Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

APPENDIX F:
ESTIMATION OF NET SEDIMENTATION RATES USING EMPIRICAL LINES OF EVIDENCE FOR THE LOWER DUWAMISH WATERWAY

Prepared for

The U.S. Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

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Prepared by: RETEC

1011 SW Klickitat Way, Suite 207 ♦ Seattle, Washington ♦ 98134

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F.1 Introduction

This appendix describes data and analyses used to estimate net sedimentation rates for the Lower Duwamish Waterway (LDW) (Figure 1). Data and analyses presented in this appendix are in addition to the analysis of radioisotopes discussed in the main body of this report. The objective of this appendix is to describe and illustrate with tables, figures, and graphs several empirical lines of evidence used to estimate net sedimentation rates. Lines of evidence considered include sediment core profiles (chemical and physical), bathymetry, geomorphology, and the physical events that have occurred in the LDW and that have potentially affected subsurface sediment conditions. The results of these analyses are then compared to estimates of net sedimentation rates based on the radioisotope cores. Because the radioisotope and sediment core data sets provide different degrees of spatial coverage of the LDW, geochronology data from both sources are combined to estimate area-wide sedimentation patterns.

F.1.1 Purpose

The scope of this analysis is two-fold:

1) To compare and augment the net sedimentation rate estimates based on radioisotope profiles using other geochronology data from LDW subsurface sediments.

2) To map net sedimentation rates in the LDW in as much detail as allowed by the available data.

The primary purpose of this analysis is to validate the predicted sediment transport modeling results using these empirically derived estimates of sedimentation rates. These estimates may then be combined with the model results in the Feasibility Study (FS) to assess and compare remedial alternatives for the LDW.

This appendix describes the process by which time markers, or tracers, are used to build age-dated geochronology profiles from physical and chemical data. After a geochronology profile is established, the time markers are then used to interpret the geologic patterns in individual cores, providing an estimated net sedimentation rate at the location of each core. *Net sedimentation rate* is defined as the rate at which particulate matter settles out of the water column and becomes part of the bottom substrate in excess of the rate at which bottom substrate is eroded. Figures and tables are provided in this appendix to illustrate how the estimated net sedimentation rates are estimated from sediment core data, how the estimates compare among various estimation methods, and how sediment cores are grouped and mapped into spatial areas.

F.1.2 Use of Stratigraphic Physical and Chemical Markers

Human activity in and around Puget Sound is reflected in subsurface sediment vertical profiles. Physical events, such as dredging or river channelization, are recorded in the geological structure of sediments. Chemical uses are also recorded in the sediments. As industrial activities increase, so do the sediment concentrations of chemicals associated with industrial use until source control measures or use limitations are put into place. These physical and chemical time markers provide fixed points in time from which the age of subsurface sediments can be estimated and offer valuable historical records of sedimentation processes in the LDW.

Age-dated cores have previously been collected in depositional environments in Puget Sound, as well as from other lakes and rivers in Washington, to monitor changes and trends in the sediment bed. In these environments, the deposition process allows correlation of a change in sediment characteristics to a time marker or event. In studies of Puget Sound, dated cores have demonstrated a general pattern consistent with historical uses, including onset or introduction of particular persistent chemicals, the ban of certain chemicals, and physical controls on chemical releases (Battelle 1997; Bloom and Crecelius 1987; Bopp et al. 1982; Johnson et al. 1990; Van Metre et al. 2000).

These patterns typically show, from bottom to top of each core: (1) a point of chemical introduction where chemical concentrations first become detectable or increase above background concentrations, (2) maximum concentrations at depth that indicate the point or year(s) of maximum release of the chemical into the environment, and (3) declining concentrations closer to the surface that correspond with reduced releases as pollution controls take effect. Such patterns are discernible only in depositional environments because active resuspension can mask the subsurface peak concentrations of chemicals by uniformly mixing them throughout the vertical profile (Battelle 1997). Therefore, when a contaminant profile with a subsurface maximum was observed in an LDW core, it was interpreted as a chemical marker to indicate a depositional environment, and net sedimentation rates were estimated. The absence of such a profile is discussed later in this memo.

Use of geologic information to date sediments is less common, but a few studies have incorporated physical information to improve the interpretation of sediment accumulation results (Santschi et al. 1999). On a core-by-core basis, the presence or absence of physical sedimentary structures (e.g., laminations and beds) may be used to indicate the extent of biological or physical mixing of sediment. Homogenized stratigraphy may signal high, recent sedimentation rates with minimal disturbances or, alternatively, downward vertical mixing that essentially eliminates physical sediment structures. Where this was noted, a physical marker was not applied. This is discussed further in Section F.4.3 (Uncertainties). Preservation of distinct physical features may signal a depositional environment with minimal disturbances (Santschi et al. 1999). On this basis, when sharp or strong sedimentary features were observed in an LDW profile, they were interpreted to indicate a physical event, and net sedimentation rates were estimated using the assumed dates assigned to the events.

The analyses presented here apply to gross geologic features in the LDW sediment cores and incorporate general historical information about the waterway. This analytical approach uses the simplest methods available (i.e., difference in depths between subsurface observations) to make comparisons between cores and within core profiles. The cores used in this analysis are shown in Figure 1. Although more detailed or sophisticated analyses are possible, this analysis adequately represents the complex sedimentation history in the LDW. Factors that may influence the observed distributions and limitations of applied time markers are discussed in the Section F.4.3 (Uncertainties).

F.1.3 Physical Events and Markers in the LDW

Historical physical events in the LDW provide fixed points in time from which to age-date subsurface sediments. For example, the LDW was created between 1910 and 1916 when the previously sinuous Duwamish River was dredged into a straight channel. The new channel was dredged through alluvial deposits and marshy intertidal areas with variable topography. Following channelization, the LDW still followed a natural cycle of seasonal flood/channel forming events, with alternating periods of silt, sandy silt, and sand deposition. Annual flooding of the Green/Duwamish River continued even without the flow previously supplied by the White and Black Rivers. These rivers were diverted to other watershed basins in the early 1900s, reducing the original watershed area from 1,600 square miles to its present-day 483 square miles and decreasing river flow. A sharp stratigraphic divide between older alluvial sediments and newer deposited sediments represents the resulting surface after the river was channelized and, thus, serves as an early time marker (1916).

In 1961, the Howard Hanson Dam was constructed on the Green River upstream of the LDW to control river flow. Its construction eliminated major/seasonal flooding events, reduced peak discharge during floods, and formed the basis for a second time marker in LDW sediment cores. Following dam construction, sediment began to deposit upstream of the dam, decreasing the sediment load to the LDW. The dam also decreased water velocities in downstream portions of the river, resulting in reduced amounts of both suspended and bed load moving downriver and into the LDW. In addition, the upper turning basin (river mile [RM] 4.6) serves as a trap for coarse-grained sediments; finer material is deposited farther downstream within the LDW, thus reducing suspended sediments and bed loads. This stratigraphic divide between layered sediments from flood events and more homogeneous sequences of mostly fine-grained silt serves as another time marker (1961)[1]. Figure 2 provides a conceptual profile of these markers.

F.1.4 Chemicals and Time Stratigraphy in the LDW

The analysis of concentration patterns of persistent chemicals in sediment cores can provide a valuable historical record of contamination (Battelle 1997; Yake 2001). Vertical profiles of chemical changes with depth can be used to evaluate how contaminant concentrations have responded to changes in population, land use, and human activities, including regulatory actions (e.g., laws, chemical bans, operational end dates) implemented to reduce contamination in the environment. The advantage of assessing chemical profiles within one sediment core is that variability in sampling and analytical techniques (which occurs when sediments are sampled over a long period) is eliminated.

Arsenic is an applicable chemical time marker for sediments in the Puget Sound region. The ASARCO copper smelter in Tacoma, Washington, was a dominant atmospheric source of arsenic while in operation from 1905 to 1986. Arsenic concentrations typically peak in Puget Sound sediments between 1925 and 1960, after which regional declines are observed (Battelle 1997). More locally, arsenic and lead were also produced from Quemetco Inc.'s smelter on Harbor Island, which operated until 1984.

Lead is also a good time marker representing the general period of industrialization in Puget Sound. Lead was introduced into the atmosphere along with arsenic and mercury during metal smelting operations. Lead was added to gasoline in the United States beginning in the 1920s and phased out of automobile use in the 1980s. Sale of lead-based paint was banned in 1978.

Mercury, which often co-appears with arsenic and lead, is also associated with the period of industrialization since about 1890. Mercury was used in anti-fouling paint on ships during the 1940s; the use of mercury in exterior paints then declined until it was eventually banned in 1991. The last registered use of mercury as a pesticide in the United States was voluntarily cancelled by the manufacturer in 1994.

Commercial production of PCBs in the United States began in 1929; PCB use rose between 1935 and 1965, peaking by 1970, then fell steeply by the mid-1970s (Smith et al. 1988). The deepest detection of PCBs in sediments is estimated at 1935 (following a few years of lag time from 1929 [the year when PCB manufacture began in the U.S.] during which PCB-containing suspended sediments became incorporated into the sediment bed). Declining PCB concentrations in sediments were linked with 1980. Annual PCB production peaked by 1970 (USEPA 1986 as cited in Wenning et al. 1994). These declines correlate with restrictions placed by the U.S. Environmental

[1] A few years of lag time is possible as the inventory of sediments below the dam moves downstream.

Protection Agency (EPA) on the production and use of PCBs in 1979 (Battelle 1997; Yake 2001).

Other chemicals such as DDT, phthalates, and tributyltin (TBT) may also provide relevant time markers when clear concentration gradients are observed in sediment cores.

F.2 Evaluation Methods

This section briefly describes the site data used in the analysis and the time markers applied to dating of LDW subsurface sediment. The process for grouping and mapping net sedimentation rates is described in Section F.4.2. Figure 1 shows the 2004/2006 subsurface sediment core locations relative to bathymetry and surface sediment grain size distribution. Figure 2 generalizes the lithology descriptions (physical interpretations) used to age-date the sediment cores. The core logs are available in the *Data Report: Subsurface Sediment Sampling for Chemical Analyses* (Windward and RETEC 2007). Figure 3 provides a conceptual illustration of relevant time markers and the extent of various chemical uses over the LDW's history.

F.2.1 Review of Available Site Data

Chemical profiles and physical characteristics of historical sediment cores and those collected for the Phase 2 Remedial Investigation (RI) were reviewed to determine whether appropriate time markers could be identified. The data review included:

1. Chemistry and stratigraphy data from 56 subsurface sediment cores (2006) collected for the Phase 2 RI
2. Historical subsurface sediment cores (1985 to 1999)
3. Commercial and industrial uses/events
4. Other physical data such as bathymetry, dredging records, historical changes in the LDW shoreline, and navigation depths.

Brief descriptions of these data types and evaluation methods are provided below. Section F.4 compares the inferences drawn from these analyses with conclusions from analysis of the radioisotope cores. The methods for estimating rates from the radioisotope cores are presented in the main body of this report.

Remedial Investigation Sediment Cores

In February 2006, 56 subsurface sediment cores were collected in the LDW in support of the Phase 2 RI; the chemical data resulting from those cores and the associated core logs are presented in the *Data Report: Subsurface Sediment Sampling for Chemical Analyses* (Windward and RETEC 2007). Samples for chemical analyses were collected at approximately either 1-ft or 2-ft depth-composited intervals and at 6-inch sample intervals from selected cores[2]. Radioisotopes were not analyzed in the 2006 cores, but several cores were co-located with, or in close proximity to, the 14 high-resolution radioisotope cores collected in 2004 and presented in the main body of this report. Of the 56 cores collected in February 2006, 49 cores exhibited strong chemistry profiles and/or intact lithology or coherent stratigraphy for defining time markers. These cores provide an important line of evidence for verifying estimates of net sedimentation rates from the radioisotope analyses. The remaining 7 cores did not exhibit strong markers or gradients from which to date the sediments. These cores are shaded gray in Table 1, and the rationale for excluding these cores is provided in Table A-1 and briefly described in Section F.3 (Results and Data Trends) and in Section F.4.3. (Uncertainties).

Physical Profiles – Stratigraphy

Detailed core logs were generated for each of the 2006 cores, and can be found in the final *Data Report for Subsurface Sediment Sampling for Chemical Analyses* (Windward and RETEC 2007). Among other visual observations, the core logs identify three distinct stratigraphic units based on groupings of similar lithology and relative depth within each core. From oldest to youngest, the major stratigraphic units are described as lower (native) alluvium, upper alluvium, and recent deposits. Where sharp contacts were identified between these stratigraphic units, physical time markers were applied. The time marker of 1916 was applied to the contact between lower and upper alluvium, to correspond with the straightening of the LDW. The time maker of 1961 was applied to the contact between the upper alluvium and the recent deposits to correspond with the construction of the Howard Hanson Dam on the Green River.

Chemical Profiles

The trend of PCB concentrations in the LDW sediment cores generally reflects the introduction (circa 1935) and the regulation (1980) of PCB use in the United States. In most cases, the maximum detected PCB concentrations are observed at subsurface depths.

Figures 4a through 4i present chemical concentrations in LDW cores sampled in 2006 at 6-inch depth intervals. Co-located surface sediment samples and deeper 2-foot interval samples were added to graphs, as appropriate, to provide a more complete chemical profile. Chemical profiles are coupled with physical data in these figures.

Figures 4a through 4i also include 6-inch profiles for chemicals other than PCBs. Review of the distributions of other chemicals (i.e., DDT, TBT, polycyclic aromatic hydrocarbons [PAHs], and other metals) did not produce

[2] These 6-inch cores were also composited and analyzed at 2-ft intervals. Chemistry analyses at 6-inch intervals were generally conducted only in the top 4 feet of selected cores.

clear time markers; those chemicals were therefore not used in the analysis. Arsenic, lead, mercury, and copper showed subsurface maximum concentrations in a few cores. Overall the concentrations were too low or inconsistent with depth to determine concentration gradients or apply time markers. In a few of the 6-inch cores, mercury and lead profiles were coincident with PCB decreases with depth and strengthen the use of PCBs as a time marker.

Chemical trends were also reviewed for 2006 cores sampled at 1-ft or 2-ft depth intervals. Profile graphs were not generated for these cores, but the data used to determine chemical time markers are presented in Table A-2. PCB peaks were assigned to the date of maximum use, 1960 (assuming plus or minus a few years of uncertainty), or the date of a known PCB spill in Slip 1, 1974, depending upon the core's proximity to Slip 1. Contour maps of pre- and post-dredging PCB concentrations in the vicinity of Slip 1, provided by EPA, were used to help estimate the extent of the 1974 spill (Blazevich et al. 1977). In areas with relatively low sedimentation rates, the 1974 peak would likely co-elute with the 1960s peak use period. These cores were also assigned chemical onset and control time markers for PCBs, lead, and bis(2-ethylhexyl) phthalate where strong trends were observed. In one core, SC-37, a strong marker for arsenic was also present.

Historical Cores

Historical subsurface cores collected from the LDW over the past twenty years (Windward 2007) were also evaluated for chemistry profiles and stratigraphy. Unfortunately, few high-resolution, detailed historical cores have been collected in the LDW. Most coring efforts have been limited to the testing dredged material management units in the upper layers (often compositing the sediment over the entire interval and/or compositing the sediment horizontally across cores) to determine appropriate disposal methods. However, a few historical cores were selected for use in this analysis when they were located in an area with a spatial data gap, there was a good stratigraphic record (i.e., good visual documentation, no missing units, and sharp contacts between units), and there were analytical chemistry data at sufficient sampling depth and resolution.

The selected historical cores also exhibited contaminant profiles with subsurface maximum concentrations and physical trends that match the site-wide stratigraphy patterns and time markers. Cores (and events) used include DUD006 (Duwamish Diagonal 1994), DR18 and DR39 (PSDDA 1999), S3 (PSDDA 1998), SC11 (Slip 4 2004), and B3 (Terminal 105).

In addition, four cores collected from the downstream East and West Waterways were age-dated for another study using radioisotopes and PCB profiles. Cores included HI-NR01 through HI-NR-04 (EVS and Hart Crowser

1995). The rates reported in that study are included in this ~~attachment~~appendix.

Commercial and Industrial Uses/Events

A review of industrial and development activities on the LDW is ongoing for the Remedial Investigation/Feasibility Study (RI/FS). Specific activities such as documented releases or shoreline construction may provide additional time markers when dates (within a range of 1 to 10 years) are available.

One such event was a documented transformer spill in 1974 in the northwest corner of Slip 1. This spill released an estimated 255 gallons of PCBs (Aroclor® 1242) to the waterway. Post-spill sampling by EPA revealed that PCBs had spread throughout, upstream, and downstream of the slip. By 1976, two dredging events were completed within and outside of Slip 1, removing an estimated 92 percent of the spilled PCBs. However, post-remediation sampling showed that PCBs remained in the surface sediments. It was estimated that 20 gallons of the spilled material remained *in situ*. Following remediation, surface concentrations were as high as 8 mg/kg dry weight for Aroclor® 1242 at the mouth of the slip (Blazevich et al. 1977).

Another industrial activity that may serve as a general time marker is Quemetco Inc.'s former lead smelter on Harbor Island adjacent to the LDW. Quemetco began smelting operations in 1937 as a secondary lead smelter that reclaimed lead from automobile and industrial batteries; lead smelting ceased in April 1984. During its time in operation, Quemetco was a source of fugitive dust emissions and groundwater contamination. The state established air quality standards for lead in 1978. Source control upgrades were implemented in 1980. Soil sampling conducted in parking areas near Quemetco in 1979 and again in 1982 by the Puget Sound Air Pollution Control Agency (PSAPCA) found a 60 percent decrease in soil lead content between the two sampling events (PSAPCA and Ecology 1983). On Harbor Island, lead-based antifouling paints were used at Lockheed Shipyard until 1966 and at Todd Shipyard until 1978 (CH2M Hill 1983). Another smelter with documented regional arsenic effects is the Asarco/Tacoma Copper Smelter, which operated from approximately 1900 to 1986.

Other Physical Data

Other physical data, such as general flow regimes, authorized navigation channel depths, bathymetry conditions, and a 20-year history of dredging events, presented in the draft *Preliminary Screening of Alternatives* (RETEC 2006) were used as secondary evidence in the net sedimentation rate analysis.

For example, when the Howard Hanson Dam was completed in 1961 on the Green River, its construction, along with river diversions, eliminated major/seasonal flooding events. Peak discharges during floods were reduced from about 34,000 cubic feet per second (cfs), as estimated from the last major flooding event in 1959, to no greater than about 12,000 cfs under current conditions. This flow rate corresponds with the 100-year flood event. The major change in flow conditions changed the depositional regime observed in the LDW.

Various fill or dredge events throughout the LDW also provide time markers. Dredging exposes a new face of previously buried material immediately following the dredge event. The geological contact of the exposed material with post-dredge deposited material often creates a sharp transition that can be used as a time marker when the dredge dates are known. Figure 2-2 of the draft *Preliminary Screening of Alternatives* (RETEC 2006) presents locations of dredging events on the LDW since 1986. Figure 5 of this memorandum also displays these dredge events in relationship to cores used in this analysis. Fill horizons or dredge/fill horizons are often defined by a sharp demarcation between dense, deeper alluvial sand units immediately overlain by very soft, black organic silt. In some cases, the sand units themselves could be the result of historical shoreline filling or capping events. In such cases, the presence of debris such as brick fragments and glass bottle shards, which are often scattered throughout the loose sandy matrix, is a key indicator of fill events.

Portions of the LDW are dredged regularly to maintain the authorized depths of the navigation channel. The need for regular maintenance dredging in the upstream portion of the navigation channel is consistent with the high sediment loads and large localized net sediment deposition rates described in the Phase 1 RI (Windward 2003). Bathymetry from the Phase 1 RI was used in this analysis in two ways: to check the estimated net sedimentation rates, and to help guide the mapping process by delineating boundaries between areas with differing sedimentation rates.

F.2.2 Summary of LDW Time Markers Used for Age-Dating

To summarize, the geochronology of cores was interpreted in this analysis using the following specific dates. (Dates are considered accurate to within about five to ten years.)

- **Pre-1900: Pre-industrial background conditions.** By the late 1800s, the City of Seattle and King County were formed, encompassing a population of less than 10,000. Seattle's population and industrial growth began to boom around 1900 with increased commercial trade along the West Coast. Chemical concentrations before about 1900 are assumed to be at pre-industrial levels.

- **1916: Formation of the LDW channel.** Active straightening and dredging of the Duwamish River and its mudflats to form the LDW channel changed the dynamics of river flow. This change is identified by a noticeable contact between the dense alluvial sand

and overlying silty layers. The channel formation was completed in 1916.

- **1920, 1935, and 1950: Onset of Lead, PCBs, and Phthalates (1960: PCB Peak Use).** Lead is an element that is naturally present in the environment. However, industrial and mining activities released lead to the atmosphere and stormwater, resulting in increased concentrations in sediment beginning in 1920. PCBs and phthalates were introduced into wide commercial use around 1935 and 1950, respectively. Because these compounds are anthropogenic, they are not detected in sediments older then these respective dates. Although the presence of these chemicals in sediment may vary somewhat relative to these dates, definitive concentration peaks are commonly present during the 1950s and 1960s, reflecting peak use. Peak use for PCBs and several metals occurred following World War II during a period of rapid economic expansion (Battelle 1997; Wenning et al. 1994).

- **1961: Construction of the Howard Hanson Dam.** Dam construction corresponds with lower flow velocities below the dam and coarser sediments trapped upstream of the dam. These two factors led to both a decrease in total sediment load and a change in the grain size of the remaining sediment load. This contact is identified as a noticeable decrease in the sand and gravel fraction present in the core profile and loss of the sediment interbeds/layering characteristic of more variable flow conditions in the pre-dam period. Sediments above this contact are primarily silt and organic silt with less than 20 percent sand fractions. Dam construction was completed in 1961.

- **1974/1976: PCB Spill in Slip 1**. This large, one-time input of PCBs (Aroclor® 1242) is used as a time marker to age-date sediments near Slip 1. In undredged areas, a PCB peak observed in core profiles in close proximity to the slip is interpreted to correspond to 1974. In dredged areas, the demarcation associated with the dredged surface represents a time marker of 1976 (when dredging activities associated with this spill came to an end) (Blazevich *et al* 1977). However, 1974 was broadly used for chemical time markers associated with this spill.

- **1980: Control of PCBs and other chemicals.** This date is approximate and generally is indicated by a decreasing trend in chemical concentrations of PCBs, arsenic, lead, mercury, and phthalates associated with ongoing source control efforts and increasing levels of treatment for waste discharges (late 1970s and mid 1980s). Several significant source control events occurred during this time period (plus or minus about 5 years):

- Congress passed the Clean Water Act in 1972, requiring secondary treatment at municipal waste water treatment plants by 1977.
- PCBs, lead, and mercury were banned in many commercial products in the 1970s.
- In 1977, a water quality study in Lake Washington showed that water clarity was vastly improved compared to historical records as a result of upgrades to stormwater and sewer management throughout Puget Sound (King County 2005).
- The ASARCO and Quemetco metal smelters were closed in the early 1980s.
- In 1968, the combined sewage from the Duwamish wastewater treatment plant (WWTP) was transferred to the West Point WWTP, thereby eliminating the Duwamish discharges and greatly reducing overflows to the LDW.
- By 1987, effluent from the South (Renton) wastewater treatment plant was diverted from the Duwamish River to Puget Sound[3].

In addition to these dates, the time markers 1954 and 1963 were used in the previous radioisotope analyses to represent the onset and peak use of cesium-137. These dates are well-established in the literature and were used to calculate net sedimentation rates at 12 locations on the benches. Some of the 2006 chemistry cores were co-located with the radioisotope cores and provide corroboratory evidence to the rate calculations. For lead-210, the slope of the decay line is used to age sediments and determine the net sedimentation rate; therefore, no time marker is applied to lead-210.

F.2.3 Assignment of Chemical Time Markers

Where a chemical trend was observed, time markers were established at one or more of the following three points:

- Chemical onset is defined by chemical concentrations changing from non-detect to a detectable concentration or a noticeable

[3] The South (Renton) wastewater treatment plant began operations in 1965 and discharged treated effluent (limit: 10 to 15 milligrams per liter [mg/L] total suspended solids) to the Duwamish River upstream of the LDW, accounting for about 25 percent of the flow in the Duwamish River during low-flow seasons. By 1987, the effluent from this wastewater treatment plant was diverted to Puget Sound.

increase above low-level concentrations. The marker is set at the top of the interval with the non-detected or low concentration. If the chemical is detected throughout the core and transitions from low to high concentrations, the bottom of the lowest interval is used for onset. If a skipped interval bridges a non-detect and a relatively high concentration, the middle of the skipped interval was used.

- A peak use marker was established when a distinct subsurface maximum (a concentration at least two times greater than other concentrations in the core) was observed. The marker was set at the middle of the interval with the maximum concentration. Section F.4.3 (Uncertainties) discusses the rates estimated by the use of the top and bottom of the intervals containing peak concentrations, to establish a range of net sedimentation rates.
- A chemical source control marker was applied when the shallower intervals of the core displayed a decrease in concentration from a subsurface maximum. If the interval contained minor chemical exceedances of the Sediment Quality Standard (SQS), then the middle of the interval was used; otherwise the bottom of the interval was used. Table A-2 indicates whether core intervals exceeded the SQS.

If typical chemical trends were not observed in a core for a particular chemical (i.e., mostly non-detect data or low-level concentrations; or elevated concentrations present at the surface or at the bottom of the core), then time markers for that chemical were not applied. Fourteen of the 2006 cores had PCB concentration peaks in the core's surface interval. Atypical chemical patterns are discussed in Sections F.4.3. (Uncertainties) and F.3 (Results).

F.3 Results and Data Trends

Physical and chemical patterns in the profiles were recognized and established among most cores in the data set (88% of the 2006 cores), revealing that large-scale morphological patterns are present within the LDW. This section defines and illustrates these patterns and trends. The patterns were then used to age-date the sediment cores and estimate net sedimentation rates, as described below.

Figures 2 and 3 summarize the chronology of events and time markers used to estimate net sedimentation rates. Figures 4a through 4i show detected chemical profiles for 6-inch interval data. Tables 1 through 3 present the net sedimentation rate estimates for selected time markers.

