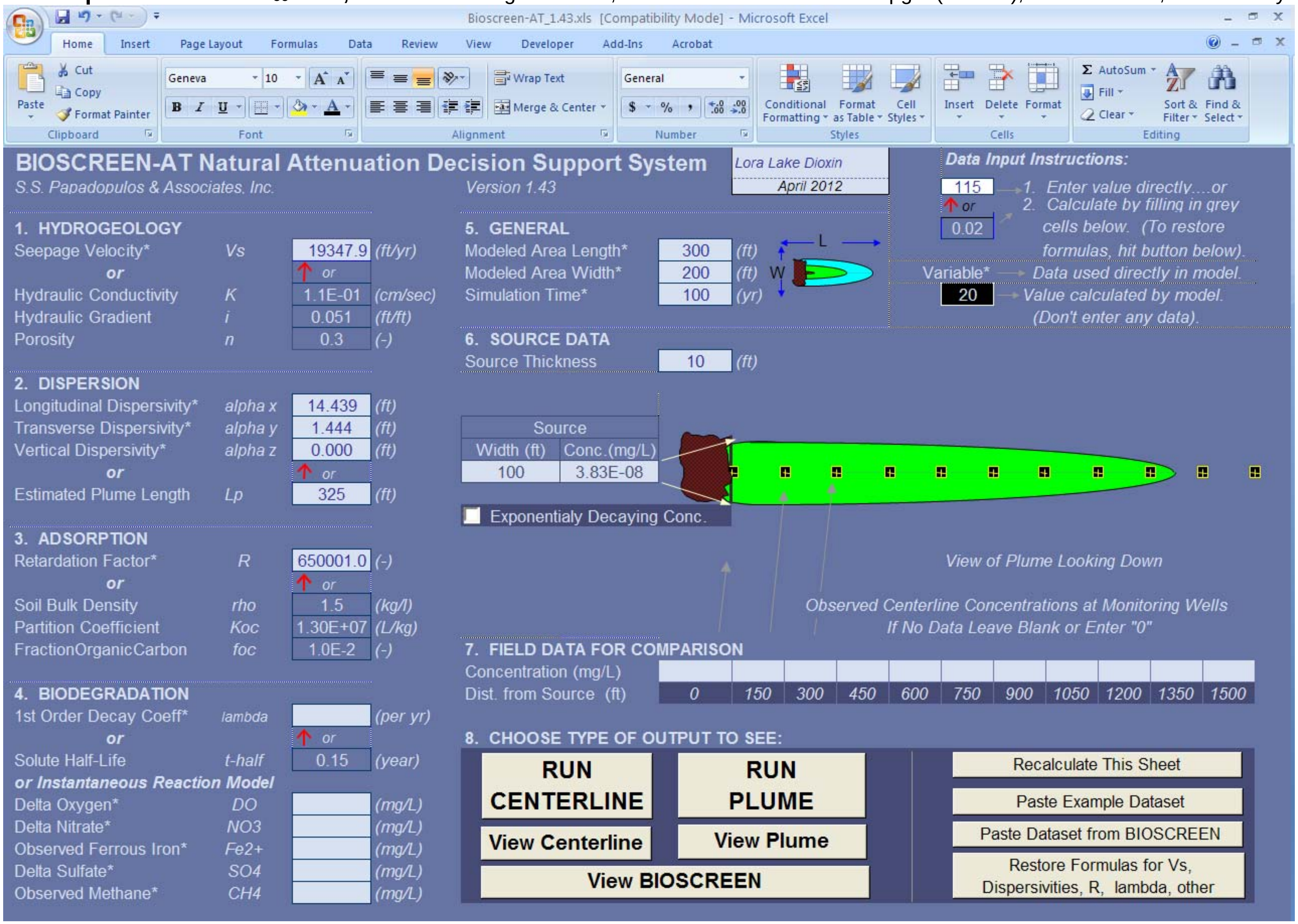
Displayed Time=100 years

Return to Input | View Plume Output



Ready

Model Input Parameters: **f_{oc} = 1%,** source zone length = 100 ft, source concentration = 38.3 pg/L (MW-01), K = 0.11 cm/s, time = 100 yrs



Bioscreen-AT_1.43.xls [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

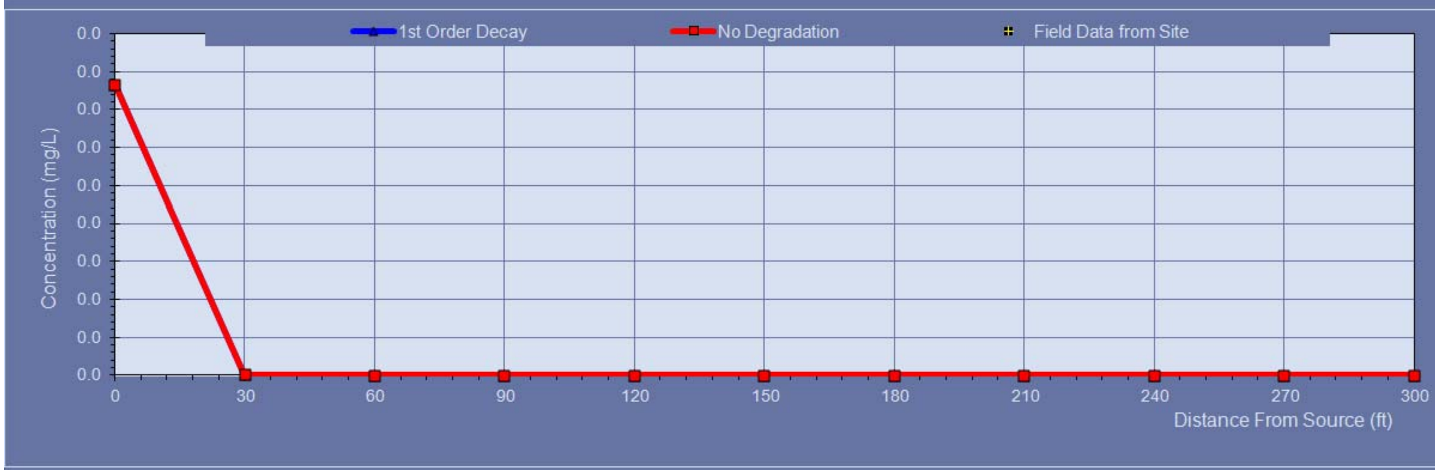
	0	30	60	90	120	150	180	210	240	270	300
No Degradation	3.83E-08	1.26E-10	2.82E-17	2.30E-28	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1st Order Decay	3.83E-08	1.26E-10	2.82E-17	2.30E-28	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Field Data from Site											

# of TimeSteps: 20

Displayed Time=100 years

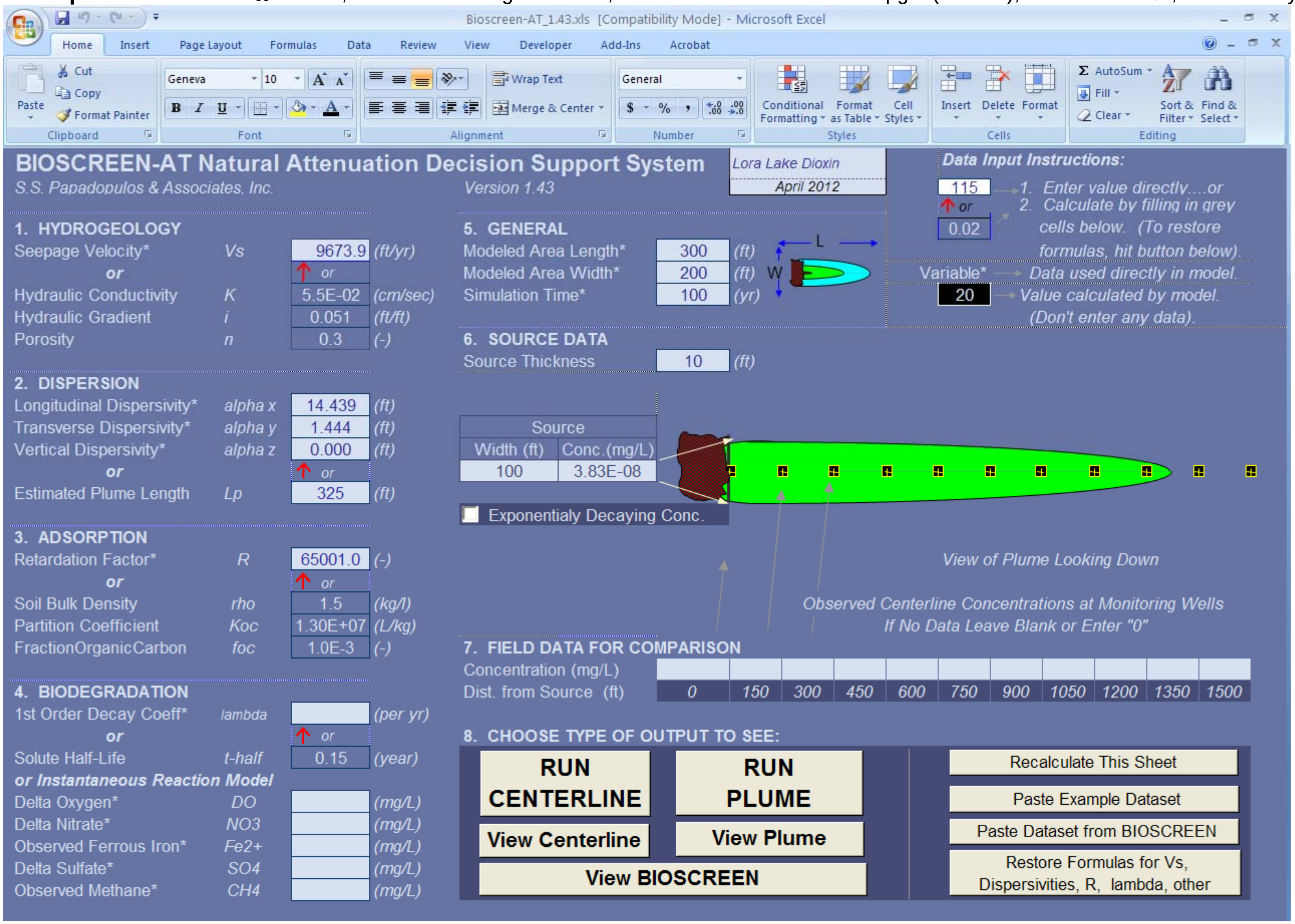
Return to Input

View Plume Output



Ready 134%

Model Input Parameters: f_{oc} = 0.1%, source zone length = 100 ft, source concentration = 38.3 pg/L (MW-01), **K = 0.055 cm/s**, time = 100 yrs



Bioscreen-AT_1.43.xlsm [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

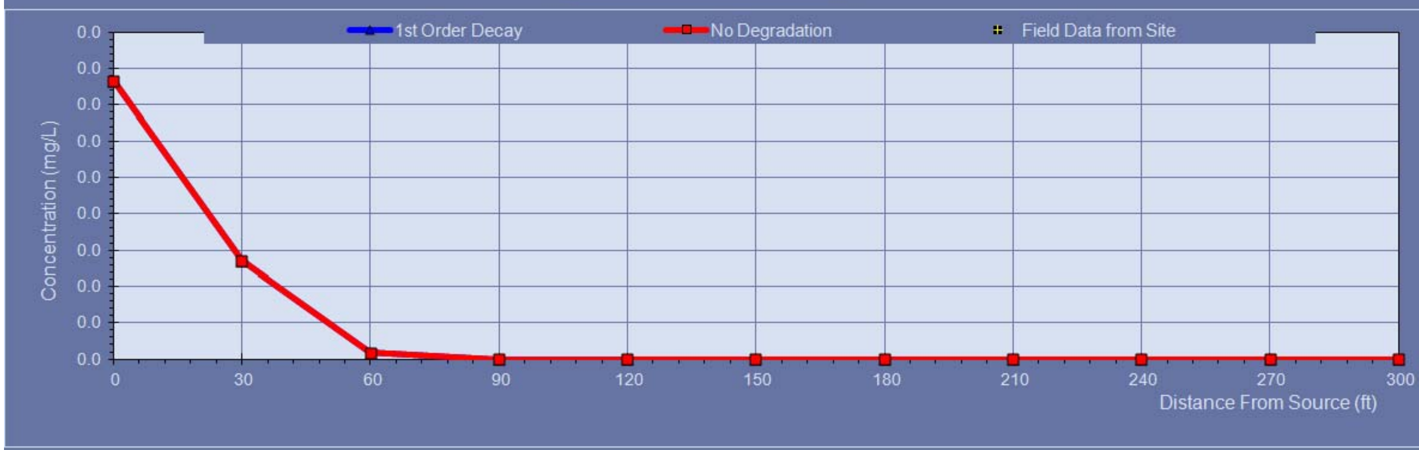
Distance from Source (ft)

	0	30	60	90	120	150	180	210	240	270	300
No Degradation	3.83E-08	1.36E-08	9.37E-10	9.68E-12	1.36E-14	2.50E-18	5.87E-23	1.74E-28	0.00E+00	0.00E+00	0.00E+00
1st Order Decay	3.83E-08	1.36E-08	9.37E-10	9.68E-12	1.36E-14	2.50E-18	5.87E-23	1.74E-28	0.00E+00	0.00E+00	0.00E+00
Field Data from Site											

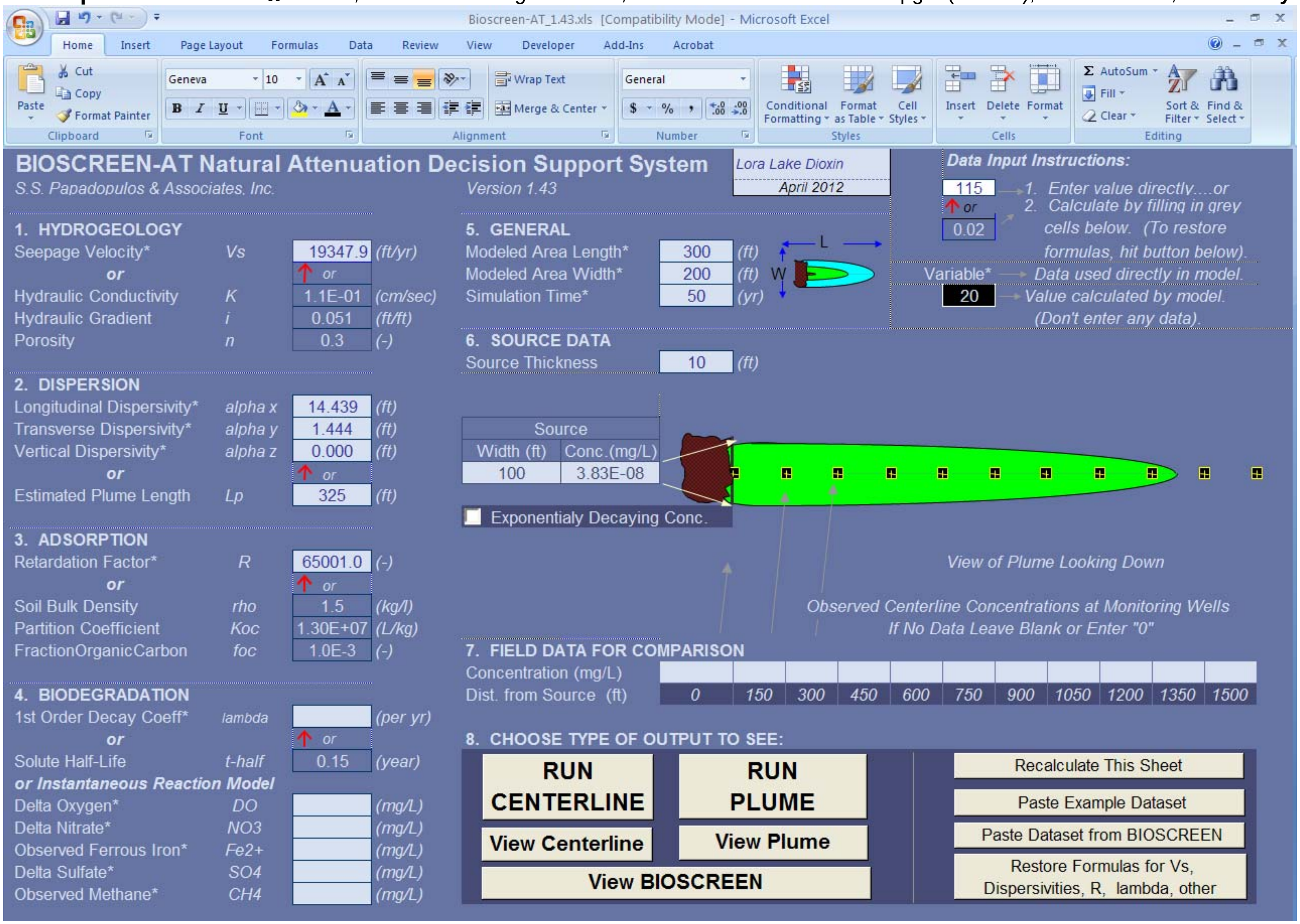
\# of TimeSteps: 20

Displayed Time=100 years

Return to Input | **View Plume Output**



Model Input Parameters: f_{oc} = 0.1%, source zone length = 100 ft, source concentration = 38.3 pg/L (MW-01), K = 0.11 cm/s, **time = 50 yrs**



Bioscreen-AT_1.43.xls [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

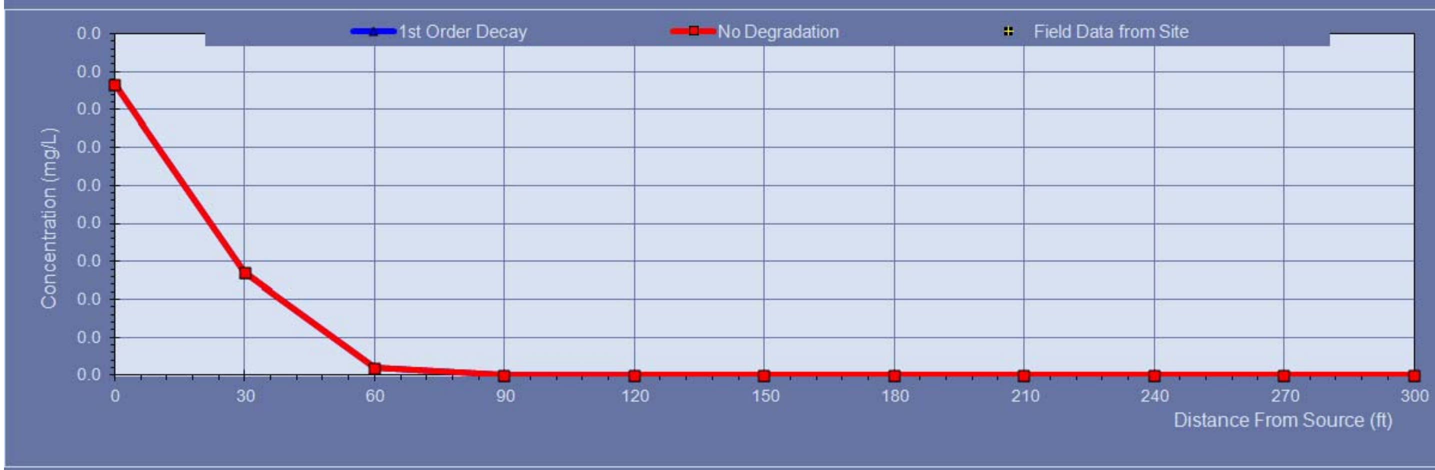
	0	30	60	90	120	150	180	210	240	270	300
No Degradation	3.83E-08	1.36E-08	9.37E-10	9.68E-12	1.36E-14	2.50E-18	5.87E-23	1.74E-28	0.00E+00	0.00E+00	0.00E+00
1st Order Decay	3.83E-08	1.36E-08	9.37E-10	9.68E-12	1.36E-14	2.50E-18	5.87E-23	1.74E-28	0.00E+00	0.00E+00	0.00E+00
Field Data from Site											

\# of TimeSteps: 20

Displayed Time=50 years

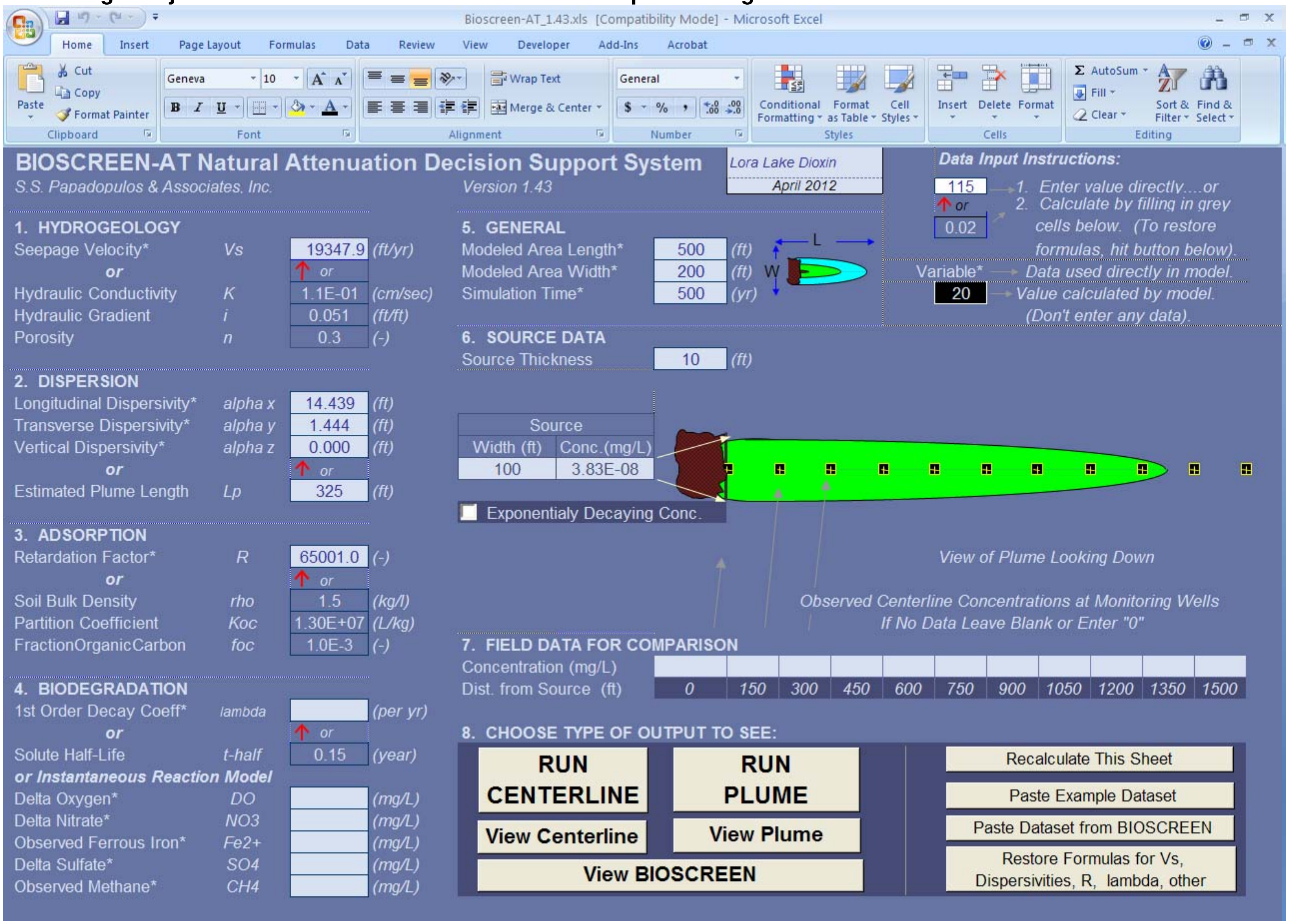
Return to Input

View Plume Output



Ready

Modeled area length adjusted to 500 feet to show distance where predicted groundwater concentrations < the surface water criterion.



Bioscreen-AT_1.43.xls [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

	0	50	100	150	200	250	300	350	400	450	500
No Degradation	3.83E-08	3.72E-08	3.23E-08	2.20E-08	1.03E-08	3.06E-09	5.51E-10	5.83E-11	3.56E-12	1.25E-13	2.49E-15
1st Order Decay	3.83E-08	3.72E-08	3.23E-08	2.20E-08	1.03E-08	3.06E-09	5.51E-10	5.83E-11	3.56E-12	1.25E-13	2.49E-15
Field Data from Site											

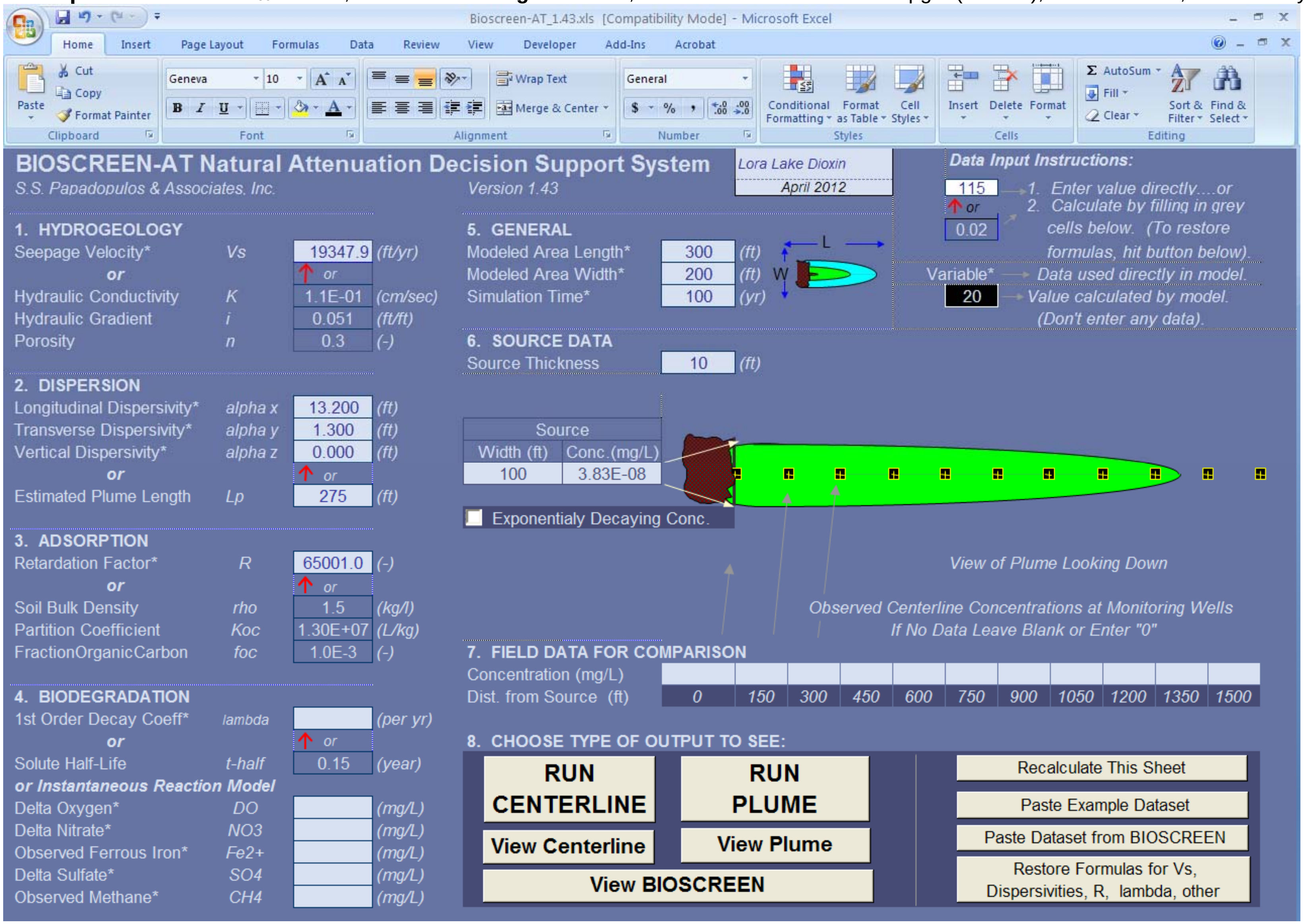
# of TimeSteps: 20

Displayed Time=500 years

Return to Input | View Plume Output

Chart Area

Model Input Parameters: f_{oc} = 0.1%, **source zone length = 150 ft**, source concentration = 38.3 pg/L (MW-01), K = 0.11 cm/s, time = 100 yrs



Bioscreen-AT_1.43.xls [Compatibility Mode] - Microsoft Excel

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

	0	30	60	90	120	150	180	210	240	270	300
No Degradation	3.83E-08	2.52E-08	7.84E-09	9.45E-10	4.02E-11	5.79E-13	2.76E-15	4.31E-18	2.19E-21	3.58E-25	1.84E-29
1st Order Decay	3.83E-08	2.52E-08	7.84E-09	9.45E-10	4.02E-11	5.79E-13	2.76E-15	4.31E-18	2.19E-21	3.58E-25	1.84E-29
Field Data from Site											

# of TimeSteps: 20

Displayed Time=100 years

Return to Input

View Plume Output

Ready

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix M
Review of Regional, National, and International Background Studies for Dioxins/Furans in Soils

FINAL

Table of Contents

List of Tables

Table M.2 Regional, National, and International Background Studies for Dioxins/Furans in Soil

List of Abbreviations/Acronyms

Abbreviation/ Acronym	**Definition**
1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin
1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
cm	Centimeters
Council	Canadian Council of Ministers of the Environment
DMMP	Dredged Material Management Program
dw	Dry weight
Exposure Reassessment Document	Estimating Exposure to Dioxin-Like Compounds
MTCA	Model Toxics Control Act
NDAMN	National Dioxin Air Monitoring Network
OCDD	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin
OSV	Ocean Survey Vessel
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-dioxins
PCDF	Polychlorinated dibenzo-furans
PCDD/Fs	Polychlorinated Dibenzo-p-Dioxin and Polychlorinated Dibenzofurans
pg/g	Picograms per grams
ppq	Parts per quadrillion
ppt	Parts per trillion
PQL	Practical quantitation limit
RI/FS	Remedial Investigation/Feasibility Study
Site	Lora Lake Apartments Site
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient

Abbreviation/ Acronym	Definition
USACE	U.S. Army Corp of Engineers
USEPA	U.S. Environmental Protection Agency
WAC	Washington Administrative Code
WDNR	Washington State Department of Natural Resources
WHO	World Health Organization
WSDOE	Washington State Department of Ecology

This page left intentionally blank.

1.0 Introduction

The purpose of this appendix is to provide a summary of dioxin/furan levels that have been detected in soils as part of multiple regional, national, and international studies. The following sections provide background information about dioxins/furans, and an overview of study findings of dioxin/furan levels in both urban and rural soils. Additionally, an overview of dioxin/furan levels in sediment from a regional study in Puget Sound is presented.

1.1 OVERVIEW OF DIOXINS/FURANS

Polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs) are commonly referred to as "dioxins/furans." Dioxins/furans are a class of chlorinated, planar organic compounds with similar chemical structures, called congeners. Each congener has a different placement and number of chlorine atoms on the molecule, influencing the chemical toxicity. The most studied and most toxic dioxin/furan compound is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). There are 16 other dioxin/furan congeners that are also considered toxic and share toxic characteristics with 2,3,7,8-TCDD. These other 16 congeners are assigned a corresponding toxicity equivalency factor (TEF) relative to the toxicity of 2,3,7,8-TCDD. 2,3,7,8-TCDD has been identified as a "known human carcinogen" (IARC 1997) and a probable human carcinogen by U.S. Environmental Protection Agency (USEPA; Group B2 carcinogen). Adverse health effects on biological systems of both humans and wildlife may be acute or chronic. Dioxin/furan compounds may cause tumor development, immune dysfunction, endocrine system disruption, and cause reproduction and developmental effects (ATSDR 1998).

Dioxin/furan compounds are not intentionally manufactured by industry. These compounds are produced as byproducts of natural or anthropogenic (e.g., of human origin) activities. They are generally formed by the incomplete combustion of materials in the presence of chloride in nature and in industry, and by other industrial processes. Natural activities include forest fires or volcanic activity, while industrial processes include coal-fired power plants, cement kilns, land application of treated sewage sludge, municipal and domestic waste incineration, chlorine bleaching of pulp and paper, and chlorinated pesticide manufacturing. Activities such as residential wood burning and backyard burning of household waste may also be an important source (USEPA 2011). It is generally believed that anthropogenic activities produce the majority of dioxins entering the environment (ATSDR 1998). Although dioxin/furan compounds are produced at very low levels (e.g., parts per trillion [ppt] or parts per quadrillion [ppq]), the compounds are ubiquitous in the environment and can be considered to be present at "background" concentrations, as discussed in further detail below.

