Memorandum

Date: 12 December 2011

To: Karen Keeley, USEPA

Copies to: Lori Blair, Carl Bach, and Brian Anderson, The Boeing Company; Jim Fitzpatrick, Black & Veatch; and Joe Kalmar, Landau

From: Jon Jones, Michael Stenstrom, and Robert Pitt, NBF Stormwater Expert Panel; jointly with Geosyntec Consultants

Subject: Alternative Interim Goal Recommendations for Protection of Slip 4 Sediment Recontamination

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Introduction

Based on a review of the methodology used to establish the current solids interim goal (IG) of 100 µg total PCBs per kg solids (100 ppb), which was primarily based on results from the SAIC Slip 4 sediment recontamination model (SAIC, 2010a), the North Boeing Field (NBF) Stormwater Expert Panel (Panel), jointly with Geosyntec Consultants, determined that a new analysis approach was necessary for developing a solids IG for NBF stormdrain discharges and for evaluating the effectiveness of the planned Long-Term Stormwater Treatment (LTST) system on NBF stormdrain discharges for protecting Slip 4 sediments from recontamination due to PCBs. As an alternative to the current PCB solids IG and the SAIC sediment recontamination model, it was recommended that:

1) A new mass load-based IG be considered for use in protecting Slip 4 sediments from recontamination due to NBF storm drain discharges; and

2) This mass load-based IG be developed through a static mass balance analysis that considers PCB and solids mass loading to Slip 4 (following completion of the LTST chitosan-enhanced sand filtration [CESF] system at the lift station), and PCB mixing in the top 10 cm of the sand cap (post removal action).

The approach used to conduct this static mass balance analysis and the results of the analysis are described further in this memo.

Overall Finding

The NBF Expert Panel and Geosyntec Consultants have determined that with the LTST in place and based on the assumptions/analysis described herein, the sediment PCB concentration standard (assumed here to be 130 ppb) would not be reached in Slip 4 within 50 years, when accounting for both onsite and offsite flow (see Figure 9). These PCB loading forecasts do not account for the reductions associated with onsite and offsite PCB source removal and control efforts and natural degradation over the 50 year simulation period, nor do they account for cleaner, "dilution" sediments from the Lower Duwamish Waterway that will be deposited in the Slip. All PCB loads to the Lift Station, including those from both NBF and the King County International Airport, were considered for this analysis.

Analysis Approach

Overview

The purpose of the analysis was to estimate a site-specific mass load-based IG that the Panel believes is protective of Slip 4 sediments from PCB recontamination due to stormdrain discharges. This approach recognizes that a long-term monitoring plan for the overall Lower Duwamish Waterway (LDW) Superfund Site has not yet been determined, that there therefore remains uncertainty with the Slip 4 interim removal action as planning proceeds, and that the proposed plan and Record of Decision have not yet been written for the LDW Site. The approach used for evaluation of PCBs in Slip 4 sediments is summarized below:

1) The anticipated post-LTST loading of solids and associated PCBs from NBF to Slip 4 was estimated based on existing available monitoring data and calibrated hydrologic model output, assuming steady-state (average) conditions for NBF stormdrain baseflows and stormflows (both treated and bypassed). This analysis considered the suspended solids loads and average whole water PCB concentrations from the following stormdrain discharge sources to Slip 4 (see Figure 1 for schematic of flows to Slip 4). Consistent with previous Slip 4 evaluations and discussions, discharges from other Slip 4 stormdrain outfalls were not considered in the model.

    a. LTST CESF-treated effluent, which includes flows from both NBF and the King County International Airport (KCIA) (including offsite re-routed flows from the north lateral), and which represents most of the discharged volume but very little of the discharged solids and PCB loads from NBF to the Slip, and

   b. Untreated onsite and offsite stormflows that are "bypassed" around the LTST CESF system during high flow events (i.e., when flows at the lift station exceed the 1500 gallons/min [gpm] design flowrate and are therefore not captured by the LTST pumps within the lift station vault).

2) The effect of varying settling distances in the Slip for different sized particles can be accounted for by inclusion of percentage (by mass) of solids settling in the Slip as a parameter. This approach allows for adjustment of the model based on variations in size distribution that may occur over time as a result of treatment. The initial assumption was that 100% of discharged suspended solids settled within the Slip; however, additional scenarios were considered using an estimate of the mass of solids that would exit the Slip based on NBF stormdrain filtered solids particle size distribution data and calculated settling velocities.

3) A mass balance of PCB solids depositing in the Slip over the course of a year fully mixed in 10 cm of clean sand cap[1] (to protect the benthos) was computed, as was a separate scenario to look at fully mixed concentrations within a 2 cm clean sand mixing depth[2] for comparison purposes only (as requested by EPA during the 9 June meeting). This resulted in an average surface sediment PCB concentration for the entire Slip (not just the cleanup area). This number was then used as the initial 10-cm sand cap PCB concentration for the next year.

4) Based on calculations described in step 3, a time series plot of average surface sediment PCB concentrations in the Slip over a 50-year period was developed. Fifty years was selected to represent "long-term" conditions but is considered conservative since PCB concentrations in the NBF stormdrain are expected to decrease over time as various NBF source control/removal (e.g., catch basin inlet filters, stormdrain cleaning, joint

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[1] 10 cm depth is consistent with Washington State regulations which define the biologically active zone where sediment quality criteria must be met (Chapter 173-204 WAC). Physical mixing of sediments, such as by resuspension/deposition processes, may not occur throughout all areas of the Slip due to its generally quiescent nature; however, PCB mixing through biological activity (e.g., bioturbation) is expected to facilitate mixing within this 10 cm active zone. Barge and boat activity is expected to further facilitate this mixing of surface sediments, although these effects may be limited to portions of the Slip closer to the LDW.

[2] As a separate but related note with respect to sediment depths, long-term sediment monitoring decisions have not been determined for the LDW Superfund Site at this time.

compound and paint removal, demolition of older buildings and other structures, etc.) and remediation efforts proceed, combined with natural PCB degradation processes.

5) Computed Slip 4 average surface sediment PCB concentrations were then compared with the State sediment standards (130 ppb PCBs dry weight and/or 12 ppm organic carbon) and with the Preliminary Remediation Goal of 2 ppb total PCBs dry weight for Remedial Action Objective (RAO) 1, as identified in Table 4-4 of the Feasibility Study for the LDW Site (LDWG, 2010). Using the time series plots, the number of years until the State standards would be exceeded was determined for a number of different scenarios (described further in the next section).

6) Using the time series plots that were developed and estimates of the mass of solids that would exit the Slip based on particle size, an allowable average annual total filterable PCBs mass load (g/year), such that State sediment standards are not exceeded within 50 years, was established.

7) In order to avoid exceedances of this average annual PCB load during above-average rainfall years, this load was divided by average annual runoff volume to compute a mass load-based allowable concentration (µg/L total filterable PCBs). For compliance assessment purposes, this Interim Goal can be compared annually with a volume-weighted average of the lift station discharge concentrations (each being a flow-weighted event mean concentration measurement).