Atypical patterns were not used for age-dating. Atypical patterns were noted where cores exhibited missing stratigraphic units, fill units with no documented time period, diffuse stratigraphic contacts, peak chemical concentrations in the shallowest intervals, and/or a lack of clear chemical trends, which can include: no strong chemical peaks or clear trends with depth, or consistent, low concentrations throughout the core.

Only a few cores (12% of the 2006 cores) could not be correlated to at least one physical or chemical time marker. In these areas, it is likely that nearshore activities, in-water structures/construction, or disturbance events have significantly altered the physical or chemical profiles. In some cases, cores SC-2 and SC-28 for example, thick sequences of anthropogenic material were observed and are recorded in the core logs (Windward and RETEC 2007). The 2006 field investigation demonstrated that these disturbance events are relatively localized and limited to the east or west benches. They do not extend across large areas.

Section F.4.3 (Uncertainties) discusses the occurrence of these atypical patterns in more detail. Table A-1 identifies specific cases where time markers were not used.

F.3.1 Large-Scale Physical Patterns

Similar or related lithologic profiles were established among most cores in the 2006 dataset, indicating that large-scale stratigraphic patterns are present within the LDW. Based on this analysis, three major sediment stratigraphy units were identified and used in the geochronology evaluation:

- **Recent:** This upper unit consists of recently deposited material dominated mostly by unconsolidated black, very soft, organic silt. This material is characterized by higher moisture content, finer texture, homogeneity with depth, and greater amounts of visible organic matter compared to the underlying materials. This unit does have some fine sand, representing 10 to 20 percent of the total sediment fraction. Some shell fragments are present in the lower reaches.

- **Upper Alluvium/Transition:** This middle unit consists of mostly medium dense, silty sand and sandy silt layers. This material is characterized by lesser amounts of organic matter, moderate density, distinct layering, and higher percentage of sand compared to the upper unit. It grades downward into coarser sediment. Some organic silt and woody layers are often present. Anthropogenic debris and fill are sometimes present in nearshore areas.

- **Lower (Native) Alluvium:** This lower unit is predominantly dense sand (non-silty) with gradational sequences of sand, with some silt bands and layers often present. This material is typically demarcated by a sharp horizon at its upper interface and has few chemical exceedances of applicable criteria. It is presumed to represent alluvial sediments deposited prior to construction of the LDW in the early 1900s.

The transitions from one unit to another vary from sharp to gradational contacts; however, distinct color, density, and content differences are observed among units. Large-scale event time markers assigned to these transitions are used to age-date sediments at the depth of the observed contact. The assigned dates are the years 1916 (initial channel development) and 1961 (completion of Howard Hanson Dam)[4]. Localized variations may exist between these contacts and dates, especially if a particular unit is not observed in the core profile; in those cases, the stratigraphic time marker associated with the missing unit is not used in the geochronology analysis.

Figure 2 presents an example age-dating evaluation of physical time markers using data from core LDW-SC-12. Core LDW-SC-12 exhibits the three stratigraphic units, with sharp demarcations between units. The upper unit consists of black organic silt extending from the mudline surface down to a depth of about 2.6 feet recovered. The lower depth of this unit was age-dated at 1961 (dam construction). From 2.6 to 6.7 feet, the middle unit is predominantly interbedded layers of fine sand and silt, with trace woody layers. The lower depth of this unit was age-dated at 1916 (LDW channelization). Below 6.7 feet in depth, gray alluvial medium to coarse sand is observed. Figure 4c shows a profile for SC-12 with assigned time markers.

F.3.2 Chemical Trends

Table 1 presents the 49 RI cores and the 10 historical cores used in this analysis, the time markers used for each core, and the estimated net sedimentation rate for each core and each time marker. Figures 4a through 4i present graphs of the 6-inch interval cores and illustrate how chemical concentrations change with depth. The 1-ft and 2-ft interval cores were not graphed, but were used to estimate the net sedimentation rates. The dates and depths applied to the chemistry data at the 1-ft, 2-ft, and 6-inch intervals, along with the calculations, are presented in Table A-1. Table A-2 shows the chemical concentrations in the 1-ft and 2-ft intervals and identifies which intervals were assigned as chemical time markers.

In most cores collected in 2006, the maximum detected PCB concentrations are observed at subsurface depths. The figures show near-surface concentrations of PCBs typically decreasing to levels less than a subsurface maximum concentration. The trend in PCB concentrations in LDW sediment cores may reflect the introduction (circa 1935) and the regulation (1980) of

[4] Dr. David Montgomery, a geomorphologist from the University of Washington, generally agreed with the interpretations used in this analysis and verbally confirmed that the RI cores support the development of a site-wide conceptual model and net sedimentation rates in the LDW. He also confirmed that the geomorphology dates of 1916 and 1961 are reasonable based on his knowledge and understanding of the Duwamish/Green River system.

PCB use in the United States. In any case, because PCB compounds are anthropogenic in origin, it's assumed that they did not occur in sediments prior to their introduction in the mid-1930s. Estimated dates were assigned to various recovered depths based on the PCB profiles. In cores where PCB concentrations are highest in the surface intervals, dates indicating maximum chemical use and for source control are not assumed to be applicable, and are not used for age-dating in this analysis. Maximum PCB concentrations in the surface could indicate a non-depositional (or relatively dynamic) sediment environment, impacts from nonpoint sources, and/or movement of impacted sediment from nearby activities, such as dredging.

F.3.3 Estimated Net Sedimentation Rates

Age-depth relationships were used to estimate net sedimentation rates[5]. The lines of evidence used to establish these relationships include: (1) relationships between contaminant profiles in sediment cores and chemical time markers; (2) relationships between observed lithologic units and physical time markers; (3) consistency of these trends with bathymetry, known dredging events, or other events. These rates were developed independently of one another and from the radioisotope profiles. Table 1 presents the estimates of net sedimentation rate for each time marker used in each core.

Physical Markers

Net sedimentation rates inferred on the basis of **physical** markers in the subsurface sediment chemistry cores collected in 2006 range from 0.4 to 4.7 cm/year. Historical cores are also in this range, with the exception of a core analyzed from Terminal 105 (B3), which exhibited a net sedimentation rate of about 5.0 cm/year, possibly due to its proximity near the mouth of a small stream at RM 0.1. The estimated rates within each core are consistent among multiple time markers to within plus or minus 1 cm/year.

The following example calculations from core SC-12 show how the net sedimentation rates were estimated from the lower (native) alluvium and the Howard Hanson Dam construction (upper alluvium) physical time markers, respectively:

$$\text{Year 1916:} \quad \frac{(6.7 \text{ ft} * 30.48 \text{ cm/ft})}{90 \text{ years}} = 2.3 \text{ cm/year}$$

[5] All net sedimentation rates described in this ~~attachment~~appendix are based on recovered sediment core depths measured in the field and not *in situ* core depths. Therefore, the results may be conservative relative to actual conditions in the field (e.g., estimates of net sedimentation rates may be slightly lower than what is actually occurring). Variability resulting from the differences in *in situ* versus recovered depths is described in the uncertainty section. Tables 3 and A-1 include rates estimated with *in situ* depths in addition to recovered depths.

$$\text{Year 1961:} \quad \frac{(2.6 \text{ ft} * 30.48 \text{ cm/ft})}{43 \text{ years}} = 1.8 \text{ cm/year}$$

The dates assigned to SC-12 and all other applicable core profiles are presented in Table 1, with detailed calculations presented in Table A-1.

Six cores were located near formerly dredged areas. The rates estimated for five of those (SC-9, SC-10, SC-18, SC-35, and SC-46) using dredge event time markers are consistent with those rates estimated from the other time markers. For the remaining core, SC-31, the net sedimentation rate since the dredge event is about 12 cm/year. This rate may not represent "ambient" conditions, but may be representative of short-term sedimentation rates after removal events. Initially higher rates would be expected as sediments quickly fill existing holes or depressions in the excavation bottom.

Rates were also estimated between physical markers to assess changes in net sedimentation rates over time. Nine of the twenty cores for which intra-marker rates could be applied exhibited lower net sedimentation rates after 1961 than before dam construction. (Rates before dam construction ranged from 0.7 to 5.6 cm/year.) Two of the cores exhibited similar rates (+/- 0.1 cm/year), and the remaining nine cores exhibited higher rates since 1961 (up to 3.4 cm/year). On average, the net change was minimal. Table 2 presents intra-marker rates for the twenty cores with both 1916 and 1961 physical markers.

The following example calculation from core SC-12 shows how the intra-marker net sedimentation rate was estimated between the lower (native) alluvium and the Howard Hanson Dam construction (upper alluvium):

$$\text{Years 1916 - 1961:} \quad \frac{(6.7 - 2.6 \text{ ft} * 30.48 \text{ cm/ft})}{45 \text{ years}} = 2.8 \text{ cm/year}$$

For the 45 years between 1916 and 1961, the "intra-marker" net sedimentation rate in SC-12 is 2.8 cm/year. This value is likely more representative of historical sedimentation rates compared to the 1961 rate of 1.8 cm/year, supporting the assumption there were higher sediment loads to the LDW before dam construction. Table A-3 presents the calculations used to derive these rates.

Chemical Markers

Net sedimentation rates based on **chemical** markers similarly range from 0.5 to 4.9 cm/year[6]. The rates estimated within each core are consistent among the various markers to within approximately 1 cm/year. Moreover, estimated net sedimentation rates based on PCBs and other chemical profiles are

[6] Applying an additional evaluation of uncertainty (see Section F.4.3), net sedimentation rates may range up to 5.9 cm/year.

generally consistent with those estimated from physical time markers, with most of the estimated rates falling between 1.0 to 4.0 cm/year. Table A-2 shows the chemistry data used to assign chemical markers in the subsurface sediment cores collected in 2006 based on 1-ft and 2-ft interval data. Figures 4a through 4i show the 6-inch interval data and profiles also used to assign chemical markers.

An example net sedimentation rate calculation using the peak PCB use marker from SC-12 at 3.0 feet follows:

$$\text{Year 1960:} \quad \frac{3.0 \text{ ft} * 30.48 \text{ cm/ft}}{46 \text{ years}} = 2.0 \text{ cm/year}$$

One historical core (DUD006, sampled at 6-inch intervals) shows subsurface concentration peaks for PCBs that correspond well with other cores. The net sedimentation rate ranges from 2 to 4 cm/year, depending upon whether the peak was assigned to 1960 (peak PCB use) or to 1974 (PCB spill in Slip 1). This net sedimentation rate is within the range of rates estimated for that portion of the LDW (DUD006 is in the Duwamish/Diagonal Early Action Area) (King County 2000; Harper-Owes 1985). Tables 1 and 3 present net sedimentation rate estimates for other relevant historical cores.

When the geochronology is reviewed collectively using both chemical and physical markers within each core, historical (pre-1960) net sedimentation rates are consistent with or slightly higher (up to 1 cm/year higher historically) than those observed in the 46 years since 1960. The rates observed after 1960 might more closely represent current and future conditions.

F.4 Discussion

This section compares the results of the empirically-derived net sedimentation rate estimates with the previously conducted radioisotope study (Table 4), discusses spatial distribution and correlation among adjacent cores (Table 3 and Figure 5), and then describes potential uncertainties associated with these estimates.

F.4.1 Comparison with Radioisotope Profiles

Radioisotope profiles were completed for the LDW by measuring the amounts of lead-210 (^{210}Pb or Pb-210) and cesium-137 (^{137}Cs or Cs-137) isotopes in a vertical sediment core profile consisting of 2-cm depth intervals, as described in the main text of this report. The geochronology field study, conducted during December 2004, included collection and analysis of fourteen 3-ft (90-cm) long sediment cores from bench areas within the LDW (Figure 1). Estimated net sedimentation rates are reported in Table 2-5 of the main text of this report and are summarized in Table 4 of this appendix. Estimated net sedimentation rates range from 0.5 cm/year to greater than 2 cm/year based on the introduction of ^{137}Cs activity and from 1.1 cm/year to greater than 2 cm/year based on the peak of ^{137}Cs activity. Net sedimentation rates estimated from the natural presence and decay rate of ^{210}Pb range from 0.4 to 1.1 cm/year (except for core Sg-5a, with an upper bound rate of 9.3 cm/year).

Overall, these rates are consistent with rates estimated from the physical and chemical geochronologies in the 2006 and historical cores. Examples of these comparisons with collocated 6-inch interval cores are graphically shown on Figures 4b, 4e, 4f, and 4i.

Five of the subsurface sediment chemistry cores collected in 2006 were co-located with or located near geochronology cores (<500 feet) (Table 4). In three of the cases (Sg-4, Sg-11b, and Sg-12), when the cores were located near each other, the rates estimated from physical and chemical markers are the same as the radioisotope-derived rates. In the other two cases (Sg-1 and Sg-3), the physical and chemical time markers result in slightly higher net sedimentation rates than the radioisotope-derived rates; this is likely due to differing water depths (i.e., one core was closer to the navigation channel than the other) or greater distances between core stations.

Tables 1 and 3 includes net sedimentation rates estimated from four historical geochronology cores using radioisotope and chemical markers collected from the East and West Waterways (immediately north and downstream of the study area). Net sedimentation rates for the East and West Waterway cores were estimated using the same analyses and time markers described above. Rates based on ^{137}Cs profiles are 1 to 2.4 cm/year; rates based on ^{210}Pb profiles are 0.5 to 0.8 cm/year; and rates based on PCB profiles are 1.3 to 2.5 cm/year (EVS and Hart Crowser 1995). These geochronology profiles are consistent within and between cores (except that the ^{210}Pb rates are slightly lower), and these net sedimentation rates are well within the ranges estimated for the LDW using the subsurface sediment chemistry cores collected in 2006. The same pattern of lower sedimentation rate estimates for ^{210}Pb compared to ^{137}Cs profiles was also observed among LDW cores.

F.4.2 Spatial Distribution of Net Sedimentation Rates

The sedimentation rates using physical, radioisotope, and chemical markers discussed above were used in combination to map net sedimentation rates for similar areas of the LDW adding certainty to individual core analyses. Table 3 presents the 56 RI cores, the 12 geochronology cores, and 6 historical cores used in this analysis (10 historical cores are presented, but 4 are downstream of the LDW). This table also shows spatial grouping of these cores into areas with similar net sedimentation rates, as described below, and graphically shown on Figure 5.

Mapping Net Sedimentation Rates

After net sedimentation rates were estimated for individual sediment cores, the cores were grouped into spatial areas, loosely referred to as "sedimentation areas", interpreted to have similar net sedimentation rates across broad areas. Because subsurface sediment cores have been collected in most areas of the LDW, it was possible to extrapolate net sedimentation rates across areas with similar physical attributes and where estimated net sedimentation rates are consistent between cores that are proximal to one other. Physical attributes considered when delineating "sedimentation areas" and their boundaries include water depth, whether the area is encompassed by the east or west bench areas or the navigation channel, channel geomorphology (e.g., bends in the waterway, changes in width), the position of the area relative to the extent of the saltwater wedge, and the three reaches defined in the Conceptual Site Model in the main text.

Intertidal areas were broadly assigned to the lowest rate interval (<0.5 cm/year) unless a core with a higher rate was present. The assignment of an area was determined by the presence/absence of sediment core data. Uncertainties associated with these estimates are described in Section F.4.3.

Some areas of the LDW were not grouped into sedimentation areas due to a lack of spatial coverage or evidence of other disturbances or incomplete trends. These areas are shown in white on Figure 5. In one exception, the Conceptual Site Model was used to apply rates to the navigation channel above RM 3.6 where spatial coverage was minimal. The highest rate category (>2.0 cm/year) was extended upstream to the upper turning basin based on the understanding of this area as a settling basin for upstream sediments.

Sediment cores were grouped together based on similarities in estimated net sedimentation rates and spatial proximity. The cores were grouped into five net sedimentation rate intervals: <0.5, ≥0.5 and <1.0, ≥1.0 and <1.5, ≥1.5 and <2.0, and ≥2 cm/year. For cores with a wide range of rates, the 0.5-cm rate interval that best fit the data, or the median value, was used to assign a rate category (and map color in Figure 5). Table 3 presents all sediment cores and time markers used in this analysis, and the extended range of rates for each core when potential uncertainties are considered. Cores in Tables 3 are first organized by location, according to whether a core was located in an intertidal area or in the navigation channel, and then by reach. Finally, cores within each of these spatial areas were further grouped if they have similar net sedimentation rates. In some cases, historical cores provided spatial coverage in areas without 2004/2006 sediment core representation.

Figure 5 depicts the spatial distribution of net sedimentation rates (in 0.5 cm/year increments) throughout the LDW, based on the combined geochronology, physical, and chemical time marker data.

Correlation among Groups

The navigation channel, which is periodically dredged, is used as a sedimentation area boundary because this region experiences different flow conditions and periodic dredging, as described in the main body of this report.

Average net sedimentation rates estimated for each group/area of the LDW are generally consistent among the various time marker methods and range from 0.4 to greater than 2 cm/year. Mid-channel net sedimentation rates are generally higher and range from 1.5 to greater than 2 cm/year. The very downstream end of the navigation channel (RM 0.0 to 0.3) has lower sedimentation rates ranging from 0.5 to 1.5 cm/year, likely due to deeper water depths and the presence of the saltwater wedge. The subtidal benches have net sedimentation rates range from 0.5 to 1.5 cm/year, with some upstream areas having rates greater than 2.0 cm/year extending to the shoreline. The intertidal areas are generally mapped as having net sedimentation rates less than 0.5 cm/year. However, the upstream intertidal areas have slightly higher net sedimentation rates between 0.5 and 1.5 cm/year. This is consistent with the Conceptual Site Model, which indicated that the net sedimentation rates increase slightly upstream, toward the upper turning basin, which was constructed to be a sink for sediment entering the LDW from upstream. Gradients in sedimentation rates may exist between areas, but for the purposes of this analysis, rate estimates are generalized into 0.5-cm/year increments based on available data without interpolating between areas.

Spatial variability in net sedimentation rates is attributable to several natural and man-made factors, including the presence of the saltwater wedge, local hydrologic regimes, bathymetry and navigation depths, dredging events, ship traffic, locations of docks and piers, and channel bed characteristics and geology.

Bathymetry data were examined to validate these estimated rates in select subtidal areas. Cross sections published in the Phase 1 RI (Windward 2003) compared elevation differences between 1992 and 2002 bathymetric surveys at RM 0.5 and from various navigation channel surveys (1963-1983) further upstream of RM 2.6. At RM 0.5, net sedimentation rates based on bathymetry ranged from 0.8 to 4.5 cm/year in the navigation channel and from 0.8 to 15 cm/year in the west bench area. Estimated rates further upstream ranges from 15 up to 50 cm/year. The rates estimated from the bathymetry data are more variable than the rates estimated by the core data; likely attributed to inaccuracies in the bathymetry methods, location control, and repeatability with time. These findings are discussed in the Spatial Coverage Limitations subsection of Section F.4.3.

An additional data review focused on bathymetric soundings recorded over time (and transcribed on historical Army Corps of Engineers [USACE 1949 - 2003] Conditions Survey Maps) at the locations of the radioisotope and six-inch subsurface sediment chemistry cores. The precision with which bathymetric soundings could be matched up to individual core locations was low. This uncertainty increased when an attempt was made to match soundings from multiple surveys to a single core location. Evaluating changes in bathymetric soundings on a core-by-core basis presented wide variability. Therefore, only the analysis using transects to estimate net sedimentation rates (discussed above) would be considered as a validation of rates estimated from time markers or modeling. However, the historic conditions surveys can be used to identify potential in-water structures or disturbances. For example, SC-6 is located near an over-water dock present between 1949 and 1963 identified on conditions surveys, SC-44 is located near historic pier ruins identified on the conditions surveys, and SC-51 is located near the historic Slip 5, which has been filled in for upland use. Net sedimentation rates have been estimated for these cores based on identified chemical markers; however, the areas around these cores are marked as having potential in-water disturbances in Figure 5. The potential variability associated with the presence of the structures/disturbances and the calculation of net sedimentation rates is discussed in Section F.4.3 (Uncertainties).

F.4.3 Uncertainties

There is a high degree of confidence in the results of this analysis because of agreement among several independent lines of evidence presented in this appendix. The extent to which radioisotope profiles are consistent with physical and chemical markers from co-located cores is depicted in Table 4. The extent to which there is consistency among cores is depicted in Table 3 and Figure 5. However, there are some uncertainties associated with this stratigraphic analysis of physical and chemical time markers, and the estimated net sedimentation rates may be underestimated or overestimated due to the following factors:

- Other physical events or disturbances not accounted for
- Differences between measured and *in situ* core depths
- Variability in net sedimentation rates estimated among different time markers in the same core
- Analytical sample resolution, thickness, and assignment of time markers to observed trends, and
- Lack of spatial coverage in some areas.

Each of these sources of uncertainty is discussed below.

Physical Events or Disturbances

Undocumented physical events related to shoreline development, navigational dredging, or localized events (e.g., sinking barges/vessels, pier/piling removals, and erosion) could influence the presence/absence of expected time markers and the depth at which time markers are observed. For example, the depth and extent of historical dredging activities are difficult to document earlier than 1980. Dredge events documented after 1980 are shown as blue stippling on Figure 5. If a dredging event occurred at or near a core location with presumed physical markers (1916 or 1961), then the applied age-dating could be inaccurate, and the resultant rate would underestimate actual net sedimentation rates. Alternatively, in areas near dredge prisms, slumping could possibly deposit large volumes of sediment in a short time period, limiting the value of estimated rates.

Table 5 lists the subsurface sediment chemistry cores collected in 2006 that were located within or adjacent to footprints for dredge events after 1980. To adjust for potential uncertainties associated with known dredge events, older time markers were adjusted so the year and depth of dredge events were subtracted from the rate estimates. Visual horizons or relative changes in grain sizes were used as markers for these dredge events.

Diffuse physical contacts in a core could be artifacts of the sample collection process or could indicate vertical mixing with depth. Vertical mixing could be a regular occurrence or part of the hydrodynamics of the LDW. It could also be the remnants of localized disturbance events (e.g., slumping, capping), either of which could mask the data and depth of the observed contact.

The correspondence of geochronology results among neighboring core locations was evaluated to minimize the influence of localized events on rate estimates. Additional information on historical bathymetric changes, dredging records, and changes in shoreline development could be reviewed to resolve potential discrepancies within a given sedimentation area.

Some sedimentation rates could not be estimated due to incomplete lithologic trends (i.e., lack of a major stratigraphic unit of diffuse contacts), proximity to known physical events, or lack of clear field documentation in historical cores. However, the absence of clearly defined trends at these locations does not necessarily mean that the area is not depositional. It simply means that more evaluation would be necessary if a definitive interpretation was required.

Measured and *In Situ* Core Depths

Measured, or recovered, core depths represent the amount of material physically observed in the sediment core tube during field processing. Because core recoveries are typically less than 100 percent, and because sediments may become compacted by the process of collecting the core, the measured core depth is often less than the depth to which the core tube was driven, or the *in situ* core depth. Recovered cores can be expanded to their penetration depth to represent *in situ* conditions, compensating for core compaction (or material loss) during core advancement. Use of recovered depths instead of *in situ* depths generally results in underestimating the net sedimentation rates. However, greater core recovery values reduce the uncertainties in age-dated markers and reduce the variability among rate calculations. For example, in cores with greater than 75 percent recovery, use of *in situ* core depths increased the net sedimentation rate estimates by less than 0.5 cm/year.

Because the RI core recoveries averaged roughly 79 percent, the error resulting from the difference between measured and *in situ* core depth is low (less than 0.5 cm/year difference). For cores with less than 75 percent recovery, the estimated net sedimentation rates increased less than 1.5 cm/year when *in situ* depths were used; therefore, the rates estimated in this analysis are minimally conservative compared to conditions observed in the field. In some cores, the upper intervals experienced percent recoveries at or near 100 percent, making recovered and *in situ* depths the same. Table A-1 provides rates based on both the recovered and the *in situ* depth for comparison. Figure 5 only presents the conservative rates estimated from recovered depths.

Variability among Time Markers

Post-depositional redistribution of sediments by physical mixing and/or biological processes can result in uniform chemical concentration gradients with depth, smoothing and widening of observed chemical peaks, or lower concentrations than typically expected in Puget Sound. Because the age-dating methods used to estimate net sedimentation rates calculate an average rate over time, they do not reveal variability over time. Table 2 shows changes over time for cores with both the 1916 and 1961 physical markers by comparing the rates estimated for each marker to the top of the core, to the rates estimated between physical marker depths (the intra-marker rates). Nine of the twenty cores evaluated have lower sedimentation rates (>0.1 cm/year difference) post-1961 compared to the previous 45 years (before dam construction was completed). These changes were typically less than 1.4 cm/year.

Time markers applied on a local scale may vary from generally accepted time periods of peak chemical use (e.g., PCBs in 1960, lead and arsenic control in 1985) and when the chemicals actually appear in the sediment and become incorporated into the sediment bed. A lag time of several years may exist for chemical and physical markers in the LDW. Variability in the assignment of these dates was explored but was within the variability observed among the lines of evidence and therefore not tabulated and presented in this analysis. It is a generally accepted limitation of this methodology.

In areas where gross and net sedimentation occurs, active mixing of the surface layer occurs. Therefore the chemical concentration peaks in cores from these areas may become obscured. Consequently, interpretation of these chemical peaks can be less accurate. Therefore, several markers spanning multiple decades are used within a single core to minimize this variability.

When grouping lithology into stratigraphic units, it is possible that variability in individual cores may be omitted or overlooked. Therefore, several cores with similar sediment profiles are used to minimize variability in delineation of larger-scale patterns.

Other factors that may affect the chemical distributions in sediment, such as geochemistry of individual substances, variations in sediment characteristics, exact dates of chemical use and/or source control efforts, and localized undocumented sources, such as spills, are not explicitly discussed in this appendix. When chemical peaks were observed in the surface, time markers for chemical peak use and for source control were not applied. Specific reasons for surface maxima were not determined for this appendix; but in general, higher concentrations detected in surface sediment may be attributed to ongoing, localized sources; redistribution of impacted sediment during dredging events; or episodic scour.

Alternatively, when clear chemical gradients for peaks were not observed in a core, chemical time markers were not applied. Low chemical concentrations detected throughout a core may be attributed to vertical mixing and homogenization with depth, an undocumented removal event, or simply that the core was located in an area not subject to significant source loading. Potential variability associated with these factors is reduced by assessing several geochronological lines of evidence.