The chemical properties that are responsible for the fate and transport of dioxins/furans in the environment include low water solubility, low vapor pressure, and a high affinity for sorption on particle surfaces and organic materials, including lipids (fat). Because of these chemical properties, dioxins/furans in the environment tend to be associated with soil, ash, or other materials with high organic carbon content. In air and water, dioxins/furans may be present in limited concentrations in the vapor or dissolved state, but they are more likely to be present in these media associated with particulate matter. They are also resistant to degradation and therefore persist in the environment and have the potential to accumulate, primarily through food webs, in the fatty tissues of animals, including humans. The estimated half-life (time required for half a given concentration to decompose or degrade) of 2,3,7,8-TCDD on surface soil ranges from 9 to 15 years. Estimated half-lifes for 2,3,7,8-TCDD in subsurface soil may range from 25 to 100 years (ATSDR 1998).

1.2 EVALUATION OF DIOXINS/FURANS USING TOXIC EQUIVALENTS

Dioxins/furans are generally present in the environment as a complex mixture of chemical congeners. USEPA dioxin/furan analytical methods report the regulated 17 dioxin/furan congeners, which are listed in Table M.1.

As stated above, the most toxic and best-studied of the dioxin/furan congeners is 2,3,7,8-TCDD. In order to compare the toxicity of samples with different dioxin/furan congener profiles, TEFs have been developed that standardize the 16 other dioxin/furan congeners considered toxic to a toxicologically equivalent amount of 2,3,7,8-TCDD. As an example, the TEF of 2,3,7,8-TCDD is designated as 1, and the TEF of 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD) is designated as 0.1 since 1,2,3,4,7,8-HxCDD is one-tenth as toxic as 2,3,7,8-TCDD.

The TEF values currently used for human and other mammalian exposures are those resulting from the World Health Organization (WHO) re-evaluation of TEFs for dioxins/furans performed in 2005 (van den Berg et al. 2006). These current TEF values are presented in Model Toxics Control Act (MTCA) Table 708-1 (Washington State Department of Ecology [WSDOE] 2007b) and in Table M.1 of this appendix. Prior to the 2005 re-evaluation, TEFs were based on the following: the international TEF convention that was adopted by the USEPA in 1989, TEFs that were first evaluated by WHO in 1993, or TEFs that were re-evaluated by WHO and established in 1998. For many of these congeners, the TEF values have remained the same over time, though there are several that have either increased or decreased.

Toxic equivalency quotients (TEQs) are used to express the total toxicity of a mixture of dioxin/furan congeners. The TEQ is calculated by multiplying the concentration of each congener by its TEF and summing the products. The calculated result—the TEQ value—can be compared to various regulatory criteria addressing human health or ecological risk.[1] Caution should be used when directly comparing earlier TEQ values calculated with older TEF values to TEQ values calculated based on the current TEFs; or TEQ values should be recalculated, where congener data is available, using the current TEFs in order to provide an accurate evaluation of the dioxin/furan data.

[1] When evaluating risk to non-human mammals under MTCA, dioxin/furan TEQ values are calculated differently. In this case, a dioxin TEQ and a furan TEQ are calculated separately for comparison against promulgated ecological screening levels known as ecological indicator criteria (WAC 173-340-900).

For the evaluation of dioxin/furan ecological toxicity for fish and birds, the TEFs used in the TEQ calculation are different than those used for humans and other mammals because these congeners have different toxic potency to fish and birds. The TEF values used to calculate TEQs for fish and bird exposures were evaluated in 1998 (Van den Berg et al. 1998) and are presented in the USEPA guidance "*Framework for Application of the Toxicity Equivalence Methodology for Polychlorinated Dioxins, Furans, and Biphenyls in Ecological Risk Assessment*" (USEPA 2008a).

1.2.1 Non-detected Dioxin/Furan Congeners

Washington Administrative Code (WAC) 173-340-740(7)(f) specifies procedures to be followed when measured chemical concentrations are less than the laboratory practical quantitation limit (PQL); however, a specific approach on how to address non-detected dioxin/furan congeners in the calculation of a TEQ value is not provided in MTCA. WSDOE's 2007 Concise Explanatory Statement and Responsiveness Summary stated the following (refer to Chapter 2 of the summary):

> "Ecology agrees that the treatment of undetected congeners, PCBs [polychlorinated biphenyls], and carcinogenic PAHs [polycyclic aromatic hydrocarbons] can affect the outcome of risk assessments and compliance evaluations. MTCA already has language addressing handling of samples with "undetected concentrations." Because of the difficulty of applying the default approach to mixtures, actual practice at most dioxin/furan, PCB, and carcinogenic PAH contaminated sites is to use alternative procedures allowed by the rule. For example, under WAC 173-340-740(7)(f)(v), the following alternative statistical procedure is typically used for dioxin/furan congeners:
>
> - For congeners that occur at the site but not in the sample of concern, assign one-half the detection limit for compliance calculations; and
> - For congeners not detected in any samples at a site, assign a value of zero for compliance calculations (assuming Ecology approved detection limits were used).
>
> …Ecology believes that using one-half the detection limit creates an incentive to use more sensitive analytical techniques with lower detection limits while not over or understating the risk at a site. Ecology's experience with TEQ calculations for samples with low levels of dioxins is that using one-half of the detection limit does not result in samples exceeding the cleanup level provided reasonable detection limits are used."

Additionally, MCTA specifies in the calculation of natural background (described below in Section 1.3), that measurements less than the method detection limit are assigned a value equal to one-half of the method detection limit (refer to WAC 173-340-709(5)(a)).

The methodology used for the handling of non-detected congeners to calculate the TEQ values for each of the regional, national, and international studies is presented below in

Section 2.0 and in Table M.2; in almost all cases the non-detected congeners were assigned a value of one-half the method detection limit.

1.3 WHAT IS "BACKGROUND"?

Dioxins/furans are observed to be ubiquitous in the environment at some low-level "background" concentration because of the wide variety of ways in which dioxins/furans can be produced as byproducts of natural and anthropogenic processes, as described above. Since dioxins/furans are produced by naturally occurring processes as well as anthropogenic processes, there are often two types of background levels that are discussed. The first is natural background, and the second is area background or urban background. MTCA (WAC 173-340-200) provides the following definitions for these two types of background:

Natural background is defined as "the concentrations of hazardous substances that are consistently present in an environment that has not been influenced by localized human activities" (WAC 173-340-200). The MTCA definition includes both substances such as metals that are found naturally in bedrock, soil, and sediment, as well as persistent organic compounds such as polychlorinated biphenyls (PCBs) or dioxins/furans that can be found in soil and sediment throughout the state as a result of global distribution of these chemicals. MTCA recognizes that setting cleanup levels less than natural background levels is impractical (WAC 173-340-705(6)).

Area background is defined as "the concentrations of hazardous substances that are consistently present in the environment in the vicinity of the site as a result of human activities unrelated to releases from the site" (WAC 173-340-200). When cleanup levels are less than area background concentrations, MTCA recognizes that area background concentrations can result in recontamination of a site to levels that exceed cleanup levels. In such cases, MTCA allows that portion of the cleanup action to be delayed until off-site sources of hazardous substances are controlled (WAC 173-340-360(4)(d)).

MTCA permits consideration of natural and area/urban background contaminant concentrations when formulating cleanup levels at a site, as sampling may be conducted to distinguish site-related from non-site-related concentrations (WAC 173-340-709). Per MTCA, background sample data are assumed to be lognormally distributed, consistent with the typical data distribution of large environmental datasets. WAC 173-340-709(3)(c) identifies the statistical definition of background for lognormal datasets as the lower of the true upper 90^{th} percentile or four times the true 50^{th} percentile (WSDOE 2007b).

2.0 Overview of Dioxin/Furan Background Studies

This section describes a number of studies conducted to assess background concentrations of dioxins/furans in soils in Washington State and elsewhere in and outside of the United States. Table M.2 divides these studies into rural or urban land uses and provides a summary of the details of each study, including the number of samples, the study results, and the statistical analysis of the background concentration by land use. Studies that include data from both rural and urban land uses are presented in both land use areas on Table M.2, with the study data divided into the appropriate type of land use. Additionally, this section summarizes dioxin/furan levels in sediment from a regional study in Puget Sound.

2.1 WSDOE REGIONAL STUDIES AND REPORTS

2.1.1 1999 WSDOE Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State

In 1998, WSDOE completed a study of dioxins/furans and metals in fertilizers, soil amendments, and soils as required by the *Washington State Fertilizer Regulation Act (SSB 6474).* This study was released by WSDOE in 1999, and is summarized in WSDOE's Concise Explanatory Statement and Responsiveness Summary released in 2007.

One of the objectives of this study was to "provide an initial assessment of typical concentrations of dioxins in Washington soils" (WSDOE 1999). In order to meet this objective, WSDOE collected 30 surface soil samples from various environments throughout Washington State including open, forested, and urban areas and analyzed them for dioxins/furans: 8 samples were collected from open areas, 8 samples were collected from forested areas, and 14 samples were collected from urban areas. Each sample was a composite comprised of 10 samples collected from within a 1-acre sampling unit. The initial sample was collected at the center of the unit, with the nine additional samples collected at the end of a radius originating from the starting point and extending a distance of 36 meters. The samples were collected to a depth of 5 cm below the ground surface.

Dioxins/furans were detected in all of the soil samples from the various sampling environments. Urban soil samples typically reported higher dioxin/furan levels. Overall, the dioxin/furan concentrations from all three areas in this study ranged from 0.033 to 19.5 picograms per grams (pg/g) TEQ using TEFs promulgated prior to the 2005 WHO re-evaluation of TEFs for dioxins (van den Berg et al. 2006) and assigning the non-detected congeners a value of zero.

A natural background value was calculated in 1999 by WSDOE using the sampling data combined from the forested and open areas, as these areas were unlikely to be influenced by localized human activity. Based on the statistical analysis of these sampling results, the 1999 natural background TEQ for dioxin/furan mixtures in Washington State soils was calculated to be **2.2 pg/g TEQ,** This natural background TEQ was calculated as four times the 50th percentile of the dataset, consistent with WAC 173-340-709(3)(c). Refer to Section 2.1.3 for WSDOE's recalculated natural background value based on the current 2005 WHO TEFs and assigning one-half the detection limits to any non-detected congeners.

2.1.2 2007 MTCA Rule Amendment—WSDOE Concise Explanatory Statement and Responsiveness Summary

In 2007, WSDOE initiated its routine process for periodic review and amendment of MTCA regulations. With respect to the Lora Lake Apartments Site Remedial Investigation/Feasibility Study (RI/FS), the 2007 review and amendment cycle resulted in significant changes to two components of dioxin/furan TEQ calculations. One amendment to MTCA updated the TEFs to reflect the 2005 WHO revisions. Additionally, WSDOE's 2007 Concise Explanatory Statement and Responsiveness Summary for the 2007 MTCA Rule Amendment provided guidance that changed the TEQ calculation such that congener concentrations reported by the laboratory as non-detect be given a substitute value of one-half the analytical detection limit, as opposed to zero, the previously substituted value typically used (WSDOE 2007a). WSDOE's 2007 Concise Explanatory Statement and Responsiveness Summary presents the regulatory rationale for adopting the final rule amendments, the differences between the initial proposals and the final rule, and a summary of public comments on the proposed rule amendments and WSDOE responses (WSDOE 2007a).

One of the public concerns addressed by WSDOE in the 2007 concise explanatory statement and responsiveness summary was that the proposed MTCA Method B soil cleanup level of 11 pg/g TEQ[2] for dioxins/furans was less than area or urban background concentrations found in Washington State. WSDOE responded that data collected in WSDOE's 1999 dioxin/furan background investigation identified a natural background value of 2.2 pg/g TEQ, significantly less than the proposed 11 pg/g TEQ[3] cleanup level. Additionally, WSDOE pointed out that the data from this investigation showed that the typical urban background of 7.7 pg/g TEQ found in Washington State was also lower than the proposed cleanup level.

2.1.3 2010 WSDOE Technical Memorandum #8

On April 28, 2010, the WSDOE Toxics Cleanup Program released a memorandum to the public regarding natural background for dioxins/furans in Washington State soils (Bradley 2010).The memorandum provided an update to the 1999 WSDOE-recommended natural background value of 2.2 pg/g TEQ. This update re-evaluated the same dataset used for the 1999 recommended natural background value to calculate a new TEQ, with incorporation of two updates to the MTCA regulation promulgated in 2007 that affected

[2] The MTCA Method B dioxins/furans soil cleanup level has changed from 11 pg/g TEQ to 13 pg/g TEQ as described in Section 2.1.5.

[3] The MTCA Method B dioxins/furans soil cleanup level has changed from 11 pg/g TEQ to 13 pg/g TEQ as described in Section 2.1.5.

the TEQ calculation. This included the use of the 2005 WHO TEFs and the requirement that natural background be calculated assigning non-detected congeners a value of one-half of the detection limit per MTCA WAC 173-340-709(5)(a).

Based on the revised calculations, WSDOE determined that appropriate natural and urban background concentrations for dioxins/furans are **5.2 pg/g TEQ** and **9.9 pg/g TEQ.**

2.1.4 2011 WSDOE Seattle Background Study

WSDOE recently released a study addressing dioxin/furan and PAH concentrations in urban Seattle soils (WSDOE 2011). The objective of the investigation was to collect data in various urban areas throughout the City of Seattle to determine the range and magnitude of concentrations of dioxins/furans in these areas. WSDOE collected samples in six Seattle neighborhoods to meet this objective: South Park, Georgetown, West Seattle, Ballard, Capitol Hill, and Ravenna.

In 5 of the 6 neighborhoods, WSDOE collected 20 shallow soil samples (0 to 3 inches below ground surface) from twenty quadrants. In the South Park neighborhood, samples were collected from 10 quadrants. Locations were selected to ensure samples were distributed throughout the entire neighborhood. Each sample consisted of a composite of five individual samples collected from within a quadrant, with the quadrants located in a city of Seattle right-of-way in front of a single property. A total of 120 composite samples were collected in this investigation. Exact locations of the samples have not been released by WSDOE.

Dioxin/furan TEQ concentrations were calculated using the current MTCA 2005 WHO TEFs and assigning non-detected congeners a value of one-half of the detection limit. Overall, dioxin/furan TEQ concentrations ranged from 1.66 pg/g TEQ to 115 pg/g TEQ, with an average concentration of **19 pg/g TEQ**. The median and nonparametric 90^{th} percentile TEQ concentrations were **12 pg/g TEQ** and **46 pg/g TEQ,** respectively. According to WAC 173-340-709, background is defined as the lower of the nonparametric 90^{th} percentile or four times the true 50^{th} percentile of a background dataset.

Of the neighborhoods included in this study, South Park and West Seattle are considered to be most similar to the Lora Lake Apartments Site (Site) because of their proximity and land use and may be indicators of likely dioxin/furan background concentrations in the area surrounding the Site, including Burien and SeaTac. The average and median dioxin/furan TEQ concentrations for the South Park neighborhood were both calculated at **12 pg/g TEQ**. The nonparametric 90^{th} percentile dioxin/furan TEQ concentration for South Park neighborhood was **19 pg/g TEQ**. The average and median dioxin/furan TEQ concentrations for the West Seattle neighborhood were calculated at **7.5 pg/g TEQ** and **4.5 pg/g TEQ,** respectively, and the nonparametric 90^{th} percentile dioxin/furan TEQ concentration was **13 pg/g TEQ**.

2.1.5 2014 Revision of MTCA Cleanup Levels for Dioxins/Furans

California EPA values for the cancer potency factor for 2,3,7,8-TCDD replaced previously-existing values in the WSDOE Cleanup Levels and Risk Calculation (CLARC) database. The resulting dioxins/furans MTCA Method B TEQ (Standard, Carcinogen) concentration for soil cleanup became 13 pg/g (revised from 11 pg/g). Other notable changes include the dioxins/furans MTCA Method C TEQ (Standard, Carcinogen, Industrial Land) concentration for soil, which was revised from 1,500 pg/g to 1,700 pg/g, and the dioxins/furans MTCA Method B TEQ (Adjusted, Carcinogen) concentration for groundwater, which was revised from 5.83 pg/L to 6.7 pg/L.

2.1.6 Lora Lake Apartments Site Chemometric Evaluation

As part of RI data assessment, the Port contracted with Infometrix, Inc., of Bothell, Washington, and Gregory Glass for evaluation of the Lora Lake Apartments Site soil dioxin/furan data through chemometric “unmixing” modeling. Chemometric mixture analysis is a mathematical evaluation of a dataset that uses a “receptor-oriented” approach to identify a number of sources that can account for the measured sample results, without specific prior knowledge of those sources. The unmixing model provides profiles for the modeled sources and the contributions of each of those modeled sources to each sample pattern in the dataset. Modeled source profiles can be compared to an inventory of known source patterns (not site-specific), and other site-specific information, to aid interpretation of the nature of the modeled sources.

Infometrix used a proprietary software package (Pirouette) to perform the chemometric analysis. Principal Components Analysis and Multivariate Curve Resolution-Alternating Least Squares methods were applied to the soil dioxin/furan data for the Lora Lake Apartments Site, as well as selected portions of the recent Washington State Department of Ecology urban soils dataset from Seattle, for these evaluations.

The soil dioxin/furan total TEQ values near the perimeter of the Lora Lake Apartments Parcel are very markedly lower than the maximum values within the property. The purpose of the chemometric evaluations was to assess the spatial extent of site-related dioxin/furan contamination via evaluation of multi-congener dioxin/furan chemical patterns. Specifically, the purpose of these evaluations was to determine whether soil samples near the property boundary represent typical urban soil dioxin/furan patterns that can be differentiated from contributions from site-related dioxin/furan contaminant sources.

An initial chemometric analysis was performed using the total soils dataset, based on normalized sample TEQ profiles. An unmixing model with suitably low residuals was obtained. All of the modeled sources had very high TEQ contributions to some samples in the Central Source Area at the Site. Source profile interpretations based on comparisons to known source profiles strongly indicated that the model included common dioxin/furan sources (e.g., pentachlorophenol and widely used herbicides), albeit with atypically high TEQ contributions at this Site. Since all perimeter samples could be “fit” for dioxin/furan patterns with the same source types that had high TEQ contributions in the Central Source Area, including very common urban sources, a degree of confounding of site-related and non-site related sources appeared possible. Therefore, a number of additional approaches were explored.

A second chemometric evaluation was performed on site soil data limited to samples near the property boundary, to reduce any possible dominant influences from the mid-property samples with very high TEQs. Two additional evaluations were performed including data from the West Seattle sampling within the WSDOE urban soils study; of the six neighborhoods sampled by WSDOE, West Seattle was deemed the most representative for the area surrounding the Site. In the first approach, only the West Seattle dataset was modeled and the results were then applied to both the West Seattle and perimeter samples from the Site. The rationale for this approach was to develop a “typical urban soils” source model (i.e., taking an “outside-in” approach) and then to see if it reasonably accounted for the perimeter sample patterns. Using this approach, comparatively high residuals for some of the perimeter samples from the Site indicated that the West Seattle mixture of modeled sources did not completely account for the perimeter samples. The second approach incorporating West Seattle soil data developed a model based on the combined West Seattle and site perimeter samples and then evaluated the comparative source contributions to TEQs for both locales.

None of these chemometric evaluation approaches proved definitive in differentiating site-related from typical urban influences on perimeter sample dioxins/furans. A strong limitation for chemometric analysis at this Site appears to be the non-uniqueness of the source profiles that account for the very high soil TEQs at the Site. Historic barrel-washing operations at the Site would have reasonably involved residues from dioxin/furan source materials that found widespread uses and were therefore packaged and transported in the very containers being washed. For example, one source profile resembles Silvex (2,4,5-T), an herbicide produced in very large quantities and recommended for use by homeowners and for roadside weed control, among other uses. Differentiating possible low-level contributions from historic site operations (including soil regrading) versus roadside weed control uses near the Site, based only on chemical patterns, is problematic. Based on the preliminary findings from multiple chemometric data evaluation approaches and the apparent high degree of potential confounding of site and non-site sources, further unmixing analysis was suspended.

2.2 USEPA NATIONAL AND INTERNATIONAL STUDIES AND REPORTS

2.2.1 USEPA 2003. Exposure and Human Health Reassessment of 2,3,7,8-TCDD and Related Compounds

In 2003, USEPA released three reports collectively known as “the Reassessment”. One of these reports, entitled: *Estimating Exposure to Dioxin-Like Compounds* (Exposure Reassessment Document; USEPA 2003) had three primary objectives: identify known dioxin/furan sources, better understand dioxins/furans in the environment (including background dioxin/furan levels), and provide procedures for evaluating dioxin/furan exposure risks.

In the Exposure Reassessment Document, USEPA provides an overview of the concentrations at which dioxin/furan compounds are found in the environment, including environmental media (soil, air, water, and sediment) and tissues (fish, shellfish, and meat products). USEPA notes that this literature summary is not meant to be all-inclusive but to provide a general overview of information available in the published literature prior to 2003, primarily studies from the 1990s.

For soil, USEPA calculates a background dioxin/furan concentration for rural and urban background scenarios based on the evaluation of a number of studies. Studies were selected to be representative of nationwide exposures and typical exposure conditions. For example, samples from typical point sources (vehicles, fireplaces, etc.) were included, but samples from uncommon point sources (smelters, etc.) were not. The mean rural background concentration of dioxin/furan was calculated as **2.6 pg/g TEQ** based on 11 studies from 7 states, including Washington State, and 2 areas in Canada. The mean urban background concentration of dioxins/furans was calculated as **8.8 pg/g TEQ** based on data from five states and Canada. In calculating TEQ concentrations, each site was weighted equally. Note, however, that these TEQ concentrations were calculated assuming non-detected congeners equal zero (required because of lack of uniformity in studies) and now-outdated TEF values. Recalculation of these TEQs would be required for a valid comparison with the current TEQ results from Washington State and the Seattle area.

2.2.2 USEPA 2007. Pilot Survey of Levels of Polychlorinated Dibenzo-p-dioxins, Polychlorinated Dibenzofurans, Polychlorinated Biphenyls, and Mercury in Rural Soils of the United States

In 2003, USEPA completed a national-scale pilot survey, described in their summary report released in 2007 (USEPA 2007). This survey was conducted primarily to obtain preliminary estimates of the levels of dioxins/furans, PCBs, and mercury in relatively undisturbed rural/remote soils of the United States. USEPA focused on these chemicals for a number of reasons including: their recalcitrance to environmental degradation, potential to bioaccumulate in plants and animal tissues, and the relatively few soil surveys of these compounds completed at the time of this pilot survey.

To meet their primary study objective, USEPA collected surface soil samples at 27 monitoring stations of the National Dioxin Air Monitoring Network (NDAMN; USEPA 2007). These stations were located in rural areas distributed widely across the continental United States and Alaska, and were therefore appropriate to address this study objective[4].

[4] The study also evaluated relationships between chemical levels in air and soil and relationships between chemical levels in soil and the organic carbon content of the soil; however, these components of the study are not discussed here.

At each of the 27 stations, USEPA established a 100-foot by 100-foot sampling grid as close to the air monitoring station as possible, with flat terrain and no visible evidence of soil disturbance. Five surface soil samples (0–15 cm below ground surface) were collected from each grid—four at each corner and one at the center. The five samples at each site were composited and analyzed for dioxins/furans, PCBs, and mercury. Dioxin/furan results of the composite samples were calculated assigning one-half the detection limits to non-detected congeners, and ranged from 0.21 pg/g TEQ to 11.4 pg/g TEQ. The mean of the 27 stations was **1.7 pg/g TEQ**. The dioxin/furan TEQs were calculated using outdated TEFs promulgated prior to the WHO re-evaluation of TEFs for dioxins performed in 2005 (Van den Berg et al. 2006). USEPA notes that the results pertain specifically to the 27 sites samples and should not be assumed statistically representative of all rural soils, but also states that the results may be an appropriate basis for preliminary characterization of soils in rural/remote areas as the surveyed sites cover a wide range of climates, geographic areas, terrains, and soil types.

In addition to the USEPA sample collection effort, USEPA also presented a literature review in their report, summarizing nine studies of rural areas in North America conducted between 1990 and 2005. These studies were conducted by a number of researchers and government agencies including WSDOE, the Connecticut Department of Environmental Protection, the British Columbia Environmental Protection Department, and an additional USEPA Study from 2001.

The nine studies were conducted in several different rural environments, including remote, open space (non-grazed), and non-commercial forest. The overall dioxin/furan TEQ concentration range across the studies was 0 to 57 pg/g TEQ (calculated assigning a value of zero to non-detected congeners and using now-outdated TEF values), with the majority of the results ranging between 0 and 22.9 pg/g TEQ. The mean TEQ concentrations across the studies ranged from **0.4** to **5.7 pg /g TEQ**. Both the overall and mean TEQ concentration ranges for these nine studies encompass the results found in USEPA's pilot survey.

2.2.3 Canadian Council Of Ministers of the Environment 2002 Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health—PCDD/Fs

The Canadian Council of Ministers of the Environment (Council) released a report titled *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health—Polychlorinated Dibenzo-p-Dioxin and Polychlorinated Dibenzofurans* (PCDD/Fs) on a number of topics related to dioxins/furans in 2002. As part of the document, a discussion is presented regarding background levels in the Canadian environment. Generally similar to the MTCA natural background definition, the Canadian report defined ambient background concentrations as dioxin/furan concentrations in soil that result mainly from aerial deposition and also cannot be attributed to point sources.

Three ambient background studies that evaluated dioxin/furan soil concentrations within a particular area were presented within the document. The first of these studies was an evaluation of dioxin/furan soil concentrations in rural parkland located in Ontario. This study reported a mean ambient background concentration of 1.7 pg/g TEQ. For this study, rural parkland included parks, cemeteries, schools, forests or woodlots, and most large undeveloped areas (Council 2002). The second was a study conducted in British Columbia where soils were generally collected from areas that were thought to not be affected by point sources of dioxins and believed to reflect ambient levels of dioxins/furans in the environment. This study reported a mean ambient background concentration of 5.0 pg/g TEQ. For the third study, soil samples were collected in Quebec in a semi-rural area surrounding, but not adjacent to, a PCB waste warehouse, a potential point-source of dioxins/furans. These samples were collected to contrast concentrations detected adjacent to the warehouse, to those in the semi-rural area surrounding the warehouse (ambient background). The mean ambient background concentration in this semi-rural area was determined to be 10.0 pg/g TEQ. It was stated in the report that the study performed in Quebec had TEQs calculated assigning a value of zero to non-detected congeners; however, there was no indication in the report of how non-detected congeners were treated for the Ontario or British Columbia studies. Additionally, the TEQs presented for these studies are based on now-outdated TEFs and could not be recalculated based on the data available in the report.

The conclusion in this report, based on these studies, was that the mean ambient background concentration of dioxins in Canadian soils is **4 pg/g TEQ.** While the Council considers these data to be appropriate to represent ambient background concentrations in Canadian soils and for background guideline derivation, they also note that the data may not be representative of the most rural areas of Canada, including the northern regions where few people reside.

2.3 DIOXINS/FURANS BACKGROUND IN PUGET SOUND SEDIMENT

2.3.1 DMMP Bold Sediment Survey

In summer 2008, the Dredged Material Management Program (DMMP) agencies (comprised of the U.S. Army Corp of Engineers [USACE], USEPA, WSDOE, and Washington State Department of Natural Resources [WDNR]) characterized the natural background in Puget Sound of several chemicals, including dioxins/furans, by collecting marine sediment data from areas within the Puget Sound not expected to be affected by localized human activities. These data represent non-urban, non-localized concentrations that exist as a result of the large-scale distribution of chemicals from anthropogenic sources.

This sampling effort, known as the USEPA *Ocean Survey Vessel (OSV) Bold Survey* (USEPA 2008b) involved the collection of surface sediment samples from 70 sampling locations throughout Puget Sound as well as the waters surrounding the San Juan Islands and the Strait of Juan de Fuca. 20 of these sample locations were located within 4 reference areas (Carr Inlet, Samish Bay, Holmes Harbor, and Dabob Bay) established by WSDOE. The remaining 50 sampling locations were distributed widely and were intended to represent areas outside the influence of urban bays and known point sources.

Of the 75 surface sediment samples collected (70 primary samples and 5 duplicate samples), at least 1 dioxin/furan congener was reported in 73 of the samples. The most commonly detected congeners were 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD) and 1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin (OCDD), which were reported in 62 and 72 of the samples, respectively. Concentrations ranged from 0.2 to 11.6 pg/g dry weight (dw) TEQ, with a mean of **1.4 pg/g TEQ** (calculated assigning one-half the reporting limits to non-detected congeners and using the 2005 WHO TEFs) and a 90th percentile of **2.7 pg/g TEQ.**

In 2010, the DMMP issued interim dioxin guidelines for the disposal of dredged materials in unconfined, open-water sites in Puget Sound. In addition to reducing risk to the environment, the guidelines were meant to “ensure that sediment dioxin concentrations at disposal sites reflect non-urban background in order to be consistent with…Sediment Management Standards”. The guidance included a dispersal site management objective of **4 pg/g TEQ**, based on the nonparametric estimation of the 90 percent upper confidence limit for the 90th percentile of the background Puget Sound dataset (rounded to the nearest whole digit).

This page intentionally left blank.

3.0 Summary

The mean dioxin/furan rural concentrations reported in all of the soil studies described in Section 2 range from **0.4 pg/g TEQ to 10.0 pg/g TEQ**. These reported dioxin/furan TEQ concentrations used differing TEF values, based on when they were calculated, and are not consistent in their treatment of non-detected dioxin/furan congeners (some concentrations set non-detected values equal to zero while others set non-detected values equal to one-half the detection limit). Concentrations with non-detected values set equal to zero would be biased low. It is unclear how differing TEF values would affect the TEQ values, as the calculations are dependent on the concentrations of the congeners in specific samples.

WSDOE identified a Washington State natural/rural background dioxin/furan concentration of **5.2 pg/g TEQ** and an urban background dioxin/furan concentration of **9.9 pg/g TEQ** in 2010 (WSDOE 2010). The background concentrations were calculated using data obtained from WSDOE's 1999 *Screening Survey for Metals and Dioxins in Fertilizer Products and Soil in Washington State* (WSDOE 1999). These background concentrations were calculated with non-detect congeners set equal to one-half the detection level, used the current 2005 WHO TEF values, and is based on the 90th percentile of the lognormally distributed dataset following WAC 173-340-709(c).

Urban background mean concentrations reported in the soil studies described in Section 2.0 ranged from **4.1 to 19 pg/g TEQ**. Again, these background concentrations represent TEQs based on differing TEF values and differences in the treatment of non-detected congeners. The highest mean concentration of 19 pg/g TEQ comes from the recent WSDOE Seattle Urban Soil Study (WSDOE 2011), where the TEQ values were calculated with non-detect congeners set equal to one-half the detection level and used the current 2005 TEF values. The urban background dioxin/furan concentrations from the soil studies calculated as the 90th percentile of each dataset range from **9.9 to 46 pg/g TEQ**, and were calculated by setting non-detect congeners equal to one-half the detection limit, using current 2005 TEF values.

In multiple locations along the Lora Lake Apartments Parcel property boundaries, the dioxin/furan TEQ concentrations in the shallow soil are within the typical range of urban background, as described above. Dioxins/furans at this level are attributable to several different sources in an urban environment.

This page intentionally left blank.

4.0 References

Agency for Toxic Substances & Disease Registry (ATSDR). 1998. *Toxicological Profile for Chlorinated Dibenzo-p-dioxins (CDDs).* U.S. Department of Health and Human Services, http://www.atsdr.cdc.gov/ToxProfiles/tp104.pdf. December.

Bradley, Dave. Department of Ecology Technical Memorandum #8 re: Natural Background for dioxins/furans in WA soils. 28 April.

Canadian Council of Ministers of the Environment (Council). 2002. *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans (PCDD/Fs)*.

International Agency for Research on Cancer (IARC). 1997. World Health Organization. *Monographs database: Polychlorinated Dibenzo-para-Dioxins*, htttp://www.iarc.fr. and htttp://193.51.164.11/htdocs/monographs/Vol69/dioxin.html.

U. S. Environmental Protection Agency (USEPA). 2003. *Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Part I: Estimating Exposure to Dioxin-Like Compounds*. EPA/600/p-00/001Cb.

———. 2007. *Pilot Survey of Levels of Polychlorinated Dibenzo-p-dioxins, Polychlorinated Dibenzofurans, Polychlorinated Biphenyls, and Mercury in Rural Soils of the United States*. EPA/600/R-05/048F. April.

———. 2008a. Office of the Science Advisor, Risk Assessment Forum. *Framework for Application of the Toxicity Equivalence Methodology for Polychlorinated Dioxins, Furans, and Biphenyls in Ecological Risk Assessment*, EPA 100/R-08/004. June.

———. 2008b. OSV Bold Survey Report: Puget Sound Sediment PCB and Dioxin 2008 Survey. July 31 to August 6, 2008.

———. 2011. *Persistent Bioaccumulative and Toxic Chemical Program: Dioxins and Furans*. Accessed April 18. http://www.epa.gov/pbt/pubs/dioxins.htm.

van den Berg, M., L.S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson. 2006. "The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds." Toxicological Sciences 93(2): 223-241. New York, New York: Oxford University Press on behalf of the Society of Toxicology.

Washington State Department of Ecology (WSDOE). 1999. *Final Report: Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State*. Ecology Publication No. 99-309. April.