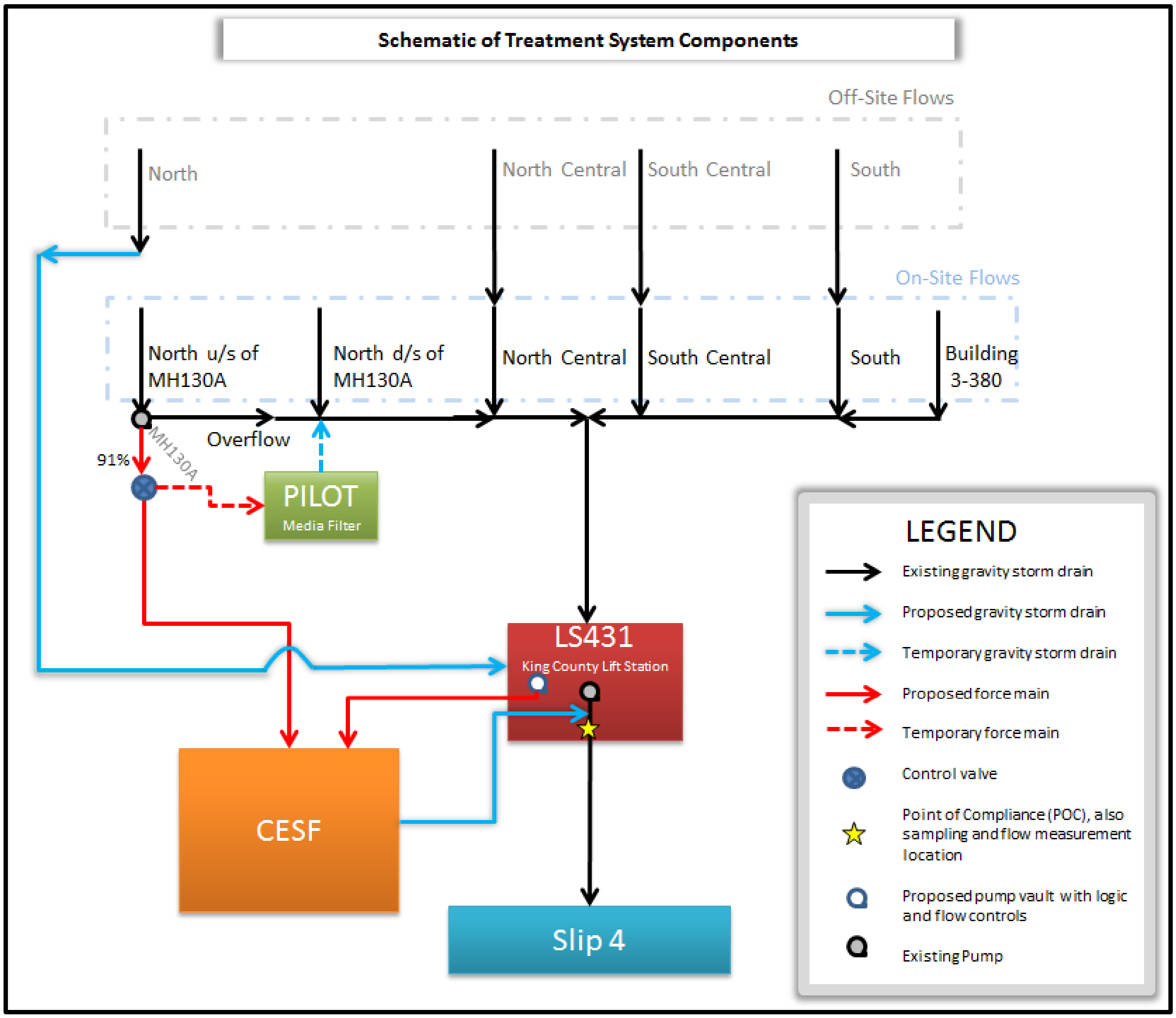


Figure 1. Schematic of flows to Slip 4 (taken from Remedial Action Work Plan (RAWP) Addendum [Geosyntec, 2011b]). This figure illustrates the proposed flow routing for the LTST CESF, where flows are preferentially treated from the north lateral first (upstream of MH130a), where PCB concentrations are highest, and then from the lift station up to the remaining available capacity of the 1500 gpm system. This approach maximizes the PCB load reduction for the design flowrate by treating 91% of long-term average annual runoff volumes from the onsite north lateral drainage area, and 59% of long-term average annual runoff volumes from the entire on- and offsite drainage area to the lift station. Offsite north lateral flows (blue line to LS431) are routed around MH130a to the lift station where they are also treated; however, this flow segregation scheme allows operational flexibility in the future in case this flow needs to be routed downstream of the LTST system to allow for more focused treatment of onsite flows.

General Assumptions

This static mass balance analysis was conducted using the following general assumptions, some of which contribute toward a conservatively high estimation of long-term average surface sediment PCB concentrations in the Slip:

1) There is no dilution of Slip 4 sediments with sediments from the LDW which are expected to have lower PCB concentrations.

2) As described in further detail in the previous section, flows from other stormdrain outfalls that discharge directly to the Slip (e.g., I-5 drain) are not considered in this analysis.

3) Resuspension processes are a negligible factor in determining average surface sediment PCB concentrations in the Slip, given its generally quiescent and enclosed nature.

4) PCB mixing in surface sediments is limited to the upper 10 cm (or 2 cm in the case of that comparative scenario).

5) Discharged solids settling distance variations (due to particle size and density) within the Slip are not considered, so that the predicted surface sediment PCB concentrations represent a Slip-wide average.

6) PSD and filtered solids data are assumed to be accurate representations of the NBF flows, although there is a potential that, due to the 5 µm bag filters used, the contribution of solids smaller than 5 µm (which would be expected to almost entirely leave the Slip) may be underestimated.

7) Flocculation of fine discharged solids is not considered. All particles are assumed to settle discretely.

8) A settled solids density of 2.2 g/cm^3 is assumed (SAIC, 2010a). Studies of PSD of solids collected during storm events suggest that this density value may be high for the particle size of interest for this analysis (<63 µm), and that a more accurate value would be approximately 1.4-1.5 g/cm^3 (Li 2008, Pitt 2011). The effect of lowering the density used in the calculations would be to raise the critical settling size (in other words, more solids would be expected to leave the Slip). As a conservative measure, therefore, the density of 2.2 g/cm^3 was used for this analysis.

9) Loading was assumed to be constant over 50 years, so source control efforts and natural degradation processes which are likely to occur during this time period were not considered. These source controls are substantial and include site-wide stormdrain line cleaning, installation of catch basin inlet filters, regular surface sweeping, proposed pilot testing of a new zero-valent metal PCB degradation technology, excavation of PCB contaminated soils, and extensive sampling and removal of concrete joint materials, building caulk, and paint containing elevated levels of PCBs. These extensive activities are anticipated to result in long-term stormwater quality improvement at NBF, but that improvement is not accounted for or quantified in this analysis, so the actual sediment PCB concentrations are expected to be less than shown in this memo.

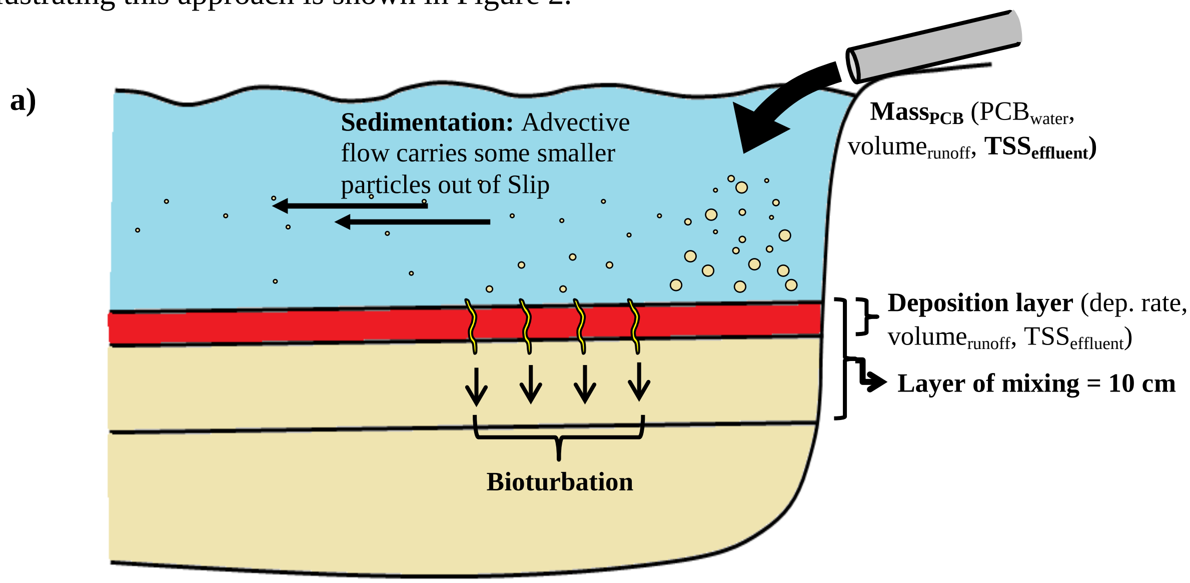
10) Bedload solids are not considered. This is considered a reasonable assumption given that bedload mass in low-slope stormdrains typically constitutes a very small percentage of the total transported solids mass, in addition to the fact that most of the bedload mass will be captured in sumps and the lift station vault.

11) The State sediment quality standard of 130 ppb PCBs dry weight assumes a Total Organic Carbon (TOC) content of approximately 1.08%. The average TOC concentrations in Slip 4 are approximately 3.5%, as described in the Landau Associates Technical Memorandum (Landau, 2010), which would result in a standard of 420 ppb PCBs dry weight. This analysis uses the more conservative level of 130 ppb PCBs dry weight.

Several of the assumptions listed above, in particular assumptions #1, 8, 9 and 11 serve as "factors of safety" in the calculated loading limit since, for the most part, they serve to make the analysis more conservative (i.e., more protective of Slip sediment quality). Though some of the assumptions made may contribute to a lower estimate of surface sediment PCB concentrations (such as 2 and 10), these factors are likely to have a considerably smaller effect than the conservative assumptions described. Of the above list of assumptions, #1 and 9 are likely the most conservative assumptions that may have the strongest influence on the results.

Given the potential for this approach to set precedent, it should be noted that a similar mass balance analysis for discharges to the main Lower Duwamish Waterway, which is a more dynamic system, would require a more complex simulation of sediment transport processes in order to develop a comparable sediment recontamination-based limit for these discharges. Therefore, this approach is not directly transferrable to that system without substantial alteration and use of more complex models.

Results of this analysis are described in the following section, and a conceptual model illustrating this approach is shown in Figure 2.



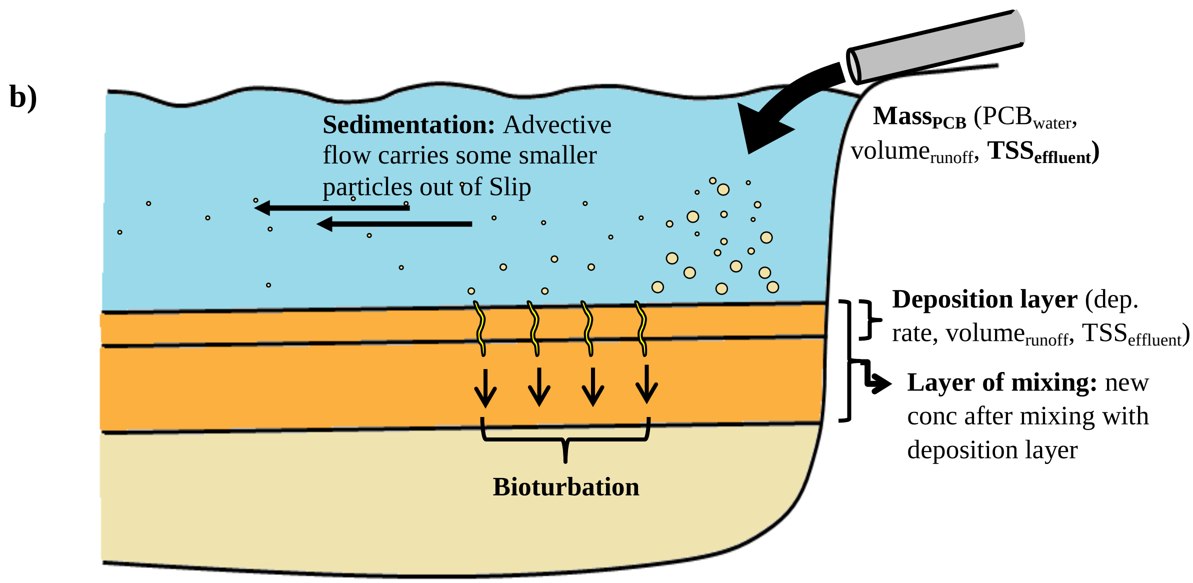


Figure 2. a) Depiction of initial (pre-mixing) PCB deposition with higher PCB concentrations in deposition layer, as reflected by the sediment colors, from yellow (lowest PCB concentration) to red (highest PCB concentration); b) Increased post-mixing surface sediment PCB concentrations as reflected by the uniform orange color. Variables in parentheses are those used in the mass balance analysis.