Overall, uncertainty is reduced by evaluating multiple markers that yield similar net sedimentation rate estimates. Because there is variability in rates over time, a range of rates is presented for each core. This range of rates captures the potential uncertainty in the calculations.

Analytical Sample Resolution

The thickness of sampling intervals from which to assign time markers results in uncertainty. Thicker samples are less precise than finer-resolution samples due to homogenization over depth. For example, 2-ft chemistry intervals may produce rates that are 4 times less precise than those determined from 6-inch intervals. Uncertainty is minimized by relying on finer-resolution 6-inch interval data, when available. Because of the uncertainty inherent in thick sampling intervals, the 4-ft chemistry data from the PSDDA98 and PSDDA99 events were not used in this analysis. The uncertainty increases where chemical onset markers were assigned to skipped intervals. Due to this uncertainty, the rates for each core are combined with the physical time markers and presented as a range of rates (Table A-1). Rates for the upper, middle, and the lower extent of 2-ft sample intervals or skipped intervals, as appropriate, are provided to estimate the uncertainty associated with these assignments. The sampling intervals and relevant chemistry results for the subsurface sediment chemistry cores collected in 2006 are presented in Table A-2 along with a color-coded guide identifying the selected intervals used for geochronology.

Spatial Coverage Limitations

There are spatial areas of the LDW where no cores were located. These are identified as "no data" areas on Figure 5. Also, certain areas of the LDW have known disturbances, such as dredge events, capping events, and pier and bridge construction activities, which may compromise interpretation of net sedimentation rates. These areas are also labeled as "no data" areas on Figure 5. Finally, other areas of the LDW may have cores with no clear trends, cores with minimal documentation, or cores with evidence of a disturbance that could not be linked to a known event. Cores with any of these characteristics are difficult to use when estimating net sedimentation rates. These cores are also labeled on Figure 5.

The spatial distance from a core over which to apply estimated sedimentation rates introduces uncertainty in the mapping of similar net sedimentation rates. This uncertainty is decreased by the use of physical attributes, including bathymetric contours, and the understanding and application of the physical Conceptual Site Model (Reaches 1, 2, and 3). However, localized variability not captured by empirical data or physical attributes may exist. Finer scale assessments typically conducted during the design phase help to delineate the boundaries between areas of differing net sedimentation rates.

As the FS progresses and the LDW Conceptual Site Model is continually updated, additional data may be reviewed to refine the current understanding of the physical system and associated net sedimentation rates.

F.5 Conclusions

Net sedimentation rates were estimated in this report using three independent age-dating methods: radioisotopes, physical characteristics, and chemistry profiles. The resulting net sedimentation rates are consistent across multiple methods and across cores within similar physical settings. Consistency among cores allows for designation of sedimentation areas where net sedimentation rates are approximately equal. Given the scale of the LDW, net sedimentation rates are spatially heterogeneous from RM 0 to RM 4.3, varying from low depositional areas (specifically the intertidal areas) to upstream areas, slips, and the navigation channel where estimated net sedimentation rates are greater than 2.0 cm/year (Figure 5). Data suggest that depositional rates vary with location in the LDW, with higher estimated net sedimentation rates in the navigation channel and slips and lower estimated net sedimentation rates in the bench areas.

Three key conclusions emerge from this analysis:

- **Validity of Time Markers.** PCB trends provide strong chemical markers as a result of clear concentration gradients spanning about 70 years (i.e., onset around 1935, peak use in the 1950s and 1960s, a documented PCB spill in 1974, and PCB source control by

1980). Lead, arsenic, and phthalate profiles, showing subsurface maximum concentrations, are also useful for age-dating sediments in come cores. Other chemicals (TBT, total PAHs, other metals, and DDT) were examined but did not provide clear, consistent marker horizons throughout the LDW. This is likely because of localized usage patterns, such as TBT at shipyards, and the gradual increase in the releases of chemicals, such as PAHs and certain metals associated with urbanization.

Concentrations of PCBs and other chemicals generally decrease toward the surface. Two stratigraphic markers validate chemical trends: construction of the LDW in 1916 and construction of the Howard Hanson Dam in 1961.

- **Correspondence with Radioisotope Cores.** The presence of man-made ^{137}Cs in subsurface deposits is a strong time marker observed in most radioisotope cores. While this peak is not observed in all of the ^{137}Cs core profiles, the physical and chemical markers in co-located subsurface sediment chemistry cores collected in 2006 confirmed interpretations based on the radioisotope profiles with a high degree of confidence at locations where the ^{137}Cs peak is not observable. Net sedimentation rates estimated on the basis of physical and chemical time markers are generally consistent with the net sedimentation rates estimated from radioisotope profiles.

Distribution of Net Sedimentation Rates. Based on multiple lines of empirical evidence, this analysis concludes that net sedimentation rates vary by location in the LDW and, in general, are highest in the navigation channel (>2 cm/year), moderate in the subtidal bench areas (0.5 to 2.0 cm/year), and lowest in the intertidal, bench areas (<0.5 to 1 cm/year) (Figure 5). These rates are consistent with the understanding of where flow velocities sufficient to cause erosion are likely to occur.

Although this analysis focuses on interpretable trends among physical and chemical time markers observed in the core profiles, atypical trends may also provide valuable information. Atypical trends may signal ongoing sources or undocumented physical events (e.g., scour, slumping, and historic dredging or filling). Evaluation of these patterns is beyond the scope of this appendix but may be considered in the broader context of the Conceptual Site Model in the RI/FS process.

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Table 1 Net Sedimentation Rates in the LDW Estimated from Physical and Chemical Time Markers

Subsurface Core ID	Approx. River Mile	Estimated Net Sedimentation Rates (cm/year) Determined From Time Markers and Event Horizons[4]								
		Physical[1]			Chemical (1-ft, 2-ft Intervals)			Chemical (6-in Intervals) from a Subset of 2006 Cores		
		Lower (Native) Alluvium[2]	Hanson Dam Const.[3]	Dredge Horizon[5]	Lead/ PCB/ Phthalate Introduction	PCB Peak Usage/ Spill	Control Sources	PCB Introduction	PCB Peak Usage/ Spill	Control Sources
		1916	1961	Variable	1920 / 1935 / 1950	1960 / 1974	1980	1935	1960 / 1974	1980
RI 2006 Cores										
SC-1	0.0	0.9			1.7			1.1	0.9	0.9
SC-2	0.1									
SC-3	0.1	0.4								
SC-4	0.2	1.1			1.7		1.2			
SC-5	0.2	0.7	0.5		0.5, 0.9					
SC-6	0.3	2.6	3.0		2.3		2.3	2.6	2.3	2.7
SC-7	0.3				0.7					
SC-8	0.4					3.3	1.2			
SC-9	0.5		1.8	1.5						
SC-10	0.5	2.4	2.7	2.4		2.9				
SC-11	0.5		0.5		0.4					
SC-12	0.6	2.3	1.8		2.9	2.0	2.3, 1.2	2.6	2.0	2.1
SC-13	0.9				1.1			1.1 to 2.1		
SC-14	0.9	2.9			4.0					
SC-15	0.9	2.5	1.4		3.0	4.8				
SC-16	0.9	2.4			3.8	2.9	2.3, 1.2			
SC-17	1.0					2.9				
SC-18	1.0	1.9		1.5, 1.9	0.7, 0.9, 1.1					
SC-19	1.0	3.0	4.7		3.4	4.3				
SC-20	1.0									
SC-21	1.0	3.3	3.4		2.7	4.9	2.3			
SC-22	1.1									
SC-23	1.3		3.3		4.3	4.8	4.7	3.4	4.8	3.3
SC-24	1.2	1.1	0.7		0.7, 0.9					
SC-25	1.3	2.0 to 2.5			2.5, 3.0					
SC-26	1.4									
SC-27	1.4	1.5 to 2 .6						1.4	1.2	0.9
SC-28	1.4									
SC-29	1.4	0.6	0.4							
SC-30	1.6	1.1								
SC-31	1.7			12.2	1.0, 1.2, 1.5					
SC-32	1.7	1.7 to 2.4	1.9		2.0, 2.5					
SC-33	1.9	2.9			3.0, 3.8			2.6	0.8 to 1.7	0.9, 1.4
SC-34	1.9		2.2							
SC-35	2.0		3.5	2.8, 3.7						
SC-36	2.1	2.8	2.2							
SC-37	2.1	1.8	1.8		2.0, 2.6	1.0	2.3			
SC-38	2.1									
SC-39	2.2	2.9								
SC-40	2.2	0.7								
SC-41	2.4	2.6								
SC-42	2.5		2.7							
SC-43	2.6	3.0	0.5							
SC-44	2.7				1.4, 1.1			1.3	0.5	0.3
SC-45	2.8									
SC-46	2.7	2.3		7.6, 1.8						
SC-47	3.1	1.0			1.3, 1.4, 2.2	1.0	1.2			
SC-48	3.3				0.4 to 0.5					
SC-49	3.5		2.4		4.3					
SC-50	3.8	0.9			1.0, 1.2, 1.5					
SC-51	3.8									0.6
SC-52	3.9				0.5, 0.7, 0.9					
SC-53	4.2	3.1	3.3							
SC-54	4.3	1.8	2.7							
SC-55	4.9	1.0	0.3							
SC-56	4.7				0.8 to 1.0					

Table 1 Net Sedimentation Rates in the LDW Estimated from Physical and Chemical Time Markers

Subsurface Core ID	Estimated Net Sedimentation Rates (cm/year) Determined From Time Markers and Event Horizons[4]									
	Approx. River Mile	Physical[1]			Chemical (1-ft, 2-ft Intervals)			Chemical (6-in Intervals) from a Subset of 2006 Cores		
		Lower (Native) Alluvium[2]	Hanson Dam Const.[3]	Dredge Horizon[5]	Lead/ PCB/ Phthalate Introduction	PCB Peak Usage/ Spill	Control Sources	PCB Introduction	PCB Peak Usage/ Spill	Control Sources
		1916	1961	Variable	1920 / 1935 / 1950	1960 / 1974	1980	1935	1960 / 1974	1980
Historical Cores										
B3 (T105 1985)	0.2	4.9	5.1							
DUD006 (D/D 1994)	0.5					1.9; 3.1	2.7			
DR18 (PSDDA99)	1.8	2.2	3.2							
DR39 (PSDDA99)	2.2	1.5								
SC11 (Slip 4 2004)	2.8	1.5	2.2							
S3 (PSDDA98)	3.8	3.0	3.3							
HI-NR-01	<0						1.4			
HI-NR-02	<0						1.3			
HI-NR-03	<0						2.5			
HI-NR-04	<0						1.3			

Notes:

= no strong marker; therefore no calculation was made for the core.

1. Sediments were grouped into three stratigraphic units identified for the LDW, primarily based on density, color, sediment type, texture, and marker bed horizons. The three sediment stratigraphy units were identified as follows: Recent, Upper Alluvium, Lower (Native) Alluvium.
2. Lower (Native) Alluvium is defined by top of dense sand unit.
3. Hanson Dam Construction is defined by the presence of organic silt.
4. All net sedimentation rate estimates are based on recovered core depths, and do not include uncertainty.
5. Dredge event rates show rate for event to top of core and intra-marker rate from stratigraphic marker to dredge effects marker.
6. Blank cells indicate that markers were not present or core was not clearly indicative of a strong time marker.

See Subsurface Data Report (Windward and RETEC 2007) for core logs
See Table A-1 for the net sedimentation rate calculations

Table 2 Comparison of Intra-Marker Rate (Between Physical Time Markers) to Rates Estimated for Individual Markers

Subsurface Core ID[1]	Physical Time Markers to Top of Core Using Recovered Depths		Net Sedimentation Rate Between Physical Time Markers		Net Change in Estimated Net Sedimentation Rate
	Native Alluvium	Hanson Dam Const.	Intramarker		
Dates:	1916 - 2006	1961 - 2006	1916 - 1961		B-C
Duration:	90 years	45 years	45 years		
	A	B		C	
	Rate (cm/year):	Rate (cm/year):	Core Thickness Between Markers (ft):	Rate (cm/year):	Rate Change with Time (cm/year)
RI 2006 Cores					
SC-5	0.7	0.5	1.4	0.9	-0.4
SC-6	2.6	3.0	3.2	2.2	0.9
SC-10	2.4	2.7	3	2.0	0.7
SC-12	2.3	1.8	4.1	2.8	-1.0
SC-15	2.5	1.4	5.4	3.7	-2.3
SC-19	3.0	4.7	2	1.4	3.4
SC-21	3.3	3.4	4.8	3.3	0.1
SC-24	1.1	0.7	2.2	1.5	-0.8
SC-29	0.6	0.4	1.1	0.7	-0.3
SC-32	1.7 to 2.4	1.9	3.4	2.3	-0.4
SC-36	2.8	2.2	5.2	3.5	-1.4
SC-37	1.8	1.8	2.7	1.8	-0.1
SC-43	3.0	0.5	8.3	5.6	-5.1
SC-53	3.1	3.3	4.2	2.8	0.5
SC-54	1.8	2.7	1.4	0.9	1.8
SC-55	1.0	0.3	2.5	1.7	-1.4
Historical Cores					
B3 (T105 1985)	4.9	5.1	7	4.7	0.3
DR18 (PSDDA99)	2.2	3.2	2	1.4	1.9
S3 (PSDDA98)	3.0	3.3	4	2.7	0.6
SC-11 (Slip 4 2004)	1.4	2.6	1	0.7	1.9
Average Change Over Time (cm/year):					-0.1

Notes:
1. Only cores with 1916 and 1961 physical markers are listed.

Table 3 Array of Time Markers Used to Estimate Net Sedimentation Rates in the LDW (Grouped by Area)

Reach / Area[1]	River Mile		Estimated Net Sedimentation Rate (cm/year) for Area	Subsurface Core ID	Net Sedimentation Rates (cm/year) using Recovered Depths													Range of Estimated Net Sedimentation Rates (cm/year) (from uncertainty analysis; see Table A-1)	
					Isotope Profiles		Physical[2]			Chemical (1-ft/2-ft Intervals)[4]					Chemical (6-in Intervals) from a Subset of 2006 Cores				
							Lower (Native) Alluvium[2]	Hanson Dam Const.[3]	Dredge Horizon[5]	Lead / PCB / Phthalate Introduction		PCB Peak Usage/Spill	Control Sources		PCB Introduction	PCB Peak Usage/ Spill	Control Sources		
	From	To			Cs-137	Pb-210	1916	1961	Variable	1920 / 1935 / 1950		1960 / 1974	1980		1935	1960 / 1974	1980	Lower	Upper
Intertidal	0.0	5.0	<0.5, or no rate calculated	Sg-2	0.5 to 0.6	0.4 to 1.1												0.4	1.1
				SC-11				0.5		0.4	bis							0.4	0.6
				SC-22														no markers	
				SC-29			0.6	0.4										0.4	0.6
				SC-38														no markers	
			>0.5	SC-39			2.9											2.9	3.5
				SC-40			0.7											0.7	0.8
				SC-44						1.4, 1.1	PCB, bis				1.3	0.5	0.3	0.3	2.1
				SC-50			0.9			1.0, 1.2, 1.5	Pb, PCB, bis							0.9	2.0
				SC-51													0.6	0.6	0.6
				Sg-11b	0.6 to 0.7													0.6	0.7
				SC-52						0.5, 0.7, 0.9	bis, Pb, PCB							0.5	1.3
				SC-54			1.8	2.7										1.8	3.3
				SC-55			1.0	0.3										0.3	1.4
				SC-56						0.8 to 1.0	Pb, PCB, bis							0.8	1.3
Navigation Channel	0.3	0.5	>1.0	SC-8								3.3	1.2	PCB				1.2	5.2
				SC-9				1.8	1.5									1.5	1.8
	0.7	1.2	>2.0	SC-14			2.9			4.0	PCB							2.9	4.0
	1.7	1.9	>2.0	DR18 (PSDDA99)*			2.2	3.2										2.2	3.2
	2.1	2.3	1.0 to 1.5	DR39 (PSDDA99)*			1.5											1.5	1.5
	3.3	3.4	<0.5, marked as disturbed	SC-48						0.4 to 0.5	Pb, PCB, bis							0.4	0.6
	3.4	4.7	>2.0	SC-49				2.4		4.3	PCB							2.4	5.0
				S3 (PSDDA98)*			3.0	3.3										3.0	3.3
	1.0	1.1	no rate	SC-20														no markers	
Reach 1	0.0	2.0	0.0 to 0.5	SC-3			0.4											0.4	0.4
			0.5 to 1.0	SC-5			0.7	0.5		0.5, 0.9	bis, PCB							0.5	1.0
				Sg-1a	0.9 to 1.3													0.9	1.3
				SC-7						0.7	PCB							0.7	0.8
				SC-24			1.1	0.7		0.7, 0.9	Pb, PCB							0.7	1.1
			1.0 to 1.5	SC-1			0.9			1.7	PCB				1.1	0.9	0.9	0.9	1.8
				SC-4			1.1			1.7	PCB		1.2	PCB				1.1	1.8
				SC-13						1.1	bis				1.1 to 2.1			1.1	2.1
				SC-30			1.1											1.1	1.2
				SC-31					12.2	1.0, 1.2, 1.5	Pb, PCB, bis							1.0	13.1
			1.5 to 2.0	SC-18			1.9		1.5, 1.9	0.7, 0.9, 1.1	Pb, PCB, bis							0.7	2.1
				Sg-3	1.9 to 2.1													1.9	2.1
				Sg-4	1.6 to 2.0													1.6	2.0
				SC-27			1.5 to 2 .6								1.4	1.2	0.9	0.9	3.1
				Sg-5a	1.4 to 1.6	0.7 to 9.3												0.7	9.3

Table 3 Array of Time Markers Used to Estimate Net Sedimentation Rates in the LDW (Grouped by Area)

Reach / Area[1]	River Mile From	River Mile To	Estimated Net Sedimentation Rate (cm/year) for Area	Subsurface Core ID	Isotope Profiles: Cs-137	Isotope Profiles: Pb-210	Physical[2]: Lower (Native) Alluvium[2] 1916	Physical[2]: Hanson Dam Const.[3] 1961	Physical[2]: Dredge Horizon[5] Variable	Chemical (1-ft/2-ft Intervals)[4]: Lead / PCB / Phthalate Introduction 1920 / 1935 / 1950		Chemical (1-ft/2-ft Intervals)[4]: PCB Peak Usage/Spill 1960 / 1974	Chemical (1-ft/2-ft Intervals)[4]: Control Sources 1980		Chemical (6-in Intervals) from a Subset of 2006 Cores: PCB Introduction 1935	Chemical (6-in Intervals) from a Subset of 2006 Cores: PCB Peak Usage/ Spill 1960 / 1974	Chemical (6-in Intervals) from a Subset of 2006 Cores: Control Sources 1980	Range of Estimated Net Sedimentation Rates (cm/year) (from uncertainty analysis; see Table A-1): Lower	Range of Estimated Net Sedimentation Rates (cm/year): Upper
Reach 1	0.0	2.0	>2.0	B3 (T105 1985)*			4.9	5.1										4.9	5.1
				SC-6			2.6	3.0		2.3	PCB		2.3	PCB	2.6	2.3	2.7	2.3	3.3
				SC-10			2.4	2.7	2.4			2.9						1.9	5.7
				SC-12			2.3	1.8		2.9	PCB	2.0	2.3, 1.2		2.6	2.0	2.1	1.2	3.0
				SC-15			2.5	1.4		3.0	PCB	4.8						1.4	6.8
				SC-16			2.4			3.8	bis	2.9	2.3, 1.2	PCB				1.2	4.3
				SC-17								2.9						1.9	5.7
				SC-19			3.0	4.7		3.4	PCB	4.3						3.0	5.1
				SC-21			3.3	3.4		2.7	PCB	4.9	2.3	PCB				2.3	6.2
				SC-23				3.3		4.3	PCB	4.8	4.7	PCB	3.4	4.8	3.3	3.3	6.1
				SC-25			2.0 to 2.5			2.5, 3.0	Pb, PCB							2.0	3.4
				SC-32			1.7 to 2.4	1.9		2.0, 2.5	PCB, bis							1.7	2.8
				SC-33			2.9			3.0, 3.8	PCB, bis				2.6	0.8 to 1.7	0.9, 1.4	0.8	4.2
				SC-34				2.2										2.2	2.6
				SC-35				3.5	2.8, 3.7									2.8	4.6
			No rate calculated or in Early Action Area	SC-2														no markers	
				DUD006 (D/D 1994)*								1.9; 3.1	2.7	Pb				1.9	4.0
				SC-26														no markers	
				SC-28														no markers	
Reach 2	2.0	3.0	**0.5 to 3.0**	SC-43			3.0	0.5										0.5	4.0
			1.5 to 2.0	SC11 (Slip 4 2004)*			1.5	2.2										1.5	2.5
			>2.0	SC-36			2.8	2.2										2.2	3.3
				SC-37			1.8	1.8		2.0, 2.6	PCB, bis	1.0	2.3	As				0.7	3.0
				SC-41			2.6											2.6	3.7
				SC-42				2.7										2.7	2.7
				Sg-6	2.5 to 2.7													2.5	2.7
				Sg-7	1.9 to 2.1	0.5 to 1.1												0.5	2.1
				SC-45														no markers	
				SC-46			2.3		7.6, 1.8									2.3	8.7
Reach 3	3.0	5.0	**0.5 to 1.0**	Sg-9	0.3 to 0.9													0.9	0.9
			1.0 to 1.5	SC-47			1.0			1.3, 1.4, 2.2	PCB, Pb, bis	1.0	1.2	PCB				0.7	2.8
			1.5 to 2.0	Sg-10	1.6-1.8	0.2-1.0												0.2	1.8
			>2.0	Sg-12	>2.0													>2.0	>2.0
				SC-53			3.1	3.3										3.1	3.8
				Sg-13	2.3 to 2.6													2.3	2.6
West Waterway			**0.5 to 1.5**	HI-NR-01*	1.0	0.5							1.4	PCB				0.5	1.4
				HI-NR-02*	1.0	0.8							1.3	PCB				0.8	1.3
East Waterway			**1.5 to 2.5**	HI-NR-03*	2.4								2.5	PCB				2.4	2.5
				HI-NR-04*	1.7								1.3	PCB				1.3	1.7

NOTES:
1. See Figure 5 for mapped areas. Areas are grouped by common net sedimentation rates.
2. Sediments were grouped into three stratigraphic units identified for the LDW, as follows: Recent, Upper Alluvium, Lower (Native) Alluvium. Lower Alluvium defined by presence of dense sand unit.
3. Hanson Dam construction is defined by the presence of organic silt.
4. Pb = lead, As = arsenic, bis = bis(2-ethylhexl) phthalate, PCB = total polychlorinated biphenyls. Order of chemical listing corresponds to order of rate for each marker.
5. Dredge event rates show rate for event to top of core and intra-marker rate from stratigraphic marker to dredge effects marker.
6. Blank cells indicate that markers were not present or core was not clearly indicative of a strong time marker.
* = historical cores
colocated core, within 100 feet of one another and in same net sedimentation rate area
no strong marker, therefore no calculation was made for the core
See Subsurface Data Report (Windward and RETEC 2007) for core logs. See Table A-1 for net sedimentation rate calculations.

Table 4 Comparison of Net Sedimentation Rates Estimated Based on Radioisotope and Physical/Chemical Data from Co-located Cores

Subsurface Core ID	Approximate Distance between Core Locations (ft)	Estimated Net Sedimentation Rates (cm/year)			
		Radioisotope Profiles[1,2]		Range of Physical/ Chemical Markers[3]	
		Cs-137	Pb-210	Lower	Upper
Sg-1a SC-6	490	1.0	—	0.5	1.0
Sg-2	—	0.5	0.5 to 1.0	NA	
Sg-3 SC-23	300	2.0	—	3.3	6.1
Sg-4 SC-27	30	2.0	—	0.9	3.1
Sg-5a	—	1.5	1.0	NA	
Sg-6	—	2.5	—	NA	
Sg-7	—	2.0	0.5 to 1	NA	
Sg-8	—	—	—	NA	
Sg-9	—	0.5	—	NA	
Sg-10	—	1.5	0.5	NA	
Sg-11b SC-52	60	0.5	—	0.5	1.3
Sg-12[4, 5] SC-54	100	>2.0	—	1.8	3.3
Sg-13	—	2.5	—	NA	

Cores located within 100 ft of each other

Notes:

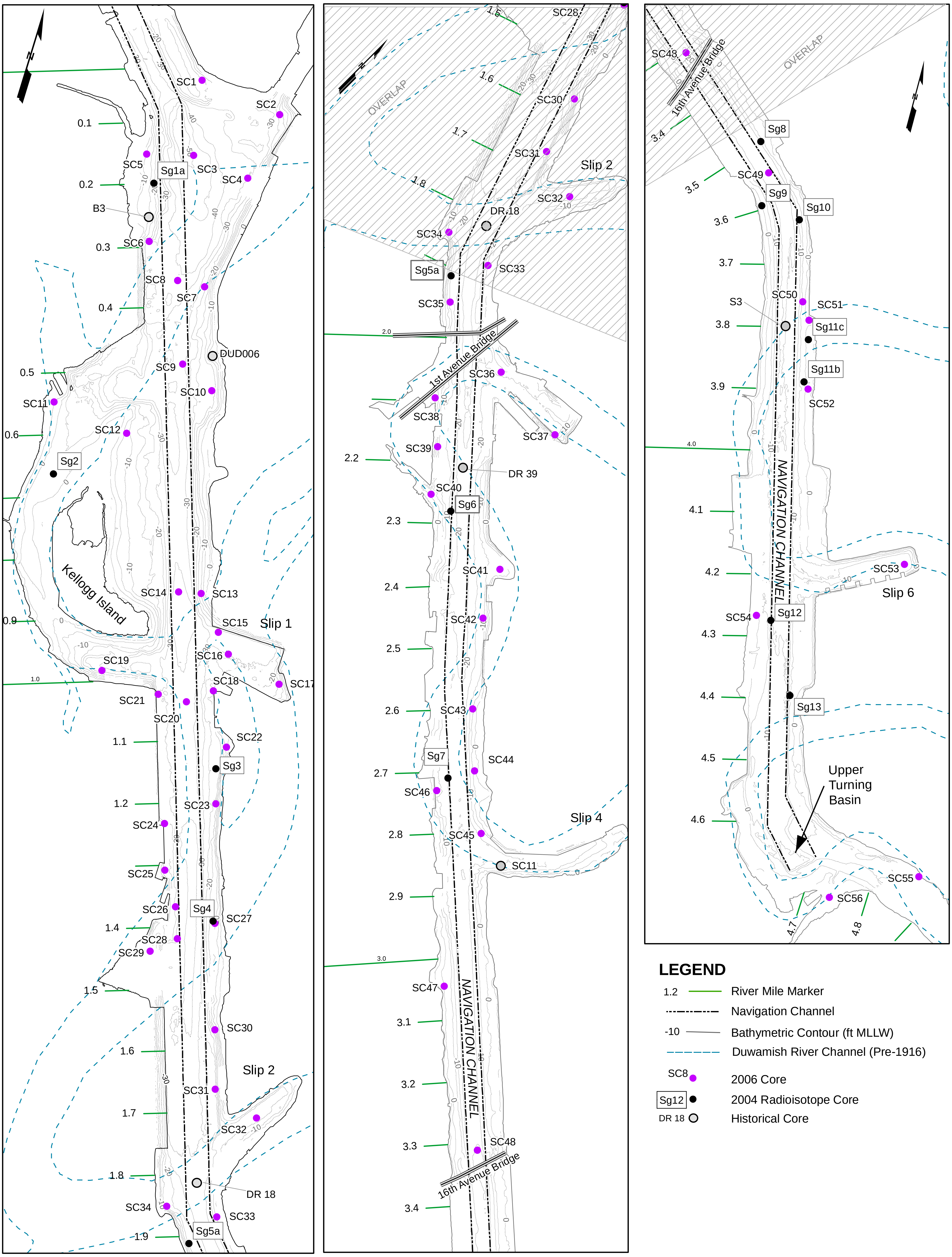
1. Rounded to the nearest 0.5 cm
2. Estimate presented in Section 2 of main body of report.
3. Range represents rates calculated using both in-situ and recovered depths for subsurface sediment chemistry cores collected in 2006.
4. SG-12 and SC-54 are located within 100 feet of each other. However they are in different bathymetric zones and net sedimentation rate areas. SC-54 is intertidal, and the mudline elevation at SG-12 is >-10 ft MLLW.
5. Cores with 6-inch interval data were selected for comparison to radioisotope cores if within 500 ft. SC-54 was compared to Sg-12 because a core with 6-inch interval data was not available nearby.