———. 2007a. *Concise Explanatory Statement and Responsiveness Summary for the Amendment of Chapter 173-340 WAC, Model Toxics Control Act Cleanup Regulation.* 10 October.

———.2007b. *Model Toxics Control Act Chapter 70.105D RCW.* Publication No. 94-06. Revised November.

———. 2010. Toxics Cleanup Program. *Natural Background for Dioxins/Furans in WA Soils. Technical Memorandum #8.* From Dave Bradley. 9 August.

———. 2011. *Urban Seattle Area Soil Dioxin and PAH concentrations Initial Summary Report*. Publication no. 11-09-049. September.

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix M
Review of Regional, National, and International Background Studies for Dioxins/Furans in Soils

Tables

FINAL

Table M.1
Toxic Equivalency Factors for Chlorinated Dibenzo-p-dioxin and Chlorinated Dibenzofuran Congeners[1]

CAS Number	Congener	TEF (unitless)
Dioxin Congeners (CDDs)		
1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	1
40321-76-4	1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PeCDD)	1
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)	0.1
57653-85-7	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)	0.1
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)	0.1
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)	0.01
3268-87-9	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin (1,2,3,4,6,7,8,9-OCDD)	0.0003
Furan Congeners (CDFs)		
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	0.1
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PeCDF)	0.03
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8- PeCDF)	0.3
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)	0.1
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8- HxCDF)	0.1
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9- HxCDF)	0.1
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)	0.1
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)	0.01
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)	0.01
39001-02-0	1,2,3,4,6,7,8,9-Octachlorodibenzofuran (1,2,3,4,6,7,8,9-OCDF)	0.0003

Note:
1 2005 World Health Organization Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds (van den Berg et al. 2006).

Abbreviations:
CDD Chlorinated dibenzo-p-dioxin
CDF Chlorinated dibenzofuran
TEF Toxic equivalency factor

Table M.2
Regional, National, and International Background Studies for Dioxins/Furans in Soil

Land Use	Study	Study Description	Year	Number of Samples	Mean TEQ (pg/g)	Median TEQ (pg/g)	Background TEQ (pg/g) [1]	Treatment of Non-detected Congeners	Notes
Rural	WSDOE, Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State	WSDOE sampled soils in numerous locations throughout Washington State to define typical concentrations of dioxins/ furans in soils.	1999	16	1.7	0.8	2.2	Non-detected con-geners set equal to zero.	Samples a combination of forested and open areas. WSDOE's 1999 natural background TEQ is based on four times the 50th percentile
	USEPA, Exposure and Human Health Reassessment of 2,3,7,8-TCDD and Related Compounds	The objectives of this study were to identify known dioxin/furan sources, better understand dioxins/furans in the environment (including background dioxin/furan levels), and provide procedures for evaluating dioxin/furan exposure risks.	2003	319	2.6	--	--	Non-detected con-geners set equal to zero.	Uses soil multiple studies from 1985
	USEPA, Pilot Survey of Levels of PCDDs, PCDFs, PCBs, and Mercury in Rural Soils of the United States	This report provides a national-scale pilot survey of the levels of the following chemicals in rural/remote soils of the United States: chlorinated dibenzo-*p*-dioxins (CDDs), chlorinated dibenzofurans (CDFs), polychlorinated biphenyls (PCBs), and mercury. The survey was completed in 2003.	2007	27	1.7	--	--	Non-detected con-geners set equal to one-half the detection limit.	Samples from 27 National Dioxin Air Monitoring Network Stations.
		In addition to the pilot survey, USEPA did a literature review on background concentrations of dioxins/furans in rural United States. The studies were performed between 1985–2000. It is important to note that these TEQ values use the older TEFs before the TEFs were updated in 2005. The literature review also included the 1999 WSDOE study referenced above.		30	0.4	--	--	Non-detected con-geners set equal to zero.	Rural—Ontario, Canada and U.S. Midwest.
				53	5	--	--		Background—British Columbia.
				36	3.1	--	--		Rural—Southern Mississippi.
				3	1.4	--	--		Rural Background—Columbus, Ohio.
				34	5.74	--	--		Rural Background—Connecticut.
				36	1.6	--	--		Open Space Background—Colorado.
	WSDOE, Natural Background for Dioxins/Furans in Washington Soils—Technical Memorandum #8	A new natural background TEQ value was calculated by WSDOE using data from their 1999 study of dioxins/furan in soil based on changes made to MTCA in 2007. MTCA revisions required the use of updated TEFs. Additionally, WAC 173-340-709(5)(a) specified that non-detected values be assigned a value equal to one-half of the detection limit.	2010	16	2.5	1.9	5.2	Non-detected con-geners set equal to one-half the detection limit.	Samples a combination of forested and open areas. WSDOE's 2010 natural background TEQ is based on the upper 90th percentile. For the TEQ calculations, the method detection limits were substituted if the lab detection limits were greater than the method detection limits.

Land Use	Study	Study Description	Year	Number of Samples	Mean TEQ (pg/g)	Median TEQ (pg/g)	Background TEQ (pg/g)[1]	Treatment of Non-detected Congeners	Notes
Rural (cont'd)	Canadian Council of Ministers of the Environment (CCME), Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Polychlorinated Dioxins and Furans (PCDD/Fs)	Canadian soil quality guidelines for PCDD/Fs for the protection of environmental and human health. This report provides a final soil quality guideline for dioxins and furans that is based on the mean ambient background concentration for Canadian soils and includes dioxin/furan data from three Canadian studies evaluating ambient soil background levels.	2002	74	1.7	--	--	Not included in this report for the Ontario and British Columbia Studies. Non-detected congeners set equal to one-half the detection limit for the Quebec Study.	Ontario Study.
				53	5.0	--	--		British Columbia Study.
				57	10	--	--		Quebec Study.
				--	--	--	4		Mean Ambient Background concentration in Canadian soils.
Urban	WSDOE, Screening Survey for Metals and Dioxins in Fertilizer Products and Soils in Washington State	Refer to study description above.	1999	14	4.1	1.7	7.7	Non-detected congeners set equal to zero.	WSDOE's 1999 urban background TEQ is based on four times the 50th percentile.
	USEPA, Exposure and Human Health Reassessment of 2,3,7,8-TCDD and Related Compounds	Refer to study description above.	2003	305	8.8	--	--	Non-detected congeners set equal to zero.	Uses soil multiple studies from 1985–2000.
	WSDOE, Natural Background for Dioxins/Furans in Washington Soils—Technical Memorandum #8	Refer to study description above.	2010	14	4.2	2.0	9.9	Non-detected congeners set equal to one-half the detection limit.	WSDOE's 2010 urban background TEQ is based on the upper 90th percentile. For the TEQ calculations, the method detection limits were substituted if the lab detection limits were greater than the method detection limits.
	WSDOE, Urban Seattle Area Soil Dioxin and PAH Concentrations Initial Summary Report	The purpose of this investigation was to collect sufficient data from various Seattle neighborhoods to determine the range and magnitude of concentrations and TEQs of dioxins/furans in urban areas.	2011	120	19	12	46	Non-detected congeners set equal to one-half the detection limit.	Areas include Ballard, Capitol Hill, Georgetown, Ravenna, South Park, and West Seattle.
		Subset of study data from South Park neighborhood.		20	12	12	19		Selection of South Park neighborhood based on spatial proximity to the Site and similarity to neighborhood land use.
		Subset of study data from West Seattle neighborhood.		20	7.5	4.5	13		Selection of West Seattle neighborhood based on spatial proximity to the Site and similarity to neighborhood land use.

Notes:
-- Not available.
1 Background is the upper 90th percentile (for lognormally distributed datasets) and the 80th percentile (for normally distributed datasets) or four times the 50th percentile, whichever is lower (WAC 173-340-709(3)(c) and (d)).

Abbreviations:

2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
MTCA	Model Toxics Control Act
PAH	Polyaromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCDF	Polychlorinated dibenzofurans
pg/g	Picograms per gram
Site	Lora Lake Apartments Site
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient
USEPA	U.S. Environmental Protection Agency
WAC	Washington Administrative Code
WSDOE	Washington State Department of Ecology

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix N
Contaminant Mass Calculations

FINAL

Table of Contents

List of Tables

List of Figures

List of Abbreviations/Acronyms

Abbreviation/ Acronym	Definition
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
bgs	Below ground surface
COC	Contaminant of concern
cPAH	Carcinogenic polycyclic aromatic hydrocarbons
MTCA	Model Toxics Control Act
PCP	Pentachlorophenol
RI/FS	Remedial Investigation/Feasibility Study
Site	Lora Lake Apartments Site
TEQ	Toxic equivalency quotient
WSDOE	Washington State Department of Ecology

This page left intentionally blank.

Appendix N
Contaminant Mass Calculations

This appendix presents the results of an analysis of the mass and volume of contamination present on the Lora Lake Apartments Site (Site). This analysis was conducted as part of the Lora Lake Apartments Remedial Investigation/Feasibility Study to comply with the requirements set forth in the Agreed Order No. DE 6703, Section VII.J. The objective of this analysis is to estimate the total mass of the contaminants of concern (COCs) present on the Site at concentrations greater than the established cleanup levels, as well as the volume of material contaminated by those COCs. The masses of contaminants and volumes of contaminated media were calculated for all relevant soil depth intervals.

For this analysis, the mass of contaminants was calculated in soil only, since the mass of contaminants present in groundwater and sediment is minor compared to the mass present in site soil. In groundwater, contamination concentrations are consistently greater than cleanup levels exclusively in one monitoring well, MW-1, located within the Central Source Area. The maximum concentration of the most commonly detected contaminant, dioxins/furans, is orders of magnitude less than soil concentrations, at a concentration of 38.3 pg/L (parts per trillion) toxic equivalency quotient (TEQ). In sediment, contamination in Lora Lake is limited to the 0 to 15 cm surface interval. Dioxins/furans are detected at the highest concentrations, with a lake-wide average of 178 pg/g TEQ. This concentration, combined with the volume of impacted lake sediment, results in an approximate mass of dioxins/furans in Lora Lake sediments that is insignificant when compared to the dioxin/furan mass present in soil.

Three site soil COCs were selected for this analysis to be representative of site COCs and contamination extent: pentachlorophenol (PCP), carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and dioxins/furans. A number of assumptions were made in the development of the calculation approach, which are presented below with the formula used to calculate the contaminant mass.

The formula used to calculate the total COC mass is as follows:

$$\text{Area} \times \text{Depth} \times \text{CF1} \times \text{Density} \times \text{Concentration} \times \text{CF2} = \text{Total Mass}$$

Where:

Area = Contaminated area (feet^2)
Depth = Contaminated area depth (feet)
CF1 (Conversion Factor) = 28.3 L /1 feet^3
Density = Model Toxics Control Act (MTCA) default dry soil bulk density of 1.5 kg/L (WAC 173-340-747 Equation 747-1)
Concentration = Average concentration of COC within area (µg/kg)
CF2 (Conversion Factor) = 1kg/1 × 10^9 µg
Total Mass = Mass of COC (kg)

- The delineation of areas within each depth interval was based on locations of samples with similar contaminant concentrations (generally within the same order of magnitude). This delineation avoids biasing the average concentrations calculated for each area either high or low due to concentration outliers.
- The horizontal extent of each area where contaminant concentrations were within the same order of magnitude was determined based on the locations of clean samples—the boundaries of each area were conservatively drawn to encompass all contaminated samples plus half of the distance to the nearest clean sample.
- The derivation of the depth intervals used in determining volume of contaminated material was generally based on the depths of the collected samples, with the vertical extent established either at the top depth of the next available sample, or at the mid-point of the depths separating contaminated and clean samples.
  - For example, the top two depth intervals used in the calculations (0–1 foot below ground surface [bgs] and 1–2 feet bgs) were established to include the samples collected within these intervals, primarily at depths of 0–0.5 foot bgs and 1.5–2 feet bgs. In several cases, borings where contamination was detected in samples at 0–0.5 foot bgs had a clean sample collected below at 1.5–2 feet bgs. As no information was available regarding the presence of contamination between 0.5 foot bgs and 1.5 feet bgs, the intervals 0--foot bgs and 1–2 feet bgs were established assuming contamination in the top interval extended to 1 foot bgs, and the second interval then encompassed material below 1 foot bgs to 2 feet bgs.
  - Depth intervals 2–4 feet bgs, 4–6 feet bgs, 6–10 feet bgs, 10–16 feet bgs (cPAHs), and 10–20 feet bgs (dioxins/furans) were established in a similar manner to the top two intervals.
- Where the vertical extent of contamination was not able to be determined based on the presence of a clean sample collected from the same soil boring, adjacent or nearby borings were used to assume the vertical extent of contamination at the location.
  - For example, in the cPAH analysis, identification of the lower depth of the 10—15 feet bgs interval in Area 4 was based on a clean sample located adjacent to the two contaminated samples at a depth of 14-16 feet bgs. The deepest contaminated samples in this area were located at depths of 14 and 14.5 feet bgs; therefore, the interval limit was established at 16 feet bgs based on the adjacent boring.
- Dioxin/furan and cPAH TEQ average concentrations were used to calculate the total dioxin/furan and cPAH mass at the Site. The TEQ represents a sum normalized to the toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) or benzo(a)pyrene, respectively. These TEQs therefore

represent the mass TEQs of 2,3,7,8-TCDD or benzo(a)pyrene. Thus, while the contaminant mass of each individual dioxin/furan congener or cPAH was not evaluated, the masses presented in these calculations represent the effective toxic mass at the Site.

- The mass calculations presented for dioxins/furans TEQ in this appendix were calculated using the dioxins/furans TEQ cleanup level of 11 pg/g. These calculations were made prior to the revision of the dioxins/furans TEQ cleanup level from 11 pg/g to 13 pg/g; however, this modification to the cleanup level is not expected to have a measurable effect on the mass calculation results.

Table N.1 presents the total contaminant mass calculations and Table N.2 provides a summary of the mass calculation results. Figures N.1 through N.8 present the areas used to calculate the contaminant mass for each soil depth interval.

The total mass of each contaminant calculated for the Site is presented below:

- PCP—4.9 kg
- cPAH TEQ—0.88 kg
- Dioxins/Furans TEQ—0.031 kg

The approximate volumes of contaminated soil are presented below:

- PCP-contaminated Soil—480 cubic yards
- cPAH TEQ-contaminated Soil—1,800 cubic yards
- Dioxins/Furans TEQ-contaminated Soil—40,000 cubic yards

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix N
Contaminant Mass Calculations

Tables

FINAL

Table N.1
Total Contaminant Mass Calculations

Analyte	Samples that Exceed Site CUL in Contaminated Area	Depth of Exceeding Samples	Square Footage of Contaminated Area	Depth of Contaminated Area (feet bgs)	Depth of Contaminated Area (ft)	Soil Volume of Contaminated Area (cubic ft)	Kilograms of Soil in Contaminated Area	Average Concentration of COC in Contaminated Area (µg/kg)	Total Mass of COC (kg)	Soil Volume of Contaminated Area (cubic yards)	Contaminated Area Depth Interval Rationale
Pentachlorophenol											
Depth Interval: 0–0.5 foot bgs											
Area 1	MW-4, MW-5	0–0.5	13,056	0–1	1	13056	554,618.88	8,850	4.91E+00	484	Clean samples bound at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
								Totals	***4.91E+00***	***484***	
Carcinogenic Polycyclic Aromatic Hydrocarbons TEQ											
Depth Interval: 0–0.5 foot bgs											
Area 1	MW-5, PSB-20	0–0.5	1,536	0–1	1	1536	65,249.28	295	1.92E-02	57	Clean samples bound at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 2	MW-4	0–0.5	1,047	0–1	1	1047	44,476.56	150	6.67E-03	39	Clean samples bound at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
								Totals	***2.59E-02***	***9.57E+01***	
Depth Interval: 2–4 feet bgs											
Area 3	LL-08	2–4	1,847	1–4	3	5541	235,381.68	160	3.77E-02	205	Clean sample starting at 4.0 feet bgs in PSB11, adjacent to LL08.
Area 4	PSB-11	1.5–4	3,345	1–4	3	10035	426,286.80	145	6.18E-02	372	Clean sample below starting at 4.0 feet bgs.
								Totals	***9.95E-02***	***5.77E+02***	
Depth Interval: 10–16 feet bgs											
Area 1	MW-5	11.5–13	1,536	10–16	6	9216	391,495.68	140	5.48E-02	341	Clean sample above MW-5 has an bottom depth of 8.0 feet bgs. Upper depth of the excavation range splits the difference between the two samples. For MW-5, no sample was collected below 13.0 feet bgs; however, a clean sample collected in the nearby source area, PSB-11, has a bottom depth of 16.0 feet bgs, therefore this depth is used as the bottom depth of the interval.
Area 4	LLP-04, MW-1	14–14.5	3,345	10–16	6	20070	852,573.60	820	6.99E-01	743	Clean sample was collected to 13.0 feet bgs at adjacent soil bore PSB-11. Upper depth of the excavation range splits the difference between the two samples. For MW1 or LLP-04, no sample was collected below 15.5 feet bgs; however, clean samples were collected at 15.5 feet bgs at adjacent soil bore LLP-05 and at 14–16 feet bgs at adjacent soil bore PSB-11, therefore to be conservative the lower depth of the range is 16.0 feet bgs.
								Totals	***7.54E-01***	***1.08E+03***	
Dioxin/Furan TEQ[1]											
Depth Interval: 0–0.5 feet bgs											
Lora Lake Apartments Parcel											
Area 1	PSB-03, MW-2	0–0.5	10,826	0–1	1	10826	459,888.48	4.45E-02	2.04E-05	401	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 2	SSB-02	0–0.5	8,098	0–1	1	8098	344,003.04	1.15E-02	3.96E-06	300	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 3	PSB-04, LL-12	0–0.5	51,274	0–1	1	51274	2,178,119.52	2.14E-01	4.66E-04	1,899	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 4	PSB-06, PSB-09A, LL-11	0–0.5	24,255	0–1	1	24255	1,030,352.40	5.50E-02	5.66E-05	898	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 5	LL-10, PSB-10, PSB-27	0–0.5	6,735	0–1	1	6735	286,102.80	3.03E-01	8.68E-05	249	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 6	LL-01, PSB-11	0–0.5	9,762	0–1	1	9762	414,689.76	2.76E-01	1.15E-04	362	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 7	PSB-15, MW-4, MW-5	0–0.5	13,056	0–1	1	13056	554,618.88	2.64E+00	1.47E-03	484	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 8	MW-13, PSB-24	0–0.5	3,683	0–1	1	3683	156,453.84	2.14E-02	3.35E-06	136	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 9	LL-HA3, LL-HA2, PSB-18, PSB-19, PSB-16, PSB-20, PSB-21, MW-12, PSB-13, PSB-14	0–0.5	54,651	0–1	1	54651	2,321,574.48	8.95E-02	2.08E-04	2,024	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
								Totals	***2.43E-03***	***6.75E+03***	
Lora Lake Parcel											
Area 10	LL-SB2	0–0.5	4,497	0–1	1	4497	191,032.56	1.32E-02	2.52E-06	167	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
Area 11	LL-SB4, LL-SB6, LL-SB5	0–0.5	13,491	0–1	1	13491	573,097.68	4.04E-02	2.32E-05	500	Next interval begins at 1.5 feet bgs, assume contamination extends to 1.0 foot bgs.
								Totals	***2.57E-05***	***6.66E+02***	
Dioxin/Furan TEQ (continued)											
Depth Interval: 0.5–2 feet bgs											
Lora Lake Apartments Parcel											
Area 1	LL-07, PSB-02, SSB-02	0.5–2	16,689	1–2	1	16689	708,948.72	2.35E-02	1.67E-05	618	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.
Area 2	LL-08, PSB-06	0.5–2	16,607	1–2	1	16607	705,465.36	3.73E-01	2.63E-04	615	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.
Area 3	PSB-05	0.5–2	14,919	1–2	1	14919	633,759.12	1.28E-02	8.11E-06	553	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.

Table N.1
Total Contaminant Mass Calculations

Analyte	Samples that Exceed Site CUL in Contaminated Area	Depth of Exceeding Samples	Square Footage of Contaminated Area	Depth of Contaminated Area (feet bgs)	Depth of Contaminated Area (ft)	Soil Volume of Contaminated Area (cubic ft)	Kilograms of Soil in Contaminated Area	Average Concentration of COC in Contaminated Area (µg/kg)	Total Mass of COC (kg)	Soil Volume of Contaminated Area (cubic yards)	Contaminated Area Depth Interval Rationale
Area 4	MW-4, MW-5, MW-12, MW-13, PSB-12, PSB-13, PSB-14, PSB-15, PSB-16, PSB-19	0.5–2	69,980	1–2	1	69980	2,972,750.40	3.76E-02	1.12E-04	2,592	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.
Area 5	LL-01, PSB-11	0.5–2	9,762	1–2	1	9762	414,689.76	1.15E+01	4.77E-03	362	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.
Area 6	LL-10, PSB-10, PSB-27	0.5–2	6,735	1–2	1	6735	286,102.80	1.55E+00	4.44E-04	249	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.
								Totals	***5.61E-03***	***4.99E+03***	
Lora Lake Parcel											
Area 7	LL-SB5, LL-SB6	0.5–2	9,020	1–2	1	9020	383,169.60	9.19E-03	3.52E-06	334	Previous interval to 1.0 foot bgs, next interval starts at 2.0 feet bgs.
								Totals	***3.52E-06***	***3.34E+02***	
Depth Interval: 2–4 feet bgs											
Lora Lake Apartments Parcel											
Area 1	LL-08	2–4	3,191	2–4	2	6382	271,107.36	6.50E-01	1.76E-04	236	Previous interval to 2.0 feet bgs, next interval starts at 4.0 feet bgs.
Area 2	PSB-10	2–4	1,888	2–4	2	3776	160,404.48	8.03E-01	1.29E-04	140	Previous interval to 2.0 feet bgs, next interval starts at 4.0 feet bgs.
Area 3	PSB-11	2–4	9,762	2–4	2	19524	829,379.52	1.17E+01	9.70E-03	723	Previous interval to 2.0 feet bgs, next interval starts at 4.0 feet bgs.
Area 4	MW-12, PSB-12, PSB-13, PSB-14, PSB-15, PSB-16, PSB-21	2–4	54,796	2–4	2	109592	4,655,468.16	2.94E-02	1.37E-04	4,059	Previous interval to 2.0 feet bgs, next interval starts at 4.0 feet bgs.
								Totals	***1.01E-02***	***5.16E+03***	
Lora Lake Parcel											
Area 5	LL-SB5	2–4	4,737	2–4	2	9474	402,455.52	2.27E-02	9.14E-06	351	Previous interval to 2.0 feet bgs, next interval starts at 4.0 feet bgs.
								Totals	***9.14E-06***	***3.51E+02***	
Depth Interval: 4–6 feet bgs											
Area 1	PSB-11	4–6	9,762	4–6	2	19524	829,379.52	2.49E+00	2.07E-03	723	Previous interval to 4.0 feet bgs, next interval starts at 6 feet bgs.
Area 2	PSB-10, PSB-12, PSB-13, PSB-14, PSB-15, PSB-16	4–6	49,212	4–6	2	98424	4,181,051.52	1.52E-01	6.35E-04	3,645	Previous interval to 4.0 feet bgs, next interval starts at 6 feet bgs.
								Totals	***2.70E-03***	***4.37E+03***	
Depth Interval: 6–10 feet bgs											
Area 1	PSB-11, MW-1	7.5–9.5	9,762	6–10	4	39048	1,658,759.04	1.78E+00	2.95E-03	1,446	Previous interval to 6.0 feet bgs, next interval starts at 10.0 feet bgs.
Area 2	MW-5, PSB-10, PSB-12, PSB-14	6.5–10	32,218	6–10	4	128872	5,474,482.56	1.94E-01	1.06E-03	4,773	Previous interval to 6.0 feet bgs, next interval starts at 10.0 feet bgs.
Area 3	MW-4	9–10.5	3,712	6–10	4	14848	630,743.04	1.26E-01	7.95E-05	550	Previous interval to 6.0 feet bgs, next interval starts at 10.0 feet bgs.
								Totals	***4.09E-03***	***6.77E+03***	
Depth Interval: 10–20 feet bgs											
Area 1	PSB-11, MW-1	11–16	9,762	10–15	10	97620	4,146,897.60	1.38E+00	5.74E-03	3,616	Upper depth is halfway to next sample (next sample will be included in a separate excavation interval). Lower depth is deepest sample depth plus 3 ft to be conservative, below point of compliance.
Area 2	MW5, PSB12, PSB14, PSB15	11.5–17	20,108	10–15	10	201080	8,541,878.40	7.47E-02	6.38E-04	7,447	Upper depth is halfway to next sample (next sample will be included in a separate excavation interval). Lower depth is deepest sample depth plus 3 ft to be conservative, below point of compliance.
								Totals	***6.38E-03***	***1.11E+04***	

Note:

1 Mass calculations conducted prior to revision of dioxin/furan cleanup level. Modification to the cleanup level is not expected to have a measureable effect on analysis results.

Abbreviations:

bgs Below ground surface
COC Contaminant of concern
CUL Cleanup level
MTCA Model Toxics Control Act
TEQ Toxic equivalency quotient

Table N.2
Mass Calculation Results Summary

Analyte	Site-wide Contamination	Individual Parcel Contamination	Parcel Contamination per Depth Inteval 0 to 0.5 foot bgs	0.5 to 2.0 feet bgs	2.0 to 4.0 feet bgs	4.0 to 6.0 feet bgs	6.0 to 10.0 feet bgs	10.0 to 16.0 feet bgs	10.0 to 20.0 feet bgs
Lora Lake Apartments Parcel									
Pentachlorophenol									
PCP Mass Present (kg)	4.9	4.9	4.9	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of Total PCP Site-wide Mass	100%	100%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Volume of Contaminated Soil (CY)	480	480	480	0.0	0.0	0.0	0.0	0.0	0.0
Tonnage of Contaminated Soil (tons)	680	680	680	0.0	0.0	0.0	0.0	0.0	0.0
Carcinogenic Polycyclic Aromatic Hydrocarbons									
cPAH Mass Present (kg)	0.88	0.88	0.026	0.0	0.099	0.0	0.0	0.75	--
Percentage of Total cPAH Site-wide Mass	100%	100%	2.9%	0.0%	11%	0.0%	0.0%	86%	--
Volume of Contaminated Soil (CY)	1,800	1,800	96	0.0	580	0.0	0.0	1,100	--
Tonnage of Contaminated Soil (tons)	2,500	2,500	130	0.0	810	0.0	0.0	1,500	--
Dioxins/Furans									
Dioxin/Furan Mass Present (kg)	0.031	0.031	0.0020	0.0056	0.010	0.0027	0.0041	--	0.0064
Percentage of Total Dioxin/Furan Site-wide Mass	100%	99.9%	7.7%	18%	32%	8.6%	13%	--	20%
Volume of Contaminated Soil (CY)	40,000	39,000	6,800	5,000	5,200	4,400	6,800	--	11,000
Tonnage of Contaminated Soil (tons)	57,000	55,000	9,500	7,000	7,200	6,100	9,500	--	15,000
Lora Lake Parcel									
Pentachlorophenol									
PCP Mass Present (kg)	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of Total PCP Site-wide Mass	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Volume of Contaminated Soil (CY)	480	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tonnage of Contaminated Soil (tons)	680	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carcinogenic Polycyclic Aromatic Hydrocarbons									
cPAH Mass Present (kg)	0.88	0.0	0.00	0.0	0.0	0.0	0.0	0.0	--
Percentage of Total cPAH Site-wide Mass	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	--
Volume of Contaminated Soil (CY)	1,800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Tonnage of Contaminated Soil (tons)	2,500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Dioxins/Furans[2]									
Dioxin/Furan Mass Present (kg)	0.031	0.00004	0.000026	0.0000035	0.0000091	0.0	0.0	--	0.0
Percentage of Total Dioxin/Furan Site-wide Mass	100%	0.12%	0.082%	0.011%	0.029%	0.0%	0.0%	--	0.0%
Volume of Contaminated Soil (CY)	40,000	1,400	670	330	350	0.0	0.0	--	0.0
Tonnage of Contaminated Soil (tons)	56,000	1,900	930	470	490	0.0	0.0	--	0.0

Notes:

-- Mass not calculated for this interval
1 All values except percentages have been rounded to two significant figures
2 Mass calculations conducted prior to revision of dioxin/furan cleanup level. Modification to the cleanup level is not expected to have a measureable effect on analysis results.

Abbreviations:

bgs Below ground surface
cPAH Carcinogenic polycyclic aromatic hydrocarbon
PCP Pentachlorophenol
CY Cubic yards
kg

Port of Seattle
Lora Lake Apartments Site

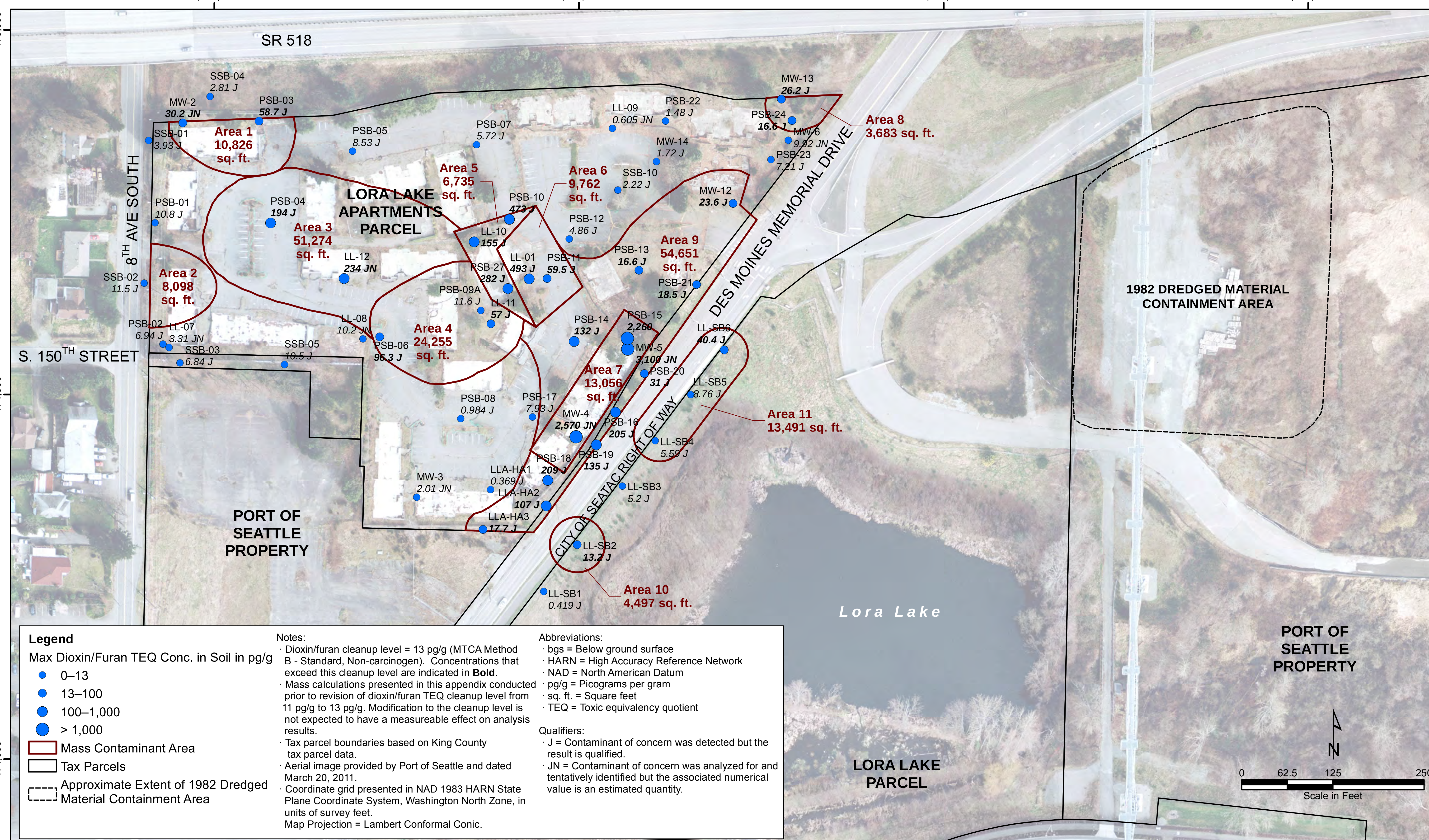
Remedial Investigation/ Feasibility Study

Volume II

Appendix N
Contaminant Mass Calculations

Figures

FINAL



Notes:
- Dioxin/furan cleanup level = 13 pg/g (MTCA Method B - Standard, Non-carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Mass calculations presented in this appendix conducted prior to revision of dioxin/furan TEQ cleanup level from 11 pg/g to 13 pg/g. Modification to the cleanup level is not expected to have a measureable effect on analysis results.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet.
  Map Projection = Lambert Conformal Conic.