Analysis Results

Discharge Volumes

Based on the LTST RAWP Addendum (Geosyntec, 2011b), 352 million gallons/year, or 1080 acre-feet (AF)/year[3], are discharged to the Slip during an average rainfall year, based on baseflow discharge measurements and long-term continuous hydrologic modeling using the USEPA's SWMM model. The model was calibrated. This total includes both baseflows and stormflows from onsite and offsite areas, including the north lateral offsite reroute, which will be routed around MH130a on the north lateral (where higher concentration north lateral flows upstream of MH130a will be preferentially pumped to the LTST system) and discharge to the lift station vault. On average, 59% of this total 1080 AF/year volume will be treated by the 1500 gpm LTST CESF based on model results shown in Table 2 of the RAWP Addendum. Based on data reported in the RAWP Addendum, 39% of this 1080 AF/year estimated average annual total discharge volume is from non-storm baseflows (which will be nearly entirely treated in the LTST system), and the remainder (61%) is from storm runoff. Furthermore, 34% of this 1080 AF/year total discharge volume is from offsite (KCIA) areas, and the remainder is from onsite (NBF) areas, although this assumes that all of the baseflows are from NBF sections of the stormdrain (no measurements of offsite baseflows are available, although low flows have been observed in MH178). This is another significant conservative assumption.

Solids Loading

Assuming an average pre-LTST lift station total suspended solids (TSS) concentration of 27 mg/L as cited in the RAWP (Geosyntec, 2011a), the average annual solids loading to the Slip is 36,000 kg/year, prior to LTST operation. Recent stormflow TSS sample results (discussed later) suggest this 27 mg/L assumed value may be a low estimate for offsite flows. This uncertainty may affect estimates of the percentage of Slip loading from offsite, however, it does not affect the total solids or PCB load estimates to the Slip presented in this memo since those estimates are based on Lift Station TSS measurements. Assuming an average CESF effluent TSS concentration of 0.5 mg/L, or half the TSS detection limit (noting that the Short-Term Stormwater Treatment [STST] system CESF has been consistently achieving non-detect (ND) TSS concentrations in treated effluent), the average annual solids loading to the Slip becomes

[3] This discharge volume does not include stormwater runoff from the small, approximately 6-acre NBF parking lot drainage area located downstream of the lift station. This runoff contribution is considered negligible and, based on Table 3 of the RAWP (Geosyntec, 2011a), represents approximately 1% of the total runoff volume at the lift station.

15,000 kg/year subsequent to LTST operation. This load is computed by volume weighting the treated and untreated concentrations and multiplying by average annual discharge volume. This represents a 58% reduction in average solids loading to the Slip as a result of the LTST system. This loading estimate is not sensitive to the ND assumption; if 1 mg/L TSS is assumed for the CESF effluent, the fraction from the treated effluent remains small enough that the average annual post-LTST solids load remains 15,000 kg/year (i.e., unchanged when reported at two significant figures).

Due to a lack of TSS measurements in baseflows and stormflows at the upstream property boundary, it is not possible to accurately apportion these estimated solids loads between onsite and offsite areas at this time. However, as a rough estimate, if TSS concentrations in baseflows and stormflows are identical between onsite and offsite stormdrain flows (i.e., assuming 27 mg/L for offsite stormflows, consistent with the RAWP, noting, however, that two recent stormflow samples collected at MH178 in May 2011 found concentrations of 51 and 67 mg/L), then solids loads will be apportioned consistent with discharge volumes, or 34% of long-term average annual solids loads are from offsite (again assuming that 100% of baseflows are from NBF sections of the stormdrain).

As a next step, these discharged solids loads to the Slip were adjusted to account for the percent of solids mass that is anticipated to deposit within the Slip based on the estimated average horizontal velocity in the Slip (or 0.4 ft/s, associated with stormdrain discharges, averaged between flood and ebb tide conditions, taken from the *North Boeing Field/Georgetown Steam Plant Site Remedial Investigation/ Feasibility Study – Slip 4 Sediment Recontamination Modeling Report* [SAIC, 2010a]), average water depth in the Slip (or approximately 10 ft relative to mean sea level[4], again taken from the SAIC sedimentation model report [SAIC, 2010a]), and estimated Stokes-based settling velocities as a function of particle size. Based on these assumptions, the estimated critical particle size for settling within the Slip is approximately 44 µm[5] (i.e., larger particles are assumed to entirely settle within the Slip, and smaller particles are

[4] This value was estimated from review of Figure 2 in the SAIC report showing bathymetry contour lines. Based on input from SAIC, this may be an underestimate of average depths in the Slip, however, since a shallower depth results in a more conservative estimate (by allowing more solids to settle), 10 feet is used for this analysis. It should be noted, however, that this is not a particularly sensitive value, therefore additional precision is not likely necessary. For instance, a change in depth from 10 ft to 5 ft will increase PCB settling only by 2%.

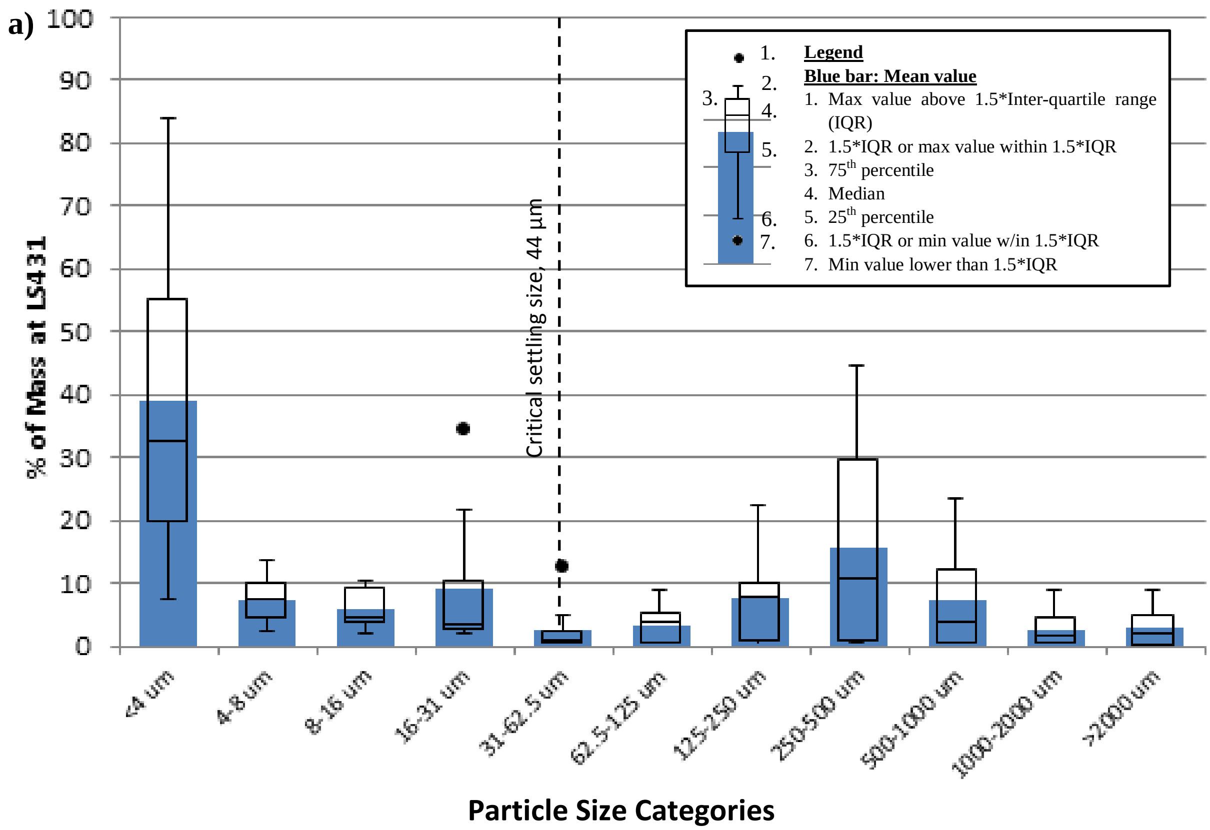
[5] The initial critical settling size calculated was approximately 20 µm which was based on usage of the Stokes settling velocity equation as cited in the SAIC Modeling Report (SAIC, 2010a). It has since been noted that the equation as cited in the report is incorrect. The critical settling size reported above, 44 µm, was calculated using the corrected equation.

assumed to entirely leave the Slip). It should be noted that solids larger than 44 µm are not expected to leave the LTST and that any particles in this size range would likely come from the overflow stream.