— Core contained un-interpretable radioisotope profiles.
NA - no co-located core within 500 ft
SC-x = 2006 sediment chemistry core
Sg-x = 2004 sediment radioisotope core

Table 5 Evaluation of Potential Effects on Physical Time Markers of Cores in Close Proximity to Dredge/Cap Events

Subsurface Core		Dredge Event			Observed Dredge/Cap Horizons			Observed Other Physical Markers				
Subsurface Core ID	Mudline Elevation (ft MLLW)	Project Name	Year	Paydepth / Overdepth (ft MLLW)	Core Potentially Exhibiting Dredge Effects?	Depth of Observed Dredge Horizon in Core (ft)	Elevation of Observed Horizon in Core (ft MLLW)	Physical Marker (s) Used	Depth of Observed Marker in Core (ft)[1]	Elevation of Observed Marker in Core (ft MLLW)[1]	Rationale for Use of Time Marker	Rate added or Modified for Event (cm/year)
SC9	-31.6	Duwamish Diagonal	2004	3-5 feet below mudline	yes, by cap placement	0.5 (bottom of sand)	-32.1	1961	2.6	-34.2	The cap placed in Areas A and B consisted of a sand layer, a layer of gravel and riprap, and a mix of rounded sand and gravel. A thin layer cap (6-inches) was placed outside of Area B. A 6-inch layer of sand in upper 0.5 of core could be sand cap material from 2004. The 1961 marker at 1.8 ft was not affected.	Intra marker rate to bottom of sand at 0.5 ft: ([2.6-0.5ft]*30.48cm)/(2004-1961)=1.5
SC10	-17.3				yes, by cap placement	0.6 (bottom of gravel)	-17.9	1916, 1961	6.0, 4.0	-23.3, -21.3	Source of gravel in core is unknown. Bottom of sand at 0.6 feet could represent 2004. No change to physical markers for 1916 or 1961 events.	Intra-marker: ([4.0-0.6ft]*30.48cm/(2004-1961) = 2.4 cm/year
SC18	-19.4	Lehigh Northwest	2004	—	yes	0.1 (bottom of silt)	-19.5	1916	5.7	-25.1	1916 physical marker remains, no chemical exceedances; atypical profile; no dredge impacts at depth	dredge event: (0.1ft*30.46cm)/2 = 1.5 cm/year intra-marker: ([5.7-0.1ft]*30.48cm/(2004-1916) = 1.9 cm/year
SC29	-4.2	Glacier Northwest	2005	-35 / -36	no	—	—	1916, 1961	1.7, 0.6	-5.9, -4.8	Core is in intertidal area outside of dredge prism, pier separates core from dredge area. No dredge effects in this core. No change to 1916 and 1961 physical markers.	
SC30	-12.2	Lone Star Hardie	1995	-30 / -31	no	—	—	1916	3.2	-15.4	Core is outside of dredge prism based on elevations and lack of dredge events seen in core.	
SC31	-31.7	James Hardie Gypsum	1999	-31	yes	2.8 (sharp sand contact)	-34.5	none		NA	Core located in dredge prism; event likely removed sediment that had accumulationed since chemical onset dates[2]. The 1997 bathymetry at edge of navigation channel was about -28 ft.	dredge event: (2.8ft*30.48)/7 = 12.2 cm/year
SC32	-17.2	Glacier Ready Mix	2001	-15 / -16	no	1.0 (potential in gravelly layer)	—	1916, 1961	7.1, 2.8	-24.3, -20	Core is outside of dredge prism based on stratigraphic profile and elevations. Possible dredge effects near 1.0 ft in gravelly layer, but unconfirmed. No change to 1916 and 1961 markers.	
SC35	-13.8	Terminal 115	1993	-15	yes	1.2 (bottom of silty sand)	-15	1961	5.1	-18.9	1961 marker is below dredge horizon and is acceptable for use.	dredge event: (1.2ft*30.46cm)/13 = 2.8 cm/year intra-marker: ([5.1-1.2ft]*30.48cm/(1993-1961) = 3.7 cm/year
SC46	-7.6	Hurlen	1998	-10	yes	2.0 (bottom of mottled silt with trace gravel)	-9.8	1916	6.8	-14.4	Core is in dredge prism, trace horizon at 2 ft but not confirmed. No change to 1916 marker at 6.8 feet, well below dredge horizon.	dredge event: (2.0 ft*30.48cm)/8 = 7.6 intra-marker: ([6.8-2.0]ft*30.48cm)/(1998-1916) = 1.8
SC54	-0.2	Delta Marine	2002	—	no	—	—	1916, 1961	5.4, 4.0	-5.6, -4.2	Core is outside of dredge prism based on typical stratigraphic profile. The core is unaffected by the dredging.	

Note:
— no dredge depth available or dredge horizon observed.
1. Mudline elevations at time of dredging event may be different from mudline elevations at time of core collection (2006); hence the thickness and depth of observed time markers may actually be thicker (with higher sedimentation rates) than expressed in this appendix.
2. Rate for chemical onset at 2.8 ft may be higher than 1.0-1.5 cm/year, as dredge event removed sediment that had accumulated since chemical onset dates.
NA - not applicable.



Notes:
1. Bathymetry data are provided by Windward Environmental LLC based on waterway-wide October 2003 survey.
2. Only those historical cores with labels were used in net sedimentation rate estimates. See Table 1.

0 400 800 Feet

ENSR | AECOM

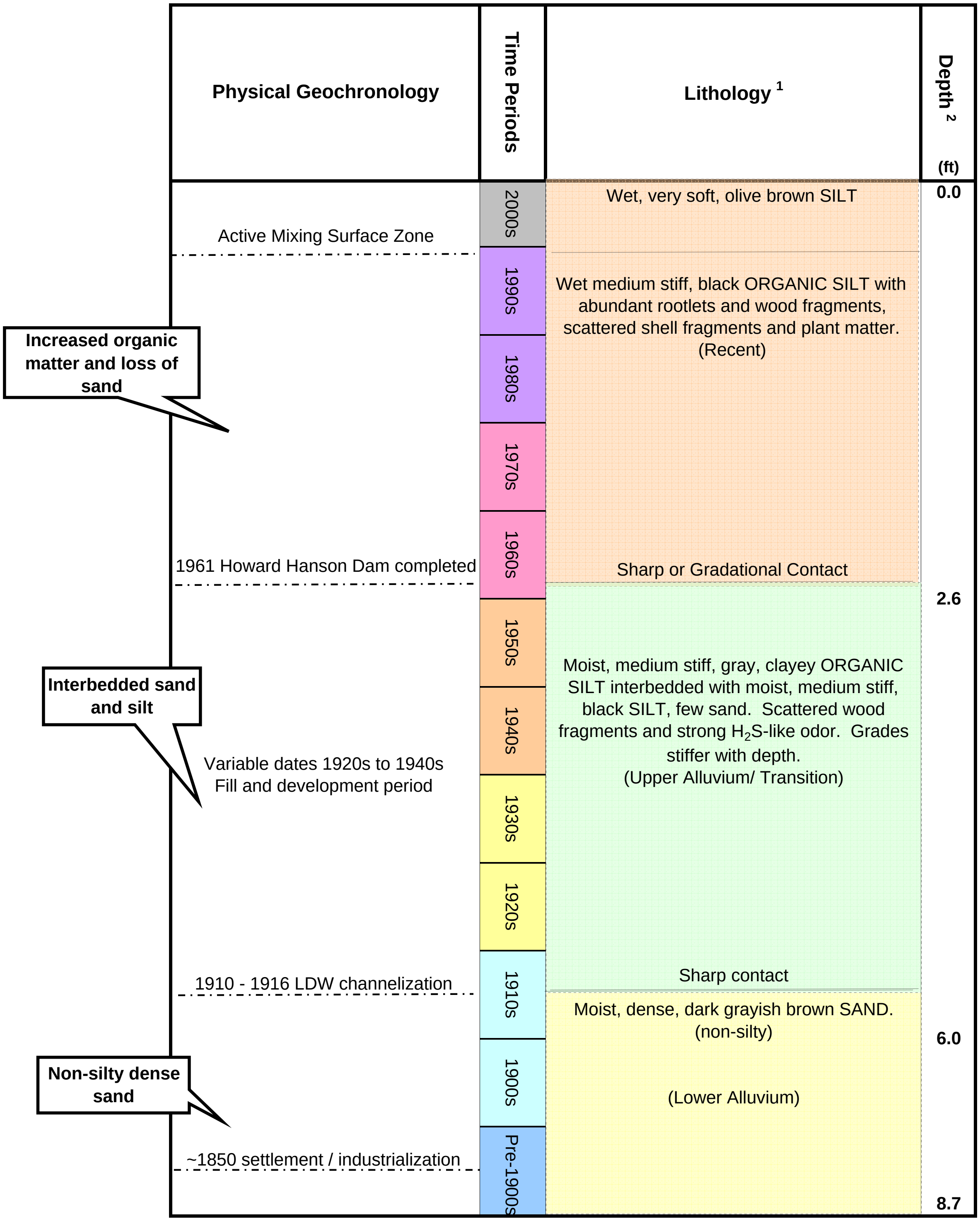
Merged with ENSR in 2007 RETEC

Lower Duwamish Waterway Group
Port of Seattle | City of Seattle | King County | The Boeing Company

LOWER DUWAMISH WATERWAY DRAFT SEDIMENT TRANSPORT ANALYSIS REPORT 05482015-611	CORE LOCATIONS AND WATER DEPTH IN THE LDW
DATE: 10/17/07 DWN. BY: MI/sea	FIGURE 1

F:\PROJECTS\GIS\Lower Duwamish FS\Projects\Sediment Transport Model\SedimentTransAnalysisReport\PercentFines_STA_rptRevised.mxd : Created Using ArcGIS 9.2

Figure 2 Generalized Concept Core of Stratigraphy and Related Time Markers



Notes:

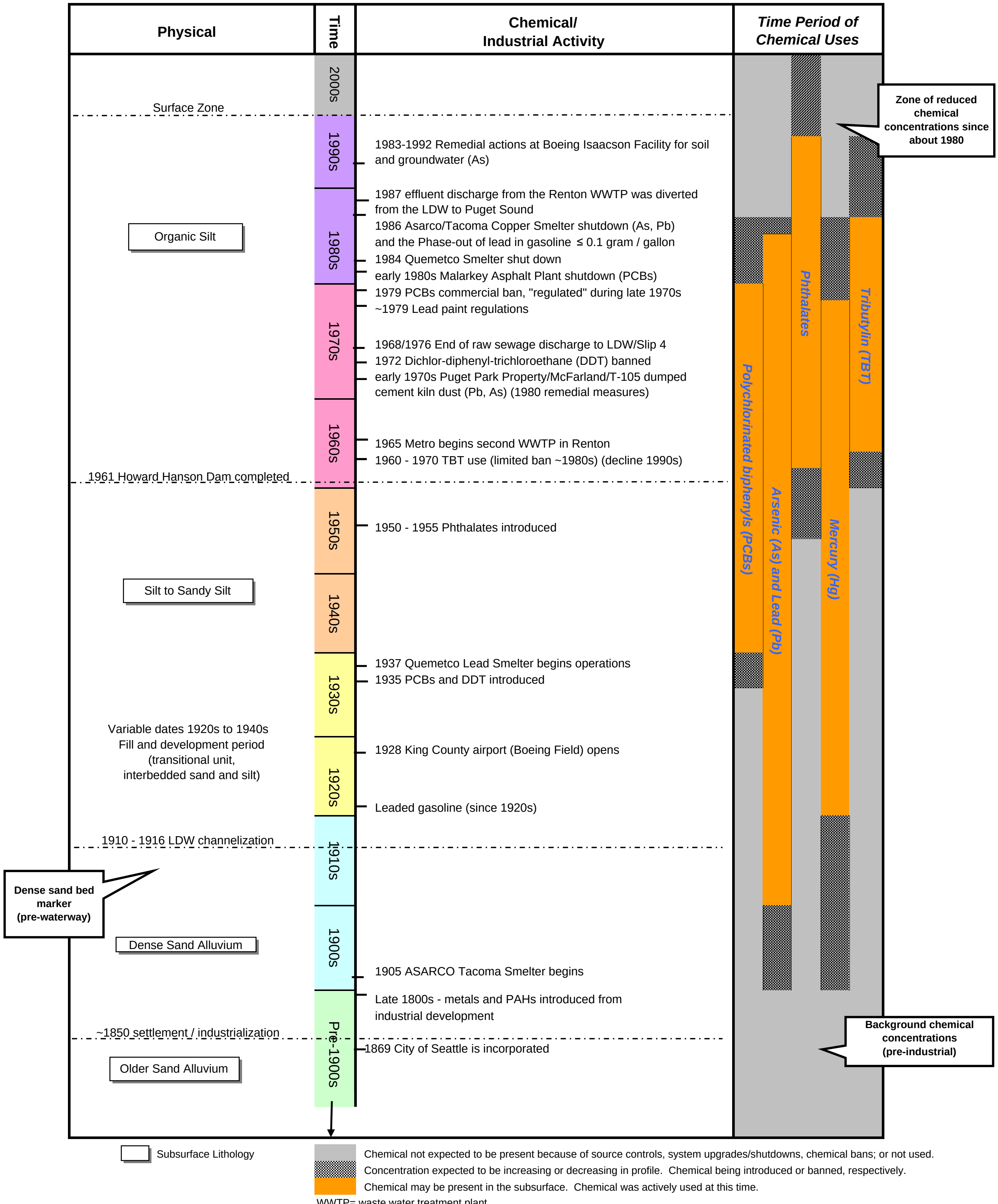
[1] Lithology descriptions from core SC-12

[2] Recovered core depths measured during SC-12 core processing

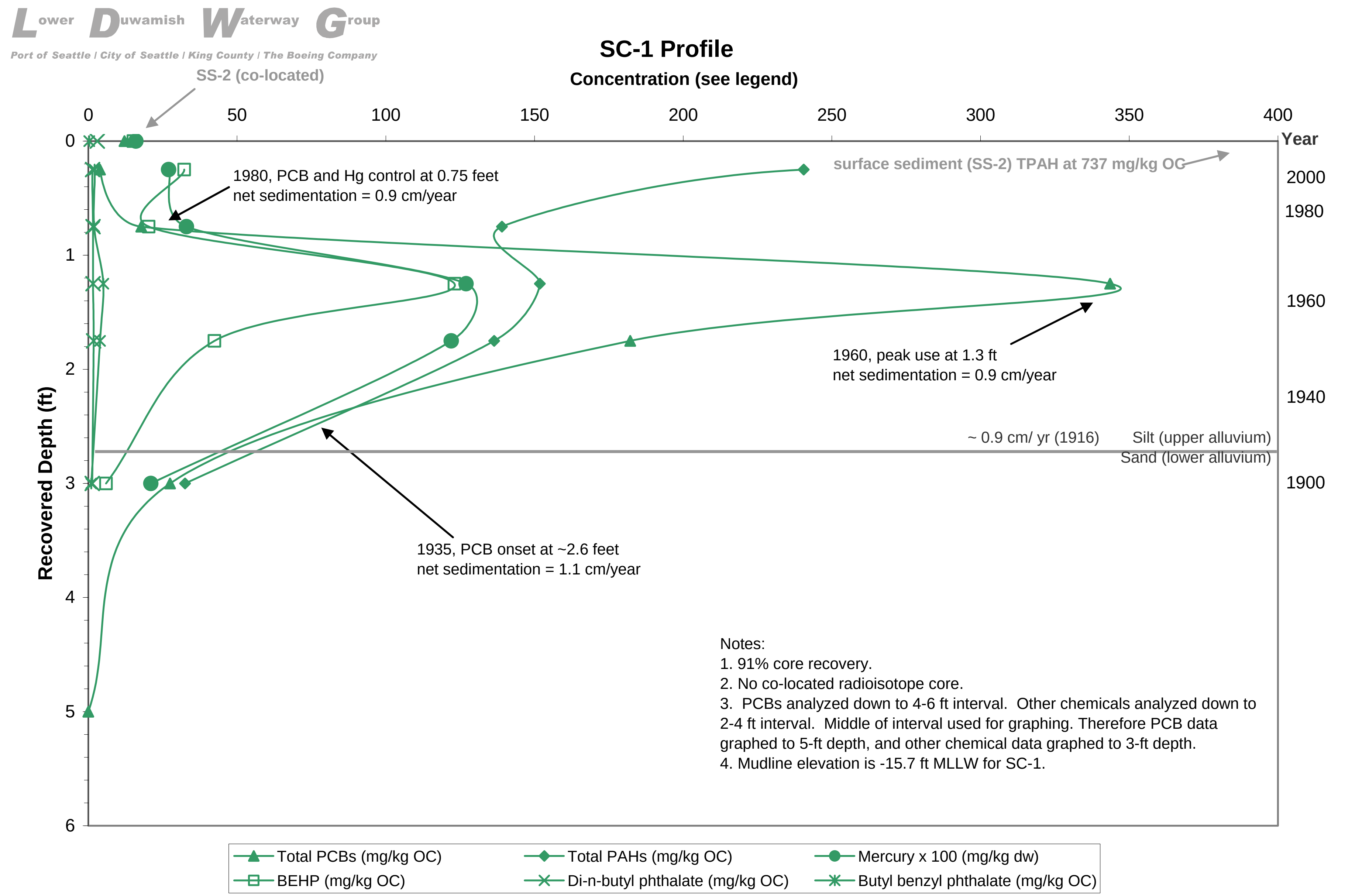
Key:

- Recent
- Upper Alluvium/ Transition
- Lower Alluvium

Figure 3 Timeline of Possible Physical and Chemical Markers



Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company



RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-1 PROFILE
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-A

Lower Duwamish Waterway Group
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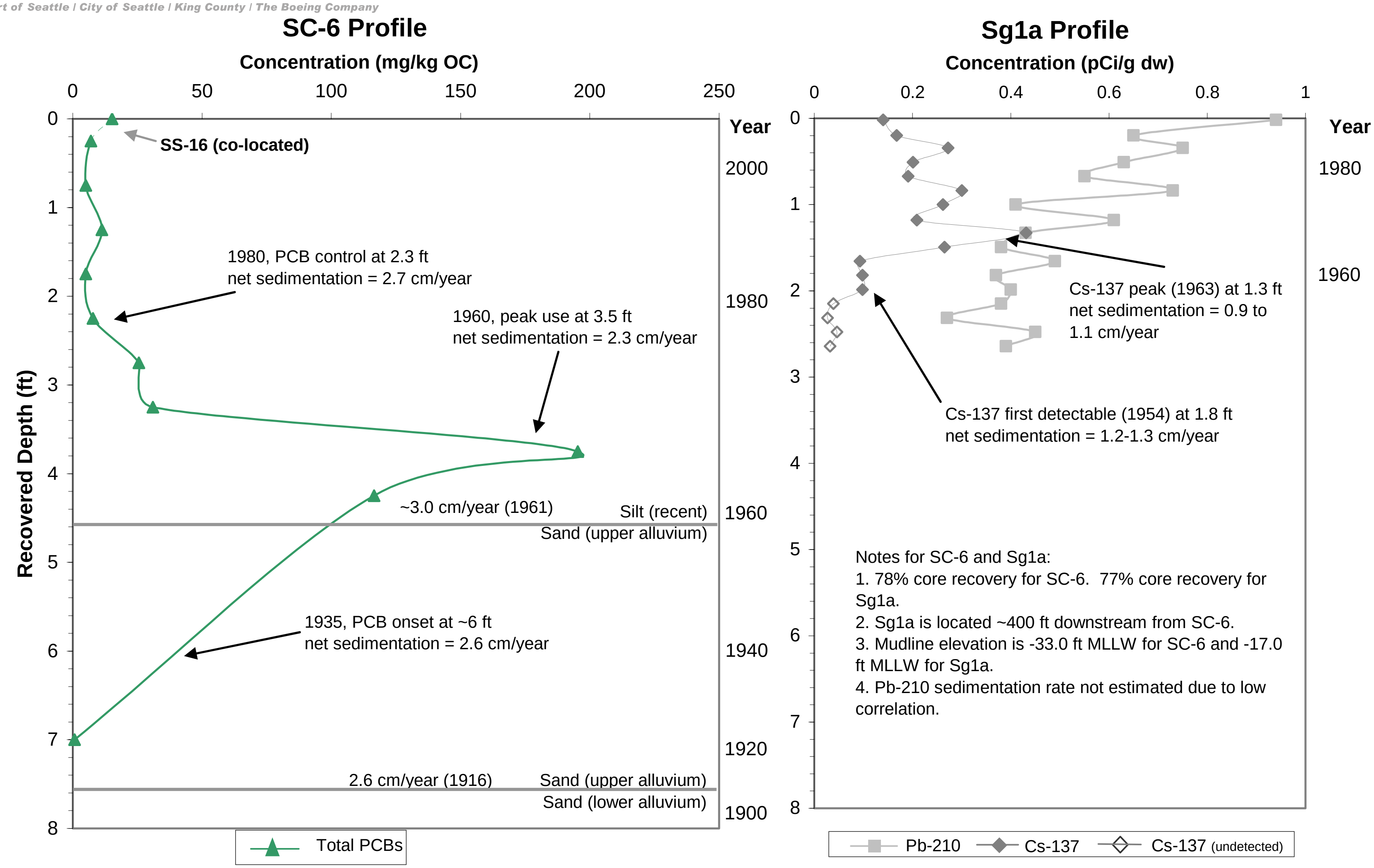

RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-6 AND SG1A PROFILES
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-B

Lower Duwamish Waterway Group

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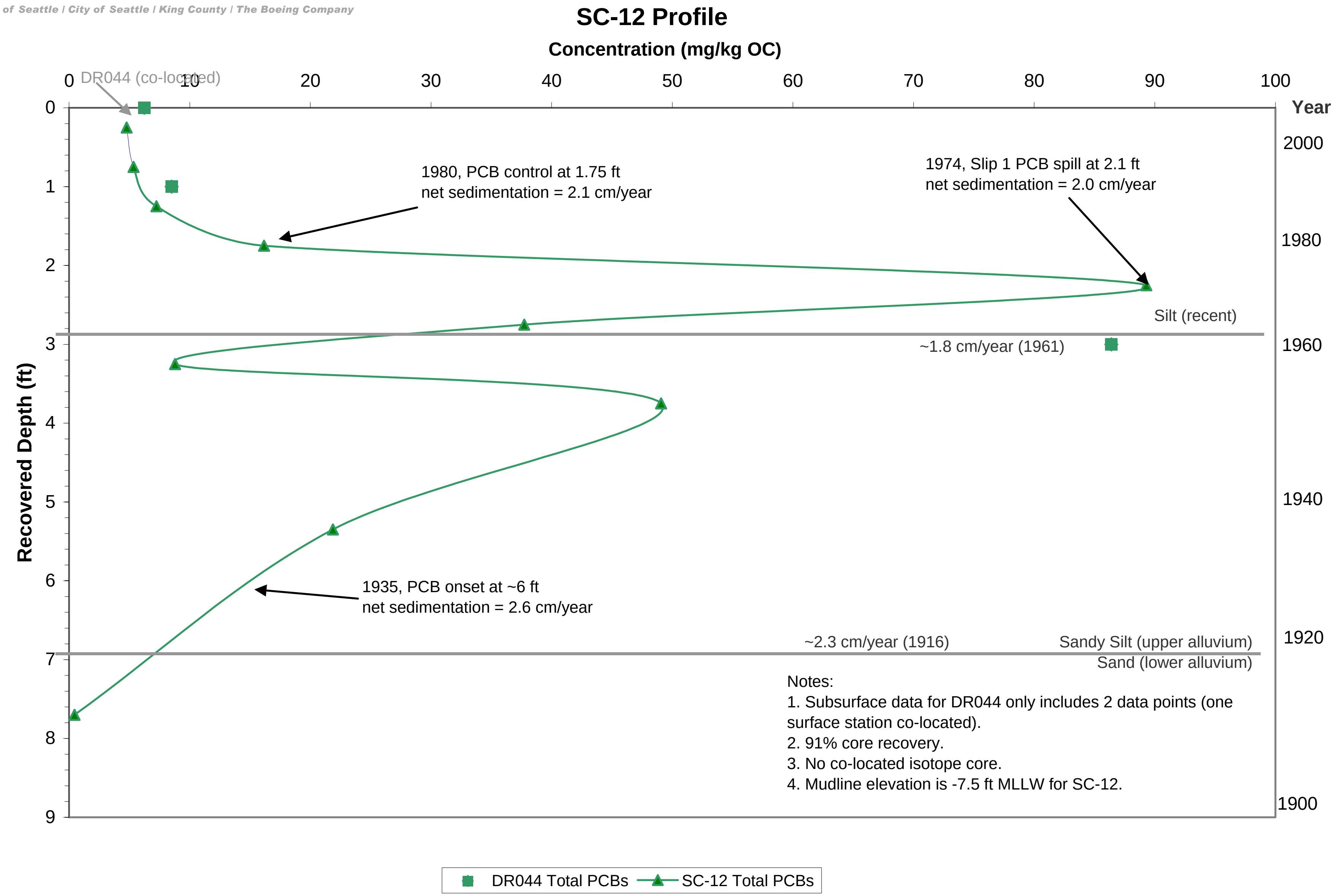

RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-12 PROFILE
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-C

Lower Duwamish Waterway Group

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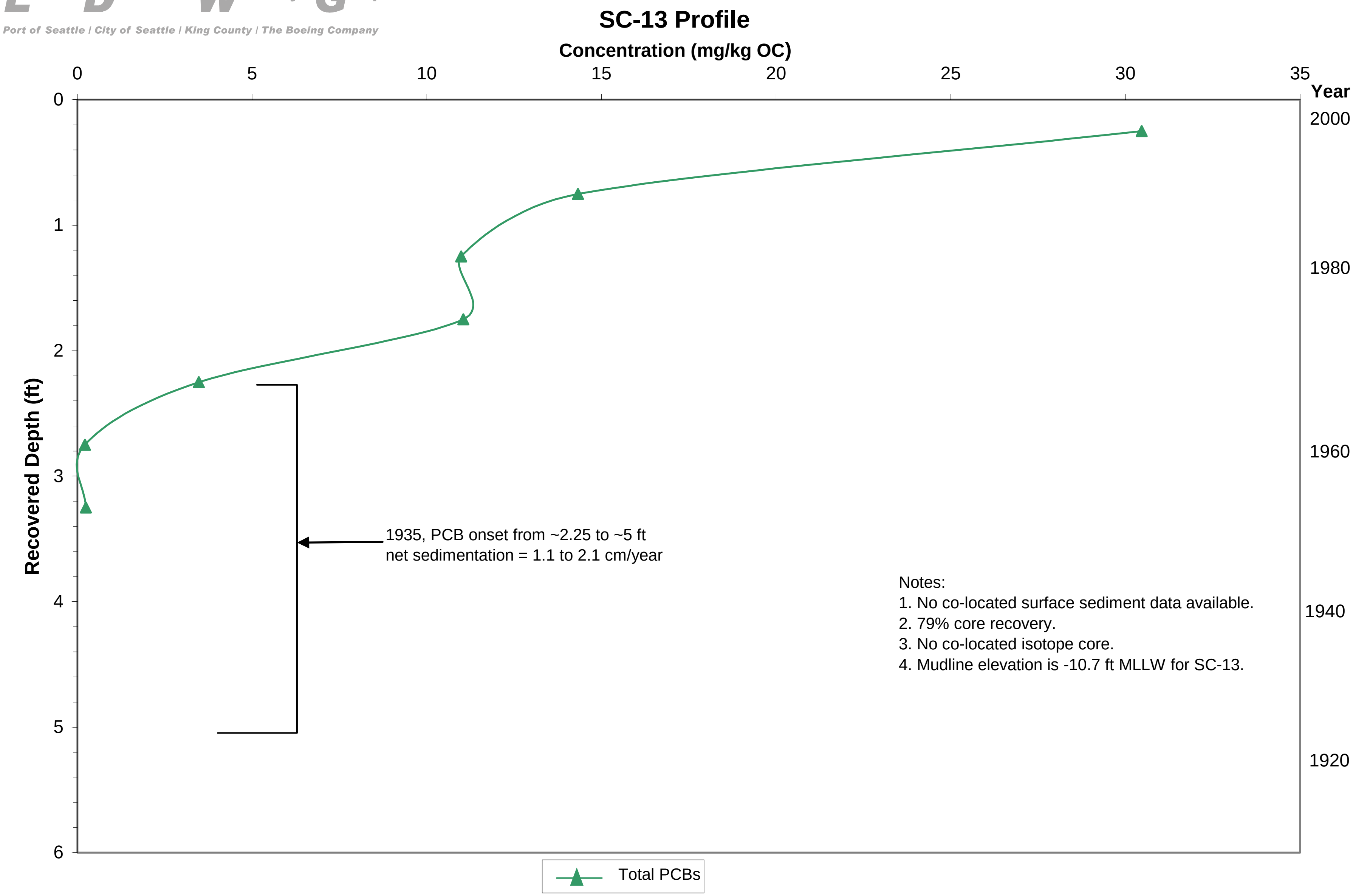
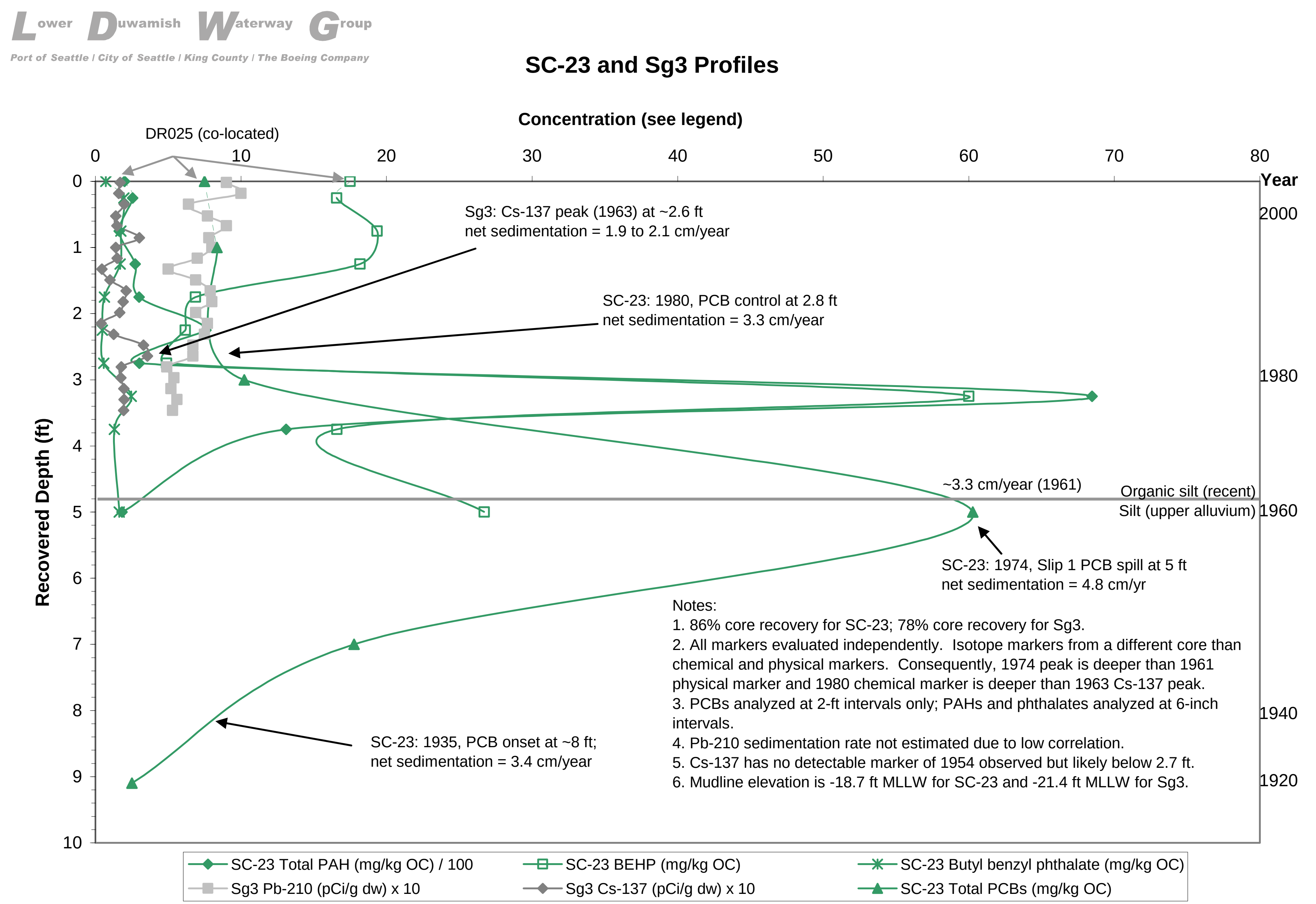


LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-13 PROFILE
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-D



RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-23 AND SG3 PROFILES
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-E

Lower Duwamish Waterway Group

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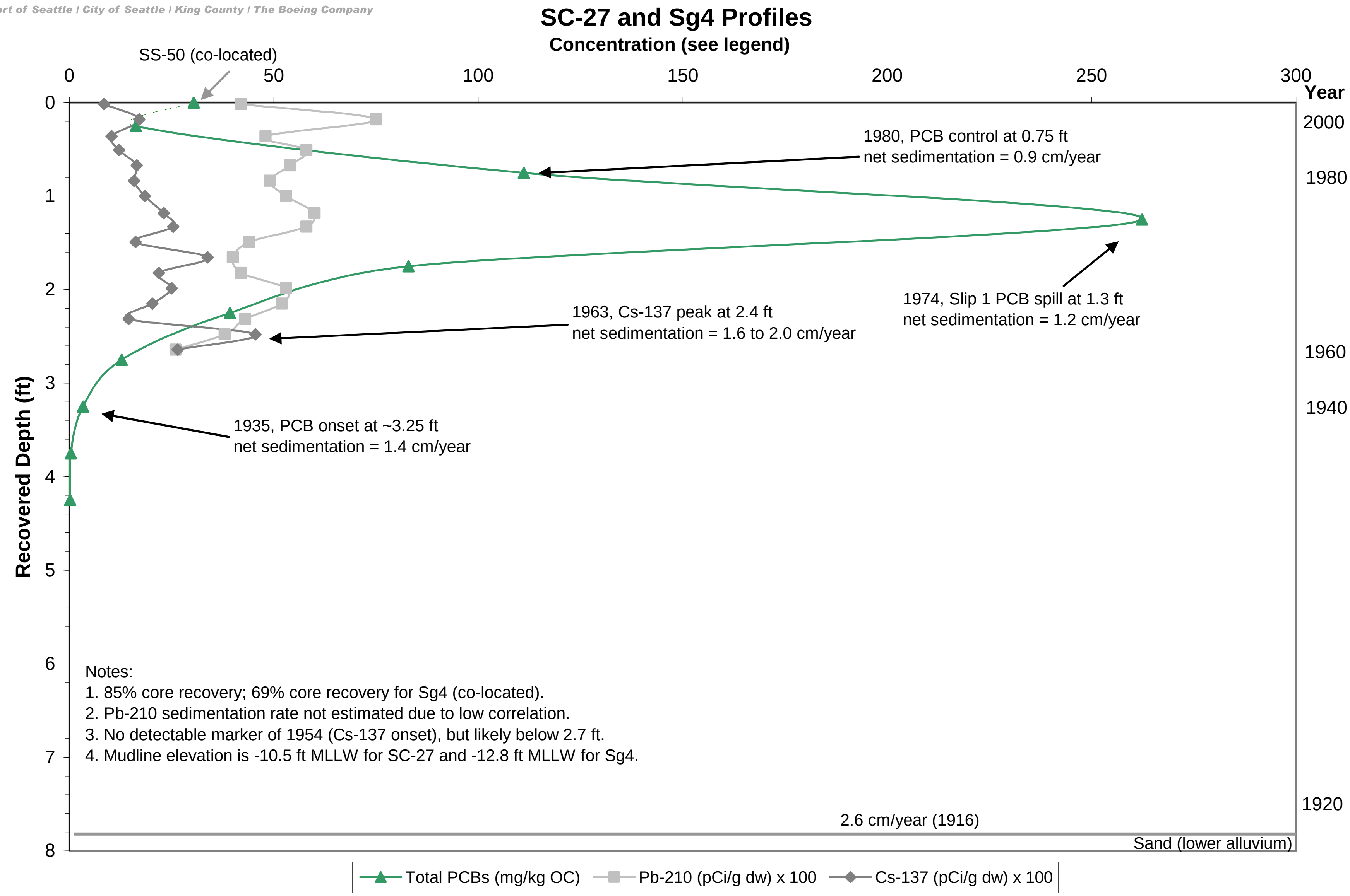

RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-27 AND SG4 PROFILES
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-F

Lower Duwamish Waterway Group

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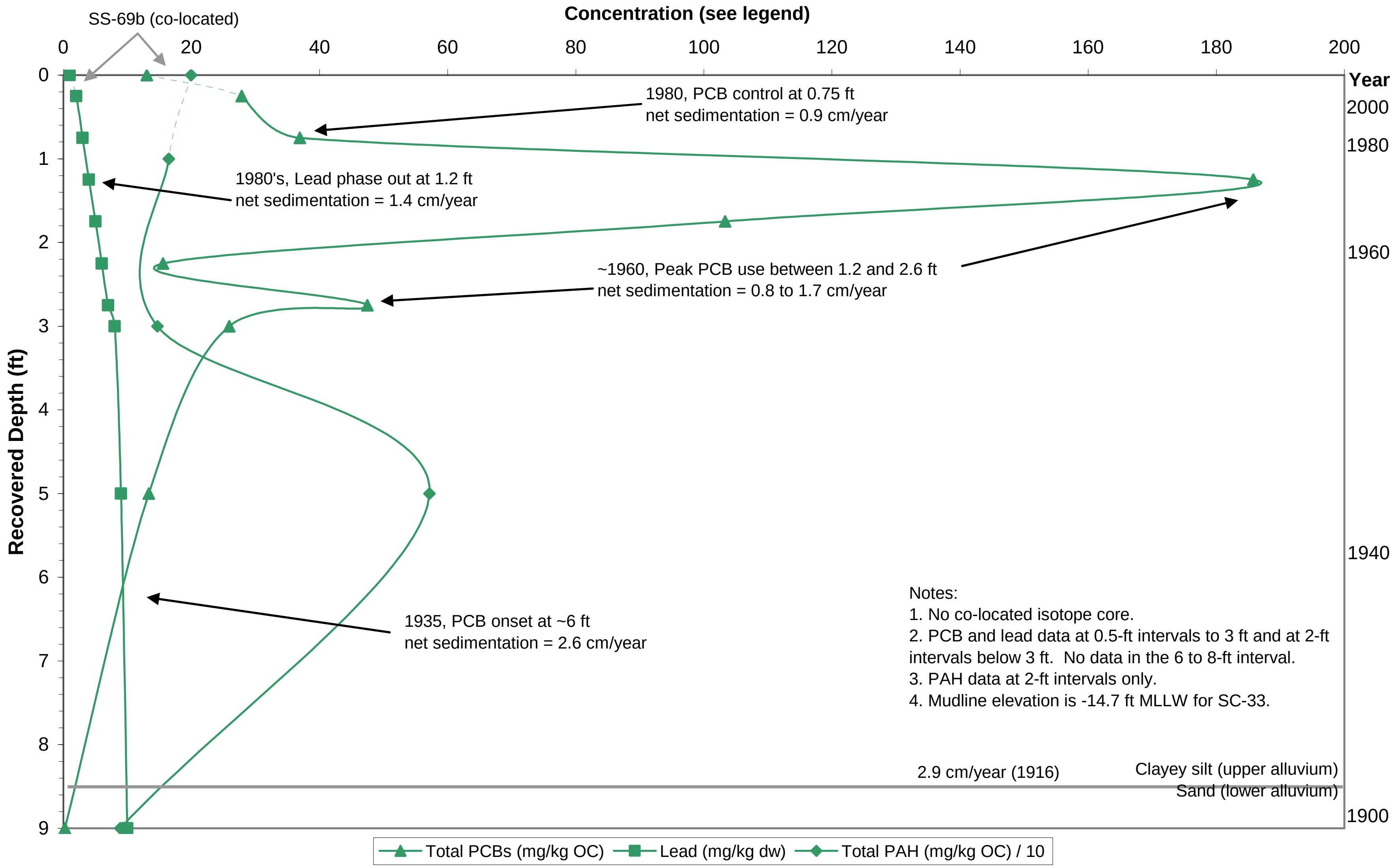
SC-33 Profile



RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-33 PROFILE
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-G

Lower Duwamish Waterway Group

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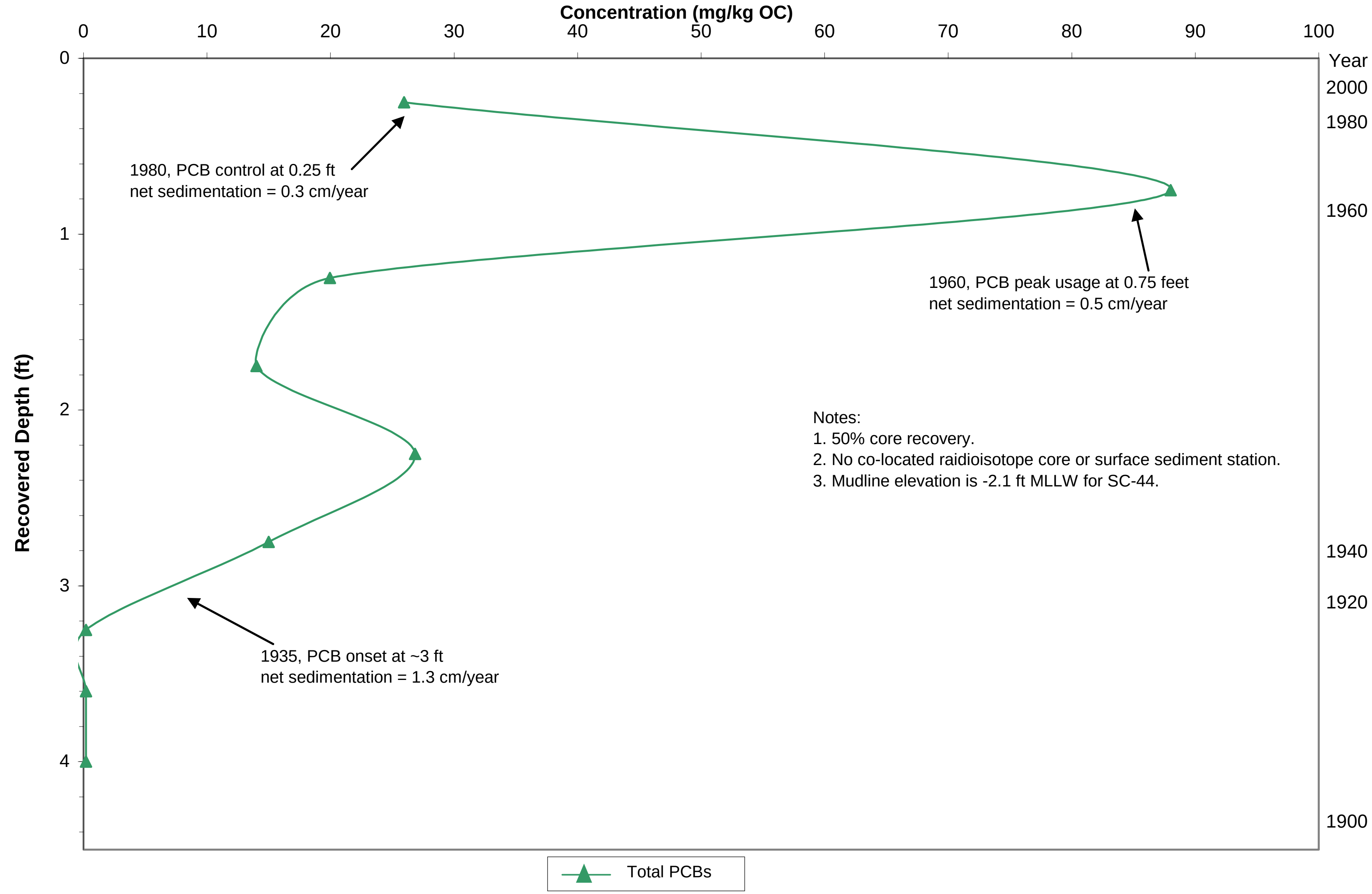
SC-44 Profile



RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)		SC-44 PROFILE
Date: 07/06/2007	File: ProjW/LDW/SedTran	FIGURE 4-H

Lower Duwamish Waterway Group

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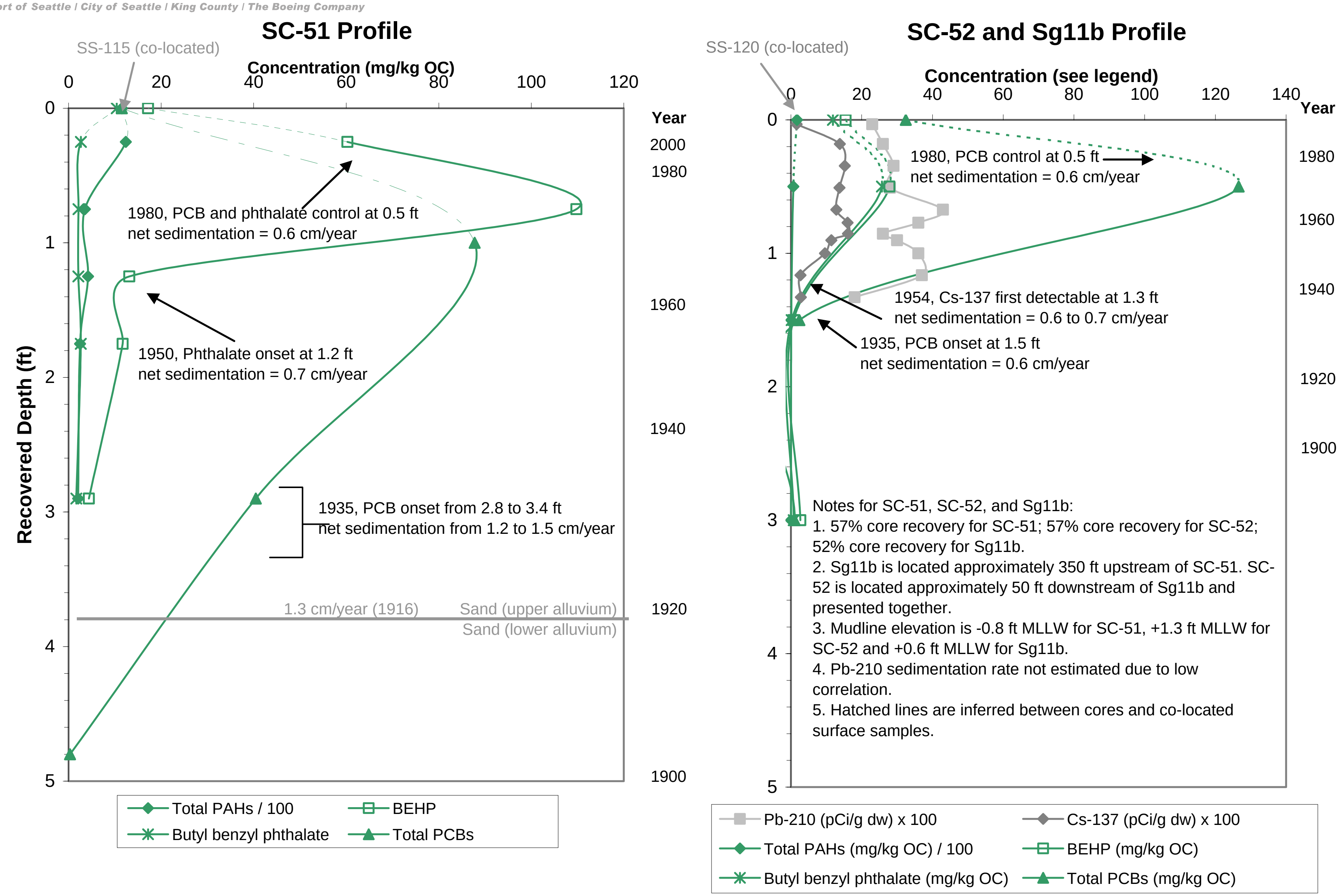
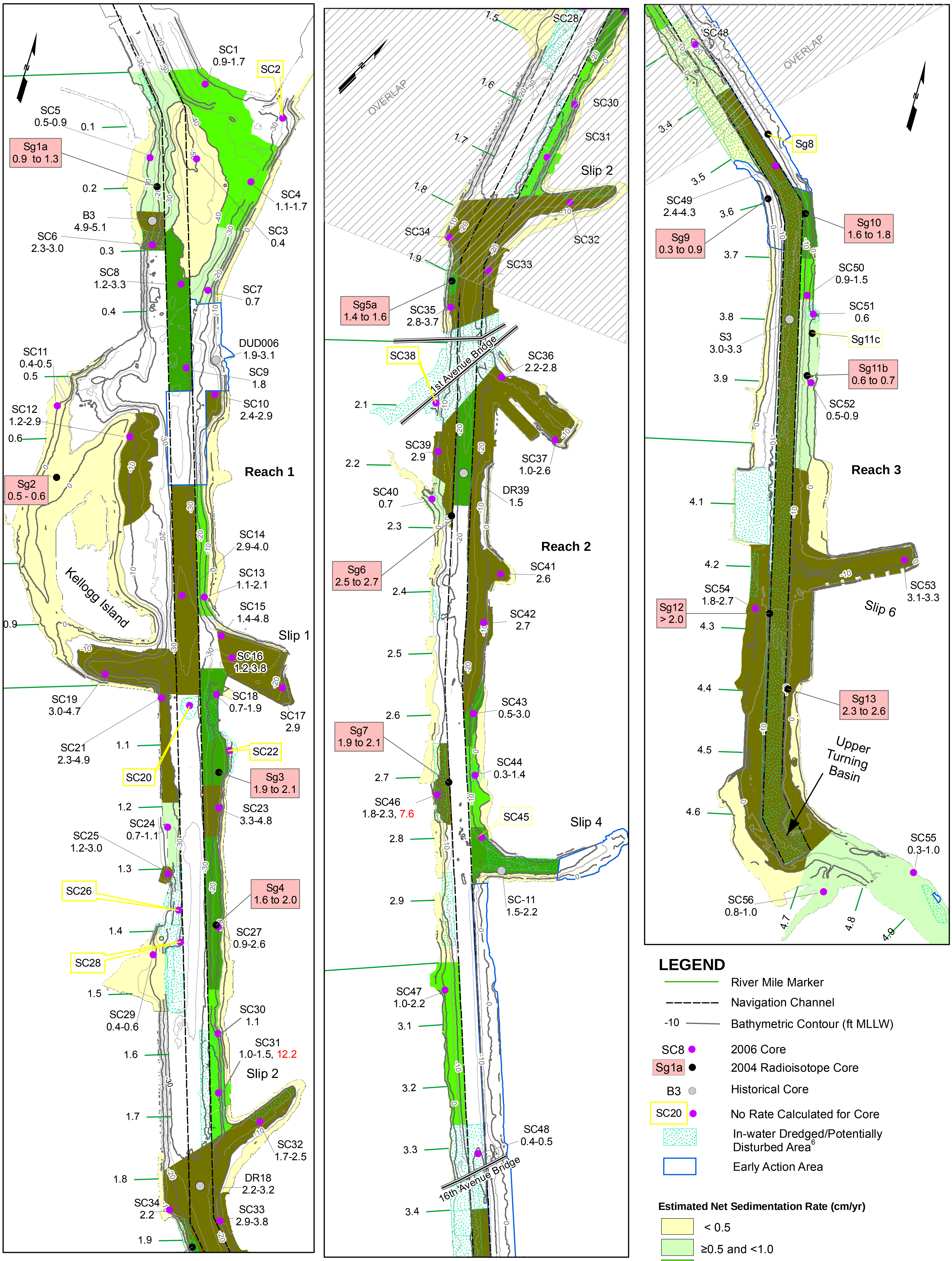
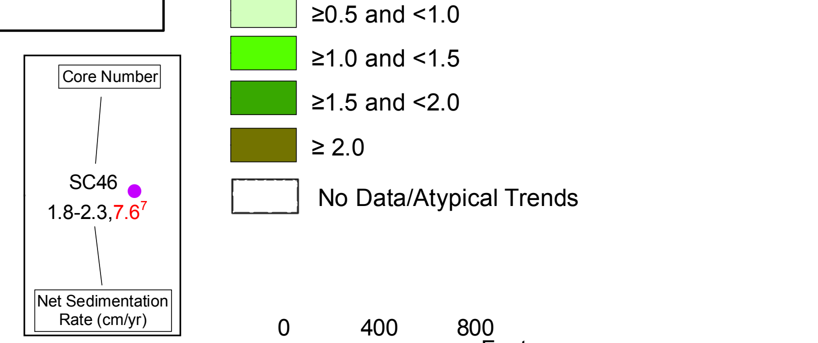


RETEC

LDW SEDIMENT TRANSPORT ANALYSIS REPORT (PORS5-18220-611)	SC-51, SC-52, AND SG11B PROFILES
Date: 07/06/2007 File: ProjW/LDW/SedTran	FIGURE 4-I





Notes:
1. Bathymetry data are provided by Windward Environmental LLC based on waterway-wide October 2003 survey.
2. Estimated net sedimentation rates calculated from radioisotope core data provided by QEA LLC; 2006 core chemistry data and historical core data provided by Windward Environmental LLC; and historical dredge event data provided by USACE.
3. Numerous time markers used to calculate estimated net sedimentation rates are from radioisotope, physical, and chemical geochronology profiles. See Tables 1 and 2.
4. Areas generally delineated within Reaches 1, 2, and 3; the east and west bench areas; and the navigation channel. Water depth, grain size, and distance to other cores also considered.
5. Ranges shown are calculated from recovered depths.
6. Potentially disturbed areas include documented dredge events after 1980, notes from USACE bathymetry surveys, or in-water debris/disturbances evident in the core logs.
7. Red font represents rate from dredge event marker outside range of other rates.