Abbreviations:
- bgs = Below ground surface
- HARN = High Accuracy Reference Network
- NAD = North American Datum
- pg/g = Picograms per gram
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

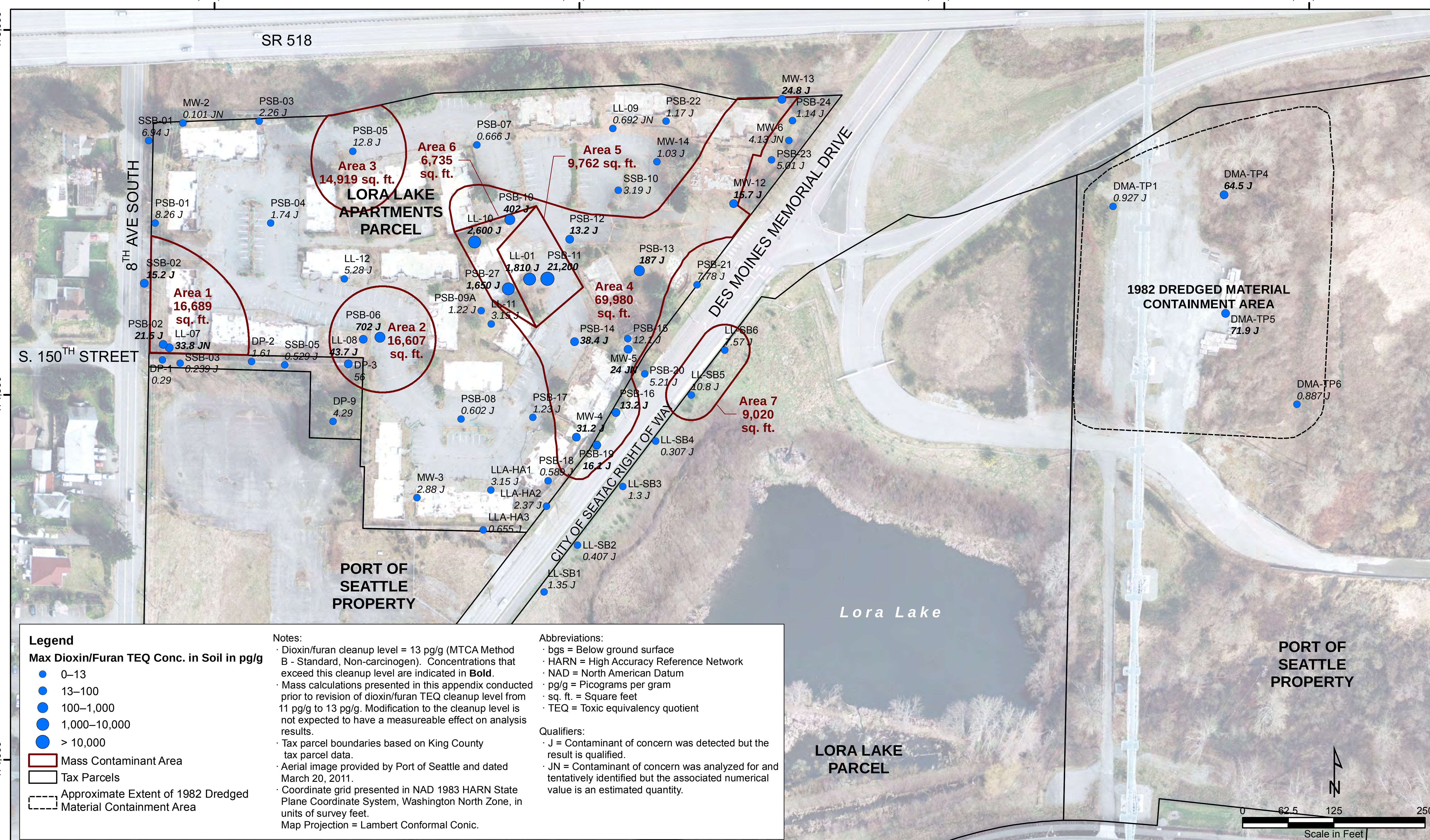
Qualifiers:
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.1
Dioxin/Furan TEQ Mass Calculations
0 to 0.5 foot bgs

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.1 DioxinFuran TEQ Mass Calculations 0-0.5ft bgs.mxd
12/12/2014



Legend

Max Dioxin/Furan TEQ Conc. in Soil in pg/g

- 0–13
- 13–100
- 100–1,000
- 1,000–10,000
- > 10,000
- Mass Contaminant Area
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:
- Dioxin/furan cleanup level = 13 pg/g (MTCA Method B - Standard, Non-carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Mass calculations presented in this appendix conducted prior to revision of dioxin/furan TEQ cleanup level from 11 pg/g to 13 pg/g. Modification to the cleanup level is not expected to have a measureable effect on analysis results.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet. Map Projection = Lambert Conformal Conic.

Abbreviations:
- bgs = Below ground surface
- HARN = High Accuracy Reference Network
- NAD = North American Datum
- pg/g = Picograms per gram
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

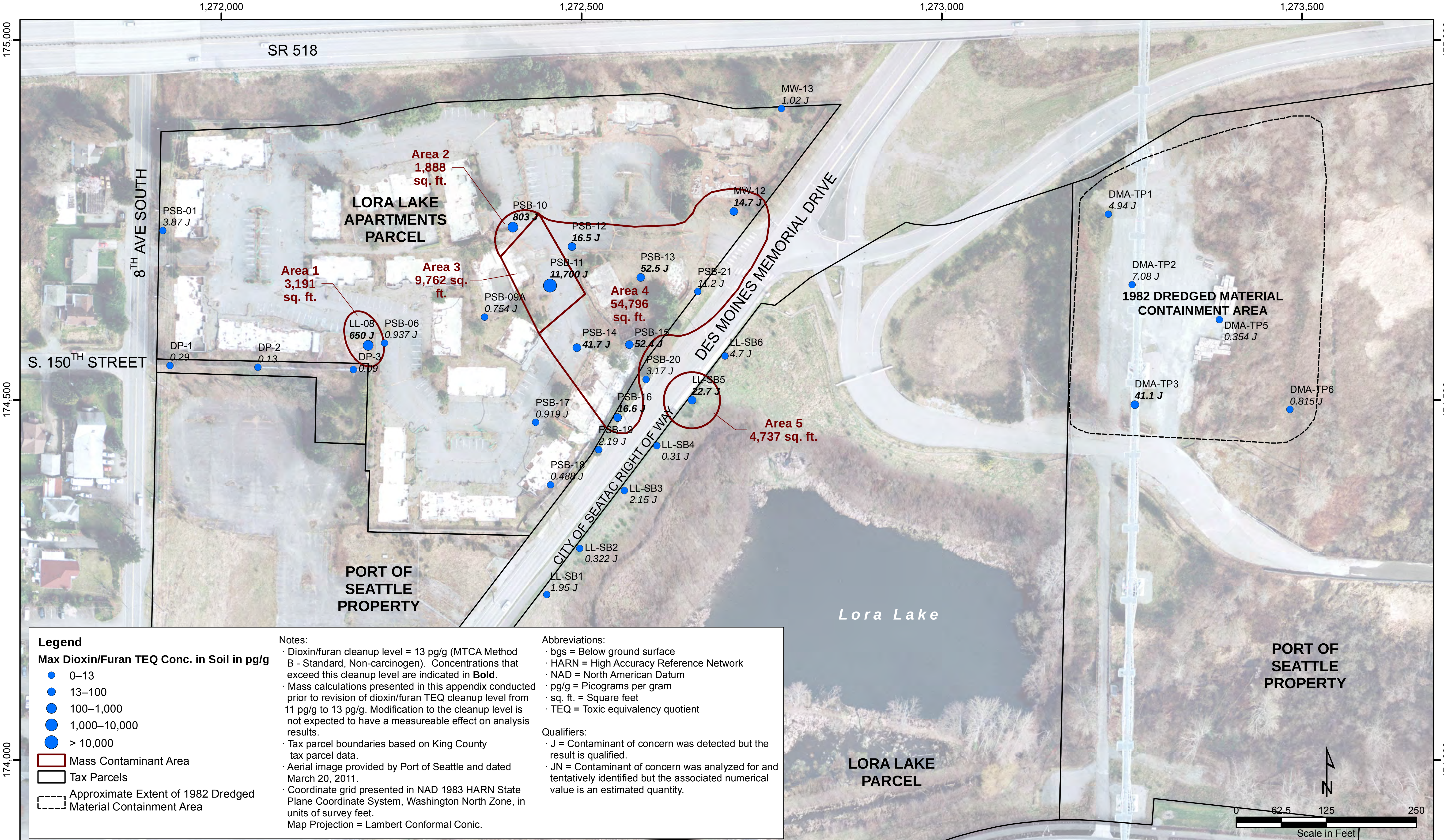
Qualifiers:
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.2
Dioxin/Furan TEQ Mass Calculations
0.5 to 2 feet bgs

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.2 DioxinFuran TEQ Mass Calculations 0.5-2.0 ft bgs.mxd
12/12/2014



Legend

Max Dioxin/Furan TEQ Conc. in Soil in pg/g

- 0–13
- 13–100
- 100–1,000
- 1,000–10,000
- > 10,000
- Mass Contaminant Area
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:

- Dioxin/furan cleanup level = 13 pg/g (MTCA Method B - Standard, Non-carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Mass calculations presented in this appendix conducted prior to revision of dioxin/furan TEQ cleanup level from 11 pg/g to 13 pg/g. Modification to the cleanup level is not expected to have a measureable effect on analysis results.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet. Map Projection = Lambert Conformal Conic.

Abbreviations:

- bgs = Below ground surface
- HARN = High Accuracy Reference Network
- NAD = North American Datum
- pg/g = Picograms per gram
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

Qualifiers:

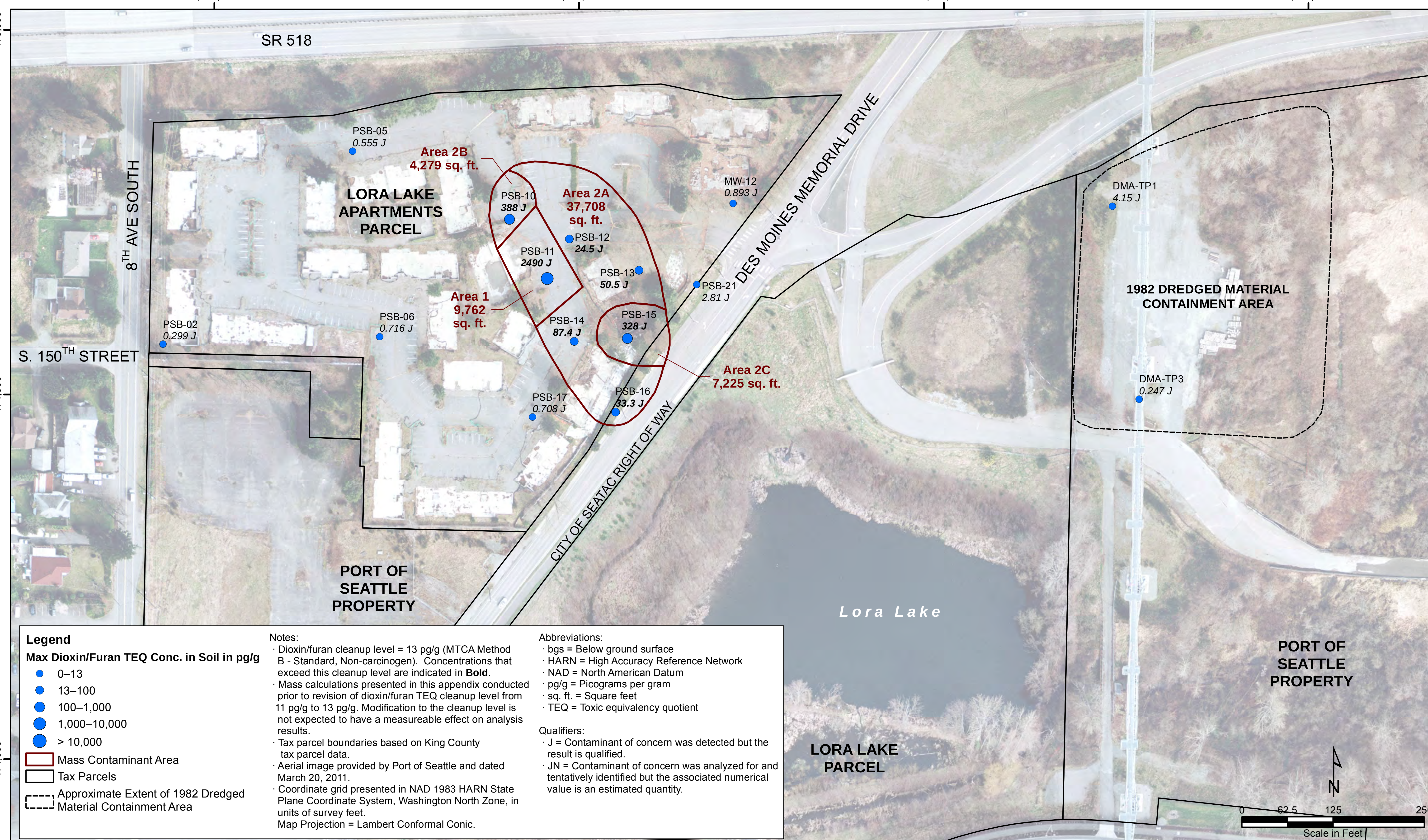
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.3
Dioxin/Furan TEQ Mass Calculations
2 to 4 feet bgs

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.3 DioxinFuran TEQ Mass Calculations 2-4 ft bgs.mxd
12/12/2014



Legend

Max Dioxin/Furan TEQ Conc. in Soil in pg/g

- 0–13
- 13–100
- 100–1,000
- 1,000–10,000
- > 10,000
- Mass Contaminant Area
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:

- Dioxin/furan cleanup level = 13 pg/g (MTCA Method B - Standard, Non-carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Mass calculations presented in this appendix conducted prior to revision of dioxin/furan TEQ cleanup level from 11 pg/g to 13 pg/g. Modification to the cleanup level is not expected to have a measureable effect on analysis results.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet.
  Map Projection = Lambert Conformal Conic.

Abbreviations:

- bgs = Below ground surface
- HARN = High Accuracy Reference Network
- NAD = North American Datum
- pg/g = Picograms per gram
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

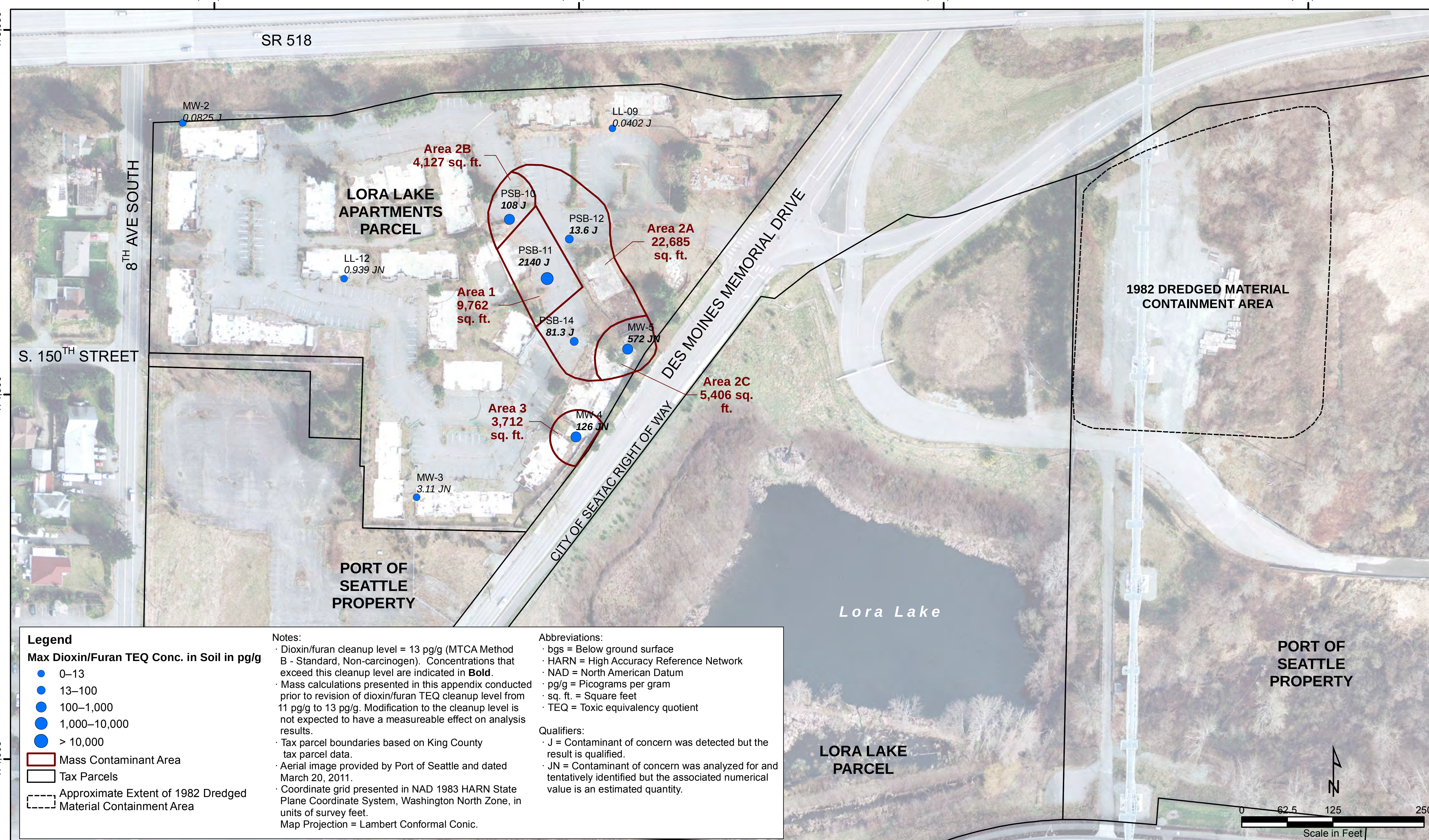
Qualifiers:

- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.4
Dioxin/Furan TEQ Mass Calculations
4 to 6 feet bgs



Legend

Max Dioxin/Furan TEQ Conc. in Soil in pg/g

- 0–13
- 13–100
- 100–1,000
- 1,000–10,000
- > 10,000
- Mass Contaminant Area
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:

- Dioxin/furan cleanup level = 13 pg/g (MTCA Method B - Standard, Non-carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Mass calculations presented in this appendix conducted prior to revision of dioxin/furan TEQ cleanup level from 11 pg/g to 13 pg/g. Modification to the cleanup level is not expected to have a measureable effect on analysis results.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet.
  Map Projection = Lambert Conformal Conic.

Abbreviations:

- bgs = Below ground surface
- HARN = High Accuracy Reference Network
- NAD = North American Datum
- pg/g = Picograms per gram
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

Qualifiers:

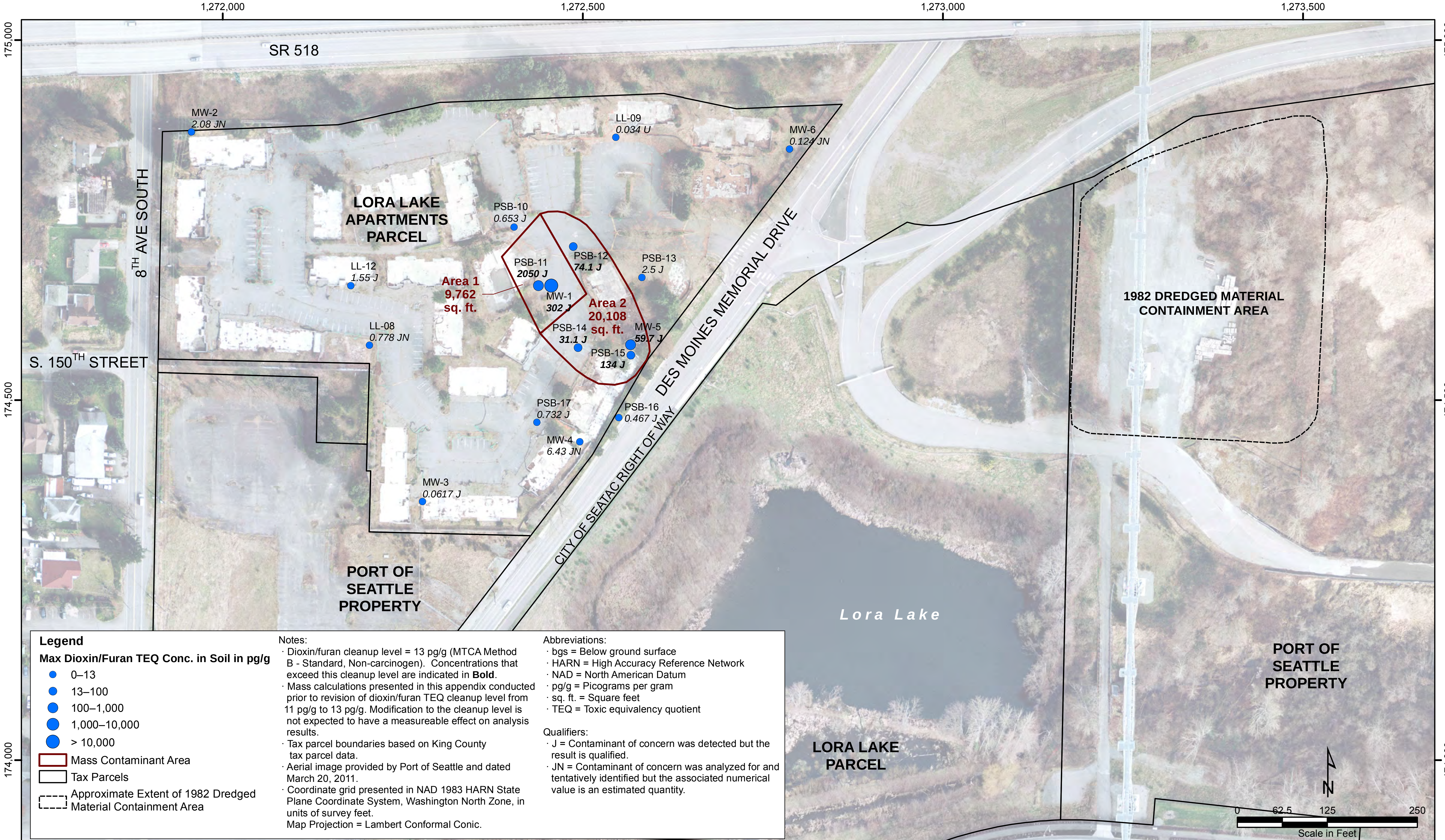
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.5
Dioxin/Furan TEQ Mass Calculations
6 to 10 feet bgs

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.5 DioxinFuran TEQ Mass Calculations 6-10 ft bgs.mxd
12/12/2014



Legend

Max Dioxin/Furan TEQ Conc. in Soil in pg/g

- 0–13
- 13–100
- 100–1,000
- 1,000–10,000
- > 10,000
- Mass Contaminant Area
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:

- Dioxin/furan cleanup level = 13 pg/g (MTCA Method B - Standard, Non-carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Mass calculations presented in this appendix conducted prior to revision of dioxin/furan TEQ cleanup level from 11 pg/g to 13 pg/g. Modification to the cleanup level is not expected to have a measureable effect on analysis results.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet.

Map Projection = Lambert Conformal Conic.

Abbreviations:

- bgs = Below ground surface
- HARN = High Accuracy Reference Network
- NAD = North American Datum
- pg/g = Picograms per gram
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

Qualifiers:

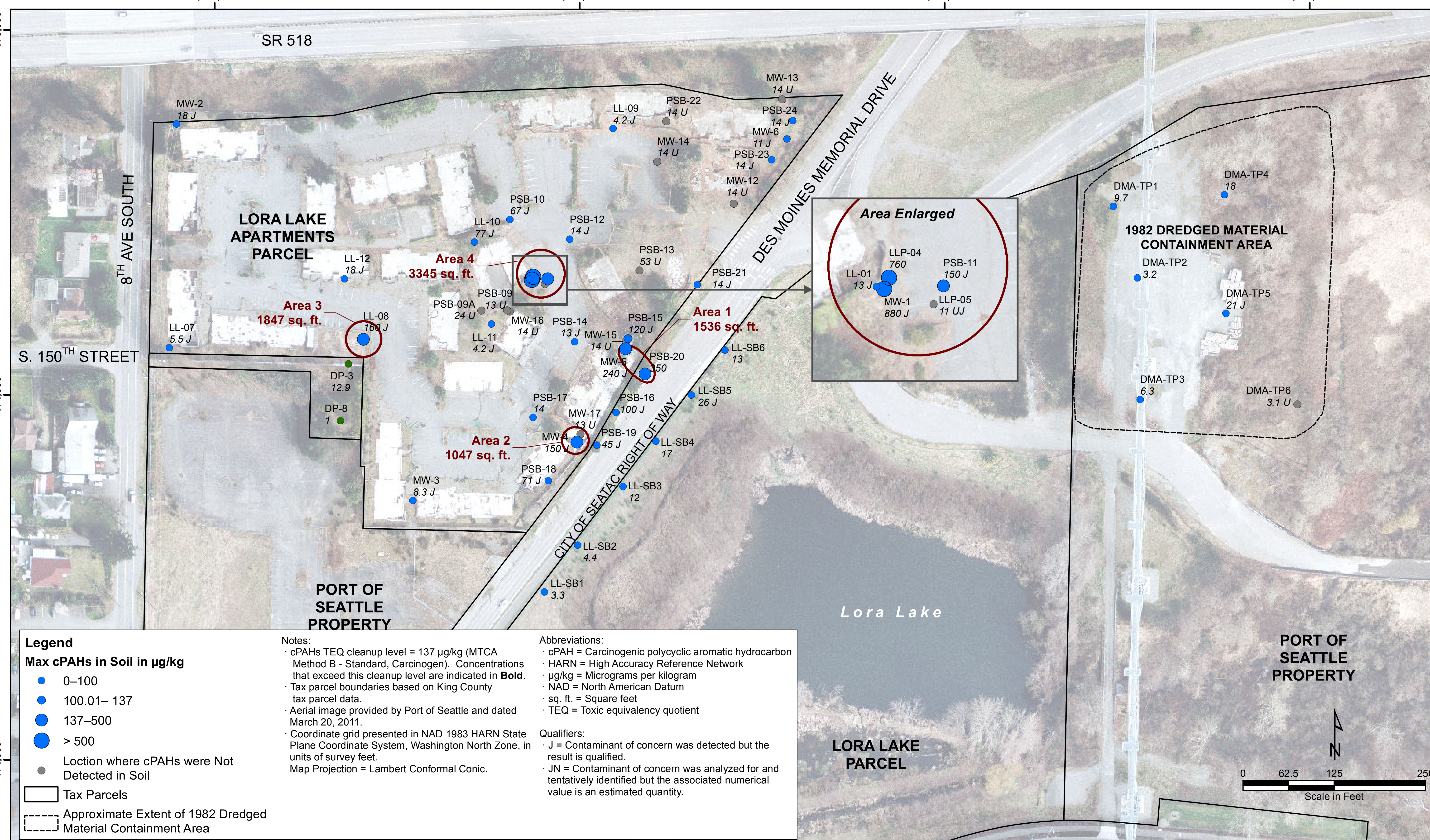
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.6
Dioxin/Furan TEQ Mass Calculations
10 to 15 feet bgs

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.6 DioxinFuran TEQ Mass Calculations gt 10 ft bgs.mxd
12/12/2014



Legend

Max cPAHs in Soil in µg/kg

- 0–100
- 100.01– 137
- 137–500
- > 500
- Loction where cPAHs were Not Detected in Soil
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:

- cPAHs TEQ cleanup level = 137 µg/kg (MTCA Method B - Standard, Carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet. Map Projection = Lambert Conformal Conic.

Abbreviations:

- cPAH = Carcinogenic polycyclic aromatic hydrocarbon
- HARN = High Accuracy Reference Network
- µg/kg = Micrograms per kilogram
- NAD = North American Datum
- sq. ft. = Square feet
- TEQ = Toxic equivalency quotient

Qualifiers:

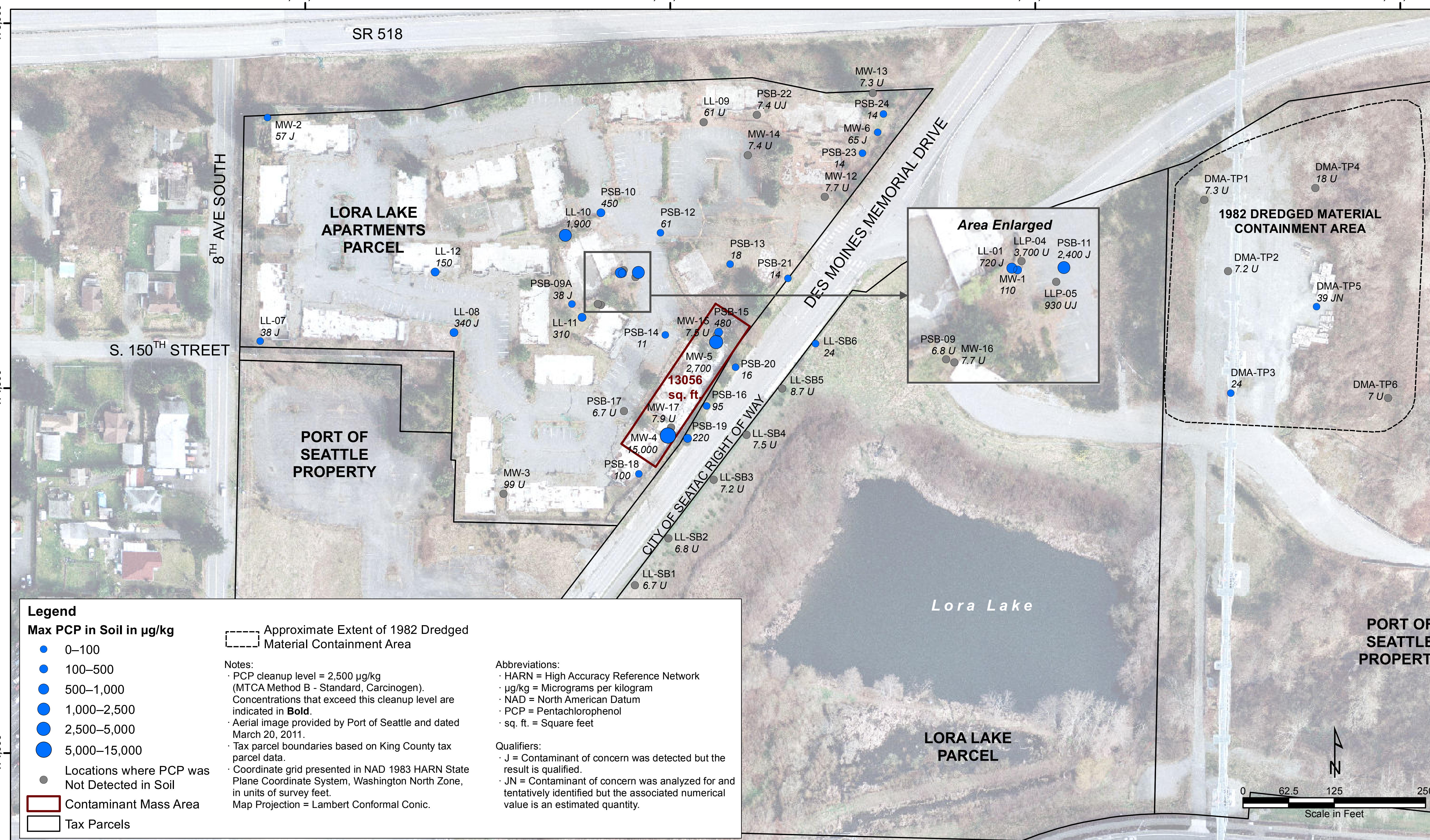
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.7
Maximum Carcinogenic Polycyclic Aromatic Hydrocarbon Mass Calculations

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.7 Max cPAHs in Soil Mass Calculations.mxd
9/16/2014



Legend

Max PCP in Soil in µg/kg

- 0–100
- 100–500
- 500–1,000
- 1,000–2,500
- 2,500–5,000
- 5,000–15,000
- Locations where PCP was Not Detected in Soil
- Contaminant Mass Area
- Tax Parcels
- Approximate Extent of 1982 Dredged Material Containment Area

Notes:
- PCP cleanup level = 2,500 µg/kg (MTCA Method B - Standard, Carcinogen). Concentrations that exceed this cleanup level are indicated in **Bold**.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Tax parcel boundaries based on King County tax parcel data.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet. Map Projection = Lambert Conformal Conic.