Particle size distribution (PSD) data for the lift station (pre- and post-STST installation filtered solids data collected between 2009 and 2011 using 5 µm filter bags) and STST CESF effluent (water sample analyses conducted by Dr. Stenstrom's UCLA lab in June 2011, which showed that essentially all of the particles in treated effluent were near or below 1 µm) were then used to estimate the fraction of discharged solids that would settle within the Slip (Landau, 2010 and SAIC, 2011). It should be noted that due to the pore size of the filter bags used (5 µm), it is likely that the portion of the sample under 5 µm was not entirely captured and accounted for in the PSD data, and therefore the value for the settleable fraction used in this analysis is an overestimate. Figure 3 summarizes the pre-STST filtered solids PSD data and compares this with more recent, post-STST lift station filtered solids PSD data using the same sample collection procedures[6]. Figure 8 (discussed later) illustrates the impact of the lift station filtered solids PSD data source on estimated post-LTST PCB loads that will settle within the Slip by showing separate PCB loading lines using the pre- and post-STST installation PSD data.

Based on Panel review of the pre- and post-STST installation PSD data, an average of the two is recommended for use in this analysis. This results in 57% of the pre-LTST and post-LTST solids loads settling in the Slip, or 21,000 kg/year of the 36,000 kg/year pre-LTST solids load, and 8,800 kg/year of the 15,000 kg/year post-LTST solids load. Therefore, the LTST is anticipated to result in a 58% reduction in average loading of solids that are expected to settle within the Slip.

[6] Pre-STST installation samples were analyzed using the ASTM D422 method (SAIC, 2010b), while post-STST installation samples were analyzed using the PSEP-PS method (Landau, 2011). Both of these methods are sediment particle size distribution methods that require large amounts of sample and were therefore based on sediment captured on the 5 µm bag filters. These methods use a combination of mechanical sieves and hydrometers for the fine material. Since the bag filter had 5 µm apertures, it is possible that some of the smaller particles passed through the filter and were not examined. This effect depends on the ability of any filter cake on the bag filters to capture particles smaller than the filter aperture. Therefore, some of the very small particle measurements may be inconsistent for these two samples.


a)
% of Mass at LS431
100
90
80
70
60
50
40
30
20
10
0
Critical settling size, 44 µm
Legend
Blue bar: Mean value
1. Max value above 1.5*Inter-quartile range (IQR)
2. 1.5*IQR or max value within 1.5*IQR
3. 75th percentile
4. Median
5. 25th percentile
6. 1.5*IQR or min value w/in 1.5*IQR
7. Min value lower than 1.5*IQR
<4 um
4-8 um
8-16 um
16-31 um
31-62.5 um
62.5-125 um
125-250 um
250-500 um
500-1000 um
1000-2000 um
>2000 um
Particle Size Categories

b)

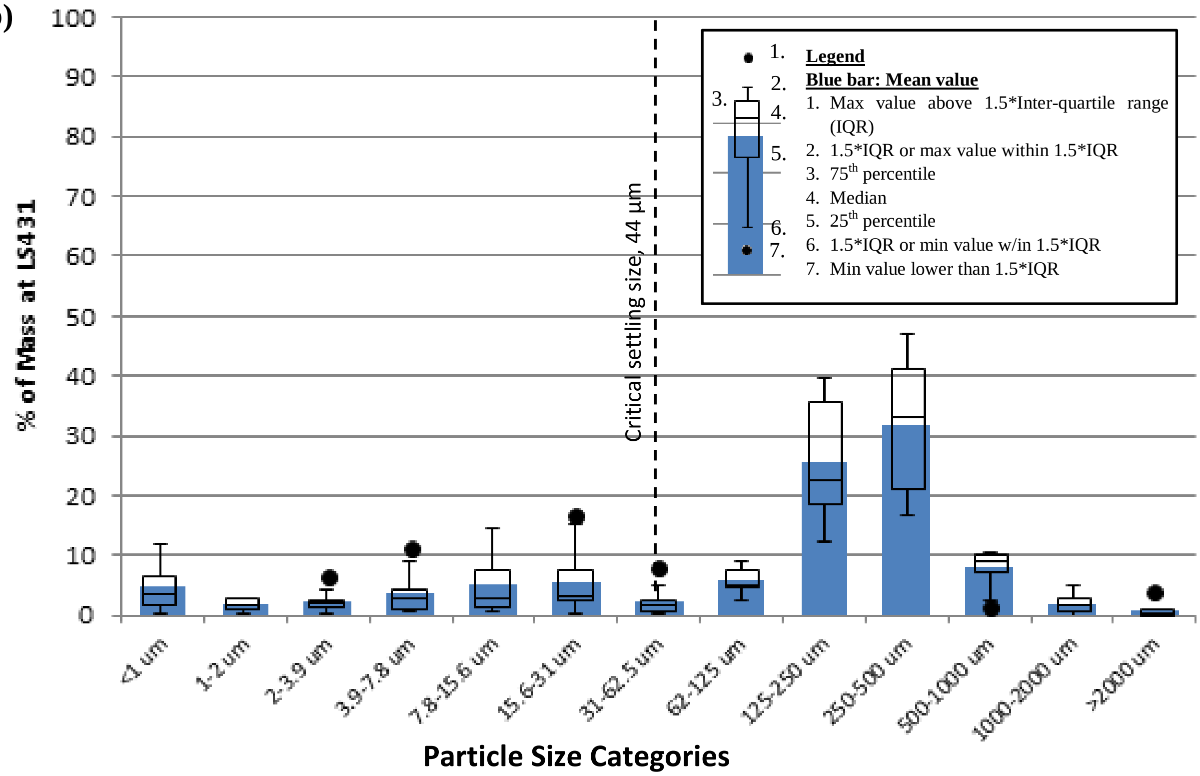


Figure 3. a) Lift station filtered solids particle size distribution data collected between 10/2009 and 5/2010 (n=7, all collected during storm events) prior to STST installation and analyzed using ASTM D422 method. b) Lift station filtered solids particle size distribution data collected between 11/2010 and 5/2011 (n=8, all collected during storm events) after STST installation, and analyzed using PSEP-PS method. All filtered solids samples were collected using 5 µm bag filter.

PCB Loading

The average annual pre-LTST PCB load to the Slip is 39 g/year based on Table 3 of the RAWP Addendum (Geosyntec, 2011b). Assuming an average pre-LTST stormflow total PCBs concentration of 0.029 µg/L in water at the lift station as cited in Table 3 of the RAWP, and an average treated effluent PCB concentration of 0.006 µg/L (calculated by using half the 0.01 µg/L

Aroclor detection level for non-detect results[7], which accounted for the majority of STST CESF effluent monitoring results prior to removal of garnet from the sand filter), the average annual PCB load to the Slip becomes 20 g/year (0.044 lbs/year) subsequent to LTST operation. This load is computed by volume weighting the treated and untreated concentrations and multiplying by average annual discharge volume. This represents a 49% reduction in average PCB loading to the Slip as a result of the LTST system. This loading estimate is relatively sensitive to the ND assumption for PCBs in CESF effluent; for example, if 0.01 µg/L total PCBs is assumed for non-detects rather than 0.005 µg/L, the average annual post-LTST PCB load becomes 24 g/year, and the CESF effluent portion increases from 20% to 33% of the total estimated PCB load. Therefore, there remains considerable uncertainty with this treated portion of the post-LTST PCB loading estimate. Figure 7 (discussed later) illustrates the impact of this treated flow ND assumption on estimated post-LTST PCB loads through the use of error bars to indicate prediction uncertainty associated with this input assumption. Figure 8 (discussed later) similarly illustrates the impact of the assumed average PCB water concentration for untreated flows (0.029 µg/L) on estimated post-LTST PCB loads through the use of error bars, to indicate prediction uncertainty associated with this input assumption.

Due to a lack of PCB water and filtered solids measurements in baseflows and stormflows at the upstream property boundary, it is not possible to accurately apportion these estimated PCB loads between onsite and offsite areas at this time. However, as a very rough approximation based on assumed TSS concentrations (27 mg/L based on the 2010 lift station average) and April 2010 sediment trap solids samples collected by SAIC in the stormdrains near the upstream property line, the RAWP reports offsite PCB loads constituting approximately 23% of the total average annual PCB load in ***stormflow-only*** discharges to the Slip[8]. More recent (2011) whole water

[7] This assumed CESF treated effluent PCB concentration in water is reasonable given how close it is to a filtered solids-based estimate. The average total PCB concentration in recent STST CESF effluent samples collected by Landau using a 1 µm filter and reported in their July progress report is 0.0058 µg/L based on volume of water filtered and assuming complete capture of suspended solids and PCBs. Alternatively, the calculated average concentration of PCBs on effluent filtered solids is approximately 8 ppm, excluding one anomalously high measurement in June 2011. Assuming a TSS concentration of 0.5 mg/L, or half the detection limit, this translates to a total PCB concentration in water of 0.004 µg/L.

[8] This is based on 5.0 g/year average annual stormflow PCB load from offsite areas (calculated based on most recent sediment trap data collected near the property line) divided by 22 g/year average annual stormflow PCB load from onsite plus offsite areas (based on most recent SAIC sediment trap data collected at the downstream end of each of the laterals; it is acknowledged that this sediment trap concentration-based total load estimate [22 g/yr] differs considerably with a water concentration-based estimate from the RAWP Addendum [39 g/yr]), as shown in Table 3 of the RAWP (Geosyntec, 2011a). This offsite load contribution is a highly uncertain number.

samples collected by SAIC at MH178 on the north lateral near the property line show non-detect (<0.01 µg/L) total PCB concentrations in the two representative stormflow samples[9], and an average of 0.089 µg/L in the two baseflow samples[10]. The two MH178 stormflow water sample results (<0.01 µg/L) very roughly confirm the sediment trap solids concentration value used for the RAWP north lateral offsite loading estimate, or 0.44 ppm, which translates to a water concentration of 0.012 µg/L, assuming an average TSS concentration of 27 mg/L.