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Lower Duwamish Waterway Group
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LOWER DUWAMISH WATERWAY
SEDIMENT TRANSPORT ANALYSIS REPORT
05482015-611

GENERALIZED ESTIMATES OF
NET SEDIMENTATION
RATES IN THE LDW

DATE: 1/18/08 | DWN. BY: MVI/sea

FIGURE 5

Table A-1 Calculations for the Time Markers Used to Estimate Net Sedimentation Rates in the LDW

Subsurface Core[1]	Physical Time Markers Using Recovered Depths						Physical Time Markers Using In-Situ Depths (2006 Cores Only)					
	Native Alluvium[3]		Hanson Dam Const.[4]		Dredge Horizon[5]		Native Alluvium[3]		Hanson Dam Const.[4]		Dredge Horizon[5]	
	Date: 1916		1961		Variable		Date: 1916		1961		Variable	
	Duration: 90 years		45 years		Variable		Duration: 90 years		45 years		Variable	
	Calculation[7]:	Rate:	Calculation:	Rate:	Calculation:	Rate:	**Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:
RI 2006 Cores												
SC-1	(2.7ft*30.48cm)/90=	0.9	Contacts too diffuse		—		(2.7ft*30.48cm)/90=	0.9	—		—	
SC-2	Fill unit				—		—		—		—	
SC-3	(1.2ft*30.48cm)/90=	0.4	No recent material		—		(1.2ft*30.48cm)/90=	0.4	—		—	
SC-4	(3.2ft*30.48cm)/90=	1.1	Contacts too diffuse		—		(3.3ft*30.48cm)/90=	1.1	—		—	
SC-5	(2.2ft*30.48cm)/90=	0.7	(0.8ft*30.48cm)/45=	0.5	—		(2.4ft*30.48cm)/90=	0.8	(1.0ft*30.48cm)/45=	0.7	—	
SC-6	(7.7ft*30.48cm)/90=	2.6	(4.5ft*30.48cm)/45=	3.0	—		(8.8ft*30.48cm)/90=	3.0	(4.8ft*30.48cm)/45=	3.3	—	
SC-7	Too close to Early Action Area				—		—		—		—	
SC-8	Native Alluvium not reached		No sand in Upper Alluvium		—		—		—		—	
SC-9	Contacts too diffuse		(2.6ft*30.48cm)/45=	1.8	cap material ([2.6ft-0.5ft]*30.48cm)/(2004-1961)=	1.5	—		(2.6ft*30.48cm)/45=	1.8	no change, 100% recovery in top 4.0ft	1.5
SC-10	(7.0ft*30.48cm)/90=*	2.4	(4.0ft*30.48cm)/45=	2.7	cap material ([4.0ft-0.6ft]*30.48cm/(2004-1961) =	2.4	no change, recovered and in situ depths are the same at 7.0ft	2.4	(4.1ft*30.48cm)/45=	2.8	—	
SC-11	Contacts too diffuse		(0.8ft*30.48cm)/45=	0.5	—		—		(0.9ft*30.48cm)/45=	0.6	—	
SC-12	(6.7ft*30.48cm)/90=	2.3	(2.6ft*30.48cm)/45=	1.8	—		(6.9ft*30.48cm)/90=	2.3	(2.6ft*30.48cm)/45=	1.8	—	
SC-13	Contacts too diffuse				—		--		—		—	
SC-14	(8.7ft*30.48cm)/90=	2.9	Contacts too diffuse		—		(8.7ft*30.48cm)/90=	2.9			—	
SC-15	(7.4ft*30.48cm)/90=	2.5	(2.0ft*30.48cm)/45=	1.4	—		(8.7ft*30.48cm)/90=	2.9	(2.0ft*30.48cm)/45=	1.4	—	
SC-16	(7.0ft*30.48cm)/90=	2.4	Bottom of organic silt		—		(7.4ft*30.48cm)/90=	2.5	—		—	
SC-17	Native Alluvium not reached		Atypical profile		—		—		—		—	
SC-18	(5.7ft*30.48cm)/90=	1.9	Atypical profile		(0.1ft*30.46cm)/2 = ([5.7ft-0.1ft]*30.48cm/(2004-1916) =	1.5, 1.9	(6.2ft*30.48cm)/90=	2.1	—		(0.1ft*30.46cm)/2 = ([6.2ft-0.1ft]*30.48cm/(2004-1916) =	1.5, 2.1
SC-19	(9.0ft*30.48cm)/90=	3.0	(7.0ft*30.48cm)/45=	4.7	—		(9.7ft*30.48cm)/90=	3.3	(7.5ft*30.48cm)/45=	5.1	—	
SC-20	Native Alluvium not reached		Bottom of organic silt		—		—		—		—	
SC-21	(9.8ft*30.48cm)/90=	3.3	(5.0ft*30.48cm)/45=	3.4	—		(10.1ft*30.48cm)/90=	3.4	(5.1ft*30.48cm)/45=	3.5	—	
SC-22	Native Alluvium not reached		Atypical profile		—		—		—		—	
SC-23	Native Alluvium not reached		(4.8ft*30.48cm)/45=	3.3	—		—		(5.3ft*30.48cm)/45=	3.6	—	
SC-24	(3.2ft*30.48cm)/90=	1.1	(1.0ft*30.48cm)/45=	0.7	—		(3.3ft*30.48cm)/90=	1.1	(1.3ft*30.48cm)/45=	0.9	—	
SC-25	(6.0ft to 7.5ft*30.48cm)/90=	2.0 to 2.5	Bottom of organic silt		—		(6.5ft to 8.6ft*30.48cm)/90=	2.1 to 2.9	—		—	
SC-26	Native Alluvium not reached		No Recent material		—		—		—		—	
SC-27	(4.7ft to 7.8ft*30.48cm)/90 =	1.5 to 2 .6	Contacts too diffuse		—		(4.7ft to 9.1ft*30.48cm)/90 =	1.6 to 3.1	—		—	
SC-28	Native Alluvium not reached		Atypical profile		—		—		—		—	
SC-29	(1.7ft*30.48cm)/90=	0.6	(0.6ft*30.48cm)/45=	0.4	—		(1.8ft*30.48cm)/90=	0.6	(0.6ft*30.48cm)/45=	0.4	—	
SC-30	(3.2ft*30.48cm)/90=*	1.1	Contacts too diffuse		—		(3.4ft*30.48cm)/90=*	1.2	—		—	
SC-31	Dredge effects				(2.8ft*30.48cm)/7 =	12.2	—				(3.0ft*30.48cm)/7 =	13.1
SC-32	(5.0ft to 7.1ft*30.48cm)/90 =	1.7 to 2.4	(2.8ft*30.48cm)/45 =	1.9	—		(7.1ft*30.48cm)/90 =	2.4	(3.1ft*30.48cm)/45 =	2.1	—	

Table A-1 Calculations for the Time Markers Used to Estimate Net Sedimentation Rates in the LDW

Subsurface Core[1]	Physical Time Markers Using Recovered Depths						Physical Time Markers Using In-Situ Depths (2006 Cores Only)					
	Native Alluvium[3]		Hanson Dam Const.[4]		Dredge Horizon[5]		Native Alluvium[3]		Hanson Dam Const.[4]		Dredge Horizon[5]	
	Date: 1916		1961		Variable		Date: 1916		1961		Variable	
	Duration: 90 years		45 years		Variable		Duration: 90 years		45 years		Variable	
	Calculation[7]:	Rate:	Calculation:	Rate:	Calculation:	Rate:	**Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:
SC-33	(8.5ft*30.48cm)/90=	2.9	Contacts too diffuse		—		(10.0ft*30.48cm)/90=	3.4	—		—	
SC-34	Native Alluvium not reached		(3.2ft*30.48cm)/45=	2.2	—		—		(3.8ft*30.48cm)/45=	2.6	—	
SC-35	Contacts too diffuse		(5.1ft*30.48cm)/45=	3.5	(1.2ft*30.48cm)/13= ([5.1ft-1.2ft]*30.48cm)/(1993-1961)=	2.8, 3.7	—		(6.0ft*30.48cm)/45=	4.1	(1.2ft*30.48cm)/13= ([6.0ft-1.2ft]*30.48cm)/(1993-1961)=	2.8, 4.6
SC-36	(8.4ft*30.48cm)/90=	2.8	(3.2ft*30.48cm)/45=	2.2	—		(9.8ft*30.48cm)/90=	3.3	(3.6ft*30.48cm)/45=	2.4	—	
SC-37	(5.3ft*30.48cm)/90=	1.8	(2.6ft*30.48cm)/45=	1.8	—		(6.3ft*30.48cm)/90=	2.1	(3.2ft*30.48cm)/45=	2.2	—	
SC-38	Atypical profile						—		—		—	
SC-39	(8.5ft*30.48cm)/90=	2.9	Atypical profile		—		(10.3ft*30.48cm)/90=	3.5	—		—	
SC-40	(2.0ft*30.48cm)/90=	0.7	No Recent material		—		(2.5ft*30.48cm)/90=	0.8	—		—	
SC-41	(7.6ft*30.48cm)/90=	2.6	Atypical profile		—		(10.9ft*30.48cm)/90=	3.7	—		—	
SC-42	Native Alluvium not reached		(4.0ft*30.48cm)/45=	2.7	—		—		no change, 100% recovery in top 4.0ft	2.7	—	
SC-43	(9.0ft*30.48cm)/90 =	3.0	(0.7ft*30.48cm)/45=	0.5	—		(11.9ft*30.48cm)/90 =	4.0	(0.7ft*30.48cm)/45=	0.5	—	
SC-44	Native Alluvium not reached		Atypical profile		—		—		—		—	
SC-45	Native Alluvium not reached		Atypical profile		Near dredge event; but no marker at dredge elevation		—		—		—	
SC-46	(6.8ft*30.48cm)/90=	2.3	Contacts too diffuse		(2.0ft*30.48cm)/8 = ([6.8ft-2.0ft]*30.48cm)/(1998-1916) =	7.6, 1.8	(7.9ft*30.48cm)/90=	2.7	—		(2.3 ft*30.48cm)/8 = ([7.9ft-2.3ft]*30.48cm)/(1998-1916) =	8.7, 2.1
SC-47	(3.0ft*30.48cm)/90=	1.0	Bottom of organic silt		—		(3.8ft*30.48cm)/90=	1.3	—		—	
SC-48	Atypical profile		No Upper Alluvium		—		—		—		—	
SC-49	Native Alluvium not reached		(3.5ft*30.48cm)/45=	2.4	—		—		(4.1ft*30.48cm)/45=	2.8	—	
SC-50	(2.8ft*30.48cm)/90=	0.9	Atypical profile		—		(3.7ft*30.48cm)/90=	1.3	—		—	
SC-51	gravel in core						gravel in core					
SC-52	Atypical profile; possible fill material from Slip 5 filling		Contacts too diffuse		—		—		—		—	
SC-53	(9.1ft*30.48cm)/90=	3.1	(4.9ft*30.48cm)/45=	3.3	—		(11.1ft*30.48cm)/90=	3.8	(6.3ft*30.48cm)/45=	3.3	—	
SC-54	(5.4ft*30.48cm)/90=	1.8	(4.0ft*30.48cm)/45=	2.7	—		(6.5ft*30.48cm)/90=	2.2	(4.8ft*30.48cm)/45=	3.3	—	
SC-55	(3.0ft*30.48cm)/90=	1.0	(0.5ft*30.48cm)/45=	0.3	—		(4.0ft*30.48cm)/90=	1.4	(0.7ft*30.48cm)/45=	0.5	—	
SC-56	Contacts too diffuse				—		—		—		—	
Historical Cores												
B3 (T105 1985)	(11.0ft*30.48cm)/69=	4.9	(4.0ft*30.48cm)/24=	5.1	—		—		—		—	
DUD006 (D/D 1994)	Not well documented				—		—		—		—	
DR18 (PSDDA99)	(6.0ft*30.48cm)/83=	2.2	(4.0ft*30.48cm)/38=	3.2	—		—		—		—	
DR39 (PSDDA99)	(4.0ft*30.48cm)/83=	1.5	Not well documented		—		—		—		—	
S3 (PSDDA98)	(8.0ft*30.48cm)/82=	3.0	(4.0ft*30.48cm)/37=	3.3	—		—		—		—	
SC-11 (Slip 4 2004)	(4.3ft*30.48cm)/88 =	1.5	(3.1ft*30.48cm)/43=	2.2	—		(4.9ft*30.48cm)/88 =	1.7	(3.5ft*30.48cm)/43=	2.5	—	

NOTES:
1. All 2006 subsurface cores are shown. Historical cores added to fill-in spatial data gaps when good core logs were available with good stratigraphic representations. Historical cores shown (B3 T105 1986; DUD006 Duwamish Diagonal; DR18 and DR39 PSDDA99; S3 PSDDA 99; SC-11 Slip 4) only use recovered values.
2. Sediments were grouped into three stratigraphic units identified for the LDW: Recent, Upper Alluvium, and Lower Alluvium based on lithology .
3. Native alluvium is defined as, but not limited to, a sharp and noticeable contact/change in lithology between Upper Alluvium/Transition and the Lower Alluvium. Typically M-C SAND but sometimes native silts in non-channel areas.
4. Hanson Dam construction is typically noted by, but not limited to, the loss of sand or sandy silt with abundant plant matter and an increase in Recent material.
5. Fill/Dredge contact is defined as the basal contact between recent material and horizons that have been filled or dredged as determined by lithology and historic dredge events.
6. See Table A-2 for chemical data.
7. Formula: x feet interval depth where marker observed multiplied by 30.48 centimeters/ft unit conversion, then divided by the number of years results in a net sedimentation rate in centimeters per year.
Formulas in table indicate conversion by 30.48 "cm" instead of cm/ft for brevity.

No strong markers in core.

* Interpretation of physical marker is different than stratigraphic unit on core log.

— Stratigraphic markers not present or not clearly indicative of a strong time marker.

Table A-1 Calculations for the Time Markers Used to Estimate Net Sedimentation Rates in the LDW

2004 / 2006 Subsurface Core[1]	Estimated Net Sedimentation Rates (cm/year) Determined From Chemical Time Markers and Event Horizons																	
	Chemical (1-ft / 2-ft Intervals), using Recovered Depths[6]						Chemical (1-ft / 2-ft Intervals), using In-Situ Depths[6] (2006 Cores only)						Chemical (6-in Intervals) from a Subset of 2006 Cores, where data available (see Figures 4a-4i)					
	Lead / PCB / Phthalate Introduction (using top of interval if ND; bottom if detected; middle if skipped interval)		PCB Peak Usage/ Spill (using middle of interval; top and bottom included for uncertainty)		Control Sources (using bottom of interval if pass, middle of interval if SQS exceedance)		Lead / PCB / Phthalate Introduction (using top of interval if ND; bottom if detected; middle if skipped interval)		PCB Peak Usage/ Spill (using middle of interval; top and bottom included for uncertainty)		Control Sources (using bottom of interval if pass, middle of interval if SMS exceedance)		PCB Introduction (mid-inflection on graph)		PCB Peak Usage / Spill (using center of peak/interval)		Control Sources (inflection on graph)	
	1920/ 1935/ 1950		1960/1974		1980		1920/ 1935/ 1950		1960/1974		1980		1935		1960 / 1974		1980	
	86 /71/ 56 years		46/32 years		26 years		86 /71/ 56 years		46/32 years		26 years		71 years		46/32 years		26 years	
	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:
RI 2006 Cores																		
SC-1	PCB (4.0ft*30.48cm)/71	1.7	peak in surface				PCB (4.1ft*30.48cm)/71	1.8	---				(2.6ft*30.48cm)/71 =	1.1	(1.3ft*30.48cm)/46 =	0.9	(0.75ft*30.48cm)/26 =	0.9
SC-2	too many skipped intervals/ high concentration near surface/ close to shore activities						---											
SC-3	no strong chemical trend						---						---					
SC-4	PCB (4.0ft*30.48cm)/71 =	1.7	no sharp peak		PCB (1.0ft*30.48cm)/26 =	1.2	PCB (4.2ft*30.48cm)/71 =	1.8	---		(1.1ft*30.48cm)/26 =	1.3	---					
SC-5	bis (1.0ft*30.48cm)/56 = PCB (2.2ft*30.48cm)/71 =	0.5, 0.9	peak in surface				bis (1.1ft*30.48cm)/56 = PCB (2.4ft*30.48cm)/71 =	0.6, 1.0	---				---					
SC-6	PCB (5.3ft*30.48cm)/71 =	2.3	reflected in 6-in data		PCB (2.0ft*30.48cm)/26 =	2.3	PCB (5.5ft*30.48cm)/71 =	2.4	---		(2.2ft*30.48cm)/26 =	2.6	(6.0ft*30.48cm)/71 =	2.6	(3.5ft*30.48cm)/46 =	2.3	(2.3ft*30.48cm)/26 =	2.7
SC-7	PCB (1.7ft*30.48cm)/71	0.7	peak in surface				PCB (1.8ft*30.48cm)/71	0.8	---				---					
SC-8	no onset		(4.0ft, 5.0ft, 6.0ft*30.48cm)/46 =	2.7, 3.3, 4.0	PCB (1.0ft*30.48cm)/26 =	1.2	---		(4.4ft, 6.2ft, 7.9ft*30.48cm)/46 =	2.9, 4.1, 5.2	(1.4ft*30.48cm)/26 =	1.6	---					
SC-9	too near EAA activities						---						---					
SC-10	no onset		(2.0ft, 3.0ft, 4.0ft*30.48cm)/32 =	1.9, 2.9, 3.8	no clear trend		---		(3.0ft, 4.5ft, 6ft*30.48cm)/32 =	2.9, 4.3, 5.7	---		---					
SC-11	bis (0.8ft*30.48cm)/56 =	0.4	peak in surface				bis (0.9ft*30.48cm)/56 =	0.5	---				---					
SC-12	PCB (6.7ft*30.48cm)/71 =	2.9	(2.0ft, 3.0ft, 4.0ft*30.48cm)/46 =	1.3, 2.0, 2.7	PCB (2.0ft*30.48cm)/26 = mid (1.0ft*30.48cm)/26 =	2.3, 1.2	PCB (6.9ft*30.48cm)/71 =	3.0	(2.0ft, 3.1ft, 4.1ft*30.48cm)/46 =	1.3, 2.1, 2.7	no change, 100% recovery in top 4.0ft	2.3	(6.0ft*30.48cm)/71 =	2.6	(2.1ft*30.48cm)/32 =	2.0	(1.75ft*30.48cm)/26 =	2.1
SC-13	bis (2.0ft*30.48cm)/56 =	1.1	peak in surface				bis (2.1ft*30.48cm)/56 =	1.1	---				(2.5ft to 5.0ft*30.48cm)/71 =	1.1 to 2.1	---			
SC-14	PCB (9.4ft*30.48cm)/71 =	4.0	peak in surface				no change; 100% recovery in top intervals	4.0	---				---					
SC-15	PCB (7.0ft*30.48cm)/71 =	3.0	(4.0ft, 5.0ft, 6.0ft*30.48cm)/32 =	3.8, 4.8, 5.7	no clear trend		PCB (8.3ft*30.48cm)/71 =	3.6	(4.1ft, 5.6ft, 7.1ft*30.48cm)/32 =	3.9, 5.3, 6.8	---		---					
SC-16	bis (7.0ft*30.48cm)/56 =	3.8	(2.0ft, 3.0ft, 4.0ft*30.48cm)/32 =	1.9, 2.9, 3.8	PCB (2.0ft*30.48cm)/26 = mid (1.0ft*30.48cm)/26 =	2.3, 1.2	bis (7.9ft*30.48cm)/56 =	4.3	(2.2ft, 3.2ft, 4.1ft*30.48cm)/32 =	2.1, 3.0, 3.9	(2.2ft*30.48cm)/26 = mid (1.1ft*30.48cm)/26 =	2.6 1.3	---					
SC-17	no onset		(2.0ft, 3.0ft, 4.0ft*30.48cm)/32 =	1.9, 2.9, 3.8	high concentration near surface		---		(3.0ft, 4.5ft, 6.0ft*30.48cm)/32 =	2.9, 4.3, 5.7	---		---					
SC-18	2.0ft for Pb, PCB, bis (2.0ft*30.48cm)/86, 71, 56=	0.7, 0.9, 1.1	no strong chemical trend				2.5ft for all chem (2.5ft*30.48cm)/86, 71, 56=	0.9, 1.1, 1.4	---				---					
SC-19	PCB (8.0ft*30.48cm)/71 =	3.4	(6.0ft, 6.5ft, 7.0ft*30.48cm)/46 =	4.0, 4.3, 4.6	no clear trend		PCB (8.6ft*30.48cm)/71 =	3.7	(7.0ft to 7.5ft*30.48cm) /46 =	4.6 to 5.0	---		---					
SC-20	no strong chemical trend/ peak in surface						---						---					
SC-21	PCB (6.2ft*30.48cm)/71 =	2.7	(4.0ft, 5.1ft, 6.2 ft*30.48cm)/32 =	3.8, 4.9, 5.9	PCB (2.0ft*30.48cm)/26 =	2.3	PCB (6.5ft*30.48cm)/71 =	2.8	(4.0ft, 5.3ft, 6.5 ft*30.48cm)/32 =	3.8, 5.0, 6.2	(2.1ft*30.48cm)/26 =	2.5	---					
SC-22	no chemical trend						---						---					
SC-23	PCB onset > 10.2ft PCB (10.2ft*30.48cm)/71 =	4.3	PCB (4.0ft, 5.0ft, 6.0 ft*30.48cm)/32 =	3.8, 4.8, 5.7	(4.0ft*30.48cm)/26 =	4.7	PCB onset > 12.0ft PCB (12.0ft*30.48cm)/71 =	5.2	(4.8ft, 5.6ft, 6.4 ft*30.48cm)/32 =	4.6, 5.3, 6.1	(4.8ft*30.48cm)/26 =	5.6	(8.0ft*30.48cm)/71 =	3.4	(5.0ft*30.48cm)/32 =	4.8	(2.8ft*30.48cm)/26 =	3.3
SC-24	Pb (2.0ft*30.48cm)/86 = PCB (2.0ft*30.48cm)/71 =	0.7, 0.9	no strong chemical trend				Pb (2.3ft*30.48cm)/86 = PCB (2.3ft*30.48cm)/71 =	0.8, 1.0	---				---					
SC-25	Pb (7.0ft*30.48cm)/86 = PCB (7.0ft*30.48cm)/71 =	2.5, 3.0	no strong peak		decrease not sharp		Pb (8.0ft*30.48cm)/86 = PCB (8.0ft*30.48cm)/71 =	2.8, 3.4	no strong peak		decrease not sharp		---					
SC-26	skipped intervals above and below max concentration, close to shore activities						---						---					
SC-27	no strong chemical trend/ peak in surface						---						(3.25ft*30.48cm)/71 =	1.4	(1.3ft*30.48cm)/32 =	1.2	(0.75ft*30.48cm)/26 =	0.9
SC-28	skipped intervals above and below max concentration, close to shore activities						---						---					
SC-29	no strong chemical trend						---						---					
SC-30	no strong chemical trend						---						---					
SC-31	2.8ft for Pb, PCB and bis (2.8ft*30.48cm)/86, 71, 56=	1.0, 1.2, 1.5	no strong chemical trend				3.0ft for Pb, PCB, bis (3.0ft*30.48cm)/86, 71, 56=	1.1, 1.3, 1.6	---				---					
SC-32	PCB (4.6ft*30.48cm)/71 = bis (4.6ft*30.48cm)/56 =	2.0, 2.5	no strong chemical trend/ high concentration in surface				PCB (5.1ft*30.48cm)/71 = bis (5.1ft*30.48cm)/56 =	2.2, 2.8	---				---					