Abbreviations:
- HARN = High Accuracy Reference Network
- µg/kg = Micrograms per kilogram
- NAD = North American Datum
- PCP = Pentachlorophenol
- sq. ft. = Square feet

Qualifiers:
- J = Contaminant of concern was detected but the result is qualified.
- JN = Contaminant of concern was analyzed for and tentatively identified but the associated numerical value is an estimated quantity.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure N.8
Maximum Pentachlorophenol Mass Calculations

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix N\Figure N.8 Max PCP in Soil Mass Calculations.mxd
9/16/2014

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix O
Lora Lake Apartments Parcel Remedial Alternative Cost Estimate Worksheets

FINAL

Table of Contents

Table O.1
Summary of Alternative Implementation Costs

Alternative Number[1]	Total Cost[2]
Alternative 1—Cap and Institutional Controls	$4,700,000
Alternative 2—Excavation to 1,000 and Cap	$6,100,000
Alternative 3—Excavation to 100 and Cap	$7,100,000
Alternative 4—Excavation to 100, On-site Consolidation	$7,700,000
Alternative 5—Full Removal to 11	$9,200,000

Notes:
1 Cost details for the alternatives are included in Tables O.2 through O.6.
2 Cost values are estimated and have been rounded up to the nearest $100,000.

Table 0.2
Alternative 1: Construction Cost Estimate Detail
(LL Apartments Parcel Cleanup Areas A, B, and C—Soil Capping)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
CONSTRUCTION—LORA LAKE APARTMENTS PARCEL					
Mobilization/Demobilization	1	LS	$63,000	$63,000	Assumed to be 3% of construction costs, assumes 6-momth construction season.
General Site Preparation and Controls (includes surveying)	1	LS	$100,000	$100,000	Assumed to be 5% of construction costs. Includes site surveying, utility location, stormwater BMPs, general site BMPs, TESC, SWPPP.
Site Clearing and Vegetation Removal	1	LS	$85,000	$85,000	Assumes average cost for removal and off-site disposal of vegetation, based on approximate costs: Stump Removal—$200 each; Tree Removal—assume 100 trees will be removed at these rates: <25-ft tall=$250 each,<75-ft tall=$750 each, >75-ft tall=$1,250 each).
Surface Prep, Curb Removal, Grading, etc.	268,000	SF	$0.25	$67,000	Assumes limited regrading prior to cap placement. Assumes existing pavement remains, and includes removal of curbs, and regrading of landscaped areas only.
Cleanup Areas A, B, and C Soil Capping—4-inch Asphalt Placement	268,000	SF	$5	$1,340,000	Cleanup Areas A, B, and C = 268,000SF, cost for placement of HMA pavement, PG 64-22, Class 1/2" from recent Port project, assumes 4 inches placed.
Stormwater Management (On-site Storage)	12	EA	$5,400	$64,800	Rainfall maximum 24-hr = 1.3 inches required storage capacity = 396,000 SF *80% pavement * 98% runoff * 1.3 inches = 42,900 cf = 252,000 gal = 12 x 20,000 Baker tanks.
Stormwater Treatment and Sanitary Sewer Discharge	2,000,000	GAL	$0.07	$140,000	Assume 9.8 inches rainfall during a 6-month construction season (summer average), 396,000 SF * 80% pavement *98% runoff coefficient = 1,896,000 gal x 0.07 / gal for treatment and disposal to sanitary.
Monitoring Well Protection	4	EA	$400	$1,600	Includes placement of three bollards at each monitoring well. Cost from 2011 Floyd|Snider project with similar scope. Assumes abandonment of 13 wells, protection of 4 wells.
Monitoring Well Abandonment	13	EA	$450	$5,850	Assumes 4 wells remain for long-term monitoring (MW-1, MW-5, upgradient and downgradient) cost per hour for driller at $200/hr.
Stormwater Infrastructure Improvements	2,700	LF	$110	$297,000	Includes replacement or abandonment of the existing on-site stormwater drainage system. Assume cost for slip-lining system per lineal foot, and additional cost for modification to catch basin and drainage structures to remain.
TOTAL CONSTRUCTION COST				**$2,165,000**	
LONG-TERM COSTS					
GROUNDWATER COMPLIANCE MONITORING					
Laboratory Analytical	25	EVENT	$8,050	$201,250	Assumes semi-annual sampling for 5 years, followed by annual sampling for 15 years. Assumes four wells monitored plus field duplicate, for all groundwater COCs.
Field Staff and Equipment	25	EVENT	$5,000	$125,000	Assumes semi-annual sampling for 20 years. Assumes two field staff for 1 day. Includes event prep, work plan, and mobilization.
Annual Reporting	20	YR	$30,000	$600,000	Assumes annual reporting of monitoring results. Unit cost estimate based on assumed level of effort.
Monitoring Well Maintenance and Repair	4	EVENT	$1,000	$4,000	Assumes 1 day of work every 5 years for well maintenance and repair.
CAP INTEGRITY MONITORING AND REPAIR	4	EVENT	$15,000	$60,000	Assumes cap integrity monitoring conducted every 5 years.
LORA LAKE ENGINEERING CONTROLS MAINTENANCE AND REPAIR	1	LS	$48,000	$48,000	Assumes $2,000 per year, plus $5,000 per year in years 10 and 20 for repair/replacement.
TOTAL LONG-TERM COST				**$1,039,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$192,000	$192,000	Assumes Engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$30,000	$30,000	ICs required for pathway protection at LL Apartments Parcel (soil and groundwater).
Permitting	1	LS	$21,700	$21,700	Assumed to be ~1% of the project construction cost for coordination, negotiation, and attainment of all required uplands permits.
Agency Oversight—Site Document Review	20	YR	$5,600	$112,000	Assumes 40 hours per year for document review, and Potentially Liable Party coordination, and 120 hours per year for 5-year reviews.
Engineering Oversight and Construction Reporting	1	LS	$150,000	$150,000	Assumes one FTE for a 6-month construction season, construction completion reporting, and associated engineering documentation.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$506,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[2]				$961,200	Contingency excludes waste disposal cost and engineering design cost, includes all other construction related tasks.
TOTAL ALTERNATIVE COST				**$4,680,000**	

Notes:
1 All cost values are estimates and should not be interpreted as final construction or project costs. Total values are rounded up to the nearest $10,000.
2 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:
BMP Best management practice
COC Contaminant of concern
EA Each
ft Feet
FTE Full Time Employee
GAL Gallon
HMA Hot mix asphalt
hr Hour
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump Sum
npv Net present value
SF Square foot
SWPPP Stormwater Pollution Prevention Plan
TESC Temporary Erosion and Sediment Control
YR Year

Table O.3
Alternative 2: Construction Cost Estimate Detail
(LL Apartments Parcel Cleanup Area A—Excavation to 1000, Off-site Disposal, Cleanup Area C—Soil Capping, Groundwater—Compliance Monitoring, Stormwater System Improvements)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
CONSTRUCTION—LL APARTMENTS PARCEL					
Mobilization/Demobilization	1	LS	$117,000	$117,000	Assumes 3% of construction costs, assumes 6-month construction season.
General Site Prep and Controls (includes surveying, erosion control, soil stabilization)	1	LS	$156,000	$156,000	Assumes 5% of LL Apartments Parcel construction costs, (excluding material disposal). Includes site surveying, utility location, stormwater BMPs, general site BMPs, TESC, SWPPP, etc.
Stormwater Management (on-site storage)	12	EA	$5,400	$64,800	Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity ~ 396,000 SF area *80% pavement * 98% runoff * 1.3 inches = 42,900 cf = 252,000 gal = 12 x 20,000 Baker tanks.
Stormwater Treatment and Sanitary Sewer Discharge	2,000,000	GAL	$0.07	$140,000	Assume ~9.8 inches rainfall during a 6-month construction season (summer average), 396,000 SF site area * 80% pavement *98% runoff coefficient = 1,896,000 gal. Assumes treatment and disposal to sanitary sewer.
Site Clearing and Vegetation Removal	1	LS	$85,000	$85,000	Assumes average cost for removal and off-site disposal of vegetation, based on approximate costs: Stump Removal—$200 each; Tree Removal—assume 100 trees will be removed at these rates: <25-ft tall=$250 each,<75-ft tall=$750 each, >75-ft tall=$1,250 each).
Monitoring Well Protection	4	EA	$400	$1,600	Unit cost includes placement of three bollards at each monitoring well. Cost from 2011 Floyd|Snider project with similar scope. Assumes protection of MW-1, MW-5, one upgradient, and one downgradient well.
Monitoring Well Abandonment (includes abandonment of MW-1)	14	EA	$450	$6,300	Assumes three wells remain for long-term monitoring (MW-5, upgradient, and downgradient), cost per hour for driller at $200/hr.
Monitoring Well Replacement (MW-1)	1	EA	$2,500	$2,500	Assumes abandonment of MW-1 prior to source area excavation and replacement of the well following completion of source area excavation activities. Decommissioning of the existing well prior to excavation is required and included in abandonment line item above.
Stormwater Infrastructure Improvements	2,700	LF	$110	$297,000	Includes replacement or abandonment of the existing on-site stormwater drainage system. Assume cost for slip-lining system per lineal foot and additional cost for modification to catch basin and drainage structures to remain.
Post-construction Surveys	1	LS	$7,000	$7,000	Assumes level of effort. Includes final surveying and construction documentation at LL Apartments Parcel.
CLEANUP AREA A EXCAVATION					
Dewatering—System Construction and Water Handling	1	LS	$275,000	$275,000	Lump sum estimate based on project cost from similar 2011 Floyd|Snider project.
Dewatering Water—Treatment and Disposal	1,000,000	GAL	$0.07	$70,000	Volume estimate a placeholder. Actual water volume expected to be calculated in design.
Excavation Shoring System	1	LS	$270,000	$270,000	Estimated from similar Port project completed in 2010 of similar scope.
Soil Excavation	12,400	TON	$20	$248,000	Assumes 1.4 tons per cubic yard; source area excavation shown on Figure 12.1.
Contaminated Soil Transport and Disposal	12,400	TON	$45	$558,000	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.
Laboratory Analytical Sampling	30	EA	$1,697	$50,922	Assumes excavation sidewall and base samples collected approximately every 100 feet. Assumes samples analyzed for lead, pentachlorophenol, carcinogenic polycyclic aromatic hydrocarbons, total petroleum hydrocrbons, dioxins/furans, and BTEX.
Purchase, Place, and Compact Backfill Material[4]	12,400	TON	$25	$310,000	Assumes cost from similar 2011 Port project for fill material import, placement, and compaction. Material cost from Washington Rock ~$9/ton.
CLEANUP AREAS A, B, and C CAPPING					
Surface Prep, Curb Removal, Grading, etc.	259,000	SF	$0.25	$64,750	Assumes limited regrading prior to cap placement. Assumes existing pavement remains, and includes removal of curbs, and regrading of landscaped areas only.
Cleanup Areas A, B, and C Soil Capping 4-inch Asphalt Placement	259,000	SF	$5	$1,295,000	Cleanup Areas A, B, and C=259,000 SF, cost for placement of HMA pavement, PG 64-22, Class 1/2" from recent Port project, assumes 4 inches placed.
			LL Apartments Parcel Subtotal	***$4,019,000***	

Table O.3
Alternative 2: Construction Cost Estimate Detail
(LL Apartments Parcel Cleanup Area A—Excavation to 1000, Off-site Disposal, Cleanup Area C—Soil Capping, Groundwater—Compliance Monitoring, Stormwater System Improvements)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
TOTAL CONSTRUCTION COST				**$4,019,000**	
LONG-TERM COSTS					
GROUNDWATER COMPLIANCE MONITORING					
Laboratory Analytical	8	EVENT	$8,050	$64,400	Assumes 2 years of quarterly groundwater monitoring for compliance with cleanup levels. Assumes four locations plus one field duplicate analyzed for all groundwater COCs.
Field Staff and Equipment	8	EVENT	$5,000	$40,000	Assumes quarterly monitoring for 2 years. Assumes two field staff for 1 day. Includes event prep, work plan, and mobilization.
Annual Reporting	2	YR	$75,000	$150,000	Assumes annual reporting of monitoring results. Unit cost estimate based on assumed level of effort.
SOIL CAP INTEGRITY MONITORING AND REPAIR	4	EVENT	$15,000	$60,000	Assumes cap integrity monitoring conducted every 5 years, unit cost includes $15,000 for LL Apartments Parcel cap.
TOTAL LONG-TERM COST				**$315,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design—Site-wide	1	LS	$260,000	$260,000	Assumes Engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development and Implementation	1	LS	$30,000	$30,000	ICs required for pathway protection at LL Apartments Parcel (soil and temporary groundwater).
Permitting	1	LS	$80,400	$80,400	Assumed to be ~2% of the project construction cost for coordination, negotiation, and attainment of all required uplands permits.
Engineering Oversight and Construction Reporting	1	LS	$150,000	$150,000	Assumes one FTE for a 6-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	6	YR	$4,000	$24,000	Assumes 40 hours per year for document review, and Potentially Liable Party coordination occurring only in years when monitoring activities occur at the Site, including 2 years following construction completion for groundwater compliance, and years 5, 10, 15, and 20 for 5-year reviews.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$545,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[3]				$1,197,000	Contingency excludes waste disposal cost and engineering design cost, includes all other construction related tasks.
TOTAL ALTERNATIVE COST				**$6,080,000**	

Notes:

1 All cost values are estimates and should not be interpreted as final construction or project costs. Total values are rounded up to the nearest $10,000.
3 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.
4 Backfill material volume was calculated assuming that capped areas would be backfilled to the existing grade and areas not requiring capping would be backfilled to 2 feet below the existing grade.

Abbreviations:

AC Acre
BMP Best management practice
BTEX Benzene, toluene, ethylbenzene, and xylenes
cf Cubic foot
COC Contaminant of concern
cy Cubic Yard
EA Each
FTE Full time employee
GAL Gallon
HMA Hot mix asphalt
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump sum
NPV Net present value
Port Port of Seattle
Site Lora Lake Apartments Site
SF Square foot
SWPPP Stormwater Pollution Prevention Plan
TESC Temporary Erosion and Sediment Control
YR Year

Table O.4
Alternative 3: Construction Cost Estimate Detail

(LL Apartments Parcel Cleanup Areas A and B—Excavation to 100, Cleanup Area C—Soil Capping, Groundwater—Compliance Monitoring, Stormwater System Improvements)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
CONSTRUCTION—LL APARTMENTS PARCEL					
Mobilization/Demobilization	1	LS	$142,000	$142,000	Assumed to be 3% of construction costs, assumes 6-month construction season.
General Site Prep and Controls (includes surveying, erosion control, soil stabilization)	1	LS	$164,000	$164,000	Assumed to be 5% of LL Apartments Parcel construction costs, (excluding material disposal). Includes site surveying, utility location, stormwater BMPs, general site BMPs, TESC, SWPPP, etc.
Stormwater Management (on-site storage)	12	EA	$5,400	$64,800	Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity ~ 396,000 SF area *80% pavement * 98% runoff * 1.3 inches = 42,900 cf = 252,000 gal = 12 x 20,000 Baker tanks.
Stormwater Treatment and Sanitary Sewer Discharge	2,000,000	GAL	$0.07	$140,000	Assumes ~9.8 inches rainfall during a 6-month construction season (summer average), 396,000 SF site area * 80% pavement *98% runoff coefficient = 1,896,000 gal. Assumes treatment and disposal to sanitary sewer.
Site Clearing and Vegetation Removal	1	LS	$85,000	$85,000	Assumes average cost for removal and off-site disposal of vegetation, based on approximate costs: Stump Removal—$200 each; Tree Removal—assume 100 trees will be removed at these rates: <25-ft tall=$250 each,<75-ft tall=$750 each, >75-ft tall=$1,250 each).
Monitoring Well Protection	4	EA	$400	$1,600	Unit cost includes placement of three bollards at each monitoring well. Cost from 2011 Floyd|Snider project with similar scope. Assumes protection of MW-1, MW-5, one upgradient, and one downgradient well.
Monitoring Well Abandonment (includes abandonment of MW-1, MW-5)	15	EA	$450	$6,750	Assumes two wells remain for long-term monitoring (upgradient and downgradient of source area); cost per hour for driller at $200/hour.
Monitoring Well Replacement (MW-1, MW-5)	2	EA	$2,500	$5,000	Assumes abandonment of MW-1 and MW-5 prior to source area excavation and replacement of the wells following completion of source area excavation activities. Decommissioning of the existing wells prior to excavation is required and included in abandonment line item above.
Stormwater Infrastructure Improvements	2,700	LF	$110	$297,000	Includes replacement or abandonment of the existing on-site stormwater drainage system. Assumes cost for slip-lining system per lineal foot, and additional cost for modification to catch basin and drainage structures to remain.
Post-construction Surveys	1	LS	$7,000	$7,000	Assumed level of effort. Includes final surveying and construction documentation at LL Apartments Parcel.
CLEANUP AREAS A and B EXCAVATION					
Dewatering—system construction and water handling	1	LS	$275,000	$275,000	Lump sum estimate based on project cost from similar 2011 Floyd|Snider project.
Dewatering Water—treatment and disposal	1,000,000	GAL	$0.07	$70,000	Volume estimate a placeholder. Actual water volume expected to be calculated in design.
Excavation Shoring System	1	LS	$270,000	$270,000	Estimated from similar Port project completed in 2010 of similar scope. Shoring cost does not increase from Alternative 3 as additional source removal is shallow (~2–4 feet).
Cleanup Area A and B Soil Excavation	26,600	TON	$20	$532,000	Assumes 1.4 tons per cubic yard; source area excavation shown on Figure 12.1.
Contaminated Soil Transport and Disposal	26,600	TON	$45	$1,197,000	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.
Laboratory Analytical Sampling	40	EA	$1,697	$67,896	Assumes excavation sidewall and base samples collected approximately every 100 feet. Assumes samples analyzed for lead, pentachlorophenol, carcinogenic polycylic aromatic hydrocarbons, total petroleum hydrocarbons, dioxins/furans, and BTEX.
Purchase, Place, and Compact Backfill Material[2]	26,600	TON	$25	$665,000	Assumes cost from similar 2011 Port project for fill material import, placement. and compaction. Material cost from Washington Rock ~$9/ton.
CLEANUP AREAS B and C CAPPING					
Surface Prep, Curb Removal, Grading, etc.	166,000	SF	$0.25	$41,500	Assumes limited regrading prior to cap placement. Assumes existing pavement remains, and includes removal of curbs, and regrading of landscaped areas only.
Cleanup Area B and C Soil Capping—4-inch Asphalt Placement	166,000	SF	$5	$830,000	Cleanup Area B and C=166,000 SF, cost for placement of HMA pavement, PG 64-22, Class 1/2" from recent Port project, assumes 4 inches placed.
			TOTAL CONSTRUCTION COST	**$4,862,000**	

Table O.4
Alternative 3: Construction Cost Estimate Detail

(LL Apartments Parcel Cleanup Areas A and B—Excavation to 100, Cleanup Area C—Soil Capping, Groundwater—Compliance Monitoring, Stormwater System Improvements)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
LONG-TERM COSTS					
GROUNDWATER COMPLIANCE MONITORING					
Laboratory Analytical	8	EVENT	$8,000	$64,000	Assumes 2 years of quarterly groundwater monitoring for compliance with cleanup levels. Assumes four locations plus one field duplicate analyzed for all groundwater COCs.
Field Staff and Equipment	8	EVENT	$5,000	$40,000	Assumes quarterly monitoring for 2 years. Assumes two field staff for 1 day. Includes event prep, work plan, and mobilization.
Annual Reporting	2	YR	$75,000	$150,000	Assumes annual reporting of monitoring results. Unit cost estimate based on assumed level of effort.
SOIL CAP INTEGRITY MONITORING AND REPAIR	4	EVENT	$15,000	$60,000	Assumes cap integrity monitoring conducted every 5 years, unit cost includes $15,000 for LL Apartments Parcel cap.
TOTAL LONG-TERM COST				**$314,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$311,000	$311,000	Assumes Engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$30,000	$30,000	ICs required for pathway protection at LL Apartments Parcel (soil and temporary groundwater).
Permitting	1	LS	$97,200	$97,200	Assumed to be ~2% of the project construction cost for coordination, negotiation, and attainment of all required uplands permits.
Engineering Oversight and Construction Reporting	1	LS	$150,000	$150,000	Assumes one FTE for a 6-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	6	YR	$4,000	$24,000	Assumes 40 hours per year for document review and Potentially Liable Party coordination occurring only in years when monitoring activities occur at the Site, including 2 years following construction completion for groundwater compliance and years 5, 10, 15, and 20 for 5-year reviews.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$613,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[3]				$1,263,000	Contingency excludes waste disposal cost and engineering design cost, includes all other construction related tasks.
TOTAL ALTERNATIVE COST				**$7,060,000**	

Notes:

1 All cost values are estimates and should not be interpreted as final construction or project costs. Total values are rounded up to the nearest $10,000.
2 Backfill material volume was calculated assuming that capped areas would be backfilled to the existing grade and areas not requiring capping would be backfilled to 2 feet below the existing grade.
3 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:

AC Acre
BMP Best management practice
BTEX Benzene, toluene, ethylbenzene, and xylenes
cf Cubic feet
COC Contaminant of concern
cy Cubic Yard
EA Each
FTE Full time employee
GAL Gallon
HMA Hot mix asphalt
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump sum
NPV Net present value
Port Port of Seattle
Site Lora Lake Apartments Site
SF Square foot
SWPPP Stormwater Pollution Prevention Plan
SY Square yard
TESC Temporary Erosion and Sediment Control
YR Year

Table O.5
Alternative 4: Construction Cost Estimate Detail

(LL Apartments Parcel Cleanup Areas A and B—Excavation to 100, Consolidate 11 to 100 On-site, Groundwater—Compliance Monitoring, Stormwater System Improvements)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
CONSTRUCTION—LL APARTMENTS PARCEL					
Mobilization/Demobilization	1	LS	$157,000	$157,000	Assumed to be 3% of construction costs, assumes 6-month construction season.
General Site Prep and Controls (includes surveying, erosion control, soil stabilization)	1	LS	$188,000	$188,000	Assumed to be 5% of LL Apartments Parcel construction costs, (excluding material disposal). Includes site surveying, utility location, stormwater BMPs, general site BMPs, TESC, SWPPP, etc.
Stormwater Management (on-site storage)	12	EA	$5,400	$64,800	Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity ~ 396,000 SF area *80% pavement * 98% runoff * 1.3 inches = 42,900 cf = 252,000 gal = 12 x 20,000 Baker tanks.
Stormwater Treatment and Sanitary Sewer Discharge	2,000,000	GAL	$0.07	$140,000	Assumes ~9.8 inches rainfall during a 6-month construction season (summer average), 396,000 SF site area * 80% pavement *98% runoff coefficient = 1,896,000 gal. Assumes treatment and disposal to sanitary sewer.
Site Clearing and Vegetation Removal	1	LS	$85,000	$85,000	Assumes average cost for removal and off-site disposal of vegetation, based on approximate costs: Stump Removal—$200 each; Tree Removal—assume 100 trees will be removed at these rates: <25-ft tall=$250 each,<75-ft tall=$750 each, >75-ft tall=$1,250 each).
Monitoring Well Protection	4	EA	$400	$1,600	Unit cost includes placement of 3 bollards at each monitoring well. Cost from 2011 Floyd|Snider project with similar scope. Assumes protection of MW-1, MW-5, one upgradient, and one downgradient well.
Monitoring Well Abandonment (includes abandonment of	15	EA	$450	$6,750	Assumes 2 wells remain for long-term monitoring (upgradient and downgradient of source area); cost per hour for driller at $200/hour.
Monitoring Well Replacement (MW-1, MW-5)	2	EA	$2,500	$5,000	Assumes abandonment of MW-1 and MW-5 prior to source area excavation and replacement of the wells following completion of source area excavation activities. Decommissioning of the existing wells prior to excavation is required and included in abandonment line item above.
Stormwater Infrastructure Improvements	2,700	LF	$110	$297,000	Includes replacement or abandonment of the existing on-site stormwater drainage system. Assumes cost for slip-lining system per lineal foot, and additional cost for modification to catch basin and drainage structures to remain.
Post-construction Surveys	1	LS	$7,000	$7,000	Assumed level of effort. Includes final surveying and construction documentation at LL Apartments Parcel.
CLEANUP AREAS A AND B EXCAVATION					
Dewatering—System Construction and Water Handling	1	LS	$275,000	$275,000	Lump sum estimate based on project cost from similar 2011 Floyd|Snider project.
Dewatering Water—Treatment and Disposal	1,000,000	GAL	$0.07	$70,000	Volume estimate a placeholder. Actual water volume expected to be calculated in design.
Excavation Shoring System	1	LS	$270,000	$270,000	Estimated from similar Port project completed in 2010 of similar scope. Shoring cost does not increase from Alternative 3 as additional source removal is shallow (~2–4 feet).
Cleanup Area A and B Soil Excavation	26,600	TON	$20	$532,000	Assumes 1.4 tons per cubic yard; source area excavation shown on Figure 12.1.
Contaminated Soil Transport and Disposal	26,600	TON	$45	$1,197,000	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.
Laboratory Analytical Sampling	40	EA	$1,697	$67,896	Assumes excavation sidewall and base samples collected approximately every 100 feet. Assumes samples analyzed for lead, pentachlorophenol, carcinogenic polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, dioxins/furans, and BTEX.
Purchase, Place, and Compact Backfill Material[2]	39,200	TON	$25	$980,000	Assumes cost from similar 2011 Port project for fill material import, placement. and compaction. Material cost from Washington Rock ~$9/ton.
ON-SITE CONSOLIDATION FROM CLEANUP AREAS B					
Soil Excavation	30,000	CY	$28	$840,000	Does not account for the subtraction of material that would be not be excavated in the consolidation area.
Haul and Unload Soil in Consolidated Location	30,000	CY	$6	$180,000	Assume all excavated soil with dioxin/furan concentrations between 11 and 100 pptr from LL Apartments Parcel is consolidated at the DMCA.
DMCA Stockpiling and Compaction	30,000	CY	$0.5	$15,000	
			LL Apartments Parcel Subtotal	***$5,380,000***	
			TOTAL CONSTRUCTION COST	**$5,380,000**	
LONG-TERM COSTS					
GROUNDWATER COMPLIANCE MONITORING					
Laboratory Analytical	8	EVENT	$8,000	$64,000	Assumes 2 years of quarterly groundwater monitoring for compliance with cleanup levels. Assumes 4 locations plus one field duplicate analyzed for all groundwater COCs.
Field Staff and Equipment	8	EVENT	$5,000	$40,000	Assumes quarterly monitoring for 2 years. Assumes 2 field staff for 1 day. Includes event prep, work plan, and mobilization.
Annual Reporting	2	YR	$75,000	$150,000	Assumes annual reporting of monitoring results. Unit cost estimate based on assumed level of effort.
			TOTAL LONG-TERM COST	**$254,000**	

Table O.5
Alternative 4: Construction Cost Estimate Detail

(LL Apartments Parcel Cleanup Areas A and B—Excavation to 100, Consolidate 11 to 100 On-site, Groundwater—Compliance Monitoring, Stormwater System Improvements)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$338,000	$338,000	Assumes Engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$30,000	$30,000	ICs required for pathway protection at LL Apartments Parcel (soil and temporary groundwater).
Permitting	1	LS	$107,600	$107,600	Assumed to be ~2% of the project construction cost for coordination, negotiation, and attainment of all required uplands permits.
Engineering Oversight and Construction Reporting	1	LS	$150,000	$150,000	Assumes 1 FTE for a 6-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	6	YR	$4,000	$24,000	Assumes 40 hours per year for document review and Potentially Liable Party coordination occurring only in years when monitoring activities occur at the Site, including 2 years following construction completion for groundwater compliance and years 5, 10, 15, and 20 for 5-year reviews.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$650,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[3]				$1,404,000	Contingency excludes waste disposal cost and engineering design cost, includes all other construction related tasks.
TOTAL ALTERNATIVE COST				**$7,690,000**	

Notes:

1 All cost values are estimates and should not be interpreted as final construction or project costs. Total values are rounded up to the nearest $10,000.
2 Backfill material volume was calculated assuming that capped areas would be backfilled to the existing grade and areas not requiring capping would be backfilled to 2 feet below the existing grade.
3 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:

AC Acre
BMP Best management practice
BTEX Benzene, toluene, ethylbenzene, and xylenes
cf Cubic foot
COC Contaminant of concern
cy Cubic Yard
DMCA Dredged Material Containment Area
EA Each
FTE Full time employee
GAL Gallon
HMA Hot mix asphalt
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump sum
NPV Net present value
Port Port of Seattle
Site Lora Lake Apartments Site
SF Square foot
SWPPP Stormwater Pollution Prevention Plan
SY Square yard
TESC Temporary Erosion and Sediment Control
YR Year

Table O.6
Alternative 5: Construction Cost Estimate Detail
(LL Apartments Parcel Cleanup Areas A, B, and C—Excavation to 11 and Off-site Disposal, Groundwater—Compliance Monitoring, Stormwater System Limited Abandonment)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
CONSTRUCTION—LL APARTMENTS PARCEL					
Mobilization/Demobilization	1	LS	$210,000	$210,000	Assumed to be 3% of construction costs, assumes 8-month construction season.
General Site Prep and Controls (includes surveying, erosion control, soil stabilization)	1	LS	$180,000	$180,000	Assumed to be 5% of LL Apartments Parcel construction costs (excluding material disposal). Includes site surveying, utility location, stormwater BMPs, general site BMPs, TESC, SWPPP, etc.
Stormwater Management (On-site Storage)	6	EA	$5,400	$32,400	Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity reduced from Alternatives 3 & 4 due to increased infiltration with open excavations. Assumed to be ~50% of stormwater runoff expected with other alternatives.
Stormwater Treatment and Sanitary Sewer Discharge	1,500,000	GAL	$0.07	$105,000	Assumes ~9.8 inches rainfall during a 6-month construction season (summer average); 396,000 SF site area * 60% runoff = 1,475,000 gal. Assumes treatment and discharge to sanitary sewer.
Site Clearing and Vegetation Removal	1	LS	$85,000	$85,000	Assumes average cost for removal and off-site disposal of vegetation, based on approximate costs: Stump Removal—$200 each; Tree Removal—assume 100 trees will be removed at these rates: <25-ft tall=$250 each,<75-ft tall=$750 each, >75-ft tall=$1,250 each).
Monitoring well protection	4	EA	$400	$1,600	Unit cost includes placement of 3 bollards at each monitoring well. Cost from 2011 Floyd|Snider project with similar scope. Assumes protection of MW-1, MW-5, one upgradient, and one downgradient well.
Monitoring Well Abandonment (Includes Abandonment of MW-1, MW-5)	15	EA	$450	$6,750	Assumes 2 wells remain for long-term monitoring (upgradient and downgradient of source area); cost per hour for driller at $200/hour.
Monitoring Well Replacement (MW-1, MW-5)	2	EA	$2,500	$5,000	Assumes abandonment of MW-1 and MW-5 prior to source area excavation and replacement of the wells following completion of source area excavation activities. Decommissioning of the existing wells prior to excavation is required and included in abandonment line item above.
Stormwater Infrastructure Abandonment/ Improvement	500	LF	$50	$25,000	Assumes slip-lining not required and any sections not in areas of excavation would remain in place in current condition. Item includes abandonment of system in source area excavations.
Post-construction Surveys	1	LS	$7,000	$7,000	Assumed level of effort. Includes final surveying and construction documentation at LL Apartments Parcel.
CLEAN AREAS A, B, AND C EXCAVATION					
Dewatering—System Construction and Water	1	LS	$275,000	$275,000	Lump sum estimate based on project cost from similar 2011 Floyd|Snider project.
Dewatering Water—Treatment and Disposal	1,800,000	GAL	$0.07	$126,000	Volume estimate a placeholder. Actual water volume expected to be calculated in design. Higher volume of dewatering expected due to increased infiltration during rain events.
Excavation Shoring System	1	LS	$270,000	$270,000	Estimated from similar Port project completed in 2010 of similar scope. Shoring cost does not increase from Alternative 3 & 4 as additional source removal is shallow (~2–4 feet).
Soil Excavation	68,600	TON	$20	$1,372,000	Assumes 1.4 tons per cubic yard. Volume estimated from Appendix N mass calculation and includes overburden.
Contaminated Soil Transport and Disposal	68,600	TON	$45	$3,087,000	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.
Laboratory Analytical Sampling	200	EA	$1,697	$339,480	Assumes excavation sidewall and base samples collected approximately every 100 feet. Assumes samples analyzed for lead, pentachlorophenol, carcinogenic polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, dioxins/furans, and BTEX.
Purchase, Place, and Compact Backfill Material[2]	43,400	TON	$25	$1,085,000	Assumes cost from similar 2011 Port project for fill material import, placement, and compaction. Material cost from Washington Rock ~$9/ton. Only backfill the deep source excavation areas.
			LL Apartments Parcel Subtotal	***$7,213,000***	
			TOTAL CONSTRUCTION COST	**$7,213,000**	
LONG-TERM COSTS					
GROUNDWATER COMPLIANCE MONITORING					
Laboratory Analytical	8	EVENT	$8,000	$64,000	Assumes 2 years of quarterly groundwater monitoring for compliance with cleanup levels. Assumes 4 locations plus one field duplicate analyzed for all groundwater COCs.
Field Staff and Equipment	8	EVENT	$5,000	$40,000	Assumes quarterly monitoring for 2 years. Assumes 2 field staff for 1 day. Includes event prep, work plan, and mobilization.
Annual Reporting	2	YR	$75,000	$150,000	Assumes annual reporting of monitoring results. Unit cost estimate based on assumed level of effort.
			TOTAL LONG-TERM COST	**$254,000**	

Table O.6
Alternative 5: Construction Cost Estimate Detail
(LL Apartments Parcel Cleanup Areas A, B, and C—Excavation to 11 and Off-site Disposal, Groundwater—Compliance Monitoring, Stormwater System Limited Abandonment)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[1]	DETAIL
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$448,000	$448,000	Assumes engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$25,000	$25,000	Assumes institutional controls required for soils beneath Des Moines Memorial Drive only.
Permitting	1	LS	$144,300	$144,300	Assumed to be ~2% of the project construction cost for coordination, negotiation, and attainment of all required uplands permits.
Engineering Oversight and Construction Reporting	1	LS	$200,000	$200,000	Assumes 1.5 FTE for a 9-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	2	YR	$4,000	$8,000	Assumes 40 hours per year for document review and coordination occurring only in years when monitoring activities occur at the Site, including 2 years following construction completion.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$378,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[3]				$1,390,000	Contingency excludes waste disposal cost and engineering design cost, includes all other construction related tasks.
TOTAL ALTERNATIVE COST				**$9,240,000**	

Notes:
1 All cost values are estimates and should not be interpreted as final construction or project costs. Total values are rounded up to the nearest $10,000.
2 Backfill material volume was calculated assuming that capped areas would be backfilled to the existing grade and areas not requiring capping would be backfilled to 2 feet below the existing grade.
3 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:
AC Acre
BMP Best management practice
BTEX Benzene, toluene, ethylbenzene, and xylenes
cf Cubic foot
COC Contaminant of concern
cy Cubic Yard
EA Each
FTE Full time employee
GAL Gallon
HMA Hot mix asphalt
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump sum
NPV Net present value
Port Port of Seattle
Site Lora Lake Apartments Site
SF Square foot
SWPPP Stormwater Pollution Prevention Plan
SY Square yard
TESC Temporary Erosion and Sediment Control
YR Year

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix P
Sediment Leaching and Numerical Cap Modeling

FINAL

Table of Contents

List of Tables

List of Figures

List of Abbreviations/Acronyms

Abbreviation/ Acronym	**Definition**
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
ARAR	Applicable, relevant, and appropriate requirements
Bold Survey	USEPA Ocean Survey Vessel Bold Survey for Puget Sound
COC	Contaminant of concern
cPAH	Carcinogenic polycyclic aromatic hydrocarbon
f_{oc}	Fraction of organic carbon in sediment sample
K_d	COC partitioning coefficient
K_{oc}	Organic carbon partitioning coefficient
LL Parcel RI	Lora Lake Parcel Remedial Investigation
OCDD	Octachlorodibenzo-p-dioxin
PAH	Polycyclic aromatic hydrocarbon
PCP	Pentachlorophenol
RI/FS	Remedial Investigation/Feasibility Study
USEPA	U.S. Environmental Protection Agency

1.0 Introduction

This appendix presents the results of the sediment leaching and numerical cap modeling evaluation conducted as part of the Lora Lake Apartments Site Remedial Investigation and Feasibility Study (RI/FS). The objective of this evaluation is to assess the potential for sediment contaminants of concern (COCs) in Lora Lake and Miller Creek to leach from sediments to surface water at concentrations greater than those permitted by applicable, relevant, and appropriate requirements (ARARs) for the protection of human health via the fish consumption exposure pathway. Therefore, this appendix presents the technical analysis that was performed in support of evaluating Lora Lake capping technology alternatives, as described in Sections 18.0 and 19.0 of the Lora Lake Apartments Site Feasibility Study.