As a next step similar to the solids loading analysis, these discharged PCB loads to the Slip were adjusted to account for the percent of PCB mass that is anticipated to deposit within the Slip, which is assumed to be equal to the percent of discharged solids that settle within the Slip. All particles >44 µm are estimated to settle within the Slip, however a sensitivity analysis was done to determine the effect of the critical settling size on predicted surface PCB concentrations and is discussed in the next section. Since NBF PCB solids concentration data are not available for this particle size range, the fraction of mass of PCB leaving the Slip was assumed to be equal to the fraction of solids leaving the Slip. As discussed earlier, an average of pre- and post-STST filtered solids particle size distribution data for the lift station was used. Based on this analysis, 57% of the discharged PCBs are expected to settle within the Slip, or 22 of the 39 g/year total PCB pre-LTST load and 12 of the 20 g/year total PCB post-LTST load). Therefore the LTST is again anticipated to result in a 47% reduction in average loading of PCBs, even when accounting for the fraction of solids that are expected to settle within the Slip.

The pie charts shown in Figure 4 summarize the estimated average annual runoff volumes, solids loads, and PCB loads that are discharged (not necessarily what actually settles) to the Slip upon operation of the LTST system. These quantities are broken out between the treated (or CESF effluent) volumes/loads and the untreated (or lift station overflow) volumes/loads. These figures clearly illustrate that the CESF effluent represents a majority of the discharged volume, a very minor portion of the discharged solids load, and a small but significant portion of the discharged PCB load. Figure 5 shows reductions in effluent loading pre- and post-treatment, as well as the

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[9] The two representative stormflow samples were collected in May; the previous two stormflow samples were collected in March and April and the TSS and PCB measurements may have been artificially high due to sample intake placement near the bottom of the pipe that may have collected a disproportionate amount of solids (Landau, 2011).

[10] Landau Associates set up flow monitoring equipment earlier this year at MH178 during sampling, however the flow measuring device was not able to collect accurate measurements during baseflow because velocities and water levels were below the minimum range of the instrument.

post-treatment scenario when solids leaving the Slip are taken into account. This data is further broken down into the offsite versus onsite contributions. Figure 6 is similar to Figure 5, except that only the volume of effluent that is treated is represented. Taken together, these figures show that though the majority of the effluent is treated, the untreated portion represents the majority of PCB loading post-treatment.

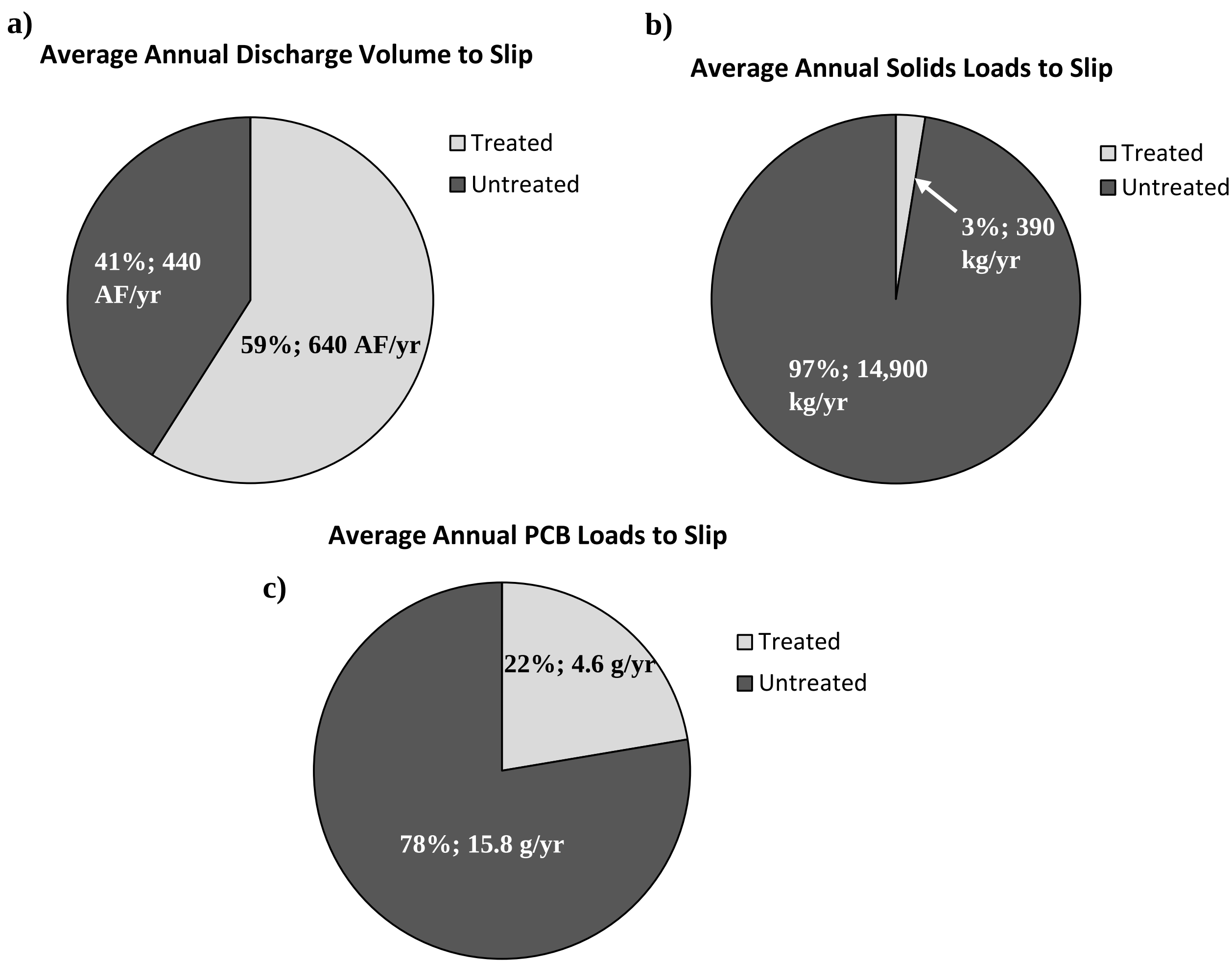

Figure 4. Contributions of treated CESF stream and untreated Lift Station overflow stream to a) annual discharge volume, b) annual solids loading and c) annual PCB loading. Loading fractions represent total loads discharged, and do not account for the fraction of discharged solids which will exit Slip. For the PCB load estimates, non-detect total PCB concentrations are treated as half the Aroclor detection limit, which is an assumption that is mostly relevant for the treated fraction since CESF effluent concentrations are almost entirely below detection.

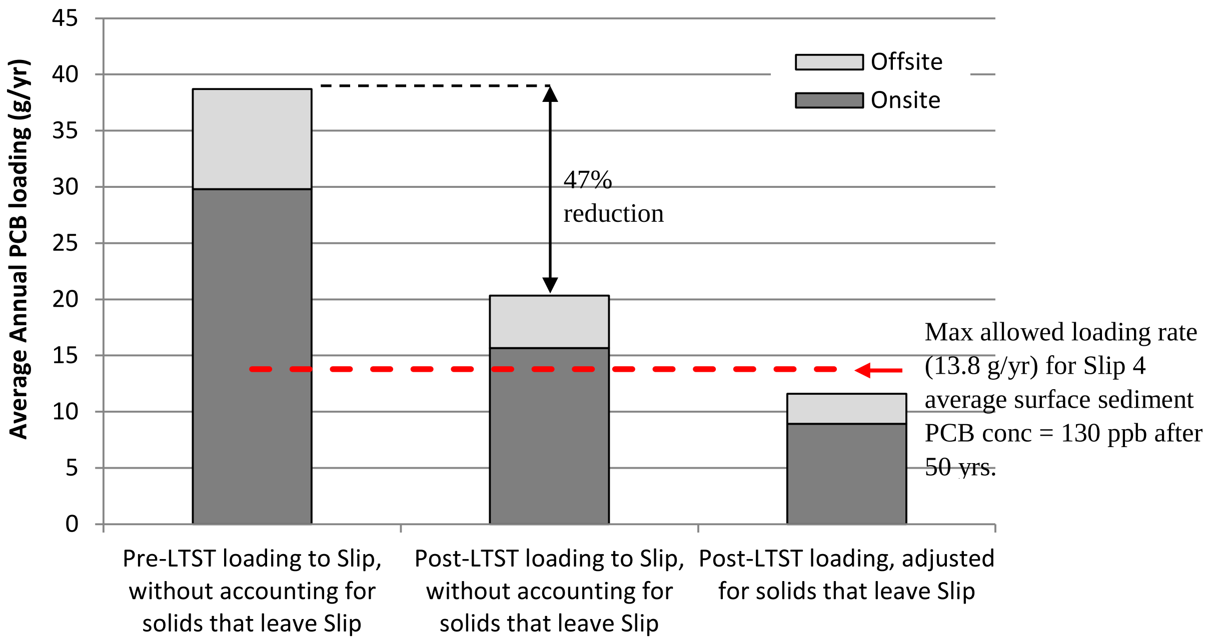

Figure 5. Average annual onsite vs. offsite PCB loads to Slip 4 for pre- and post-LTST conditions. Loading calculations assume ND=0.5DL (which primarily affects the PCB loading estimate for treated flows) and that all baseflow PCB loading is from onsite sources. Average of pre- and post-STST installation PSD data used to calculate solids leaving Slip 4 (3^{rd} bar). The fraction of total PCB load from offsite (23%) is highly uncertain due to a lack of offsite PCB and discharge monitoring data; the fraction shown here is taken from the RAWP and is based on sediment trap PCB concentration data and estimated runoff volumes.