Table A-1 Calculations for the Time Markers Used to Estimate Net Sedimentation Rates in the LDW

2004 / 2006 Subsurface Core[1]	Estimated Net Sedimentation Rates (cm/year) Determined From Chemical Time Markers and Event Horizons																	
	Chemical (1-ft / 2-ft Intervals), using Recovered Depths[6]						Chemical (1-ft / 2-ft Intervals), using In-Situ Depths[6] (2006 Cores only)						Chemical (6-in Intervals) from a Subset of 2006 Cores, where data available (see Figures 4a-4i)					
	Lead / PCB / Phthalate Introduction (using top of interval if ND; bottom if detected; middle if skipped interval)		PCB Peak Usage/ Spill (using middle of interval; top and bottom included for uncertainty)		Control Sources (using bottom of interval if pass, middle of interval if SQS exceedance)		Lead / PCB / Phthalate Introduction (using top of interval if ND; bottom if detected; middle if skipped interval)		PCB Peak Usage/ Spill (using middle of interval; top and bottom included for uncertainty)		Control Sources (using bottom of interval if pass, middle of interval if SMS exceedance)		PCB Introduction (mid-inflection on graph)		PCB Peak Usage / Spill (using center of peak/interval)		Control Sources (inflection on graph)	
	1920/ 1935/ 1950		1960/1974		1980		1920/ 1935/ 1950		1960/1974		1980		1935		1960 / 1974		1980	
	86 /71/ 56 years		46/32 years		26 years		86 /71/ 56 years		46/32 years		26 years		71 years		46/32 years		26 years	
	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:	Calculation:	Rate:
SC-33	PCB (7.0ft*30.48cm)/71 = bis (7.0ft*30.48cm)/56 =	3.0, 3.8	peak in surface				PCB (7.7ft*30.48cm)/71 = bis (7.7ft*30.48cm)/56 =	3.3, 4.2	---				(6.0ft*30.48cm)/71 =	2.6	(1.2ft to 2.6ft*39.48cm)/46 =	0.8 to 1.7	PCB (0.75ft*30.48cm) /26 = Pb (1.2ft*30.48cm)/26 =	0.9, 1.4
SC-34	no strong chemical trend/ no time date for bis peak						---						---					
SC-35	no strong chemical trend						---						---					
SC-36	no strong chemical trend/ low concentrations						---						---					
SC-37	PCB (4.7ft*30.48cm)/71 = bis (4.7ft*30.48cm)/56 =	2.0, 2.6	(1.0ft, 1.5ft, 2.0ft*30.48cm)/46 =	0.7, 1.0, 1.3	As (2.0ft*30.48cm)/26 =	2.3	PCB (5.5ft*30.48cm)/71 = bis (5.5ft*30.48cm)/56 =	2.4, 3.0	(1.7ft, 2.2ft, 2.6ft*30.48cm)/46 =	1.1, 1.5, 1.8	Cu, As, Pb (2.6ft*30.48cm)/26 =	3.0	---					
SC-38	no strong chemical trend						---						---					
SC-39	no strong chemical trend						---						---					
SC-40	no strong chemical trend						---						---					
SC-41	no strong chemical trend						---						---					
SC-42	no strong chemical trend/ low concentrations						---						---					
SC-43	no strong chemical trend/ low concentrations						---						---					
SC-44	PCB (3.2ft*30.48cm)/71= bis (2ft*30.48cm)/56 =	1.4, 1.1	peak in surface				PCB (4.8ft*30.48cm)/71= bis (2.9ft*30.48cm)/56 =	2.1, 1.6	---				(3.0ft*30.48cm)/71 =	1.3	(0.75ft*30.48cm)/46=	0.5	(0.25ft*30.48cm)/26 =	0.3
SC-45	no strong chemical trend						---						---					
SC-46	no strong chemical trend						---						---					
SC-47	PCB (3.0ft*30.48cm)/71= Pb (4.0ft*30.48cm)/86= bis (4.0ft*30.48cm)/56=	1.3, 1.4, 2.2	(1.0ft, 1.5ft, 2.0ft*30.48cm)/46 =	0.7, 1.0, 1.3	PCB (1.0ft*30.48cm)/26 =	1.2	PCB (3.8ft*30.48cm)/71= Pb (4.1ft*30.48cm)/86= bis (5.1ft*30.48cm)/56=	1.6, 1.8, 2.8	(1.3ft, 1.9ft, 2.5ft*30.48cm)/46 =	0.9, 1.3, 1.7	(1.3ft*30.48cm)/26 =	1.5	---					
SC-48	1.0ft for Pb, PCB, bis (1.0ft*30.48cm)/86,71,56 =	0.4 to 0.5	onset near surface, no peak				1.1ft for all chemicals (1.1ft*30.48cm)/86,71,56 =	0.4 to 0.6	---				---					
SC-49	PCB onset > 10.0ft PCB (10.0ft*30.48cm)/71 =	4.3	no strong chemical trend				PCB onset > 11.7ft PCB (11.7ft*30.48cm)/71 =	5.0	---				---					
SC-50	2.8ft for Pb, PCB, bis (2.8ft*30.48cm)/86, 71, 56	1.0, 1.2, 1.5	high concentration in surface				3.7ft for all chem (3.7ft*30.48cm)/86, 71, 56	1.3, 1.6, 2.0	---				---					
SC-51	gravel in interval		peak in surface				gravel in interval		---				gravel in interval		---		(0.5ft*30.48cm)/26 =	0.6
SC-52	bis(1.0ft*30.48cm)/56 = Pb (2.0ft*30.48cm)/86 = PCB(2.0 ft*30.48cm)/71 =	0.5, 0.7, 0.9	peak in surface				bis(1.5ft*30.48cm)/56 = Pb (3.0ft*30.48cm)/86 = PCB(3.0 ft*30.48cm)/71 =	0.8, 1.1, 1.3	---				---					
SC-53	no strong chemical trend						---						---					
SC-54	no strong chemical trend						---						---					
SC-55	no strong chemical trend						---						---					
SC-56	2.0ft for Pb, PCB, bis (2.0ft*30.48cm)/86,71,56 =	0.8 to 1.0	onset near surface, no peak				2.0ft for all chemicals (2.4ft*30.48cm)/86,71,56 =	0.9, 1.0, 1.3	---				---					
Historical Cores																		
B3 (T105 1985)*	top 5.5 ft horizontally composited, peak in surface						---						---					
DUD006 (D/D 1994)*	---		Spill (1.25ft*30.48cm)/20 = Peak (2.5ft, 3.5ft, 4.5ft*30.48cm)/34 =	1.9; 2.2, 3.1, 4.0	Pb (1.25ft*30.48cm)/14 =	2.7	---						---					
DR18 (PSDDA99)*	4-foot chemistry composite data						---						---					
DR39 (PSDDA99)*	4-foot chemistry composite data						---						---					
S3 (PSDDA98)*	4-foot chemistry composite data						---						---					
SC-11 (Slip 4 2004)*	mercury data only in RI dataset/ peak in surface						---						---					

NOTES:
1. All 2006 subsurface cores are shown. Historical cores added to fill-in spatial data gaps when good core logs were available with good stratigraphic representations. Historical cores shown (B3 T105 1986; DUD006 Duwamish Diagonal; DR18 and DR39 PSDDA99; S3 PSDDA 99; SC-11 Slip 4) only use recovered values.
2. Sediments were grouped into three stratigraphic units identified for the LDW: Recent, Upper Alluvium, and Lower Alluvium based on lithology .
3. Native alluvium is defined as, but not limited to, a sharp and noticeable contact/change in lithology between Upper Alluvium/Transition and the Lower Alluvium. Typically M-C SAND but sometimes native silts in non-channel areas.
4. Hanson Dam construction is typically noted by, but not limited to, the loss of sand or sandy silt with abundant plant matter and an increase in Recent material.
5. Fill/Dredge contact is defined as the basal contact between recent material and horizons that have been filled or dredged as determined by lithology and historic dredge events.
6. See Table A-2 for chemical data.
7. Formula: x feet interval depth where marker observed multiplied by 30.48 centimeters/ft unit conversion, then divided by the number of years results in a net sedimentation rate in centimeters per year.
Formulas in table indicate conversion by 30.48 "cm" instead of cm/ft for brevity.
No strong markers in core.
* Interpretation of physical marker is different than stratigraphic unit on core log.
— Stratigraphic markers not present or not clearly indicative of a strong time marker.

Table A-2 Data Used to Assign Chemical Markers to the Subsurface Sediment Chemistry Cores Collected in 2006

Subsurface Core ID and Sample ID (recovered depth in feet)[4]	Recovered Depth Interval (feet)	Core Notes	Chemical Results [1,2] Lead	Bis (2-ethylhexyl) phthalate	PCBs (total calc'd)	Insitu Depths (feet) upper	lower	notes	Sample SMS Status[3]
			mg/kg dw	ug/kg dw	ug/kg dw	upper	lower	notes	
LDW-SC1									
LDW-SC1-0-2	0–2	peak in surface	**149 J**	**1,800**	**3,400**	0.0	2.1		csl exceed
LDW-SC1-2-4	2–4		**23 J**	**95**	**440**	2.1	4.1		pass
LDW-SC1-4-6	4–6				3.8 U	4.1	6.6		pass
LDW-SC2									
LDW-SC2-0-2	0–2	high conc in surface, 8-10 ft interval analyzed in Round 4, don't use for chemical onset because unit has fill, concentration could be due to filling (date unknown)	**569**	**900**	**1,380**	0.0	2.4		csl exceed
LDW-SC2-2-4	2–4		**1,050**	**1,800**	**2,900**	2.4	4.1	center of peak at 3.3	csl exceed
LDW-SC2-4-6	4–6		**1,210**	**92**	**209**	4.1	6.0		sqs exceed
LDW-SC2-8-10	8-10		**1400**	not analyzed	**237**	6.0	10.0	analyzed in Round 4	csl exceed
LDW-SC2-10.7-12	10.7–12		2 U	66 U	3.8 U	10.7	12.0		pass
LDW-SC3									
LDW-SC3-0-2	0–2	no clear trend	3 U	42 U	4.0 U	0.0	2.1		pass
LDW-SC3-2-4	2–4		3 U	20 U	3.9 U	2.1	4.1		pass
LDW-SC4									
LDW-SC4-0-1	0–1	no sharp peak	**92**	**420**	**143**	0	1.1		pass
LDW-SC4-1-2	1–2		**320**	**830**	**490**	1.1	2.2		sqs exceed
LDW-SC4-2-4	2–4		**123**	**330**	**600**	2.2	4.2		sqs exceed
LDW-SC4-4-6	4–6				3.9 U	4.2	6.1		pass
LDW-SC5									
LDW-SC5-0-1	0–1	peak in surface	**86**	**390**	**510**	0.0	1.1		sqs exceed
LDW-SC5-1-2.2	1–2.2		**74**	20 U	**66**	1.1	2.4		pass
LDW-SC5-2.2-4	2.2–4		**13**	20 U	3.9 U	2.4	4.3		pass
LDW-SC6									
LDW-SC6-0-2	0–2	gap at 4.5-6, onset at 5.3, used 6-inch data for peak	**67**	**480**	**172**	0.0	2.2		pass
LDW-SC6-2-4.5	2–4.5		**141**	**1,100**	**1,640**	2.2	4.8		csl exceed
LDW-SC6-6-8	6–8		**42**	65 U	**4.5 J**	6.2	9.9	onset at 5.5	pass
LDW-SC7									
LDW-SC7-0-1	0–1	peak in surface	**137**	**1,200**	**1,300**	0.0	1.0		sqs exceed
LDW-SC7-1-1.7	1–1.7		**60**	**240**	**1,270 J**	1.0	1.8		csl exceed
LDW-SC7-1.7-4	1.7–4		**5**	**13 J**	5.5 U	1.8	4.7		pass
LDW-SC8									
LDW-SC8-0-1	0–1	top interval for control as drops by 5x from interval below, no onset	**110**	**630**	**290**	0	1.4		sqs exceed
LDW-SC8-1-2	1–2		**137**	**470**	**1,030**	1.4	2.4		csl exceed
LDW-SC8-2-4	2–4		**149**	**1,600**	**2,900**	2.4	4.4		csl exceed
LDW-SC8-4-6	4–6		**209**	**2,200**	**5,500**	4.4	7.9	center of peak at 6.2	csl exceed
LDW-SC8-6-8	6–8			**1,400**	**3,800**	7.9	11.3		csl exceed
LDW-SC8-8-10	8–10		**89**	**260**	**540**	11.3	14.6		sqs exceed
LDW-SC9									
LDW-SC9-0-1	0–1	no clear trend; peak in surface; too near EAA	**99 J**	**1,700**	**3,600**	0	1.3		csl exceed
LDW-SC9-1-2.6	1–2.6		**133 J**	**1,200 J**	**2,700**	1.3	2.6		csl exceed
LDW-SC9-2.6-4	2.6–4		**37 J**	20 U	**67**	2.6	3.7		pass
LDW-SC10									
LDW-SC10-0-1	0–1	potentially influenced by D/D area, only use peak	**43**	**1,200**	**260 J**	0.0	1.1		sqs exceed
LDW-SC10-1-2	1–2		**87**	**2,800**	**290**	1.1	2.0		sqs exceed
LDW-SC10-2-4	2–4		**308**	**3,900**	**1,120**	2.0	4.1		sqs exceed
LDW-SC10-4-5	4–5			**290**	**410**	4.1	5.2		sqs exceed
LDW-SC10-6-8	6–8				**350**	6.0	8.8		sqs exceed
LDW-SC11									
LDW-SC11-0-0.8	0–0.8	peak in surface,used bis onset only	**639**	**310**	**3,000**	0.0	0.9		csl exceed
LDW-SC11-0.8-2	0.8–2		**3**	19 U	3.9 U	0.9	2.3		pass
LDW-SC11-2-3.4	2–3.4		**3**	20 U	3.9 U	2.0	4.1		pass
LDW-SC11-3.4-4.1	3.4–4.1		**3**	19 U	4.0 U	4.1	4.9		pass
LDW-SC12									
LDW-SC12-0-2	0–2	no Pb, bis trends, calculate PCB control at 1 and 2 ft	**66**	**210**	**350**	0.0	2.0		sqs exceed
LDW-SC12-2-4	2–4		**74**	**380 J**	**2,500**	2.0	4.1	center of peak at 3.1	csl exceed
LDW-SC12-4-6.7	4–6.7				**420**	4.1	6.9		sqs exceed
LDW-SC12-6.7-8.7	6.7–8.7				3.9 U	6.9	9.6		pass
LDW-SC13									
LDW-SC13-0-2	0–2	peak in surface	**71 J**	**160**	**480**	0.0	2.1		sqs exceed
LDW-SC13-2-4	2–4		**36 J**	20 U	**53**	2.1	4.2		pass
LDW-SC14									
LDW-SC14-0-1.4	0–1.4	peak in surface; skipped interval 8.7-10, onset at 9.4	**140**	**1,200**	**4,500**	0.0	1.4		csl exceed
LDW-SC14-1.4-2	1.4–2		**68**	**470**	**2,060**	1.4	2.0		csl exceed
LDW-SC14-2-4.1	2–4.1		**60**	**250**	**1,550**	2.0	4.1		csl exceed
LDW-SC14-4.1-6	4.1–6			**160**	**420**	4.1	5.8	100% recovery	sqs exceed
LDW-SC14-6-8.7	6–8.7				**70**	5.8	8.7		pass
LDW-SC14-10-11	10–11				3.9 U	10.1	11.2		pass
LDW-SC15									
LDW-SC15-0-1	0–1	no clear Pb or bis onset; skipped interval 6-8, onset at 7	**56**	**350**	**360**	0.0	1.2		sqs exceed
LDW-SC15-1-2	1–2		**55**	**290**	**340 J**	1.2	2.0		sqs exceed
LDW-SC15-2-4	2–4		**116**	**480**	**510**	2.0	4.1		sqs exceed
LDW-SC15-4-6	4–6				**1,950**	4.1	7.1	middle of peak at 5.6	csl exceed
LDW-SC15-8-10	8–10				4.0 U	9.5	12.4	onset at 8.3	pass
LDW-SC16									
LDW-SC16-0-2	0–2	skipped interval at 6-8; onset at 7, PCB control at 1 and 2 ft	**105**	**400**	**330 J**	0.0	2.2		sqs exceed
LDW-SC16-2-4	2–4		**158**	**3,100**	**5,400**	2.2	4.1	middle of peak at 3.2	csl exceed
LDW-SC16-4-6	4–6		**113**	**1,600**	**3,400**	4.1	6.1	onset at 7.9	csl exceed
LDW-SC16-8-10	8–10		**79**	66 U	**18 J**	9.6	11.3		pass
LDW-SC17									
LDW-SC17-0-1	0–1	high conc in surface; no onset	**173**	**570**	**1,220**	0.0	1.5		sqs exceed
LDW-SC17-1-2	1–2		**286**	**440 J**	**1,040**	1.5	3.0		sqs exceed
LDW-SC17-2-4	2–4		**1,740**	**2,300**	**9,800**	3.0	6.0	middle of peak at 4.5	csl exceed
LDW-SC17-6-8.2	6–8.2		**470**	**1,000**	**1,900**	9.1	13.0		sqs exceed
LDW-SC18									
LDW-SC18-0-1	0–1	all onset dates at 2	**22**	**87**	**182**	0.0	1.4		pass
LDW-SC18-1-2	1–2		**7**	**18 J**	**19.6**	1.4	2.5		pass
LDW-SC18-2-4	2–4		2 U	20 U	3.9 U	2.5	4.3		pass
LDW-SC19									
LDW-SC19-0-1	0–1	skipped interval 7-9, onset at 8; no Pb or bis trends; top 6 ft roughly same conc, no clear control trend	**60**	**220**	**280**	0.0	1.1		pass
LDW-SC19-1-2	1–2		**50**	**140**	**233**	1.1	2.1		sqs exceed
LDW-SC19-2-4	2–4		**70**	**270**	**250**	2.1	4.3		sqs exceed
LDW-SC19-4-6	4–6				**440**	4.3	6.4		sqs exceed
LDW-SC19-6-7	6–7				**2,400**	6.4	7.5	middle of peak at 7.0	csl exceed
LDW-SC19-9-11.9	9–11.9				3.9 U	9.7	13.0	onset at 8.6	pass

Table A-2 Data Used to Assign Chemical Markers to the Subsurface Sediment Chemistry Cores Collected in 2006

Subsurface Core ID and Sample ID (recovered depth in feet)[4]	Recovered Depth Interval (feet)	Core Notes	Chemical Results [1,2] Lead	Bis (2-ethylhexyl) phthalate	PCBs (total calc'd)	Insitu Depths (feet) upper	lower	notes	Sample SMS Status[3]
			mg/kg dw	ug/kg dw	ug/kg dw	upper	lower	notes	
LDW-SC1									
LDW-SC1-0-2	0–2	peak in surface	**149 J**	**1,800**	**3,400**	0.0	2.1		csl exceed
LDW-SC1-2-4	2–4		**23 J**	**95**	**440**	2.1	4.1		pass
LDW-SC1-4-6	4–6				3.8 U	4.1	6.6		pass
LDW-SC2									
LDW-SC2-0-2	0–2	high conc in surface, 8-10 ft interval analyzed in Round 4, don't use for chemical onset because unit has fill, concentration could be due to filling (date unknown)	**569**	**900**	**1,380**	0.0	2.4		csl exceed
LDW-SC2-2-4	2–4		**1,050**	**1,800**	**2,900**	2.4	4.1	center of peak at 3.3	csl exceed
LDW-SC2-4-6	4–6		**1,210**	**92**	**209**	4.1	6.0		sqs exceed
LDW-SC2-8-10	8-10		**1400**	not analyzed	**237**	6.0	10.0	analyzed in Round 4	csl exceed
LDW-SC2-10.7-12	10.7–12		2 U	66 U	3.8 U	10.7	12.0		pass
LDW-SC3									
LDW-SC3-0-2	0–2	no clear trend	3 U	42 U	4.0 U	0.0	2.1		pass
LDW-SC3-2-4	2–4		3 U	20 U	3.9 U	2.1	4.1		pass
LDW-SC4									
LDW-SC4-0-1	0–1	no sharp peak	**92**	**420**	**143**	0	1.1		pass
LDW-SC4-1-2	1–2		**320**	**830**	**490**	1.1	2.2		sqs exceed
LDW-SC4-2-4	2–4		**123**	**330**	**600**	2.2	4.2		sqs exceed
LDW-SC4-4-6	4–6				3.9 U	4.2	6.1		pass
LDW-SC5									
LDW-SC5-0-1	0–1	peak in surface	**86**	**390**	**510**	0.0	1.1		sqs exceed
LDW-SC5-1-2.2	1–2.2		**74**	20 U	**66**	1.1	2.4		pass
LDW-SC5-2.2-4	2.2–4		**13**	20 U	3.9 U	2.4	4.3		pass
LDW-SC6									
LDW-SC6-0-2	0–2	gap at 4.5-6, onset at 5.3, used 6-inch data for peak	**67**	**480**	**172**	0.0	2.2		pass
LDW-SC6-2-4.5	2–4.5		**141**	**1,100**	**1,640**	2.2	4.8		csl exceed
LDW-SC6-6-8	6–8		**42**	65 U	**4.5 J**	6.2	9.9	onset at 5.5	pass
LDW-SC7									
LDW-SC7-0-1	0–1	peak in surface	**137**	**1,200**	**1,300**	0.0	1.0		sqs exceed
LDW-SC7-1-1.7	1–1.7		**60**	**240**	**1,270 J**	1.0	1.8		csl exceed
LDW-SC7-1.7-4	1.7–4		**5**	**13 J**	5.5 U	1.8	4.7		pass
LDW-SC8									
LDW-SC8-0-1	0–1	top interval for control as drops by 5x from interval below, no onset	**110**	**630**	**290**	0	1.4		sqs exceed
LDW-SC8-1-2	1–2		**137**	**470**	**1,030**	1.4	2.4		csl exceed
LDW-SC8-2-4	2–4		**149**	**1,600**	**2,900**	2.4	4.4		csl exceed
LDW-SC8-4-6	4–6		**209**	**2,200**	**5,500**	4.4	7.9	center of peak at 6.2	csl exceed
LDW-SC8-6-8	6–8			**1,400**	**3,800**	7.9	11.3		csl exceed
LDW-SC8-8-10	8–10		**89**	**260**	**540**	11.3	14.6		sqs exceed
LDW-SC9									
LDW-SC9-0-1	0–1	no clear trend; peak in surface; too near EAA	**99 J**	**1,700**	**3,600**	0	1.3		csl exceed
LDW-SC9-1-2.6	1–2.6		**133 J**	**1,200 J**	**2,700**	1.3	2.6		csl exceed
LDW-SC9-2.6-4	2.6–4		**37 J**	20 U	**67**	2.6	3.7		pass
LDW-SC10									
LDW-SC10-0-1	0–1	potentially influenced by D/D area, only use peak	**43**	**1,200**	**260 J**	0.0	1.1		sqs exceed
LDW-SC10-1-2	1–2		**87**	**2,800**	**290**	1.1	2.0		sqs exceed
LDW-SC10-2-4	2–4		**308**	**3,900**	**1,120**	2.0	4.1		sqs exceed
LDW-SC10-4-5	4–5			**290**	**410**	4.1	5.2		sqs exceed
LDW-SC10-6-8	6–8				**350**	6.0	8.8		sqs exceed
LDW-SC11									
LDW-SC11-0-0.8	0–0.8	peak in surface,used bis onset only	**639**	**310**	**3,000**	0.0	0.9		csl exceed
LDW-SC11-0.8-2	0.8–2		**3**	19 U	3.9 U	0.9	2.3		pass
LDW-SC11-2-3.4	2–3.4		**3**	20 U	3.9 U	2.0	4.1		pass
LDW-SC11-3.4-4.1	3.4–4.1		**3**	19 U	4.0 U	4.1	4.9		pass
LDW-SC12									
LDW-SC12-0-2	0–2	no Pb, bis trends, calculate PCB control at 1 and 2 ft	**66**	**210**	**350**	0.0	2.0		sqs exceed
LDW-SC12-2-4	2–4		**74**	**380 J**	**2,500**	2.0	4.1	center of peak at 3.1	csl exceed
LDW-SC12-4-6.7	4–6.7				**420**	4.1	6.9		sqs exceed
LDW-SC12-6.7-8.7	6.7–8.7				3.9 U	6.9	9.6		pass
LDW-SC13									
LDW-SC13-0-2	0–2	peak in surface	**71 J**	**160**	**480**	0.0	2.1		sqs exceed
LDW-SC13-2-4	2–4		**36 J**	20 U	**53**	2.1	4.2		pass
LDW-SC14									
LDW-SC14-0-1.4	0–1.4	peak in surface; skipped interval 8.7-10, onset at 9.4	**140**	**1,200**	**4,500**	0.0	1.4		csl exceed
LDW-SC14-1.4-2	1.4–2		**68**	**470**	**2,060**	1.4	2.0		csl exceed
LDW-SC14-2-4.1	2–4.1		**60**	**250**	**1,550**	2.0	4.1		csl exceed
LDW-SC14-4.1-6	4.1–6			**160**	**420**	4.1	5.8	100% recovery	sqs exceed
LDW-SC14-6-8.7	6–8.7				**70**	5.8	8.7		pass
LDW-SC14-10-11	10–11				3.9 U	10.1	11.2		pass
LDW-SC15									
LDW-SC15-0-1	0–1	no clear Pb or bis onset; skipped interval 6-8, onset at 7	**56**	**350**	**360**	0.0	1.2		sqs exceed
LDW-SC15-1-2	1–2		**55**	**290**	**340 J**	1.2	2.0		sqs exceed
LDW-SC15-2-4	2–4		**116**	**480**	**510**	2.0	4.1		sqs exceed
LDW-SC15-4-6	4–6				**1,950**	4.1	7.1	middle of peak at 5.6	csl exceed
LDW-SC15-8-10	8–10				4.0 U	9.5	12.4	onset at 8.3	pass
LDW-SC16									
LDW-SC16-0-2	0–2	skipped interval at 6-8; onset at 7, PCB control at 1 and 2 ft	**105**	**400**	**330 J**	0.0	2.2		sqs exceed
LDW-SC16-2-4	2–4		**158**	**3,100**	**5,400**	2.2	4.1	middle of peak at 3.2	csl exceed
LDW-SC16-4-6	4–6		**113**	**1,600**	**3,400**	4.1	6.1	onset at 7.9	csl exceed
LDW-SC16-8-10	8–10		**79**	66 U	**18 J**	9.6	11.3		pass
LDW-SC17									
LDW-SC17-0-1	0–1	high conc in surface; no onset	**173**	**570**	**1,220**	0.0	1.5		sqs exceed
LDW-SC17-1-2	1–2		**286**	**440 J**	**1,040**	1.5	3.0		sqs exceed
LDW-SC17-2-4	2–4		**1,740**	**2,300**	**9,800**	3.0	6.0	middle of peak at 4.5	csl exceed
LDW-SC17-6-8.2	6–8.2		**470**	**1,000**	**1,900**	9.1	13.0		sqs exceed
LDW-SC18									
LDW-SC18-0-1	0–1	all onset dates at 2	**22**	**87**	**182**	0.0	1.4		pass
LDW-SC18-1-2	1–2		**7**	**18 J**	**19.6**	1.4	2.5		pass
LDW-SC18-2-4	2–4		2 U	20 U	3.9 U	2.5	4.3		pass
LDW-SC19									
LDW-SC19-0-1	0–1	skipped interval 7-9, onset at 8; no Pb or bis trends; top 6 ft roughly same conc, no clear control trend	**60**	**220**	**280**	0.0	1.1		pass
LDW-SC19-1-2	1–2		**50**	**140**	**233**	1.1	2.1		sqs exceed
LDW-SC19-2-4	2–4		**70**	**270**	**250**	2.1	4.3		sqs exceed
LDW-SC19-4-6	4–6				**440**	4.3	6.4		sqs exceed
LDW-SC19-6-7	6–7				**2,400**	6.4	7.5	middle of peak at 7.0	csl exceed
LDW-SC19-9-11.9	9–11.9				3.9 U	9.7	13.0	onset at 8.6	pass