The selected capping remedial alternative places capping materials within Lora Lake to appropriately manage elevated concentrations of dioxins/furans detected in the lake sediments. For Miller Creek, no remedial action is recommended since there are no sediment cleanup level exceedances and only low levels of dioxins/furans have been detected in the creek sediment (maximum detected concentration of 0.442 picograms per gram). There are no available dioxin/furan sediment cleanup levels, however, and the protectiveness of Miller Creek surface sediment is assessed by evaluating the potential pathway of sediment leaching to surface water.

Contamination located underneath surface sediment caps can migrate through the underlying sediment and cap materials via pore water transport and can result in surface water quality exceedances. Sand caps attenuate such transport based on their material type and thickness. The selection of capping material for the attenuation of contaminants at Lora Lake is dependent upon the nature and extent of contamination, groundwater flow velocity, and physical constraints of placing cap materials on the sediment surface. Sand caps can be constructed with variable thicknesses and amendments to effectively attenuate and contain contaminants that are transported in pore water from underlying sediments. High organic carbon content amendments to the sand cap, such as organoclays or sorbents, can be used to enhance the attenuation of COCs. These amendments can reduce the thickness of the cap that is required to attenuate and contain underlying contaminants.

This appendix presents a cap modeling evaluation that was conducted to determine the appropriate capping material thickness (with or without organic carbon amendment) to ensure that the material effectively contains underlying contaminants (i.e., COC concentrations leaching from Lora Lake sediments do not exceed the applicable surface water ARAR for the protection of human health via the fish consumption exposure pathway).

The COC concentrations in Miller Creek sediment are also evaluated to determine if there is a potential that COC concentrations leaching from Miller Creek sediment exceed surface water quality criteria.

The COC concentrations leaching from the sediment and discharging to surface water in Lora Lake and Miller Creek are compared to the Federal Clean Water Act (Section 304) Surface Water Quality Criteria for human consumption of organisms and water. The Clean Water Act Surface Water Quality Criteria were selected as the most stringent surface water ARARs for this human health pathway. For this evaluation in Lora Lake and Miller Creek, the quality of pore water being transported through the underlying sediments, and the cap material in Lora Lake, is represented using sediment quality data collected from the LL Parcel RI (Appendix G). Lora Lake and Miller Creek sediment sampling locations and the sampling locations used as the modeling sediment source concentrations are presented in Figure P.1.

2.0 Evaluation Approach

2.1 SOURCE CONCENTRATION EQUILIBRIUM PARTITIONING

The numerical cap model (described below in Section 2.2) evaluated COC pore water transport based on the input of initial pore water COC source concentrations. Lora Lake surface sediment pore water concentrations were calculated using equilibrium partitioning based on surface sediment source concentrations. Equilibrium partitioning assumes instantaneous chemical equilibrium between the contaminants in the underlying sediment particles and the sediment pore water; this assumption typically overestimates the amount of contaminant that is in the dissolved phase or in pore water. Equilibrium partitioning was calculated with the following equation:

$$C_{sed} = C_{pw} \times K_d$$

Where: C_{sed} = Equilibrium sediment concentration
C_{pw} = Pore water concentration
K_d = COC partitioning coefficient

The individual K_d values for the organic COCs were calculated using the organic carbon content associated with each sediment sample and the organic carbon partitioning coefficient (K_{oc}) associated with each individual organic COC. The K_d values were calculated using the following equation:

$$K_d = K_{oc} \times f_{oc}$$

Where: K_d = Organic COC partitioning coefficient
K_{oc} = Organic carbon partitioning coefficient
f_{oc} = Fraction of organic carbon in sediment sample

Metal-specific K_d values for arsenic and lead were based on an extensive literature review for the sediment water interface performed by the U.S. Environmental Protection Agency (USEPA) in 2005, and were not calculated. As described in "Partition Coefficients for Metals in Surface Water, Soil, and Waste," K_d values for metals in sediment are largely dependent on various geochemical characteristics of the sediment, suspended sediment, and pore water (USEPA 2005). It is important to note that the partitioning and potential sorption of metals is based on the metal speciation and local geochemical conditions that have the greatest influence on the magnitude of K_d values, such as redox conditions, pH, and the concentration of sorbing phases in the soil matrix (e.g., weight percent organic matter content and weight percent hydrous ferric oxides and corresponding oxides of aluminum and manganese; USEPA 2005). Equilibrium partitioning and the numerical design tools available to predict metal transport often greatly simplify the behaviors of metals in natural media environments and may over predict the availability and transport of metals in sediment and pore water.

2.2 LORA LAKE SEDIMENT CAP EVALUATION

The cap modeling evaluation was conducted using a numerical model that was developed and provided by Dr. Danny Reible from the University of Texas at Austin. The model simulates the fate and transport of chemicals (dissolved and sorbed phase) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and exchange with the overlying surface water.

Earlier versions of this model have been used to support the evaluation and design of sediment caps at numerous sites in the United States: the St. Lawrence River and Onondaga Lake in New York, where caps will be placed over more than 400 acres of sediment (Parsons and Anchor QEA 2011); and, most recently, the Portland Harbor Superfund Site (Anchor 2006, Parsons and Anchor QEA 2011, and Anchor QEA 2012). The details on the model structure, underlying theory, and equations used in this evaluation are provided in the capping guidance authored by Reible and Lampert (2012) and the USEPA capping guidance document (Appendix B of Palermo et al. 1998).

To evaluate cap performance for Lora Lake, the numerical cap model was used to predict the contaminant migration in pore water moving from sediments located below the cap through the cap materials. The results of the sediment sampling performed in Lora Lake as part of the LL Parcel RI (Appendix G of the Lora Lake Apartments Site RI/FS) were used as sediment source concentrations to evaluate if a cap is needed for COC attenuation and, if so, to determine the necessary thickness and composition of the cap so that COC concentrations in pore water discharging from the cap will not exceed the Clean Water Act Surface Water Criteria.

Using this model, a pore water concentration at a specified time and location in the cap was predicted. The modeling was performed with a simulation period of 100 years. This simulation period is a standard environmental numerical transport model input assumption. It is commonly used in remedial investigations and feasibility studies, particularly when the conservative model assumption of an infinite source is also used. The pore water concentration that is emitted from the cap surface was then compared to Surface Water Clean Water Act criteria for each modeled COC. The model assumes that the underlying contaminant source sediment concentrations are constant and infinite. In reality, the underlying contaminant source sediment concentrations would decrease as contaminants migrate from the former underlying sediment-water interface to the clean cap material.

2.3 MILLER CREEK SURFACE SEDIMENT LEACHING

The potential for contaminant migration by pore water leaching from existing surface sediments in Miller Creek was evaluated by using the equilibrium partitioning approach to assess whether remediation of Miller Creek sediments is necessary.. The pore water concentrations for Miller Creek, calculated using the equations as shown in Section 2.1, were compared directly to the Clean Water Act Surface Water Criteria.

2.4 MODELED CONTAMINANT OF CONCERN SOURCES

2.4.1 Lora Lake Contaminant of Concern Sources

A total of five COCs were evaluated for the numerical cap modeling for Lora Lake: arsenic, lead, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), pentachlorophenol (PCP), and dioxins/furans. These COCs were detected in Lora Lake surface sediment samples collected as part of the LL Parcel RI (Appendix G of the Lora Lake Apartments Site RI/FS). Benzo(a)pyrene was selected to represent cPAHs because it is the most toxic of the cPAHs, one of the most frequently detected cPAHs, and a relatively mobile cPAH. Similarly, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) was selected to represent dioxins/furans because it was detected in Lora Lake surface sediments, is the most toxic congener, and the least chlorinated congener, thereby making it the most mobile congener.

The maximum COC concentration detected in Lora Lake surface sediment samples (Sample LL-SED2) was selected for source concentration modeling (Figure P.1). The average organic carbon content of the surface sediment samples collected from within the lake, excluding LL-SED5, was used for source concentration modeling.[1] The Lora Lake surface sediment source concentrations are provided in Table P.1.

2.4.2 Miller Creek Contaminant of Concern Sources

Dioxins/furans and lead were evaluated for the surface sediment leaching modeling for Miller Creek; these COCs were detected at all three Miller Creek surface sediment sampling locations. The only other detected COC, arsenic, was in sediment from Miller Creek Station MC-SED1; no other additional COCs were detected in Miller Creek sediment samples (Figure P.1).

To determine if arsenic should be included in the Miller Creek modeling evaluation, the MC-SED1 arsenic concentration was compared to available arsenic sediment background concentrations for the Puget Sound area. The most extensive dataset available for sediment background contaminant concentrations within Western Washington is from the USEPA Ocean Survey Vessel Bold Survey for Puget Sound (Bold Survey; USEPA 2008). This survey collected and analyzed Puget Sound surface sediments from locations away from known sources of contamination and cleanup sites. Sediment was collected from locations within four existing sediment reference areas: Dabob Bay, Carr Inlet, Holmes Harbor, and Samish Bay. The Bold Survey background data are for marine sediments. There are no datasets available for natural background sediment freshwater concentrations. The MC-SED1 arsenic concentration was 8 mg/kg, within the range of the natural background concentrations (1.1 to 21 mg/kg dry weight) measured as part of the Bold Survey (USEPA 2008).

1 The organic carbon measurement from surface Sample LL-SED5 was not included in the calculation of an average lake surface sediment organic carbon content because of its location within the rock berm settling basin, its low organic carbon content relative to the other lake surface sediment samples, and its markedly different sediment composition of brown coarse sand with some silt and gravel present. Additionally, the elevated COC concentrations were detected from surface sediment samples from within the lake.

Additionally, the area-wide soil arsenic concentrations surrounding Lora Lake and Miller Creek identified in the WSDOE Tacoma Smelter Plume map, range from non-detect to 20 mg/kg, consistent with the Washington State background arsenic soil concentration of 20 mg/kg. In the vicinity of Lora Lake the arsenic soil concentration range is 20 to 40 mg/kg as indicated on the Washington State Everett and Tacoma Smelter Search Website (WSDOE 2012). Therefore, arsenic was not included in the Miller Creek modeling evaluation.

In the Miller Creek surface sediment samples, three dioxin/furan congeners were detected:

- 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin (HpCDD)
- Octachlorodibenzo-p-dioxin (OCDD)
- 1,2,3,4,6,7,8-heptalchlorodibenzo-p-furan (HpCDF)

These congeners consist of 7 or 8 chlorine atoms, and are the most chlorinated congeners of the 17 used in the toxic equivalency quotient (TEQ) calculation. Of the three congeners detected in the Miller Creek sediment samples, OCDD was selected to represent dioxins/furans in Miller Creek because it was the most prevalent of the three congeners detected in creek samples and a peer reviewed and published K_{oc} value was available for OCDD (which was not available for the other, less studied congeners). Sediment Sample MC-SED1 was selected as the dioxin/furan source concentration for modeling because the highest dioxin/furan concentration in Miller Creek was detected at this location. The Miller Creek dioxin/furan surface sediment source concentration is provided in Table P.1 and Figure P.1.

2.5 MODEL INPUT PARAMETERS

In general, the selected numerical model input values were based on literature values, experience with other modeling projects, and site-specific data. The model includes a number of parameters that describe the properties of the chemical isolation cap material and chemical mass transfer rates associated with processes such as bioturbation, groundwater flow, and sediment deposition.

As the dissolved contaminants move upward through the cap, some contaminants are predicted to undergo biodegradation while at the same time partitioning onto the cap material. Bioturbation mixes the surface layer, further reducing concentrations. The model calculates the chemical concentrations in the bioturbation layer as a balance between the flux from the underlying chemical isolation layer, the flux leaving the bioturbation layer, and the benthic boundary layer in the overlying water column. Numerical cap model inputs are summarized in Table P.2, where they are divided into the following three categories based on the processes they characterize:

- Chemical-specific properties (e.g., coefficients that vary by contaminant)
- Cap properties, which include physical properties of the anticipated capping material

- Mass transport properties, which include the coefficients that describe the rates of potential contaminant movement through the cap media

Table P.2 contains the numerical values for each model input coefficient, as well as the sources from which the values were obtained. Model input parameters are discussed in greater detail below.

2.5.1 Chemical-Specific Properties

Numerical model simulations were conducted to determine what cap thickness and composition would be required to result in the model prediction that COC pore water concentrations exiting the cap surface would not exceed surface water criteria. Partitioning of contaminants between the aqueous and sorbed (i.e., sediment) phases is described in the model using chemical-specific equilibrium partition coefficients. In addition, several of the contaminants simulated by the model have been found to experience biological degradation under both aerobic and anaerobic conditions in the sediment bed. As such, appropriately conservative degradation rates were derived from available literature to represent biodegradation of contaminants.

2.5.1.1 Partitioning Coefficients

The K_d values for arsenic and lead, the inorganic COCs that were modeled for Lora Lake, were taken from the USEPA document “Partition Coefficients for Metals in Surface Water, Soil, and Waste,” which is a summary review of literature values for several transport pathways, including the sediment-water pathway (USEPA 2005). The review presents a median arsenic K_d value of 320 L/kg and a median lead K_d value of 126,000 L/kg. The K_{oc} values for organic COCs were taken from an extensive literature review that consisted of the Model Toxics Control Act (WSDOE 2007), American Society of Testing Materials (ASTM 1992), USEPA (1996), and peer-reviewed technical publications (Schroy et al. 1985, Jackson et al. 1986). When multiple values were available, an average K_{oc} value was used for this evaluation. Table P.3 provides the partitioning coefficients.

For evaluating the chemical attenuation of lake dioxins/furans in Lora Lake, 2,3,7,8-TCDD K_{oc} values were conservatively used because multiple dioxin and furan congeners, including 2,3,7,8-TCDD, were detected in Lora Lake surface sediments. The use of 2,3,7,8-TCDD K_{oc} values for dioxin/furan modeling is conservative because this congener is the most mobile congener and will result in an over estimation of the movement and transport of dioxin/furans, due to an underestimation of dioxin/furan attenuation to the cap materials.

As mentioned in Section 2.4.2, only three, more chlorinated dioxin and furan congeners were detected in the Miller Creek sediment samples. For the evaluation of Miller Creek sediment leaching, an OCDD K_{oc} value was used to more accurately predict the leaching of the dioxin/furan congeners detected in Miller Creek surface sediments (ASTM 1992).

2.5.1.2 Degradation Rates

Biodegradation rates used for the organic COCs benzo(a)pyrene, PCP, and 2,3,7,8-TCDD were selected based on an extensive literature review of the following: regulatory guidance, studies conducted for USEPA, studies conducted by the California Environmental Protection Agency (CalEPA), evaluations conducted by the Syracuse Research Corporation Environmental Science Center (Syracuse Research), and peer-reviewed technical publications (ATSDR 1994, CalEPA 2000, Syracuse Research 1998, Henner et al. 1997, van Gestel and Ma 1988, Kuwatsuka and Igarashi 1975, and Ide et al. 1972). Emphasis was placed on selecting degradation rates that were from a sediment environment, if available, and slower rates within the available range to more conservatively estimate the rate of contaminant degradation in the system. Aerobic degradation rates were used within the sediment deposition layer on top of the cap, and within the sand cap layer. During the biodegradation rate literature review half-lives from field studies were given preference as were longer term laboratory studies. The greater the half life of a chemical, or the time required for a chemical quantity to fall to half its value as measured at the beginning of the time period, the lower the degradation rate, or the slower the chemical is biodegraded in the environment.

A small amount of biodegradation of benzo(a)pyrene is expected to occur over the model simulation time scale (100 years). The average of low and high estimates of soil half-lives presented in the “Handbook of Environmental Degradation Rates” for various polycyclic aromatic hydrocarbons (PAHs) ranges from 24 to 1,524 days (Howard et al. 1991). A half-life for total PAHs, including both low and high molecular weight PAHs, has been recommended at 570 days (0.4 yr^{-1}; CalEPA 2000). On behalf of the USEPA, the Syracuse Research Corporation Environmental Science Center conducted an extensive review of environmental degradation rate constants for Toxics Release Inventory Chemicals, including benzo(a)pyrene (Syracuse Research Corporation Environmental Science Center 1998). Biodegradation data were initially screened for aerobic field and grab sample studies. No pure culture, screening, or biotreatment studies were incorporated into the summaries. Only studies conducted in soil, sediment, marine or fresh water, or groundwater were included. The data from comparable soil or sediment matrices, such as sandy loams, reported aerobic degradation rates ranging from 229 to 309 days or 1.1 to 0.8 yr^{-1} (Park et al. 1990). Therefore, based on a literature review of PAH and benzo(a)pyrene biodegradation rates, an aerobic half-life of 309 days or 0.8 yr^{-1} was used in the cap modeling; however, the total PAH degradation rate of 0.4 yr^{-1}, as reported by CalEPA in 2000 was evaluated in the sensitivity analysis.

Some biodegradation of PCP is expected to occur over the model simulation time scale. Estimates of soil half-life for PCP in an aerobic unacclimated environment were reported to range from 23 to 178 days (Howard et al. 1991). Increased content of organic matter in the soil has also been reported to increase the half-life of PCP in soil by decreasing the bioavailability of the compound (ATSDR 1994). Flooded soils and paddy soils have half-lives on the order of 10 to 120 days (ATSDR 1994, Ide et al. 1972, Kuwatsuka and Igarashi 1975). The arithmetic mean of the limits of the range (100 days) is recommended as the default half-life for PCP. Van Gestel and Ma (1988) determined PCP half-lives in low pH and organically rich (pH of 5.0 and 5.6 and 3.7 and 6.1 percent organic matter) sediments of 23.2 and 47.9 days. Based on a literature review of PCP biodegradation rates, an aerobic half-life of 100 days or 2.5 yr^{-1} was conservatively used in the cap modeling and the most conservative (i.e., slowest) degradation rate of 1.4 yr^{-1} (178-day half-life) as reported by Howard et al. 1991 was evaluated in the sensitivity analysis.

Because of the highly chlorinated structures of dioxin/furans and recalcitrant nature, significant biodegradation of 2,3,7,8-TCDD is not expected to occur over the model simulation time scale. A very slow biodegradation rate was used in the numerical modeling. Based on a literature review of 2,3,7,8-TCDD biodegradation rates, which are limited, an aerobic half-life of 4,720 days or 0.05 yr^{-1} was used in the cap modeling. This half-life is an arithmetic mean of 12 reported values based on contaminated soil studies and the recommended estimated value for use (CalEPA 2000, Hsieh et al. 1994).

2.5.2 Cap Properties

The Lora Lake numerical cap modeling evaluated what thickness of sand and organic carbon content would be required to attenuate sediment COC concentrations so that pore water concentrations emitted from the cap surface would not exceed surface water quality criteria. The cap material is readily available from a number of sources and meets the various design requirements. Because of the soft lake bottom sediments in Lora Lake, it is anticipated that the sand cap will need to be placed in thin lifts. If capping was the selected remedial alternative for Lora Lake, bench studies or a pilot test study could be conducted during design to determine the appropriate lift thickness and placement methodology based on constructability considerations and the strength and cohesiveness of the soft lake sediments.

Based on the constructability limitations of placing sand in thin lifts, the minimum cap thickness that could be placed in the lake was assumed to be 6 inches, which was used as the minimum thickness in the cap modeling evaluation. An organic carbon content of 0.06 percent (<0.1 percent) was assumed for cap modeling. This organic carbon content is readily available from non-amended quarry supplied fine-to-medium grained sand. If the model predicted that a sand cap thickness of 6 inches and an organic carbon content of 0.06 percent were not adequate to attenuate and contain the contaminant, then the cap thickness and/or organic carbon content was increased until the predicted cap surface pore water COC concentrations were less than the surface water quality criteria.

The effective porosity and bulk density values used in cap modeling to represent the cap were standard fine-to-medium grained sand values.

Based on experience with other modeling projects, the soft sediment nature of the lake sediments, and input from Dr. Danny Reible, consolidation of the underlying sediment was accounted for in the modeling and assumed to be 25 percent of the cap thickness. For example if the cap thickness is 12 inches or 30.5 cm, it is assumed in the model that the consolidation of the underlying sediments would be 3 inches or 7.6 cm.

2.5.3 Mass Transport Properties

Mass transport properties used in the model include mass transfer and biodiffusion coefficients, as well hydraulic parameters that impact the rate of groundwater and pore water movement. The deposition of sediment onto the cap following completion of the remedial action was also included in the numerical cap modeling.

2.5.3.1 Bioturbation and Boundary Layer Parameters

The numerical cap model accounts for bioturbation (the physical mixing of sediments by organisms) as a physical process that occurs within the biologically active surface or bioturbation layer of the cap. The sediment-water interface or benthic boundary layer is also simulated in the model. Within the bioturbation layer, bioturbation-induced movement of particles and bioirrigation of pore water are also considered. Bioturbation-related processes are assumed to increase the effective diffusion/dispersion coefficient. A commonly assumed depth of bioturbation (or the thickness of the bioturbation layer of the cap) of 10 cm was used in the modeling evaluation. Pore water biodiffusion and particle biodiffusion coefficient values of 100 cm/yr^2 and 1 cm/yr^2 were used in the modeling evaluation per the recommendations and modeling experience of the numerical model development group.

Transport from the cap surface and through the aqueous boundary layer is dictated by the benthic boundary layer mass transfer coefficient (Lampert and Reible 2009). Benthic boundary layer mass transfer is controlled by the turbulence in the overlying water. In lake systems, the coefficient is typically controlled by lake mixing processes (Imberger and Hamblin 1982; Lampert and Reible 2009). A default benthic boundary layer mass transfer coefficient of 1 cm/hr was used in the modeling evaluation per the recommendations and modeling experience of the numerical model development group.

2.5.3.2 Hydraulic Parameters

Remedial Investigation groundwater elevation contour maps were reviewed to determine an accurate and conservative horizontal gradient that could be used as a model input value based on available site-specific data. Based on the August 2010 and January 2011 groundwater elevation contour maps prepared by Aspect Consulting (Lora Lake Apartments Site RI/FS Figures 2.14 and 2.15), the horizontal gradients within the LL Parcel range between 0.044 and 0.051 feet/feet. A value of 0.051 feet/feet was used as a model input parameter as a conservative (higher mobility) horizontal gradient, which would also be representative of site-specific conditions.

A horizontal hydraulic conductivity of 5×10^{-5} centimeters per second (cm/s) was selected as an estimate of hydraulic conductivity. Hydraulic conductivity varies from 1×10^{-9} cm/s to 1 cm/s and is dependent on the type of soil or underlying sediment present on-site; well-sorted gravel has the greatest hydraulic conductivity while clay has the lowest hydraulic conductivity. Hydraulic conductivities for peat sediment, assumed to be similar to sandy silts or clayey sands, typically fall within the range of 1×10^{-6} to 1×10^{-4} cm/s (Fetter 2001). A value of 5×10^{-5} cm/s, representing a mid-range potential hydraulic conductivity, was selected for consistency with the LL Apartments Parcel BIOSCREEN-AT modeling, as a conservative hydraulic gradient for the underlying sediments within Lora Lake. However, it is anticipated that this value likely over-estimates the hydraulic conductivity of the LL Parcel site conditions.

2.5.3.3 Sediment Depositional Velocity

Lora Lake is a depositional environment that receives input of solids from storm drainage discharges as well as organic debris from the surrounding area. The existing storm drainage system has been in place since the development of the apartment building complex in the late 1980s. In addition, leaves and other organic inputs from the vegetation around the lake settle to the bottom, decay, and contribute to the sediment accumulation rate within the lake. Typical sedimentation rates for Puget Sound range from 0.1 to 2.4 cm/year (Carpenter et al. 1985, Schell and Nevissi 1977, Crecelius et al. 1975). Low energy depositional environments, such as a small urban lake similar to Lora Lake, have elevated sedimentation rates close to the higher range of those rates that are well documented in the Puget Sound marine environment. A sediment deposition rate of 3 cm/year was used in the numerical modeling as a realistic estimation of the deposition velocity.

This page intentionally left blank.

3.0 Modeling Results

3.1 LORA LAKE SEDIMENT CAP DESIGN

The Reible and Lampert numerical cap model (Reible and Lampert 2012) was used to predict COC pore water concentrations at the top of the cap assuming the industry standard simulation period for sediment caps of 100 years.[2] The results of a simulation period of 100 years are particularly conservative as the model assumes an infinite source, which is common of most numerical transport models. The resulting pore water concentrations were then compared to Clean Water Act Surface Water Quality Criteria for human health consumption of organisms and water. The surface water quality criteria are presented in Table P.4. The overall conclusion that can be drawn from the evaluation is that capping is a viable technology and remedial alternative in terms of the effectiveness of isolating contaminants.

Using the empirically-derived COC pore water concentrations and hydraulic transport parameters, COCs were predicted to discharge from a non-organic carbon amended sand cap at concentrations less than surface water criteria. The results of this evaluation indicate that a sand cap thickness of 6 inches and 0.06 percent organic carbon content would effectively attenuate and isolate the surface sediment concentrations of lead, cPAHs, and PCP. The results also indicate that a thicker sand cap of 18 inches and 0.06 percent organic carbon content would be needed to effectively attenuate and isolate the surface sediment concentrations of arsenic and dioxins/furans. Table P.4 summarizes the modeling evaluation results and shows the model-predicted surface pore water concentrations at 100 years relative to the COC surface water quality criteria, and the cap design (thickness and organic carbon content) that would be needed to comply with the surface water quality criteria. As the model assumes an infinite source, the predicted pore water concentrations increase over time such that the concentrations at 100 years would be greater than the concentrations at 10 years. With an infinite source the cap material would eventually become saturated, and the predicted surface pore water concentrations would equal the underlying sediment source concentrations. However, in reality with a finite source (such as the soil at the LL Apartments Parcel), and the partial or complete removal of the contaminated soils, the pore water COC concentrations would increase for a limited duration as contaminants migrate in pore water, but then the concentrations would stabilize and then decrease as the source contaminants are finite and removed, and additional sedimentation occurs.

Therefore, based on the modeling results, the placement of an 18-inch sand cap within Lora Lake would be protective of the human health pathway via fish and water consumption.

[2] This assumption is conservative because not only is the source (LL Apartments Parcel contaminated soil) finite, but also because those source soils will be partially or completely removed as part of this site remediation, as described elsewhere in this RI/FS,

3.2 MILLER CREEK SURFACE SEDIMENT LEACHING

Equilibrium partitioning was used to predict the dioxin/furan and lead pore water concentrations that would leach from the sediment surface in Miller Creek. The resulting pore water dioxin/furan concentration was then compared to Clean Water Act Surface Water Quality Criteria for human health consumption of organisms and water, and to the Safe Water Drinking Act lead Action Level (since Surface Water Quality Criteria for protection of human health are not available). The results of this evaluation indicate that the dioxin/furan and lead concentrations that could potentially leach from Miller Creek surface sediments do not exceed the applicable human health criteria (Table P.5). Therefore, based on the modeling results, Miller Creek surface sediments are protective of the human health pathway via fish and water consumption.

3.3 NUMERICAL CAP MODEL SENSITIVITY ANALYSIS

The input parameters that have the greatest influence on model results were further evaluated in a sensitivity analysis. The sensitivity analysis included model runs that were conducted with varying values of the following parameters that would lead to a more conservative modeling scenario to understand how differences in these parameters influence the modeling results:

- Hydraulic conductivity
- Depositional velocity
- COC degradation rates
- COC partitioning coefficients

As described above, the hydraulic conductivity used in the numerical cap modeling (5×10^{-5} cm/s) was selected for consistency with the LL Apartments Parcel BIOSCREEN-AT modeling, as a conservative hydraulic gradient for the underlying sediments within Lora Lake and the mid-range of hydraulic gradients for peat sediment, assumed to be similar to sandy silts or clayey sands of 1×10^{-6} to 1×10^{-4} cm/s (Fetter 2001). The sensitivity model runs were performed using a greater hydraulic conductivity (6×10^{-5} cm/s), an increase that results in increased potential water and contaminant mobility, as well as a lower hydraulic conductivity (2×10^{-5} cm/s), which is a best estimate of actual LL parcel site conditions.

In low energy depositional environments, such as Lora Lake, elevated sedimentation rates are typical relative to marine or higher energy environments. A sediment deposition rate of 3 cm/year was used in the numerical modeling as a realistic estimation of the deposition velocity. As part of the sensitivity analysis a slower deposition rate of 2 cm/year was evaluated.

The degradation rates of the organic COCs were also varied as part of the sensitivity analysis. For benzo(a)pyrene a biodegradation rate of 0.44 yr^{-1} (slower than the rate of 0.8 yr^{-1} used in the cap modeling) was evaluated, as observed in the literature as an average for soils over multiple studies (CalEPA 2000). The PCP degradation rates observed in various regulatory studies and literature review articles range from 23 to 178 days or 10.9 to 1.4 yr^{-1}. The rate used in the cap modeling was 100 days or 2.5 yr^{-1}. In the sensitivity analysis the slower degradation rate of 1.4 yr^{-1} was also evaluated. Because very little biodegradation is expected to occur over the model simulation period, and such a slow degradation rate was used in the cap modeling evaluation, other 2,3,7,8-TCDD degradation rates were not included in the sensitivity analysis.

Finally, the lower end of the peer-reviewed partitioning coefficients for organic COCs, as shown in Table P.3, were adjusted to decrease the sorption of the COCs to the cap material. Decreasing the coefficients has the subsequent effect of increased COC transport and greater model-predicted pore water concentrations.