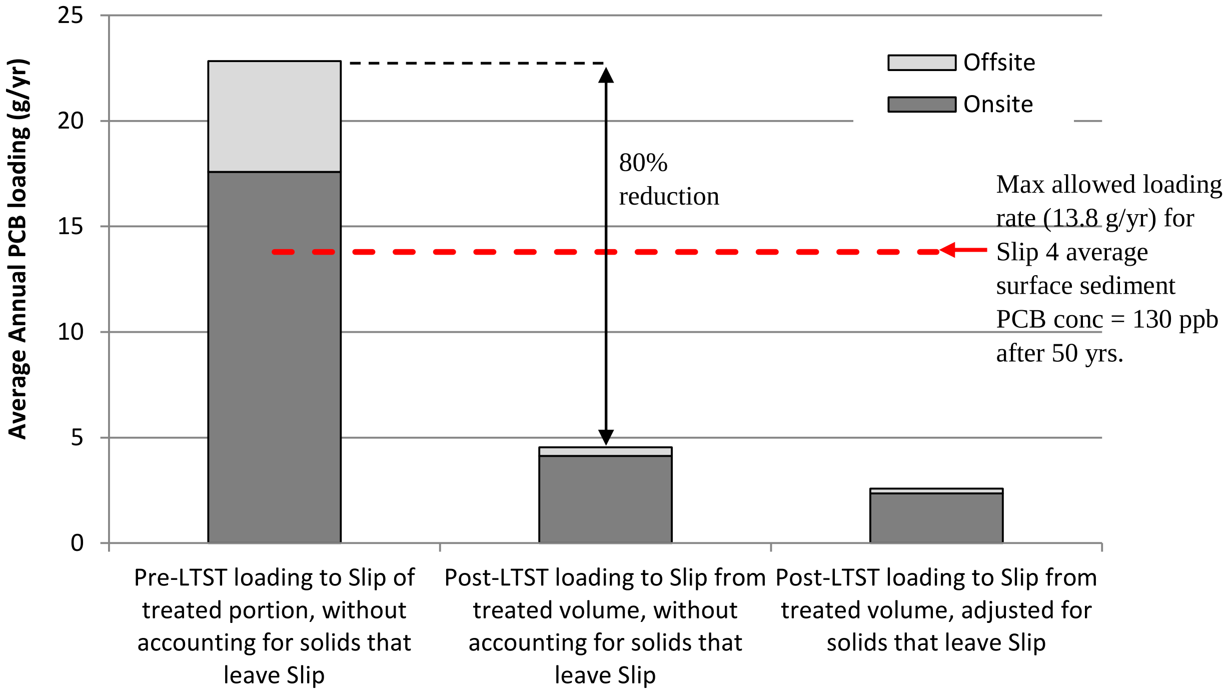

Figure 6. Onsite vs. offsite PCB loads to Slip 4 from treated flow volume only. Loading calculations assume ND=0.5DL and that PCB loading is proportional to flow volume. Average of pre- and post-STST installation PSD data used to calculate solids leaving Slip 4.

Surface Sediment PCB Concentrations in the Slip

Average Slip-wide sediment PCB concentrations are estimated for the 10 cm surface layer based on a mass balance of discharged solids completely mixing within the clean sand cap. For this calculation, a settled solids density of 2.2 g/cm^3 and a Slip 4 surface area of 240,500 square feet are assumed (SAIC, 2010a). Studies of PSD of solids collected during storm events suggest that this density value may be high for the particle size of interest for this analysis (<63 µm), and that a more accurate value would be approximately 1.4-1.5 g/cm^3 (Li 2008, Pitt 2011). The effect of lowering the density used in the calculations would be to raise the critical settling size (in other words, more solids would be expected to leave the Slip). As a conservative measure, therefore, the density of 2.2 g/cm^3 was used for this analysis. The predicted surface sediment PCB concentrations are shown in Figure 7 over a 50-year simulation period. For the pre-LTST PCB loading rate, the State sediment standard of 130 ppb is reached in 18 years, whereas this standard is reached in 34 years based on the post-LTST loading rate prior to adjusting for solids that leave the Slip. By comparison, the 2 ppb PCB comparison threshold based on the RAO1 Feasibility Study is met within the first year. Again by comparison, these times become 4 and 7 years, respectively, when assuming a surface sediment mixing depth of just 2 cm. To achieve the 130 ppb State sediment standard after 50 years, an average annual PCB loading rate of 13.8 g/year is required (i.e., the "maximum allowed loading rate"). Figure 7 shows these three loading rate scenarios – pre-LTST, post-LTST (without accounting for solids that leave the Slip, and with error bars to illustrate the impact of the ND assumption for treated flows, as discussed previously), and the maximum allowed loading rate. Since a fraction of the fine discharged solids is expected to leave the Slip, additional post-LTST scenarios were run for comparison with the 130 ppb/50 year target. Figure 8 shows the post-LTST "no solids leaving" results again (with error bars to illustrate the impact of the assumed PCB concentration for untreated flows, as discussed previously), in comparison to post-LTST scenarios that account for solids leaving the Slip based on pre- and post-STST installation PSD data for untreated flows. Another scenario that uses the average of these two PSD datasets, as shown in Figure 9, is recommended by the Panel for use in representing final post-LTST conditions (and accounting for solids that leave the Slip).

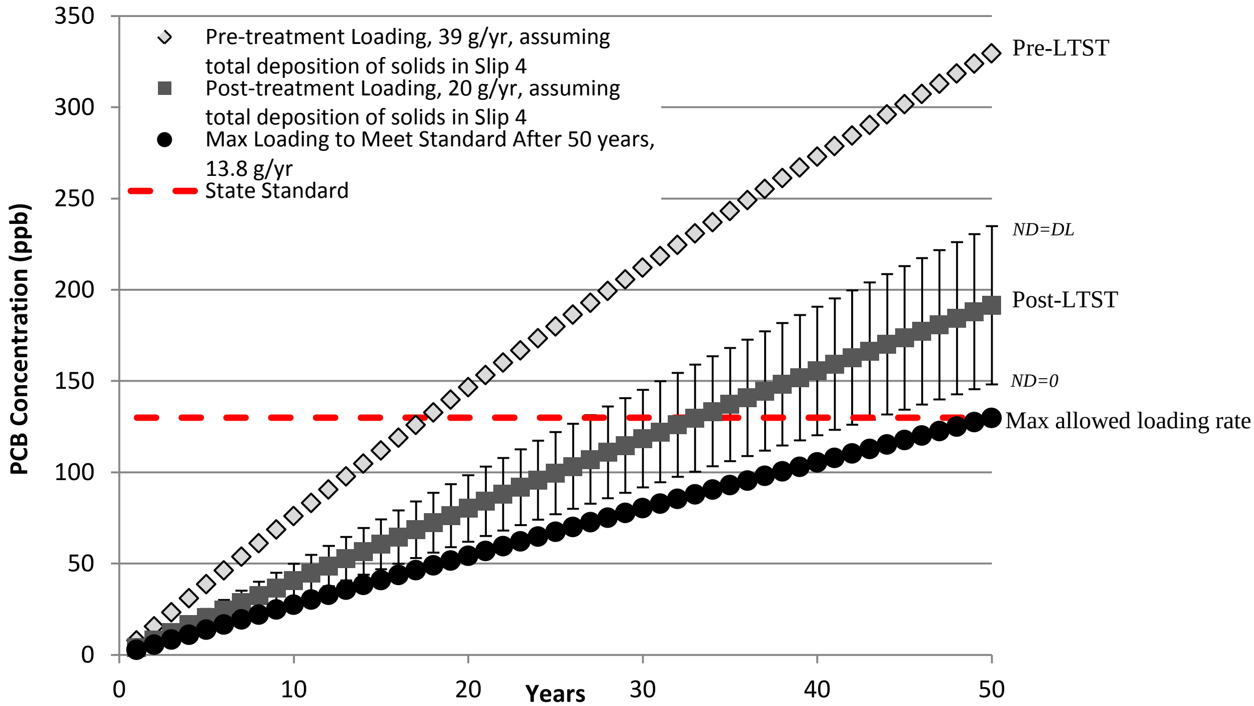

Figure 7. Predicted Pre- and Post-LTST Slip 4 surface sediment PCB concentrations over 50 years at different loading levels, without consideration for fraction of discharged solids that leave the Slip. Post-treatment loading line assumes non-detect results equal to half of detection limit. Error bars on Post-treatment loading line reflect interpretation of non-detect PCB concentrations as zero (lower whiskers) or as equal to the detection limit (upper whiskers) *for the treated CESF effluent flow only*, which represent 22% of the total post-LTST PCB load to the Slip (assuming ND=0.5DL), and which are expected to be below detection for PCBs in water using method 8082 (aroclors). The State sediment standard assumes no adjustment for actual total organic carbon content of sediment in Slip 4.