Table A-2 Data Used to Assign Chemical Markers to the Subsurface Sediment Chemistry Cores Collected in 2006

Subsurface Core ID and Sample ID (recovered depth in feet)[4]	Recovered Depth Interval (feet)	Core Notes	Chemical Results[1,2] Lead	Bis (2-ethylhexyl) phthalate	PCBs (total calc'd)	Insitu Depths (feet) upper	lower	notes	Sample SMS Status[3]
			mg/kg dw	ug/kg dw	ug/kg dw	upper	lower	notes	
LDW-SC20									
LDW-SC20-0-2	0–2	no clear trends; peak in surface	**82**	**620**	**3,200**	0.0	2.0		csl exceed
LDW-SC20-2-4	2–4		**33**	**71 J**	**600**	2.0	4.0		sqs exceed
LDW-SC20-4-6	4–6				**400**	4.0	6.1		sqs exceed
LDW-SC20-8-10	8–10				**95**	8.2	12.6		pass
LDW-SC21									
LDW-SC21-0-1	0–1	skipped interval 8-10, onset at 6.2; no Pb, bis onset	**55**	**360**	**250**	0.0	1.1		sqs exceed
LDW-SC21-1-2	1–2		**46**	**340**	**145**	1.1	2.1		pass
LDW-SC21-2-4	2–4		**107**	**600**	**380 J**	2.1	4.0		sqs exceed
LDW-SC21-4-6.2	4–6.2				**1,680**	4.0	6.5	middle of peak at 5.3	csl exceed
LDW-SC21-6.3-8	6.2-8				4U	6.5	10.4	onset at 6.2	pass
LDW-SC21-10-11.3	10–11.3				3.9 U	10.4	12.7		pass
LDW-SC22									
LDW-SC22-0-1.1	0–1.1	no clear trend	**46**	**56**	**56**	0.0	1.3		pass
LDW-SC22-1.1-2	1.1–2		**36**	20 U	**26 J**	1.3	2.2		pass
LDW-SC22-2-4	2–4		**25**	20 U	**7.8 J**	2.2	4.2		pass
LDW-SC23									
LDW-SC23-0-2	0–2	no clear Pb, bis trends, no PCB onset	**56 J**	**180**	**177**	0.0	2.1		pass
LDW-SC23-2-4	2–4		**46 J**	**1,600**	**219**	2.1	4.8		pass
LDW-SC23-4-6	4–6			**390**	**880**	4.8	6.4	middle of peak at 5.6	sqs exceed
LDW-SC23-6-8	6–8				**400**	6.4	7.7		sqs exceed
LDW-SC23-8-10.2	8–10.2				**41**	7.7	12.0		pass
LDW-SC24									
LDW-SC24-0-1	0–1	peak in surface	**69**	**390**	**280**	0.0	1.3		sqs exceed
LDW-SC24-1-2	1–2		**8**	**15 J**	**36**	1.3	2.3		pass
LDW-SC24-2-4	2–4		3 U	**16 J**	3.9 U	2.3	4.2		pass
LDW-SC25									
LDW-SC25-0-1	0–1	skipped interval 6-8, onset at 7; no sharp decrease at top, used As for control point	**76**	**350**	**310**	0.0	1.5		sqs exceed
LDW-SC25-1-2	1–2		**98**	**320**	**360**	1.5	2.4		sqs exceed
LDW-SC25-2-4	2–4		**173**	**740**	**430**	2.4	4.4		sqs exceed
LDW-SC25-4-6	4–6		**310**		**800 J**	4.4	6.6		sqs exceed
LDW-SC25-8-9.1	8–9.1		2 U		3.9 U	9.3	10.3	onset at 8	pass
LDW-SC26									
LDW-SC26-0-1	0–1	skipped intervals above and below max concentration, close to ship yard	**58 J**	**330**	**280**	0.0	1.2		sqs exceed
LDW-SC26-1-2	1–2		**57 J**	**320**	**226**	1.2	2.3		pass
LDW-SC26-2-4	2–4		**91 J**	**590**	**310**	2.3	4.2		sqs exceed
LDW-SC26-6-8	6–8		**1,350**	**3,800**	**2,300**	6.6	8.9		csl exceed
LDW-SC26-11.1-12.1	11.1–12.1		**9**		**140**	12.9	14.6		sqs exceed
LDW-SC27									
LDW-SC27-0-2	0–2	peak in surface; no clear trend	**108**	**910**	**3,300**	0.0	2.0		csl exceed
LDW-SC27-2-4.5	2–4.5		**43**	**55**	**250 J**	2.0	4.6		pass
LDW-SC28									
LDW-SC28-0-1	0–1	skipped intervals above and below max concentration, close to ship yard	**114**	510 U	**440**	0.0	1.0		sqs exceed
LDW-SC28-1-2	1–2		**40**	310 U	**360 J**	1.0	2.1		sqs exceed
LDW-SC28-2-4	2–4		**65**	280 U	**290**	2.1	4.2		pass
LDW-SC28-5.5-7.5	5.5–7.5		**583**	**1,000**	**3,200**	5.8	7.9		csl exceed
LDW-SC28-12-12.6	12–12.6		**37**	**96**	**540**	12.6	13.0		sqs exceed
LDW-SC29									
LDW-SC29-0-1	0–1	no clear trend, low concentrations throughout	**18**	**40 J**	**33 J**	0.0	1.0		pass
LDW-SC29-1-2	1–2		**6**	20 U	3.9 UJ	1.0	2.1		pass
LDW-SC29-2-3.6	2–3.6		**4**	20 U	3.9 U	2.1	6.1		pass
LDW-SC30									
LDW-SC30-0-2.5	0–2.5	no clear trend, low concentrations	**3**	**30**	**12.9**	0.0	2.7		pass
LDW-SC30-2.5-4	2.5–4		3 U	19 U	3.9 U	2.7	4.2		pass
LDW-SC31									
LDW-SC31-0-1	0–1	peak in surface	**49**	**270**	**370**	0.0	1.4		sqs exceed
LDW-SC31-1-2.8	1–2.8		**43**	**260**	**330**	1.4	3.0		sqs exceed
LDW-SC31-2.8-4	2.8–4		3 U	20 U	**2.7 J**	3.0	4.2		pass
LDW-SC32									
LDW-SC32-0-1	0–1	high conc in surface; skipped interval 4-5.2, onset at 4.6	**59**	**200**	**1,010**	0.0	1.2		sqs exceed
LDW-SC32-1-2	1–2		**87**	**650**	**1,720**	1.2	2.4		csl exceed
LDW-SC32-2-4	2–4		**51**	**460**	**2,450**	2.4	4.3		csl exceed
LDW-SC32-5.2-8	5.2–8			66 U	3.8 U	5.8	8.0	onset at 5.1	pass
LDW-SC33									
LDW-SC33-0-2	0–2	peak in surface; skipped interval 6-8, onset at 7	**108**	**400**	**3,100**	0.0	2.3		csl exceed
LDW-SC33-2-4	2–4		**33**	**130 J**	**420**	2.3	4.2		sqs exceed
LDW-SC33-4-6	4–6		**33**	**56 J**	**280**	4.2	7.0		sqs exceed
LDW-SC33-8-10	8–10			61 U	3.9 UJ	8.4	11.2	onset at 7.7	pass
LDW-SC201									
LDW-SC201-0-1.5	0–1.5	replicate of SC33	**772**	**380**	**1,450**				csl exceed
LDW-SC201-1.5-4	1.5–4		**42**	**100**	**530 J**				sqs exceed
LDW-SC201-4-6	4–6			65 U	**340**				sqs exceed
LDW-SC201-8-10	8–10			61 U	3.9 U				pass
LDW-SC34									
LDW-SC34-0-1	0–1	no trend, no data for bis peak	**60**	**920**	**210**	0.0	1.4		sqs exceed
LDW-SC34-1-2	1–2		**87**	**3,900**	**280**	1.4	2.5		csl exceed
LDW-SC34-2-4	2–4		**78**	**670**	**250**	2.5	4.7		pass
LDW-SC203									
LDW-SC203-0-1	0–1	replicate of SC34	**78**	**1,800**	**250**				sqs exceed
LDW-SC203-1-2	1–2		**68**	**2,600**	**110**				csl exceed
LDW-SC203-2-4	2–4		**58**	**590**	**174**				sqs exceed
LDW-SC203-4-6	4–6			**770**	**181**				pass
LDW-SC35									
LDW-SC35-0-2	0–2	no clear trend	**42**	**400**	**370 J**	0.0	1.8		sqs exceed
LDW-SC35-2-4	2–4		**73**	**380**	**150 J**	1.8	3.8		pass
LDW-SC36									
LDW-SC36-0-1	0–1	no clear trend	**26**	**73**	**75**	0.0	1.0		pass
LDW-SC36-1-2	1–2		**16**	40 U	4.0 U	1.0	2.2		pass
LDW-SC36-2-4	2–4		**7**	38 U	3.8 U	2.2	4.6		pass
LDW-SC202									
LDW-SC202-0-1	0–1	replicate of SC36	**19**	**54 J**	**30**				pass
LDW-SC202-1-2	1–2		**16**	39 U	3.8 UJ				pass
LDW-SC202-2-4	2–4		**6**	39 U	3.9 UJ				pass
LDW-SC37									
LDW-SC37-0-1	0–1	skipped interval 4-5.3, onset at 4.7, control sources for As, Cu, Pb	**121 J**	**850**	**450**	0.0	1.7		sqs exceed
LDW-SC37-1-2	1–2		**247 J**	**1,100 J**	**950 J**	1.7	2.6	middle of peak at 2.2	sqs exceed
LDW-SC37-2-4	2–4		**3,520 J**	**540 J**	**550**	2.6	4.6		sqs exceed
LDW-SC37-5.3-6.9	5.3–6.9		**16**	66 U	3.9 U	6.3	8.6	onset at 5.5	pass
LDW-SC38a									
LDW-SC38-0-1	0–1		**28**	**22**	**450**	0	1.2		sqs exceed
LDW-SC38-1-2	1–2		**19**	**13 J**	**710**	1.2	2.5		sqs exceed
LDW-SC38-2-3	2–3	no clear trend	**36**	**80 J**	**3,400**	2.5	3.8		csl exceed

Table A-2 Data Used to Assign Chemical Markers to the Subsurface Sediment Chemistry Cores Collected in 2006

Subsurface Core ID and Sample ID (recovered depth in feet)[4]	Recovered Depth Interval (feet)	Core Notes	Chemical Results [1,2] Lead	Bis (2-ethylhexyl) phthalate	PCBs (total calc'd)	Insitu Depths (feet) upper	lower	notes	Sample SMS Status[3]
			mg/kg dw	ug/kg dw	ug/kg dw	upper	lower	notes	
LDW-SC38b									
LDW-SC38-3-3.3	3–3.3		**8**	19 U	**14**				
LDW-SC39									
LDW-SC39-0-1	0–1	no clear trend	**23**	**45 J**	**208**	0.0	2.0		sqs exceed
LDW-SC39-1-2	1–2		**35**	60 U	**440**	2.0	3.3		csl exceed
LDW-SC39-2-4	2–4		**48**	39 U	**220**	3.3	4.3		sqs exceed
LDW-SC39-4-6	4–6				**150**	4.3	6.8		pass
LDW-SC40									
LDW-SC40-0-1.3	0–1.3	no clear trend	**18**	**48**	**160 J**	0.0	1.7		sqs exceed
LDW-SC40-1.3-2	1.3–2		**44**	20 U	4.0 UJ	1.7	2.6		pass
LDW-SC40-2-4	2–4		2 U	20 U	3.9 UJ	2.6	5.2		pass
LDW-SC41									
LDW-SC41-0-1	0–1	no clear trend	**42**	**480**	**370 J**	0.0	1.2		sqs exceed
LDW-SC41-1-2	1–2		**31**	**69 J**	**256**	1.2	2.2		pass
LDW-SC41-2-4	2–4		**35**	**240**	**270**	2.2	4.2		pass
LDW-SC41-4-6	4–6			**430**	**510**	4.2	6.7		sqs exceed
LDW-SC41-6-7.9	6–7.9				**190**	6.7	11.6		sqs exceed
LDW-SC42									
LDW-SC42-0-1	0–1	no clear trend	**20 J**	180 U	**107**	0.0	1.3		pass
LDW-SC42-1-2	1–2		**38 J**	400 U	**163 J**	1.3	2.4		pass
LDW-SC42-2-4	2–4		**33 J**	210 U	**88 J**	2.4	4.0		pass
LDW-SC43									
LDW-SC43-0-2	0–2	no trend, low concentrations	**4**	**12 J**	4.0 UJ	0.0	2.4		pass
LDW-SC43-2-4	2–4		2 U	19 U	3.9 UJ	2.4	5.1		pass
LDW-SC44									
LDW-SC44-0-2	0–2	peak in surface	**33**	**35 J**	**510**	0.0	2.9		sqs exceed
LDW-SC44-2-3.2	2–3.2		**74**	59 U	**450**	2.9	4.8		sqs exceed
LDW-SC44-3.2-4	3.2–4		**9**	20 U	3.9 U	4.8	6.7		pass
LDW-SC45									
LDW-SC45-0-1	0–1	no clear trend	**25**	**220**	**230 J**	0.0	1.0		sqs exceed
LDW-SC45-1-2	1–2		**21**	**120**	**270**	1.0	2.1		sqs exceed
LDW-SC45-2-4	2–4		**52**	**170**	**570**	2.1	4.5		sqs exceed
LDW-SC45-5-6	5–6				**122**	5.5	6.9		pass
LDW-SC46									
LDW-SC46-0-1	0–1	no clear trend	**29**	**250**	**214**	0.0	1.2		pass
LDW-SC46-1-2	1–2		**24**	**220**	**185 J**	1.2	2.3		sqs exceed
LDW-SC46-2-4	2–4		**31**	**200**	**270**	2.3	4.6		sqs exceed
LDW-SC46-4-6.8	4–6.8				**195**	4.6	7.9		pass
LDW-SC47									
LDW-SC47-0-1	0–1	no Pb, bis onset	**14**	**43 J**	**72 J**	0.0	1.3		pass
LDW-SC47-1-2	1–2		**46**	**180**	**2,000**	1.3	2.5	middle of peak at 1.9	csl exceed
LDW-SC47-2-3	2–3		**22**	**350**	**490 J**	2.5	3.8		sqs exceed
LDW-SC47-3-4	3–4		**7**	**17 J**	4.0 UJ	3.8	5.1		pass
LDW-SC48									
LDW-SC48-0-1	0–1	onset at 1 ft, no other clear trends	**6 J**	**61**	**77**	0.0	1.1		pass
LDW-SC48-1-2	1–2		3 U	20 U	3.8 U	1.1	2.2		pass
LDW-SC48-2-4	2–4		3 U	19 U	3.9 U	2.2	4.2		pass
LDW-SC49a									
LDW-SC49-0-1	0–1	no clear Pb, bis trends; no ***strong*** PCB trend; PCB onset below 10 ft	**18**	230 U	**75**	0.0	1.4		pass
LDW-SC49-1-2	1–2		**28**	210 U	**150**	1.4	2.5		pass
LDW-SC49-2-4	2–4		**36**	210 U	**420**	2.5	4.6		sqs exceed
LDW-SC49-4-6	4–6				**780**	4.6	6.8		sqs exceed
LDW-SC49-6-8	6–8				**810**	6.8	9.0		sqs exceed
LDW-SC49-8-10	8–10				**130**	9.0	11.7		pass
LDW-SC50a									
LDW-SC50-0-1	0–1	peak in surface	**47**	**680**	**510**	0.0	1.3		csl exceed
LDW-SC50-1-2	1–2		**22**	**64**	**780**	1.3	2.7		csl exceed
LDW-SC50-2-2.8	2–2.8		**11**	**63**	**75 J**	2.7	3.7		pass
LDW-SC50-2.8-4	2.8–4		2 U	20 U	3.8 UJ	3.7	5.3		pass
LDW-SC51									
LDW-SC51-0-2	0–2	peak in surface	**76 J**	**480**	**1,290**	0.0	2.7		csl exceed
LDW-SC51-2-3.8	2–3.8		**41 J**	**76**	**700**	2.7	5.0		sqs exceed
LDW-SC51-3.8-5.8	3.8–5.8				3.9 U	5.0	10.6		pass
LDW-SC52									
LDW-SC52-0-1	0–1	peak in surface	**222 J**	**660**	**3,000 J**	0.0	1.5		csl exceed
LDW-SC52-1-2	1–2		**36 J**	39 U	**65**	1.5	3.0		pass
LDW-SC52-2-4	2–4		2 UJ	20 U	4.0 U	3.0	6.2		pass
LDW-SC53									
LDW-SC53-0-2	0–2	no clear trend	**28**	530 U	**68**	0.0	2.8		pass
LDW-SC53-2-4	2–4		**41**	**880**	**77**	2.8	5.1		pass
LDW-SC54									
LDW-SC54-0-2	0–2	no clear trend	**17**	**100**	**109**	0.0	2.2		pass
LDW-SC54-2-4	2–4		**18**	**130**	**111**	2.2	4.8		pass
LDW-SC55									
LDW-SC55-0-1	0–1	no clear trend	**10**	27 U	**13.5**	0.0	1.3		pass
LDW-SC55-1-2	1–2		**3**	20 U	59 U	1.3	2.7		pass
LDW-SC55-2-3	2–3		**3**	20 U	4.0 U	2.7	4.0		pass
LDW-SC56									
LDW-SC56-0-2	0–2	peak in surface, onset at 2ft	**40 J**	**23**	**330**	0.0	2.4		sqs exceed
LDW-SC56-2-4	2–4		2 U	20 U	3.9 U	2.4	5.8		pass

Shading indicates interval used in Table A-1 for chemical time marker

- chemical control (use bottom of interval in SMS pass, use middle of interval if SQS exceedance)
- concentration peak in subsurface (use top, middle, and bottom of intervals to present range)
- chemical onset (use top of interval or within skipped interval above)

Shading indicates interval for time markers considered but not used in Table A-1

- concentration decreases from interval below, potential control sources marker
- maximum concentration, potential peak marker
- concentration rises from non-detect to higher concentrations above, potential onset marker

Notes:

1. Other chemicals were also reviewed for 2006 cores, including copper, arsenic, and mercury. See Subsurface Sediment Data Report (Windward and RETEC 2007) for all chemistry results.
2. Blank cell indicates chemical not analyzed in interval.
3. SMS status was used when assigning chemical control depths; if the interval had an SMS exceedance, then the middle of the interval was used; if the interval had a pass, then the bottom of the interval was used. SMS status indicated for detected chemicals only.
4. Only 2-ft interval data show. See Figures 4a through 4i for 6-inch interval data.

SMS - Sediment Management Standards
SQS - sediment quality standard
CSL - cleanup screening level

Table A3 Calculations for Intra-Marker Sedimentation Rates (Between Physical Time Markers)

Subsurface Core ID[1]	Physical Time Markers to Top of Core Using Recovered Depths				Net Sedimentation Rate Between Physical Time Markers		
	Native Alluvium		Hanson Dam Const.		Intramarker		
	Date: 1916		1961		Date: 1916 - 1961		
	Duration: 90 years		45 years		Duration: 46 years		
	Calculation:	Rate (cm/year):	Calculation:	Rate (cm/year):	Calculation:	Distance Between Markers (ft):	Rate (cm/year):
2006 Cores							
SC-5	(2.2ft*30.48cm)/90=	0.7	(0.8ft*30.48cm)/45=	0.5	([2.2-0.8ft]*30.48cm)/45=	1.4	0.9
SC-6	(7.7ft*30.48cm)/90=	2.6	(4.5ft*30.48cm)/45=	3.0	([7.7-4.5ft]*30.48cm)/45=	3.2	2.2
SC-10	(7.0ft*30.48cm)/90=	2.4	(4.0ft*30.48cm)/45=	2.7	([7.0-4.0ft]*30.48cm)/45=	3	2.0
SC-12	(6.7ft*30.48cm)/90=	2.3	(2.6ft*30.48cm)/45=	1.8	([6.7-2.6ft]*30.48cm)/45=	4.1	2.8
SC-15	(7.4ft*30.48cm)/90=	2.5	(2.0ft*30.48cm)/45=	1.4	([7.4-2.0ft]*30.48cm)/45=	5.4	3.7
SC-19	(9.0ft*30.48cm)/90=	3.0	(7.0ft*30.48cm)/45=	4.7	([9.0-7.0ft]*30.48cm)/45=	2	1.4
SC-21	(9.8ft*30.48cm)/90=	3.3	(5.0ft*30.48cm)/45=	3.4	([9.8-5.0ft]*30.48cm)/45=	4.8	3.3
SC-24	(3.2ft*30.48cm)/90=	1.1	(1.0ft*30.48cm)/45=	0.7	([3.2-1.0ft]*30.48cm)/45=	2.2	1.5
SC-29	(1.7ft*30.48cm)/90=	0.6	(0.6ft*30.48cm)/45=	0.4	([1.7-0.6ft]*30.48cm)/45=	1.1	0.7
SC-32	(5 to 7.1ft*30.48cm)/90 =	1.7 to 2.4	(2.8ft*30.48cm)/45 =	1.9	([6.0-2.8ft]*30.48cm)/45=[2]	3.4	2.3
SC-36	(8.4ft*30.48cm)/90=	2.8	(3.2ft*30.48cm)/45=	2.2	([8.4-3.2ft]*30.48cm)/45=	5.2	3.5
SC-37	(5.3ft*30.48cm)/90=	1.8	(2.6ft*30.48cm)/45=	1.8	([5.3-2.6ft]*30.48cm)/45=	2.7	1.8
SC-43	(9.0ft*30.48cm)/90 =	3.0	(0.7ft*30.48cm)/45=	0.5	([9.0-0.7ft]*30.48cm)/45=	8.3	5.6
SC-53	(9.1ft*30.48cm)/90=	3.1	(4.9ft*30.48cm)/45=	3.3	([9.1-4.9ft]*30.48cm)/45=	4.2	2.8
SC-54	(5.4ft*30.48cm)/90=	1.8	(4.0ft*30.48cm)/45=	2.7	([5.4-4.0ft]*30.48cm)/45=	1.4	0.9
SC-55	(3ft*30.48cm)/90=	1.0	(0.5ft*30.48cm)/45=	0.3	([3.0-0.5ft]*30.48cm)/45=	2.5	1.7
Historical Cores							
SC-11 (Slip 4 2004)	(4.1ft*30.48cm)/90 =	1.4	(3.1ft*30.48)/45=	2.6	([4.1-3.1ft]*30.48cm)/45=	1	0.7
B3 (T105 1985)	(11.0ft*30.48cm)/69=	4.9	(4.0ft*30.48cm)/24=	5.1	([11.0-4.0ft]*30.48cm)/45=	7	4.7
DR18 (PSDDA99)	(6.0ft*30.48 cm)/83=	2.2	(4ft*30.48cm)/38=	3.2	([6.0-4.0ft]*30.48cm)/45=	2	1.4
S3 (PSDDA98)	(8.0ft*30.48)/82=	3.0	(4.0ft*30.48cm)/37=	3.3	([8.0-4.0ft]*30.48cm)/45=	4	2.7

Notes:

1. Only cores with 1916 and 1961 physical markers are listed.
2. Depth used for native alluvium in equation represents an average depth.