Table P.6 presents the values of the parameters that were adjusted for the sensitivity analysis model runs and the associated results. The results of the sensitivity analysis confirm the relationships described previously:

- A lower K_{oc} value, but still within an appropriate range of values, for PCP and benzo(a)pyrene has little impact on the modeled results.
- A lower biodegradation rate for PCP and benzo(a)pyrene has little impact on the modeled results, but does result in slightly higher predicted pore water concentrations, still at concentrations less than the surface water ARARs.
- A slower sediment deposition velocity has little to no impact on the modeled results. A slightly higher benzo(a)pyrene pore water concentration was predicted, but still at a concentration less than the surface water ARAR.
- A higher hydraulic conductivity results in greater groundwater and upwelling velocities and therefore greater movement of COCs in pore water.

The specific results for each of the modeled scenarios indicate that when a single variable is altered, predicted pore water concentrations emitted from the cap surface are less than the surface water criteria for all model runs. The results of modeling and the sensitivity analysis indicate that capping of Lora Lake sediments is a protective remedial alternative even when using conservative model input parameters applicable to the site and COCs.

This page intentionally left blank.

4.0 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. U.S. Public Health Service Toxicological Profile for Pentachlorophenol.

American Society of Testing Materials (ASTM). 1992. *Waste Testing and Quality Assurance.* Third Volume. ASTM STP 1075. David Friedman, editor. Baltimore, MD: ASTM Committee on Publications.

Anchor Engineering, P.L.L.C. (Anchor). 2006. *Design/Work Plan for Installation of PAH Cap in the St. Lawrence River*. Prepared for Alcoa, Massena, New York. September.

Anchor QEA. 2012. *Draft Portland Harbor Remedial Investigation/Feasibility Study: Appendix Hc Cap Effectiveness and Stability Monitoring*. Prepared for The Lower Willamette Group. 30 March.

California Environmental Protection Agency (CalEPA). 2000. *Air Toxics Hot Spots Program Risk Assessment Guidelines Part IV: Technical Support Document for Exposure Assessment and Stochastic Analysis. Appendix G: Chemical Specific Soil Half-Lives*. Office of Environmental Health Hazard Assessment. September.

Carpenter, S.R., J.F. Kitchell, and J.R. Hodgson. 1985. “Cascading trophic interactions and lake productivity.” *BioScience* 35: 634–639.

Crecelius, E.A., M.H. Bothner, and R. Carpenter. 1975. ”Geochemistries of arsenic, antimony, mercury and related elements in sediments of Puget Sound.” *Environmental Science and Technology* 9: 325–333.

Dougherty, E.J., M.R. Overcash, and R.G. Carbonell. 1991. “Diffusivity of 2,3,7,8-Tetreachlorodibenzo-p-dioxin in Organic Solvents.” *Hazardous Waste and Hazardous Materials* 8: 43–53.

Fetter, C.W. 2001. *Applied Hydrogeology*. Fourth Edition. University of Wisconsin-OshKosh. Upper Saddle River, New Jersey: Prentice-Hall, Inc.

Henner, P., M. Schiavon, J.L. Morel, E. Lichtfouse. 1997. “Polycyclic Aromatic Hydrocarbon (PAH) Occurrence and Remediation Methods.” *Analusis Magazine* 25: M56–M59.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko. 1991. *Handbook of Environmental Degradation Rates,* ed. H.T. Printup. Chelsea, MI: Lewis Publishers, Inc..

Hsieh, D.P.H., T.E. McKone, F. Chiao, R.C. Currie, and L. Kleinschmidt. 1994. *Final Draft Report: Intermedia transfer factors for contaminants found at hazardous* *waste sites*. Prepared for the Office of Scientific Affairs, Department of Toxic Substances Control, California Environmental Protection Agency. November.

Ide, A., Y. Niki, F. Sakamoto, and H. Watanabe. 1972. "Decomposition of pentachlorophenol in paddy soil." *Agricultural and Biological Chemistry* 36(11): 1937–1944.

Imberger, J. and P.F. Hamblin. 1982. "Dynamics of lakes, reservoirs and cooling ponds." *Annual Review of Fluid Mechanics* 14: 153–187.

Jackson, D.R., M.H. Roulier, H.M. Grotta, S.W. Rust, and J.S. Warner. 1986. "Solubility of 2,3,7,8-TCDD in Contaminated Soils." pp. 185–200 in *Chlorinated Dioxins and Dibenzofurans in Perspective*, ed. C. Rappe, G. Choudhary, and L.H. Keith. Lewis Publishers, Inc.

Kuwatsuka, S. and M. Igarashi. 1975. "Degradation of PCP in Soils: II. The Relationship between the Degradation of PCP and the Properties of Soils and the Identification of the Degradation Products of PCP." *Soil Science and Plant Nutrition* 21: 405–14.

Lampert, D.J. and D.D. Reible. 2009. "An Analytical Modeling Approach for Evaluation of Capping of Contaminated Sediments." *Soil and Sediment Contamination: An International Journal* 18(4): 470–488.

Palermo, M.R., J.E. Clausner, M.P. Rollings, G.L. Williams, and T.E. Myers. 1998. *Guidance for Subaqueous Dredged Material Capping.* June.

Park, K.S., R.C. Sims, R.R. Dupont, W.J. Doucette, and J.E. Matthews. 1990. "Fate of PAH compounds in two soil types: Influence of volatilization, abiotic loss and biological activity." *Environmental Toxicology and Chemistry* 9(2): 187–95.

Parsons and Anchor QEA, LLC. 2011. Draft Onondaga Lake Capping, Dredging, and Habitat Intermediate Design. Prepared for Honeywell. January.

Reible, D.D. and D.J. Lampert. 2012. Capping for remediation in contaminated sediments, Chapter 12 in Processes, Assessment and Remediation of Contaminated Sediment, D.D. Reible Ed., SERDP/ESTCP Remediation Technology Monograph Series, Springer (in press).

Schell, W.R. and A. Nevissi. 1977. "Heavy metals from waste disposed in central Puget Sound." *Environmental Science and Technology* 11(9): 887–893.

Schroy, J.M., F.D. Hileman, and S.C. Cheng. 1985. "Physical/chemical properties of 2,3,7,8-TCDD." *Chemosphere* 14: 877–880.

Syracuse Research Corporation Environmental Science Center (Syracuse Research). 1998. *Chemical Fate Half-Lives for Toxics Release Inventory (TRI) Chemicals.*

Prepared by Dallas Aronson, Heather Printup, Kirsten Shuler, and Philip Howard. Prepared for U.S. Environmental Protection Agency. 30 July.

The Risk Assessment Information System (RAIS). 2009. *Basic Information for Pentachlorophenol*. The University of Tennessee.

U.S. Environmental Protection Agency (USEPA). 1996. *Soil Screening Guidance: Technical Background Document, Second Edition.* Office of Solid Waste and Emergency Response. EPA/540/R95/128. Publication 9355.4-17A. May.

———. 2005. *Partition Coefficients for Metals in Surface Water, Soil, and Waste*. Office of Research and Development. EPA/600/R-05/074. July.

———. 2008. *Ocean Survey Vessel BOLD SURVEY REPORT: Puget Sound Sediment PCB and Dioxin 2008 Survey, July 31 to August 6, 2008*. Final Report. Prepared by M. Liebman of U.S. Environmental Protection Agency, New England, Oceans and Coast Protection Unit, Boston, MA. 11 September.

van Gestel, C.A and W.C. Ma. 1988. "Toxicity and bioaccumulation of chlorophenols in earthworms, in relation to bioavailability in soil." *Ecotoxicology And Environmental Safety* 15(3): 289–297.

Washington State Department of Ecology (WSDOE). 2007. *Model Toxics Control Act Chapter 70.105D RCW.* Publication No. 94-06. Revised November.

———. 2012. Washington State Everett and Tacoma Smelter Search Website. https://fortress.wa.gov/ecy/smeltersearch/. Last accessed 10/2/2012.

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix P
Sediment Leaching and Numerical Cap Modeling

Tables

FINAL

Table P.1
Lora Lake and Miller Creek Maximum Surface Sediment Source Concentrations

Contaminant of Concern	Maximum Detected Sediment Concentration[1]	Unit
Maximum COC Concentrations for Lora Lake Surface Sediment Samples		
Arsenic	70	mg/kg
Lead	492	mg/kg
Pentachlorophenol	50	µg/kg
cPAHs[2]	180	µg/kg
Dioxins/Furans[3]	217	pg/g
Maximum COC Concentrations for Miller Creek Surface Sediment Samples		
Dioxins/Furans[4]	0.442	pg/g
Lead	12	mg/kg

Notes:

1 Maximum concentrations detected in the RI Lora Lake surface sediment sampling event were used for modeling.
2 Benzo(a)pyrene is evaluated to represent cPAHs.
3 2,3,7,8-TCDD is evaluated to represent dioxin/furan congeners in Lora Lake.
4 OCDD is evaluated to represent dioxin/furan congeners in Miller Creek as only OCDD and HpCDD/HpCDF congeners were detected.

Abbreviations:

µg/kg	Micrograms per kilogram
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
COC	Contaminant of concern
cPAH	Carcinogenic polycyclic aromatic hydrocarbons
HpCDD	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin
HpCDF	1,2,3,4,7,8,9-Heptachlorodibenzofuran
mg/kg	Milligrams per kilogram
OCDD	Octachlorodibenzo-p-dioxin
pg/g	Picograms per gram

Table P.2
Sediment Leaching and Numerical Cap Modeling Input Parameters

Model Input Parameter	Unit	Value					Source/Comments
		Arsenic	Lead	Benzo(a)pyrene	Pentachlorphenol	2,3,7,8-TCDD	
Chemical Properties							
Contaminant Source Sediment Concentration	µg/kg	70,000	492,000	180	50	0.217	Maximum concentrations detected in surface sediments.
Calculated Contaminant Initial Pore Water Concentration	µg/L	219	3.90	0.002	0.09	2.17E-07	Calculated from the maximum lake sediment concentrations and the average lake surface sediment TOC content of 8% (excluding LL-SED-5).
Organic Carbon Partition Coefficient, K_{oc}	L/kg	320	126,000	995,000	7,000	12,500,000	Refer to Table P.3.
Organic Carbon Partition Coefficient, Log K_{oc}	log L/kg	2.5	5.1	6.0	3.8	7.1	Refer to Table P.3.
Water Diffusivity	cm^2/s	NA	NA	9.0E-06	6.10E-06	5.60E-06	USEPA 1996, RAIS 2009, Dougherty et al. 1991
Chemical Decay Rate in Bioturbation Zone	yr^{-1}	0	0	0.8	2.5	0.059	Syracuse Research Corporation Environmental Science Center 1998 (benzo(a)pyrene 0.8); CalEPA 2000 (pentachlorophenol 2.5, 2,3,7,8-TCDD 0.059)
Cap Properties							
Cap Effective Porosity		0.5					Assumed standard fine-to-medium sand porosity.
Cap Bulk Density	gm/cm^3	1.5					Assumed standard fine-to-medium sand density.
Cap Thickness	cm	15.2 to 45.7					A minimum of 6 inches of sand cap simulated, up to the predicted required cap thickness of 18 inches.
Sand Cap Organic Carbon Content	%	0.06 (<0.1% in sand cap material)					Assumed minimal carbon content of sand cap material.
Consolidation of Underlying Sediments Based on Cap	%	10% of the sand cap thickness					Dr. Reible recommended standard value based on experience with similar sediment modeling projects.
Mass Transport Properties							
Boundary Layer Mass Transfer	cm/hr	1.0					Dr. Reible recommended and model default value.
Hydraulic Conductivity	cm/s	0.00005					Mid-range value for the assumption that peat material is similar in permeability to silt, sandy silts, and clayey sands (refer to Table 3.7 of Fetter 2001).
Horizontal Hydraulic Gradient	ft/ft	0.051					Site-specific value estimated based on RI groundwater elevation contour maps.
Darcy Velocity	ft/day (cm/yr)	0.007 (80)					Calculated based on hydraulic conductivity and gradient.
Depositional velocity	cm/yr	3.0					Assumed value based on estimated range of lake deposition.
Organic Carbon Content of Sediments Deposited on the Sand Cap	%	8.0					The organic carbon in deposited sediments was estimated to be the average lake surface sediment TOC content of 8% (excluding LL-SED-5) as measured in RI surface sediment samples. Post-capping and over time the sediments deposited on top of the cap would also include organic leaf litter and debris from the surrounding wetland vegetation with a higher organic carbon content.
Dissolved Organic Carbon Content	mg/L	10					Dr. Reible recommended standard value based on experience with similar sediment modeling projects.
Bioturbation Layer Thickness	cm	10					Typical surface sediment bioturbation depth.
Porewater Biodiffusion Coefficient	cm^2/yr	100					Dr. Reible recommended standard value based on experience with similar sediment modeling projects.
Particle Biodiffusion Coefficient	cm^2/yr	1.0					Dr. Reible recommended standard value based on experience with similar sediment modeling projects.

Abbreviations:

µg Microgram
2,3,7,8-TCDD 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
cm Centimeter
f_{oc} Fraction of organic carbon in sediment sample
ft Feet
g Gram
hr Hour
kg Kilogram
K_{oc} Organic carbon partitioning coefficient
L Liter
MCL Maximum cleanup level
mg Milligram
MTCA Model Toxics Control Act
RI Remedial Investigation
s Second
TOC Total organic carbon
USACE U.S. Army Corps of Engineers
yr Year

Table P.3
Partitioning Coefficients (K_d and K_{oc})[1] in L/kg

Inorganic COC	USEPA (2005)[2]					
Metals						
Arsenic	320					
Lead	126,000					
Organic COC	**MTCA (2007)[3]**	**ASTM (1992)[4]**	**USEPA (1996)**	**Schroy et al. (1985)**	**Jackson et al. (1986)**	**Average K_{oc} Used**
Polycyclic Aromatic Hydrocarbons						
Benzo(a)pyrene	970,000	NA	1,020,000	NA	NA	995,000
Semivolatile Organic Compounds						
Pentachlorophenol	9,000	NA	5,000	NA	NA	7,000
Dioxins/Furans						
2,3,7,8-TCDD	NA	NA	NA	1,000,000	24,000,000	12,500,000
OCDD	NA	190,000,000	NA	NA	NA	190,000,000

Notes:

1 K_d values are presented for metal COCs and K_{oc} values are presented for organic COCs.

2 USEPA reference provides a summary of literature based arsenic Kd values specific to the sediment-water pathway.

3 Source of Washington State Department of Ecology's MTCA K_{oc} values is the 1996 USEPA Soil Screening Guidance: Technical Background Document.

4 Source of ASTM K_{oc} value is 1992 Waste Testing and Quality Assurance: Third Volume.

Abbreviations:

2,3,7,8-TCDD 2,3,7,8-Tetrachlorodibenzo-p-dioxin
ASTM American Society for Testing and Materials
COC Contaminant of concern
K_d Partition coefficient
K_{oc} Soil organic carbon-water partitioning coefficient
L/kg Liter per kilogram
MTCA Model Toxics Control Act
NA Not applicable
OCDD Octachlorodibenzo-p-dioxin
USEPA U.S. Environmental Protection Agency

Table P.4
Summary of Lora Lake Numerical Cap Design Modeling Results

Contaminant of Concern	Surface Pore Water Concentration at 100 Years (µg/L)	Surface Water ARARs[1,2] (µg/L)	Cap Required for ARAR Compliance
Arsenic	0.0002	0.02	18 inches sand, OC 0.06%
Lead[3]	2.0E-33	15	6 inches sand, OC 0.06%
cPAHs (Benzo(a)pyrene)	9.8E-06	0.004	6 inches sand, OC 0.06%
Pentachlorophenol	0.072	0.3	6 inches sand, OC 0.06%
Dioxins/Furans (2,3,7,8-TCDD)	1.2E-09	5.00E-09	18 inches sand, OC 0.06%

Notes:

1 Federal Ambient Water Quality Criteria, Clean Water Act Section 304, Human Health, Consumption of Organism and Water.

2 A Federal Ambient Water Quality Criterion (Surface Water) for the protection of human health is not available for lead; however, the Federal Safe Drinking Water Act action level for lead is 15 µg/L. Therefore, based on protection of human health via the pathway of potential consumption of Miller Creek surface water and organisms this criterion was used in the evaluation of cap modeling.

3 The calculated lead initial pore water concentration from the maximum surface sediment concentration detected of 492 mg/kg is 3.9 µg/L, less than the surface water quality criteria of 15 µg/L. The lead pore water concentration was modeled using the minimum cap thickness and organic carbon content for completeness.

Abbreviations:

µg/L Micrograms per liter
2,3,7,8-TCDD 2,3,7,8-Tetrachlorodibenzo-p-dioxin
ARAR Applicable, Relevant, and Appropriate Requirement
cPAH Carcinogenic polycyclic aromatic hydrocarbons
mg/kg Milligrams per kilogram
OC Organic carbon

Table P.5
Summary of Miller Creek Sediment Leaching Results

Contaminant of Concern	Surface Pore Water Concentration (µg/L)	Surface Water ARARs[1,2] (µg/L)
Lead	3.9	15
Dioxins/Furans[3,4]	4.1E-10	5.00E-09

Notes:

1. Federal Ambient Water Quality Criteria, Clean Water Act Section 304, Human Health, Consumption of Organism and Water.
2. A Federal Ambient Water Quality Criterion (Surface Water) for the protection of human health is not available for lead; however, the Federal Safe Drinking Water Act action level for lead is 15 µg/L. Therefore, based on protection of human health via the pathway of potential consumption of Miller Creek surface water and organisms this criterion was used in the evaluation of cap modeling.
3. Dioxins/furans and lead were evaluated for the surface sediment leaching modeling for Miller Creek. At the three Miller Creek surface sediment sampling locations, lead and dioxins/furans were detected at all three locations. Arsenic was detected only at Miller Creek Station MC-SED1 within soil and sediment background concentrations as described in Section 2.4.2. Other COCs were not detected in Miller Creek sediment samples.
4. OCDD is evaluated to represent dioxin/furan congeners in Miller Creek as only OCDD and HpCDD/HpCDF congeners were detected.

Abbreviations:

µg/L Micrograms per liter
ARAR Applicable, relevant, and appropriate requirement
HpCDD 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin
HpCDF 1,2,3,4,7,8,9-Heptachlorodibenzofuran
OCDD Octachlorodibenzo-p-dioxin

Table P.6
Modeling Sensitivity Analysis Results

Modeled Input Parameters						Result	Criteria
Model Run No.	K_{oc} (L/kg)	Hydraulic Conductivity (cm/s)	Deposition Velocity (cm/yr)	Degradation Rate (yr)	Parameter Comments	Predicted Pore Water Concentration (µg/L)	Surface Water ARARs[2] (µg/L)
Pentachlorophenol							
Base	7,000	5.0E-05	3	2.5	Hydraulic conductivity used for consistency with RI BIOSCREEN-AT modeling at the LL Apartments Parcel, but anticipated to be greater than the actual LL Parcel hydraulic conductivity.	0.072	0.3
1	7,000	**2.0E-05**	3	2.5	Estimated hydraulic conductivity representative of site conditions at the LL Parcel.	0.047	
2	7,000	**6.0E-05**	3	2.5	Potential upper end of hydraulic conductivities for peat and sandy silts conditions at the LL Parcel.	0.075	
3	**5,000**	5.0E-05	3	2.5	Lower end of K_{oc} value range based on USEPA 1996 reference.	0.072	
4	7,000	5.0E-05	**2**	2.5	Lower end of potential sediment deposition velocities; however, in the lake low energy conditions it is anticipated that this value under-represents actual site conditions.	0.072	
5	7,000	5.0E-05	3	**1.4**	Lower end and most conservative (i.e., slowest) degradation rate as reported by Howard et al. 1991.	0.079	
Benzo(a)pyrene							
Base	995,000	5.0E-05	3	0.8	Hydraulic conductivity used for consistency with RI BIOSCREEN-AT modeling at the LL Apartments Parcel, but anticipated to be greater than the actual LL Parcel hydraulic conductivity.	9.8E-06	3.8E-03
1	995,000	**2.0E-05**	3	0.8	Estimated hydraulic conductivity representative of site conditions at the LL Parcel.	4.7E-10	
2	995,000	**6.0E-05**	3	0.8	Potential upper end of hydraulic conductivities for peat and sandy silts conditions at the LL Parcel.	2.2E-05	
3	**970,000**	5.0E-05	3	0.8	Lower end of K_{oc} value range based on MTCA 2007 reference.	9.8E-06	
4	995,000	5.0E-05	**2**	0.8	Lower end of potential sediment deposition velocities; however, in the lake low energy conditions it is anticipated that this value under represents actual site conditions.	9.7E-06	
5	995,000	5.0E-05	3	**0.4**	Lower end and most conservative (i.e., slowest) degradation rate for total PAHs as reported by CalEPA 2000.	9.9E-06	
2,3,7,8-Tetrachlorodibenzo-p-dioxin							
Base	12,500,000	5.0E-05	3	0.05	Hydraulic conductivity used for consistency with RI BIOSCREEN-AT modeling at the LL Apartments Parcel, but anticipated to be greater than the actual LL Parcel hydraulic conductivity.	1.2E-09	5.0E-09
1	12,500,000	**2.0E-05**	3	0.05	Estimated hydraulic conductivity representative of site conditions at the LL Parcel.	3.2E-13	
2	12,500,000	**6.0E-05**	3	0.05	Potential upper end of hydraulic conductivities for peat and sandy silts conditions at the LL Parcel.	3.7E-09	
3	12,500,000	5.0E-05	**2**	0.05	Lower end of potential sediment deposition velocities; however, in the lake low energy conditions it is anticipated that this value under represents actual site conditions.	1.2E-09	
Arsenic							
Base	320	5.0E-05	3	0	Hydraulic conductivity used for consistency with RI BIOSCREEN-AT modeling at the LL Apartments Parcel, but anticipated to be greater than the actual LL Parcel hydraulic conductivity.	1.9E-04	2.0E-02
1	320	**2.0E-05**	3	0	Estimated hydraulic conductivity representative of site conditions at the LL Parcel.	2.7E-21	
2	320	**6.0E-05**	3	0	Potential upper end of hydraulic conductivities for peat and sandy silts conditions at the LL Parcel.	1.9E-02	
3	320	5.0E-05	**2**	0	Lower end of potential sediment deposition velocities; however, in the lake low energy conditions it is anticipated that this value under represents actual site conditions.	1.8E-04	

Notes:

Bold input parameters indicate the specific parameter and value that was changed for the sensitivity analysis model run.

Base The "Base" model run indicates the actual numerical model run that was used for the model predicted results comparison to surface water criteria in the cap design.

1 Assumes organic carbon content (0.06 percent) of standard quarry supplied sand.

2 Federal Ambient Water Quality Criteria, Clean Water Act Section 304, Human Health, Consumption of Organism and Water.

Abbreviations:

ARAR Applicable, relevant, and appropriate requirement
µg/L Micrograms per liter
cm/s Centimeters per second
cm/yr Centimeters per year
Koc Partition coefficient
LL Lora Lake
L/kg Liters per kilogram
MTCA Model Toxics Control Act
PAH Polycyclic aromatic hydrocarbon
RI Remedial Investigation
yr Year
USEPA U.S. Environmental Protection Agency

Port of Seattle
Lora Lake Apartments Site

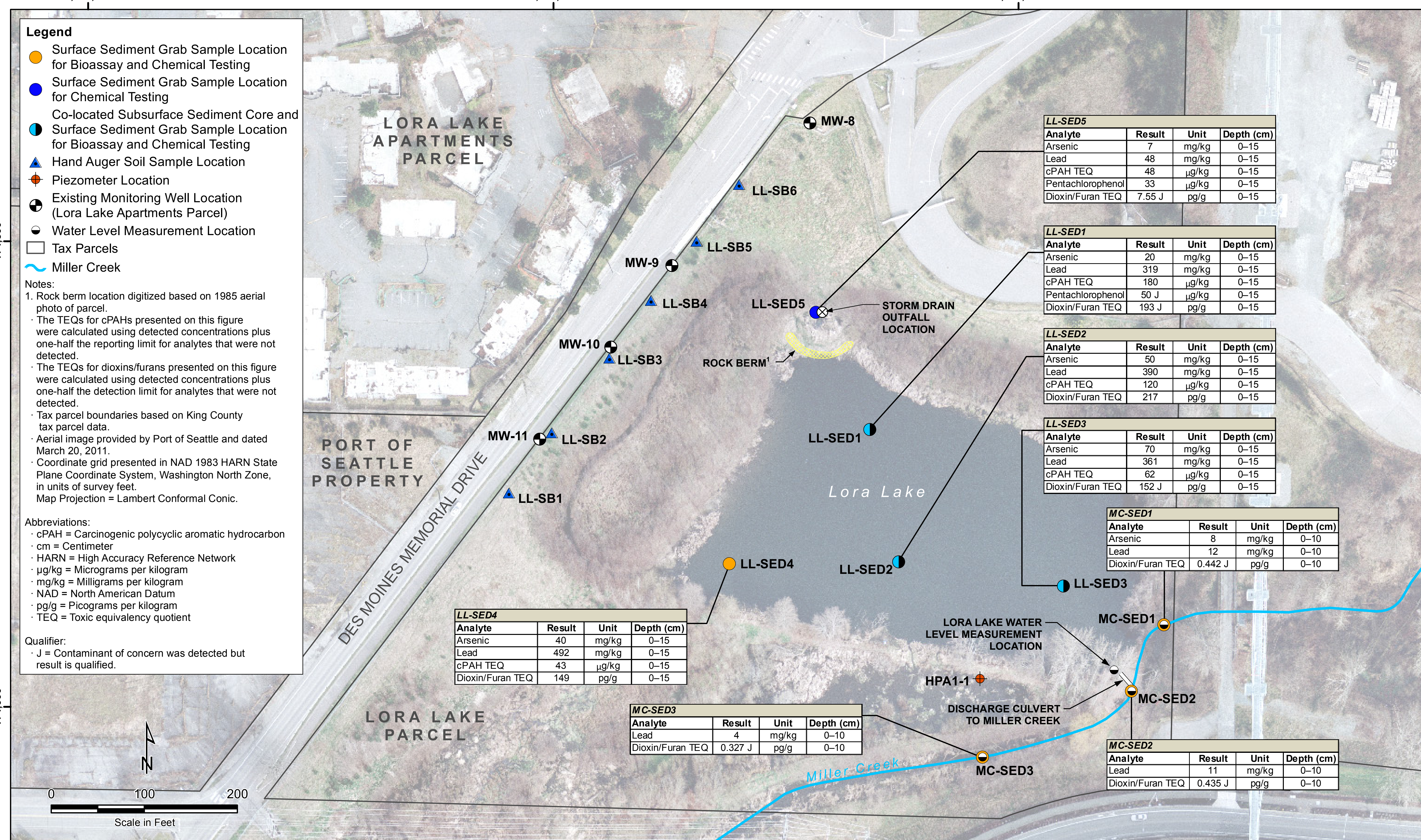
Remedial Investigation/ Feasibility Study

Volume II

Appendix P
Sediment Leaching and Numerical Cap Modeling

Figures

FINAL



Legend

- Surface Sediment Grab Sample Location for Bioassay and Chemical Testing
- Surface Sediment Grab Sample Location for Chemical Testing
- Co-located Subsurface Sediment Core and Surface Sediment Grab Sample Location for Bioassay and Chemical Testing
- Hand Auger Soil Sample Location
- Piezometer Location
- Existing Monitoring Well Location (Lora Lake Apartments Parcel)
- Water Level Measurement Location
- Tax Parcels
- Miller Creek

Notes:
1. Rock berm location digitized based on 1985 aerial photo of parcel.
- The TEQs for cPAHs presented on this figure were calculated using detected concentrations plus one-half the reporting limit for analytes that were not detected.
- The TEQs for dioxins/furans presented on this figure were calculated using detected concentrations plus one-half the detection limit for analytes that were not detected.
- Tax parcel boundaries based on King County tax parcel data.
- Aerial image provided by Port of Seattle and dated March 20, 2011.
- Coordinate grid presented in NAD 1983 HARN State Plane Coordinate System, Washington North Zone, in units of survey feet. Map Projection = Lambert Conformal Conic.

Abbreviations:
- cPAH = Carcinogenic polycyclic aromatic hydrocarbon
- cm = Centimeter
- HARN = High Accuracy Reference Network
- µg/kg = Micrograms per kilogram
- mg/kg = Milligrams per kilogram
- NAD = North American Datum
- pg/g = Picograms per kilogram
- TEQ = Toxic equivalency quotient

Qualifier:
- J = Contaminant of concern was detected but result is qualified.

LL-SED5

Analyte	Result	Unit	Depth (cm)
Arsenic	7	mg/kg	0–15
Lead	48	mg/kg	0–15
cPAH TEQ	48	µg/kg	0–15
Pentachlorophenol	33	µg/kg	0–15
Dioxin/Furan TEQ	7.55 J	pg/g	0–15

LL-SED1

Analyte	Result	Unit	Depth (cm)
Arsenic	20	mg/kg	0–15
Lead	319	mg/kg	0–15
cPAH TEQ	180	µg/kg	0–15
Pentachlorophenol	50 J	µg/kg	0–15
Dioxin/Furan TEQ	193 J	pg/g	0–15

LL-SED2

Analyte	Result	Unit	Depth (cm)
Arsenic	50	mg/kg	0–15
Lead	390	mg/kg	0–15
cPAH TEQ	120	µg/kg	0–15
Dioxin/Furan TEQ	217	pg/g	0–15

LL-SED3

Analyte	Result	Unit	Depth (cm)
Arsenic	70	mg/kg	0–15
Lead	361	mg/kg	0–15
cPAH TEQ	62	µg/kg	0–15
Dioxin/Furan TEQ	152 J	pg/g	0–15

MC-SED1

Analyte	Result	Unit	Depth (cm)
Arsenic	8	mg/kg	0–10
Lead	12	mg/kg	0–10
Dioxin/Furan TEQ	0.442 J	pg/g	0–10

LL-SED4

Analyte	Result	Unit	Depth (cm)
Arsenic	40	mg/kg	0–15
Lead	492	mg/kg	0–15
cPAH TEQ	43	µg/kg	0–15
Dioxin/Furan TEQ	149	pg/g	0–15

MC-SED3

Analyte	Result	Unit	Depth (cm)
Lead	4	mg/kg	0–10
Dioxin/Furan TEQ	0.327 J	pg/g	0–10

MC-SED2

Analyte	Result	Unit	Depth (cm)
Lead	11	mg/kg	0–10
Dioxin/Furan TEQ	0.435 J	pg/g	0–10

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Remedial Investigation/Feasibility Study
Port of Seattle
Lora Lake Apartments Site
Burien, Washington

Figure P.1
Detected Concentrations of Contaminants of Concern in Lora Lake and Miller Creek Surface Sediments

I:\GIS\Projects\POS_LLA\MXD\T6030\Appendix P\Figure P.1 Detected PCOC Conc in Surface Sediments.mxd
9/16/2014

Port of Seattle
Lora Lake Apartments Site

Remedial Investigation/ Feasibility Study

Volume II

Appendix Q
Lora Lake Parcel Remedial Alternative Cost Estimate Worksheets

FINAL

Table of Contents

Table Q.1
Summary of Lora Lake Parcel Alternative Implementation Costs

Alternative Number[1]	**Total Cost**[2]
Alternative 1: Engineering Controls and Institutional Controls	$358,000
Alternative 2: Sediment Thin Capping and Soil Excavation	$3,280,000
Alternative 3: Lake Filling and Soil Excavation	$4,320,000
Alternative 4: Sediment Dredging and Soil Excavation	$7,340,000

Resource Impact Relative to Mitigation Requirements[3]

10,000 SF	All Alternatives: Construction access road—temporary wetland vegetation removal and replacement.
8,640 SF	Thin Capping: Filling of open water due to cap placement.

Notes:

1 Cost details for the alternatives are included in Tables Q.2 through Q.5.

2 Cost values are estimated and have been rounded up to the nearest $10,000.

3 All alternatives assume that the Dredged Material Containment Area can be used for construction staging and parking, and dredge slurry dewatering for hydraulic dredging.