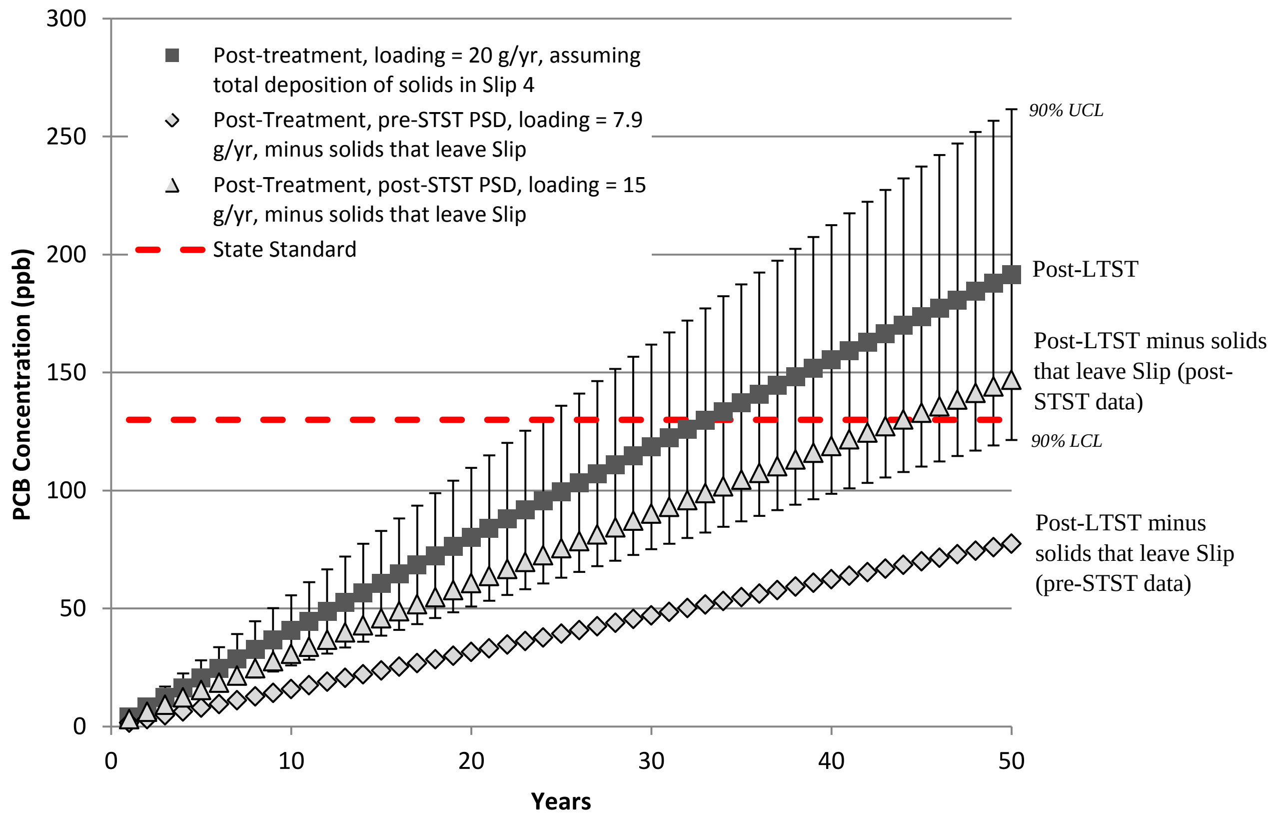

Figure 8. Predicted Post-LTST Slip 4 surface sediment PCB concentrations with and without consideration of discharged solids that leave the Slip. Error bars on post-treatment loading line (without solids exiting) reflect upper and lower 90% confidence levels (UCL and LCL, respectively) on the average PCB concentration for the untreated flows at the lift station, which contribute the majority of the PCB load to the Slip. Non-detect results for the treated flows are interpreted here as equal to half the detection limit.

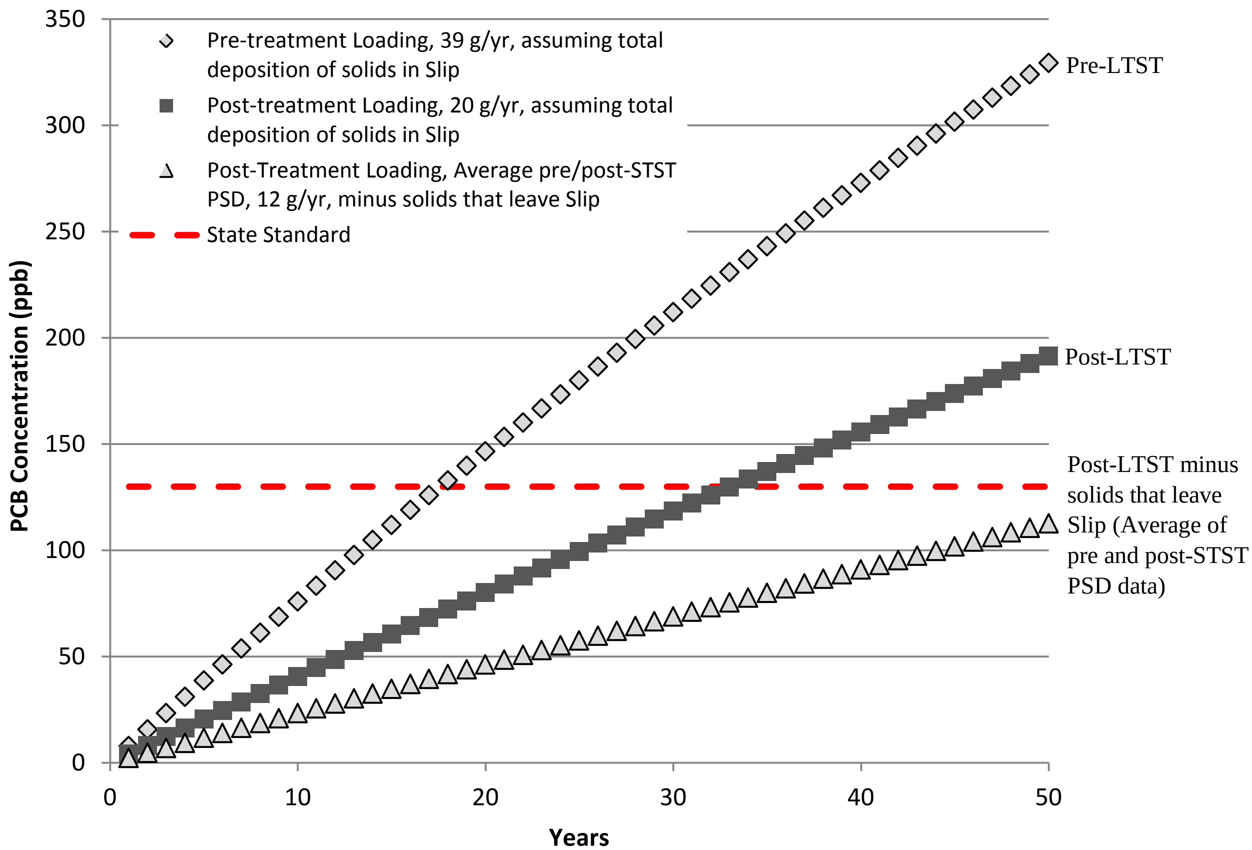

Figure 9. Predicted Post-LTST Slip 4 surface sediment PCB concentrations with and without consideration of discharged solids that leave the Slip, with the latter based on an average of the pre- and post-STST installation filtered solids PSD data, which is the Panel's recommended data interpretation method. Non-detect results for the treated flows are interpreted here as equal to half the detection limit.

Based on this analysis, when solids smaller than the critical settling size of 44 µm are predicted to leave the Slip, the State standard of 130 ppb is not exceeded within 50 years. Calculations were done to test the sensitivity of this result to the critical settling size, and it was found that particles as small as 15 µm could be assumed to settle without the State standard being exceeded within 50 years.

These PCB loading forecasts do not account for the reductions associated with onsite and offsite PCB source controls and natural degradation over the 50 year simulation period. The Panel is confident that the planned source removal/reduction activities that will be implemented by Boeing will be effective and that these activities will reduce PCBs in the untreated storm and baseflows. The effect of these activities then would be to gradually reduce the slope of these loading curves (as shown in the charts above) each year, thereby delaying the year in which the 130 ppb threshold is exceeded. The magnitude of these reductions will not be as large as has been experienced to date, because the largest or most concentrated sources have likely already been addressed. Nevertheless, Boeing knows of specific sources that remain and has developed plans to remove these sources. Consequently, continued reductions are anticipated. Indeed, this is consistent with the experiences of Panel members at other industrial sites, including refineries, mines and U.S. Department of Energy industrial sites. The Panel was interested in whether we could develop a defensible methodology to project the magnitude of future PCB reductions in stormdrain discharges due to the implementation of additional source controls. Unfortunately, without the benefit of more detailed, site-specific analysis, we have not been able to develop a defensible methodology. Consequently, for the purposes of this technical memorandum, the conservative assumption was made that there will be no reduction in current PCB concentrations in untreated stormwater runoff from the site attributable to Boeing's continued source removal/reduction activities. For purposes of illustration of the possible impact source reductions could have, however, calculations were done to represent a 50% reduction in PCB discharges after 10 years with no further reduction after. A time series showing expected surface sediment concentrations under this scenario is shown in Figure 10. Note that for simplicity and to be more conservative, this figure implies that all reductions would occur after year 10, whereas a more likely scenario would be that the reductions occur incrementally over the 10 year period. This would lead to a lower concentration in surface sediments at the end of the 50 years than what is currently shown in the figure.