Table Q.2
Alternative 1: Construction Cost Estimate Detail[1]
(LL Parcel Surface Sediment—Engineering Controls; LL Parcel Shallow Soil—Institutional Controls)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
CONSTRUCTION—Lora Lake Parcel[3]					
Mobilization/Demobilization	1	LS	$2,500	$2,500	Assumed to be a lump sum based on size of the project, assumes 1-month construction season.
General Site Preparation and Controls (includes surveying)	1	LS	$2,500	$2,500	Assumed to be a lump sum based on the size of the project. Includes site surveying, utility location, stormwater BMPs, general site BMPs, TESC, SWPPP.
LORA LAKE ENGINEERING CONTROLS					
Purchase and place berm material	178	CY	$25	$4,450	Assumes purchase and placement of 178 CY of material to construct an elevated berm between the lake and Miller Creek for 600 feet along southeast portion of the lake adjacent to Miller Creek.
Installation of culvert with fish screens/grates	1	LS	$2,000	$2,000	Assumed to be grates on each end of a corrugated metal culvert pipe from lake to creek.
Hydroseed for wetland enhancement	2,400	SF	$1	$2,400	Assumes that the newly constructed berm would require hydroseeding to "jump start" the recovery. Based on a mix of native emergent species.
TOTAL CONSTRUCTION COST				**$14,000**	
LONG-TERM COSTS					
Lora Lake Engineering Controls Maintenance and Repair	1	LS	$48,000	$48,000	Assumes $2,000/year, plus $5,000/year in Years 10 and 20 for repair/replacement.
TOTAL LONG-TERM COST				**$48,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$1,000	$1,000	Assumes engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$75,000	$75,000	ICs required for pathway protection at LL Parcel (soil and sediment). Assumes that the existing Port field protocols and Health and Safety Plans would be modified.
Agency Oversight—Site Document Review	20	YR	$5,600	$112,000	Assumes 40 hours per year for document review, and Potentially Liable Party coordination, and 120 hours per year for 5-year reviews.
Engineering Oversight and Construction Reporting	1	LS	$25,000	$25,000	Assumes 1 FTE for a 1-month construction season, construction completion reporting, and associated engineering documentation.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$213,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[4]				$82,500	
TOTAL ALTERNATIVE COST				**$358,000**	

Notes:
1 For the purposes of this Feasibility Study, remedial alternative cost estimates presented in this appendix do not include additional internal Port of Seattle Administrative and Staff costs.
2 All cost values are estimates and should not be interpreted as final construction or project costs. Subtotal and total values are rounded up to the nearest $1,000.
3 The cost for additional mitigation measures is not included with Alternative 1 because the alternative does not include a remedial action throughout the lake, however, the resource agencies may require additional mitigation measures, if Alternative 1 was selected.
4 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:
BMP Best management practice
CY Cubic yards
FTE Full Time Employee
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump Sum
SF Square foot
SWPPP Stormwater Pollution Prevention Plan
TESC Temporary Erosion and Sediment Control
YR Year

Table Q.3
Alternative 2: Construction Cost Estimate Detail[1]
(LL Parcel Surface Sediment—Thin Capping; LL Parcel Shallow Soil—Capping)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
CONSTRUCTION—LORA LAKE PARCEL					
Mobilization/Demobilization	1	LS	$41,000	$41,000	Assumed to be 5% of construction costs, assumes 4-month construction season.
General Site Prep and Controls (includes surveying, erosion control)	1	LS	$31,800	$31,800	Assumes ~5% of construction cost (not including waste disposal fees) and Includes surveying, cost for site setup including purchase and placement of erosion controls and BMPs, delineation of cap areas.
Parcel Uplands Stormwater Management (on-site storage)	1	EA	$40,000	$40,000	For the parcel uplands soil excavation area: Stormwater volume assumes ~40% infiltration of rainwater. Storage capacity for 24-hour storm. Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity ~ 31,000 SF area * 60% runoff * 1.3 inches = 2000 CF = 15,000 GAL = 1 x 20,000 Baker Tanks. Tank Cost = 2500/mo x 4-month construction season.
Parcel Uplands Stormwater Treatment and Sanitary Sewer Discharge	1	LS	$20,000	$20,000	For the parcel uplands soil excavation area: Assumes 3 inches rainfall during a 2-month construction season (summer average). Assumes stormwater collected via sumps and pumps. Assumes moderate infiltration of rainwater with ~ 60% runoff. Assumes and includes cost for the treatment and disposal to sanitary sewer.
LAKE ACCESS ROAD CONSTRUCTION					
Road Area Clearing and Vegetation Removal	1	DAY	$2,000	$2,000	Assumes all vegetation to be removed and discarded. Area is assumed to be replanted following cap placement. Rate based on similar Floyd|Snider project bid with similar size, scope, and vegetation type.
Purchase and Place Filter Fabric	9,600	SF	$0.28	$2,688	Assumes a 75-foot-wide access road down to the lake for a SF of 9,565. Cost for purchase/placement of 600 lb heavy duty tensile strength woven geotextile, 2.45/SF from RSMeans.
Purchase Place and Compact Gravel/Quarry Spall Road	462	TON	$20	$9,244	Assumes placement of 1-foot imported crushed rock/quarry spalls over currently vegetated area; 9,600 SF. Material cost of $9/ton for 2-inch clean crushed or quarry spall, Washington Rock Quarries. Cost includes placement and compaction. Unit cost equivalent to 2011 Port project with similar scope for import placement and compaction of backfill.
Removal and Disposal of Compact Gravel/Quarry	462	TON	$8	$3,698	Assumes removal of the construction road following remedy completion to facilitate the vegetation replacement.
Plantings and Vegetation Replacement	0.22	AC	$108,900	$24,000	Assumes replacement of wetland/riparian vegetation on ~6 foot centers. Includes material and labor for replanting, and ground preparation costs. Does not include maintenance costs.
LORA LAKE SEDIMENT CAPPING					
Pre- and Post-Capping Surveys and Capping Soundings	1	LS	$26,000	$26,000	Includes both pre- and post-capping surveys estimated at $6,000 each, plus staff required for constant soundings during cap placement over a 3 plus week capping period.
Settling Basin Material Removal and Disposal	300	TON	$100	$30,000	Assumes removal of 2 feet of sediment from within the 50' x 50' settling basin in the northwest corner of the lake. Assumes activity conducted in summer with low-water conditions and minimal dewatering required prior to disposal.
Purchase and Transport of Sand Cap Material	11,600	TON	$20	$232,000	Assumes area of lake = 120,000 SF and placement of 2 feet of standard quarry sand = 8,888 CY = 11,555 TON. Assumes a dry weight of sand of 90 pounds/CF = 1.3 tons/CY. Cost based on CalPortland quote of $20/ton material cost.
Placement of Sand Cap (Equipment Rental of telescopic belt conveyor [Telebelt], flexifloats, float crane, and conveyors)	1	LS	$39,397	$39,397	Assumes output per vendor discussions of 50 CY/hr for 5,000 CY with belt, hopper, and conveyer set up time for a total of 3 weeks of rental and mob fee, and $2/ton placement. $13,000 for belt, hopper, conveyor and generator rental, and $3,000 for flexifloat rental. $500 per day for 7 days for crane rental to set flexifloats $3,500 total.
Physical Parameter Water Quality Monitoring	1	LS	$30,000	$30,000	As required, may include items such as physical parameter monitoring during construction, and prior to construction for comparison, aquatic species removal prior to capping, etc.
LL PARCEL SHALLOW SOIL CAPPING					
Site Clearing and Vegetation Removal	1	DAY	$2,000	$2,000	Assumes all vegetation to be removed and discarded. Area is assumed to be replanted following cap placement. Rate based on similar Floyd|Snider project bid with similar size, scope, and vegetation type.
Limited Surface Soil Excavation	2,700	TON	$20	$54,000	Assumes per ton cost based on similar 2011 Port project. Tonnage estimate assumes removal of 2 feet of soil from 31,000 square foot area.
Contaminated Soil Transport and Disposal	2,700	TON	$45	$121,500	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.
Purchase, Place, and Compact Cap Material and Indicator Layer.	2,700	TON	$27	$72,900	Assumes cost from similar 2011 Port project for fill material for import, placement, and compaction plus added cost for wetland soil amendments.
Plantings and Vegetation Replacement	0.70	AC	$109,000	$76,300	Assumes replacement of wetland/riparian vegetation and includes costs for decompaction, soil amendment, bark, plants and labor for replanting, and assumes ground preparation covered under excavation and backfill line items. Cost from 2012 Port mitigation project of similar size. Does not include maintenance costs.
WETLAND, BUFFER, AND WATER QUALITY MITIGATION					
Wetland and Buffer Mitigation	7,860	SF	$5	$39,300	Assumes the temporal loss of 1,000 SF of wetland and 9,000 SF of buffer and a wetland mitigation ratio of 3:1 and buffer mitigation ratio of 1.5:1, for a total mitigation area of 16,500 SF. Assumes the enhancement of 8,640 SF of vegetated wetland offsets a little more than half of the required mitigation area. Costs for restoring wetlands and buffers ranges from about $1 to 10 per SF. For mitigation that includes tree and shrub planting, a median value of $5 per SF is reasonable.

Table Q.3

Alternative 2: Construction Cost Estimate Detail[1]

(LL Parcel Surface Sediment—Thin Capping; LL Parcel Shallow Soil—Capping)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
Hydroseed for Wetland Enhancement	8,640	SF	$1	$8,640	Assumes that the wetland enhancement would require hydroseeding to "jump start" the recovery. Based on a mix of native emergent species. Over the long-term native trees and shrubs would colonize these areas naturally.
Additional Mitigation Measures[3]	111,360	SF	$5	$556,800	Assumes additional mitigation measures would be required over the entire open water footprint of the lake to address the temperature and dissolved oxygen content in Lora Lake and Miller Creek.
TOTAL CONSTRUCTION COST				**$1,464,000**	
LONG-TERM COSTS					
SEDIMENT CAP COMPLIANCE MONITORING					
Field Staff and Equipment	5	EVENT	$19,950	$99,750	Assumes cap compliance monitoring for 10 years in years 1, 2, 4,7, and 10 post construction for a total of 5 events. This includes cap thickness measurement or other visual monitoring methods, and analytical sampling. Assumes 2 field staff for 1 day. Includes event prep, work plan, and mob.
Annual Reporting	5	YR	$25,000	$125,000	Assumes annual reporting of monitoring results for each monitoring year. Unit cost estimate based on assumed level of effort.
Additional Mitigation Measures[3]	111,360	SF	$5	$556,800	Assumes that the additional mitigation measures would require replacement and maintenance every 5 years. Cost included for 1 replacement, coinciding with the 5-year cap integrity monitoring.
SOIL CAP INTEGRITY MONITORING AND REPAIR	4	EVENT	$5,000	$20,000	Assumes cap integrity monitoring conducted every 5 years.
TOTAL LONG-TERM COST				**$802,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design - LL Parcel	1	LS	$88,000	$88,000	Assumes engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$25,000	$25,000	ICs required for pathway protection for soil and sediment.
Permitting	1	LS	$60,000	$60,000	Assumed cost for coordination, negotiation, and attainment of all required uplands and in-water work and mitigation area related permits.
Engineering Oversight and Construction Reporting	1	LS	$93,200	$93,200	Assumes 1 FTE for a 4-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	5	YR	$4,000	$20,000	Assumes 40 hours per year for document review and coordination occurring only in years when monitoring activities occur at the Site.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$287,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[4]				$719,000	Contingency excludes waste disposal cost, includes all other construction-related tasks.
TOTAL ALTERNATIVE COST				**$3,280,000**	

Notes:

1 For the purposes of this Feasibility Study, remedial alternative cost estimates presented in this appendix do not include additional internal Port of Seattle Administrative and Staff costs.
2 All cost values are estimates and should not be interpreted as final construction or project costs. Subtotal and total values are rounded up to the $10,000.
3 Input from the resource agencies indicate that this remedial action may require additional mitigation measures to decrease the Lora Lake water temperature that is discharged to Miller Creek because of ongoing and current resource agency concerns regarding the water quality of Lora Lake and that the higher temperature water of the lake adversely impacting the water quality of Miller Creek.
4 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:

AC Acre
BMP Best management practice
CF Cubic foot
CY Cubic Yard
EA Each
DO dissolved oxygen
FTE Full time employee
GAL Gallon
hr Hour
IC Institutional control
lb Pound
LL Lora Lake
LS Lump sum
mo Month
Port Port of Seattle
SF Square foot
Site Lora Lake Apartments Site
SY Square yard
YR Year

Table Q.4
Alternative 3: Construction Cost Estimate Detail[1]
(LL Parcel Surface Sediment—Open Water Filling to Rehabilitate the Wetland; LL Parcel Shallow Soil—Excavation)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
CONSTRUCTION—LORA LAKE PARCEL					
Mobilization/Demobilization	1	LS	$112,000	$112,000	Assumed to be 5% of construction costs, assumes 4-month construction season.
General Site Prep and Controls (includes Surveying and Erosion Control)	1	LS	$99,600	$99,600	Assumes ~5% of construction cost and includes surveying, cost for site setup including purchase and placement of erosion controls and BMPs, delineation of cap and fill area.
Parcel Uplands Stormwater Management (On-site Storage)	1	EA	$40,000	$40,000	For the parcel uplands soil excavation area: Stormwater volume assumes ~40% infiltration of rainwater. Storage capacity for 24-hour storm. Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity ~ 31,000 SF area * 60% runoff * 1.3 inches = 2000 CF = 15,000 GAL = 1 x 20,000 Baker Tanks. Tank Cost = 2500/mo x 4-month construction season.
Parcel Uplands Stormwater Treatment and Sanitary Sewer Discharge	1	LS	$20,000	$20,000	For the parcel uplands soil excavation area: Assumes 3 inches rainfall during a 2-month construction season (summer average). Assumes stormwater collected via sumps and pumps. Assumes moderate infiltration of rainwater with ~ 60% runoff. Assumes and includes cost for the treatment and disposal to sanitary sewer.
LAKE ACCESS ROAD CONSTRUCTION					
Road Area Clearing and Vegetation Removal	1	DAY	$2,000	$2,000	Assumes all vegetation to be removed and discarded. Area is assumed to be replanted following cap placement. Rate based on similar Floyd|Snider project bid with similar size, scope, and vegetation type.
Purchase and Place Filter Fabric	9,600	SF	$0.28	$2,688	Assumes a 75-foot wide access road down to the lake for a SF of 9,565. Cost for purchase/placement of 600-lb heavy duty tensile strength woven geotextile, 2.45/SY from RSMeans.
Purchase Place and Compact Gravel/Quarry Spall Road	462	TON	$20	$9,244	Assumes placement of 1 foot imported crushed rock/quarry spalls over currently vegetated area; 9,600 square feet. Material cost of $9/ton for 2-inch clean crushed or quarry spall, Washington Rock Quarries. Cost includes placement and compaction. Unit cost equivalent to 2011 Port project with similar scope for import placement and compaction of backfill.
Removal and Disposal of Compact Gravel/Quarry	462	TON	$8	$3,698	Assumes removal of the construction road following remedy completion to facilitate the vegetation replacement.
Plantings and Vegetation Replacement	0.22	AC	$108,900	$24,000	Assumes replacement of wetland/riparian vegetation on ~6 foot centers. Includes material and labor for replanting, and ground preparation costs. Does not include maintenance costs.
LORA LAKE SEDIMENT FILLING					
Settling Basin Material Removal and Disposal	300	TON	$100	$30,000	Assumes removal of 2 feet of sediment from within the 50' x 50' settling basin in the northwest corner of the lake. Assumes activity conducted in summer with low water conditions and minimal dewatering required prior to disposal.
Rental of Telescopic Belt Conveyor (Telebelt), Flexifloats, Float Crane, and Conveyors for Sand Cap Placement	1	LS	$38,897	$38,897	Assumes output per vendor discussions of 60 CY/hr with belt, hopper, and conveyer set up time for a total of five 8-hr days of rental and mob fee, and $2/ton placement. $13,000 for belt, hopper, conveyor and generator rental, and $3,000 for flexifloat rental. $500 per day for 6 days for crane rental to set flexifloats $3,00 total. Assumes that the telebelt may be used for initial 6 inches of sand placement prior to filling.
Purchase and Place of Fill Material	64,512	TON	$22	$1,419,264	Assumes volume required to fill the lake to existing adjacent grade is 38,400 CY, plus an additional 20% volume to allow for potential subsidence and compaction. Assumes a dry weight of sandy gravel of 90 pounds/CF = 1.4 tons/CY. Unit cost from June 2012 quote from CalPortland, $20/ton for material, and an assumed $2/ton for placement.
Fine Grading and Compacting of the Filled Surface for Habitat Rehabilitation	120,000	SF	$0.15	$18,000	Assumes regrading and compacting of the fill material based on habitat design requirements.
Purchase and Place of Surface Habitat Fill/Soils	2.8	AC	$31,460	$86,515	Furnish and place topsoil, from truck, 4 inches to 6 inches deep, from Site Work and Landscape RSMeans 32 91 19.13, $6.50/SY over the 120,000 SF of the filled lake.
Physical Parameter Water Quality Monitoring	1	LS	$30,000	$30,000	As required, may include items such as physical parameter monitoring during construction, and prior to construction for comparison, aquatic species removal prior to filling, etc.
LL PARCEL SHALLOW SOIL EXCAVATION					
Site Clearing and Vegetation Removal	1	DAY	$2,000	$2,000	Assumes all vegetation to be removed and discarded. Area is assumed to be replanted following excavation. Rate based on similar Floyd|Snider project bid with similar size, scope, and vegetation type.
Soil Excavation	3,200	TON	$20	$64,000	Assumes per ton cost based on similar 2011 Port project. Tonnage estimate assumes removal of 0.5 to 4 feet of soil from 30,800 SF (LL Parcel Shallow Soil Cleanup Area, refer to Figure 16.1) and includes overburden.
Contaminated Soil Transport and Disposal	3,200	TON	$45	$144,000	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.

Table Q.4
Alternative 3: Construction Cost Estimate Detail[1]
(LL Parcel Surface Sediment—Open Water Filling to Rehabilitate the Wetland; LL Parcel Shallow Soil—Excavation)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
LL PARCEL SHALLOW SOIL EXCAVATION (continued)					
Laboratory Analytical Sampling	25	EA	$1,697	$42,425	Assumes excavation sidewall and base samples collected approximately every 100 feet. Assumes samples analyzed for lead, pentachlorophenol, carcinogenic polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, dioxins/furans, and BTEX.
Purchase, Place, and Compact Backfill Material	3,200	TON	$27	$86,400	Assumes cost from similar 2011 Port project for fill material for import, placement, and compaction plus added cost for wetland soil amendments.
Plantings and Vegetation Replacement	0.70	AC	$109,000	$76,300	Assumes replacement of wetland/riparian vegetation and includes costs for decompaction, soil amendment, bark, plants and labor for replanting, and assumes ground preparation covered under excavation and backfill line items. Cost from 2012 Port mitigation project of similar size. Does not include maintenance costs.
WETLAND, BUFFER, AND WATER QUALITY MITIGATION[3]					
Wetland and Buffer Mitigation	0	SF	$5	$0	Assumes that mitigation is not required for the temporal loss of 1,000 SF of wetland and 9,000 SF of buffer because the alternative is considered self-mitigating.
Hydroseed for Wetland Rehabilitation	120,000	SF	$1	$120,000	Assumes that the wetland rehabilitation would require hydroseeding to "jump start" the recovery over the entire footprint of the lake. Based on a mix of native emergent species. Over the long-term native trees and shrubs would colonize these areas naturally.
TOTAL CONSTRUCTION COST				**$2,472,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$148,000	$148,000	Assumes engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$10,000	$10,000	The effort associated with development and implementation of institutional controls is assumed to be primarily covered by the existing STIA and 3rd Runway Mitigation Area restrictive covenants on the Site for management as a special use area under the NRMP and WHMP.
Permitting	1	LS	$60,000	$60,000	Assumed cost for coordination, negotiation, and attainment of all required uplands and in-water work and mitigation area related permits.
Engineering Oversight and Construction Reporting	1	LS	$93,200	$93,200	Assumes 1 FTE for a 4-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	2	YR	$4,000	$8,000	Assumes 40 hours per year for document review and coordination occurring only in the year construction and construction reporting occurs.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				**$320,000**	
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG-TERM COSTS)[4]				$1,526,000	Contingency excludes waste disposal cost, includes all other costs.
TOTAL ALTERNATIVE COST				**$4,320,000**	

Notes:
1 For the purposes of this Feasibility Study, remedial alternative cost estimates presented in this appendix do not include additional internal Port of Seattle Administrative and Staff costs.
2 All cost values are estimates and should not be interpreted as final construction or project costs. Subtotal and total values are rounded up to the $10,000.
3 Maintenance and resource agency required monitoring costs for the rehabilitated wetland are not included in this cost estimate because those costs are not part of the MTCA remedial action.
4 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:
AC Acre
BMP Best management practice
BTEX Benzene, toluene, ethylbenzene, xylenes
CF Cubic foot
CY Cubic Yard
EA Each
FTE Full time employee
GAL Gallon
hr Hour
IC Institutional control
LL Lora Lake
LS Lump sum
mo Month
MTCA Model Toxics Control Act
NRMP Natural Resources Management Plan
Port Port of Seattle
SF Square foot
STIA Seattle-Tacoma International Airport
SY Square yard
WHMP Wildlife Hazard Management Plan
YR Year

Table Q.5
Alternative 4: Construction Cost Estimate Detail[1]
(LL Parcel Surface Sediment—Hydraulic Dredging; LL Parcel Shallow Soil—Excavation)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
CONSTRUCTION—LORA LAKE SEDIMENTS					
Mobilization/Demobilization	1	LS	$186,000	$186,000	Assumed to be 5% of construction costs for additional complexity of mobilizing the dredge, fusing its pipeline, crossing the road etc, assumes 5-month construction season.
General Site Prep and Controls (includes surveying, erosion control)	1	LS	$125,000	$125,000	Assumes ~5% of construction cost (not including waste disposal fees) and Includes surveying, cost for site setup including purchase and placement of erosion controls and BMPs, delineation of dredge and cap area.
Parcel Uplands Stormwater Management (on-site storage)	1	EA	$40,000	$40,000	For the parcel uplands soil excavation area: Stormwater volume assumes ~40% infiltration of rainwater. Storage capacity for 24-hour storm. Assumes summer construction, max 24-hour rainfall = 1.3 inches, required storage capacity ~ 31,000 SF area * 60% runoff * 1.3 inches = 2000 CF = 15,000 GAL = 1 x 20,000 Baker Tanks. Tank Cost = 2500/mo x 4-month construction season.
Parcel Uplands Stormwater Treatment and Sanitary Sewer Discharge	1	LS	$20,000	$20,000	For the parcel uplands soil excavation area: Assumes 3 inches rainfall during a 2-month construction season (summer average). Assumes stormwater collected via sumps and pumps. Assumes moderate infiltration of rainwater with ~ 60% runoff. Assumes and includes cost for the treatment and disposal to sanitary sewer.
LAKE ACCESS ROAD CONSTRUCTION					
Road Area Clearing and Vegetation Removal	1	DAY	$2,000	$2,000	Assumes all vegetation to be removed and discarded. Area is assumed to be replanted following cap placement. Rate based on similar Floyd|Snider project bid with similar size, scope, and vegetation type.
Purchase and Place Filter Fabric	9,600	SF	$0.28	$2,688	Assumes a 75-foot wide access road down to the lake for a SF of 9,565. Cost for purchase/placement of 600-lb heavy duty tensile strength woven geotextile, 2.45/SF from RSMeans.
Purchase Place and Compact Gravel/Quarry Spall Road	462	TON	$20	$9,244	Assumes placement of 1-foot imported crushed rock/quarry spalls over currently vegetated area; 9,600 square feet. Material cost of $9/ton for 2-inch clean crushed or quarry spall, Washington Rock Quarries. Cost includes placement and compaction. Unit cost equivalent to 2011 Port project with similar scope for import placement and compaction of backfill.
Removal and Disposal of Compact Gravel/Quarry Spall	462	TON	$8	$3,698	Assumes removal of the construction road following remedy completion to facilitate the vegetation replacement.
Plantings and Vegetation Replacement	0.22	AC	$108,900	$24,000	Assumes replacement of wetland/riparian vegetation on ~6 foot centers. Includes material and labor for replanting, and ground preparation costs. Does not include maintenance costs.
DREDGE SLURRY HANDLING AREA CONSTRUCTION (DMCA)					
Parcel Clearing and Grubbing	4	DAY	$2,000	$8,000	Assumes mulching and removal of vegetation. Estimate based on rate for similar Floyd|Snider site of similar size and vegetation type.
Surface Prep, Grading, and Compaction	10,000	CY	$2	$20,000	Assumes grading and prep of area currently vegetated, approximately 88,923 square feet = 9,880 square yards currently not graded/compacted.
Paving of Dewatering Area and Construction of 12-inch Asphalt Curb	119,790	SF	$5.17	$619,674	DMCA 2.75 acres = 119790 SF per RI/FS text, Cost from 2011 Port project of similar scope, for placement of HMA pavement, PG 64-22, Class 1/2". Assumes 4 inches placed. Cost is 1/2 material + placement, 1/2 hauling. Verified by RSMeans. Includes construction of 12-inch berm around entire dewatering area—DMCA or other.
Purchase and Transport of Geobags for Dredge Slurry Dewatering	1	LS	$367,500	$367,500	Vendor supplied quote for purchase of bags, as well as estimate for piping and valves to distribute the slurry. Assumes flocculent needed to be added to add in sediment dewatering in bags, and no further post-treatment.
Dewatered Sediment Water—Treatment Following Geobag Drainage	160	DAY	$800	$128,000	Sand or chitosan filtration cost based off of recent project WaterTectonics treatment for a 300 GPM system. Assumes five month construction season.
Effluent Slurry and Return Water Piping—Open Cut Roadway and Place Piping Inc. Material, Trenching and Backfilling	500	LF	$18.47	$9,235	Assumes drainage return water collected via sumps and pumps to 8-inch pipe line to the lake. Cost assumes corrugated HDPE sewage pipe, $8.65/LF, water-tight joints. Slurry pipeline 8-inch to10-inch line from pipeline dredge to dewatering area. Discharge line 8-inch pipe to lake. Trench/backfill and compaction assumes chain trencher, trench 12 inches wide, 36 inches deep (pipes stacked). Includes vibratory compaction.
LORA LAKE SEDIMENT DREDGING					
Temporary Barrier for Silt Control	1	LS	$50,000	$50,000	For management of silt resuspension and transport.
Hydraulic Dredging of Lake Sediments	29,000	CY	$22	$638,000	Assumes 3 feet of sediment removal based on chemical data and dredge residuals, and assumes an additional 50% water content of the dredge slurry for a total volume of 6 feet x the lake area of 3 acres for a total volume of 29,000 CY.
Dredged Sediment-filled Geobag Handling, Transport, and Disposal	18,200	TON	$48	$873,600	Assumes that half of the dredged slurry is solid sediment contained within geobags for disposal ~14,000 CY with a 1.3 CY/TON conversion factor for a weight of 18,200 tons. $40/TON for transport and disposal, and $10/TON for loading and cleanup.
Dredge Compliance Testing	25	EA	$1,697	$42,425	Assumes analytical testing required to confirm dredge surface concentrations. Assumed analyzed for all site COCs.

Table Q.5

Alternative 4: Construction Cost Estimate Detail[1]

(LL Parcel Surface Sediment—Hydraulic Dredging; LL Parcel Shallow Soil—Excavation)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
Physical Parameter Water Quality Monitoring	1	LS	$60,000	$60,000	As required, may include items such as physical parameter monitoring during construction, and prior to construction for comparison, aquatic species removal prior to capping, etc.
LORA LAKE SEDIMENT DREDGING (continued)					
Purchase and Transport of Sand Cap Material to Address Dredge Residuals	11,600	TON	$20	$232,000	Assumes area of lake = 120,000 square feet, and placement of 2 feet of standard quarry sand = 8,888 CY = 11,555 TON. Assumes a dry weight of sand of 90 pounds/CF = 1.3 tons/CY. Cost based on CalPortland quote of $20/ton material cost.
Placement of Residual Sand Cap (Equipment Rental of Telescopic Belt Conveyor [Telebelt], Flexifloats, Float Crane, and Conveyors)	1	LS	$39,397	$39,397	Assumes output per vendor discussions of 50 CY/hr with belt, hopper, and conveyer set up time for a total of five 8-hr days of rental and mob fee, and $2/ton placement. $13,000 for belt, hopper, conveyor and generator rental, and $3,000 for flexifloat rental. $500 per day for 6 days for crane rental to set flexifloats $3,500 total.
LL PARCEL SHALLOW SOIL EXCAVATION					
Site Clearing and Vegetation Removal	1	DAY	$2,000	$2,000	Assumes all vegetation to be removed and discarded. Area is assumed to be replanted following excavation. Rate based on similar Floyd|Snider project bid with similar size, scope, and vegetation type.
Soil Excavation	3,200	TON	$20	$64,000	Assumes per ton cost based on similar 2011 Port project. Tonnage estimate assumes removal of 0.5 to 4 feet of soil from 30,800 square feet (LL Parcel Shallow Soil Cleanup Area, refer to Figure 16.1) and includes overburden.
Contaminated Soil Transport and Disposal	3,200	TON	$45	$144,000	Cost from 2010 quote from Waste Management for similar Port project located 10 miles from Site. Quoted cost of $42 increased to account for additional travel distance and increase in rates since 2010.
Laboratory Analytical Sampling	25	EA	$1,697	$42,425	Assumes excavation sidewall and base samples collected approximately every 100 feet. Assumes samples analyzed for lead, pentachlorophenol, carcinogenic polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, dioxins/furans, and BTEX.
Purchase, Place, and Compact Backfill Material	3,200	TON	$27	$86,400	Assumes cost from similar 2011 Port project for fill material for import, placement, and compaction plus added cost for wetland soil amendments.
Plantings and Vegetation Replacement	0.70	AC	$109,000	$76,300	Assumes replacement of wetland/riparian vegetation and includes costs for decompaction, soil amendment, bark, plants and labor for replanting, and assumes ground preparation covered under excavation and backfill line items. Cost from 2012 Port mitigation project of similar size. Does not include maintenance costs.
WETLAND, BUFFER, AND WATER QUALITY MITIGATION					
Wetland and Buffer Mitigation	16,500	SF	$5	$82,500	Assumes the temporal loss of 1,000 SF of wetland and 9,000 SF of buffer and a wetland mitigation ratio of 3:1 and buffer mitigation ration of 1.5:1, for a total mitigation area of 16,500 SF. Assumes the enhancement of 8,640 SF of vegetated wetland offsets a little more than half of the required mitigation area. Costs for restoring wetlands and buffers ranges from about $1 to 10 per SF. For mitigation that includes tree and shrub planting, a median value of $5 per SF is reasonable.
Additional Mitigation Measures[3]	120,000	SF	$5	$600,000	Assumes additional mitigation measures would be required over the entire open water footprint of the lake to address the temperature and dissolved oxygen content in Lora Lake and Miller Creek.
TOTAL CONSTRUCTION COST				***$4,599,000***	
LONG-TERM COSTS					
Additional Mitigation Measures[3]	120,000	SF	$5	$600,000	Assumes that the additional mitigation measures would require replacement and maintenance every 5 years. Cost included for 1 replacement.
TOTAL LONG-TERM COST				**$600,000**	
AGENCY OVERSIGHT, PLANNING, AND PERMITTING COSTS					
Engineering Design	1	LS	$276,000	$276,000	Assumes engineering design and planning is approximately 6% of the overall project cost.
Institutional Controls Development & Implementation	1	LS	$10,000	$10,000	The effort associated with development and implementation of institutional controls is assumed to be primarily covered by the existing STIA and 3rd Runway Mitigation Area restrictive covenants on the site for management as a special use area under the NRMP and WHMP.
Permitting	1	LS	$80,000	$80,000	Assumed cost for coordination, negotiation, and attainment of all required uplands and in-water work and mitigation area related permits.
Engineering Oversight and Construction Reporting	1	LS	$109,200	$109,200	Assumes 1 FTE for a 5-month construction season, construction completion reporting, and associated engineering documentation.
Agency Oversight—Site Document Review	1	YR	$4,000	$4,000	Assumes 40 hours per year for document review and coordination occurring only in the year construction and completion reporting occurs.
TOTAL AGENCY OVERSIGHT, PLANNING, AND PERMITTING COST				***$480,000***	

Table Q.5

Alternative 4: Construction Cost Estimate Detail[1]

(LL Parcel Surface Sediment—Hydraulic Dredging; LL Parcel Shallow Soil—Excavation)

TASK	QUANTITY	UNIT	UNIT COST	TOTAL COST[2]	DETAIL
CONTINGENCY (30 PERCENT OF CONSTRUCTION AND LONG TERM COSTS)[4]				$1,659,000	Contingency excludes soil disposal cost, but does include dredged sediment handling, transport, and disposal costs due to the constructability and technical challenges associated with dredged sediment, and includes all other costs.
TOTAL ALTERNATIVE COST				**$7,340,000**	

Notes:

1 For the purposes of this Feasibility Study, remedial alternative cost estimates presented in this appendix do not include additional internal Port of Seattle Administrative and Staff costs.
2 All cost values are estimates and should not be interpreted as final construction or project costs. Subtotal and total values are rounded up to the $10,000.
3 Input from the resource agencies indicate that this remedial action may require additional mitigation measures to decrease the Lora Lake water temperature that is discharged to Miller Creek because of ongoing and current resource agency concerns regarding the water quality of Lora Lake and that the higher temperature water of the lake adversely impacting the water quality of Miller Creek.
4 Construction contingency includes both direct initial construction and long-term monitoring and repair costs. Agency and indirect costs not included in contingency.

Abbreviations:

AC Acre
BMP Best management practice
CF Cubic foot
COC Contaminant of concern
CY Cubic Yard
DMCA Dredged Material Containment Area
EA Each
FTE Full time employee
GAL Gallon
HMA Hot mix asphalt
hr Hour
IC Institutional control
LF Linear foot
LL Lora Lake
LS Lump sum
mo Month
NRMP Natural Resources Management Plan
Port Port of Seattle
RI/FS Remedial investigation/feasibility study
SF Square foot
STIA Seattle-Tacoma International Airport
SY Square yard
WHMP Wildlife Hazard Management Plan
YR Year