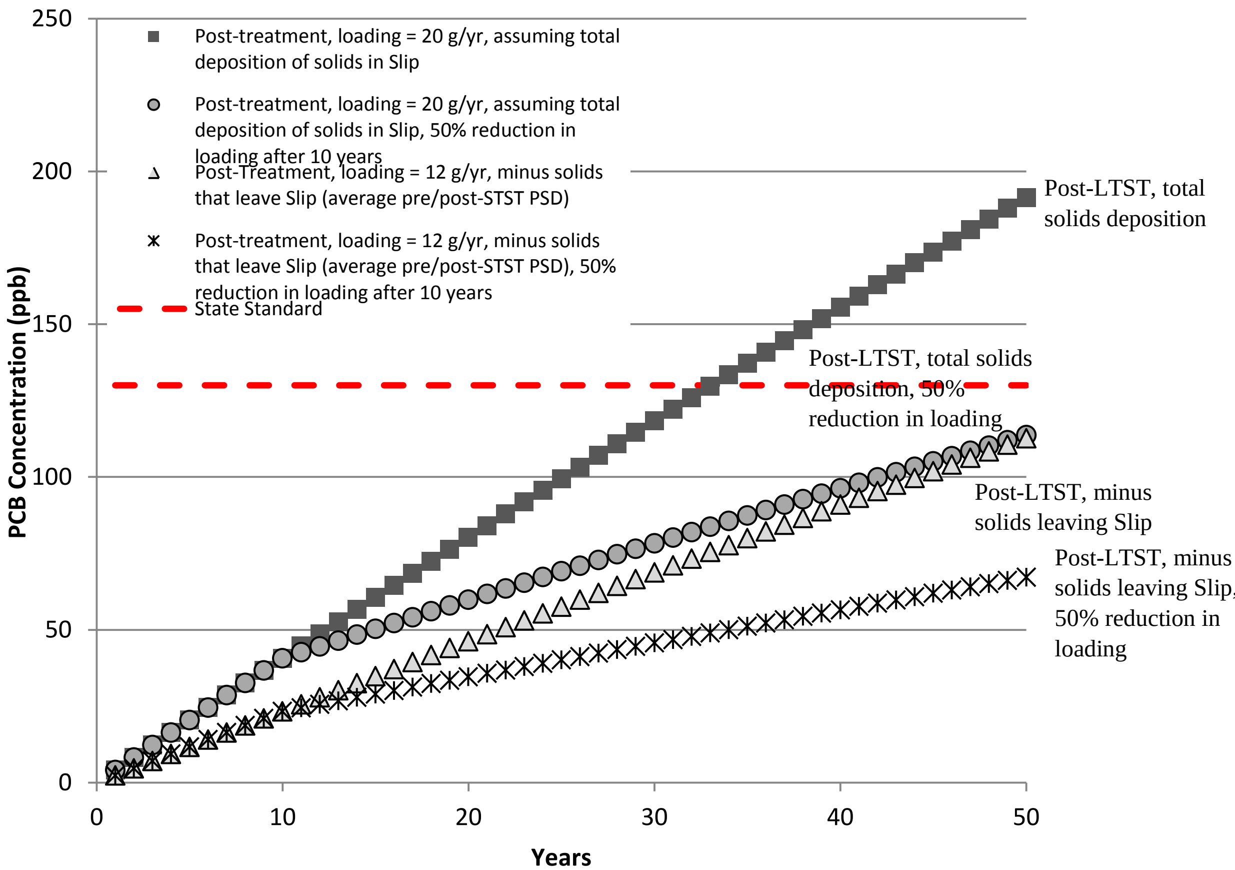

Figure 10. Predicted Post-LTST Slip 4 surface sediment PCB concentrations with and without the assumption of a 50% reduction in loading after 10 years and also with and without consideration of discharged solids that leave the Slip, with the latter based on an average of the pre- and post-STST installation filtered solids PSD data, which is the Panel's recommended data interpretation method. Non-detect results for the treated flows are interpreted here as equal to half the detection limit.

In addition, a substantial portion of the PCB loading from the Slip comes from offsite (KCIA) areas, and Figure 11 is provided to indicate the PCB surface sediment concentration trajectory that would be due solely to the NBF load over time (i.e., as if the offsite loading was completely treated or routed away from the Slip). The post-LTST PCB surface sediment concentration trajectory has a significantly milder slope with only NBF discharging to the Slip given the fact that a substantial portion of the runoff volume and solids loads to Slip 4 are generated from the approximately 190 acre offsite area. Consistent with previous recommendations from the RAWP (Geosyntec, 2011a), as feasible, given sampling safety concerns relative to the flightline, the Panel recommends that whole water PCB samples and discharge measurements be collected at each of the laterals along the property boundary during both baseflow and stormflow conditions to reduce the uncertainty of this estimated offsite loading contribution.

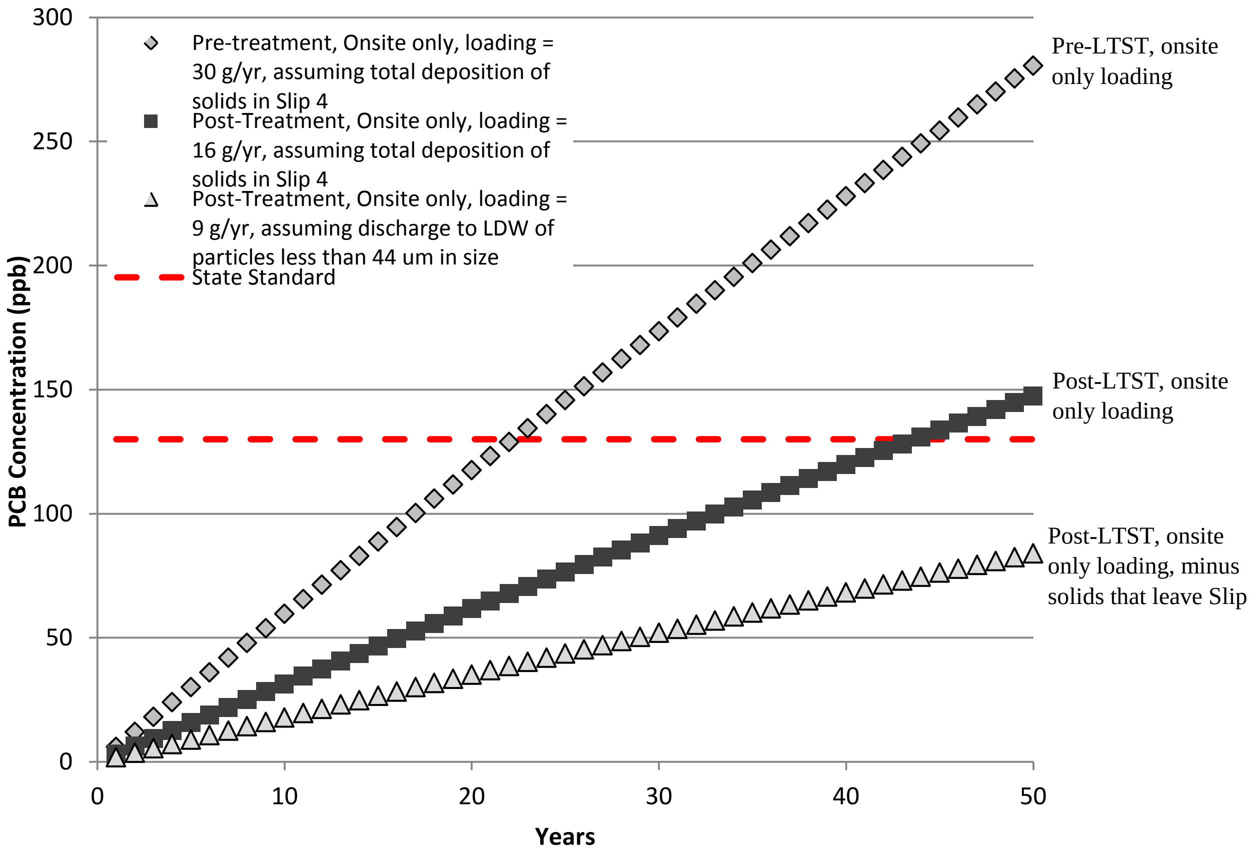

Figure 11. Predicted Post-LTST Slip 4 surface sediment PCB concentrations based on onsite PCB load contributions only (i.e., 77% of total load). Non-detect results for the treated flows are interpreted here as equal to half the detection limit. Average of pre- and post-STST installation PSD data used to calculate fraction of solids exiting Slip.

Conclusion and Recommendations

The recommended loading-based yearly average interim goal (IG) is 0.018 µg/L total PCBs in water. This value is based on the calculated "maximum allowable loading rate," or the average annual PCB mass that is expected to settle in the Slip (13.8 g) that is conservatively protective of the State sediment standard over a 50-year period. Applying a factor to account for the estimated 43% of discharged solids that is expected to exit the Slip, the maximum allowable PCB load that may be discharged into the Slip is 24 g/year. The recommended loading-based yearly average IG (0.018 µg/L) is then determined by dividing by the estimated average annual runoff volume at the lift station, or 1080 AF/year. This solids loading-based IG is intended to accompany the water IG, or the 0.03 µg/L total PCBs Washington State marine chronic water quality criterion, which is for protection of aquatic life. It is recommended that a full year of monitoring be performed to collect lift station sample results for both wet and dry weather seasons in order to evaluate the sampling methodology, the assumptions used to develop the load-based IG and to compare the average annual value to the recommended load-based IG. It is highly unlikely that a one-year monitoring period would lead to any significant environmental risk because increases in sediment PCB concentrations will occur very gradually over time and will not be potentially significant until decades into the future, if ever.

It should be noted that this recommended IG is very close to the typical Aroclor reporting limit for method 8082 (typically 0.01 µg/L). Furthermore, since LTST CESF discharged effluent is expected to be ND the vast majority of the time (exceptions might be during large storms when flowrates to the lift station exceed the 1500 gpm design rate), it is essential that the compliance reporting and assessment procedure explicitly specify how to deal with ND results. If detection limit values are substituted, then the discharge will very likely be out of compliance. Therefore, we suggest a ND substitution value of zero be considered for this process. Furthermore, it should be noted that while lift station filtered solids PCB data would not be used for compliance assessment purposes based on this proposed approach, it is our recommendation that this data continue to be collected during the initial wet and dry season operation of the system to allow for confirmation of the very low (generally ND) water concentrations in CESF effluent.

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