Pollutant Removal from Stormwater with Biochar Amended Bioretention Soil Media (BSM)

Project Report

Prepared for:

Bay Area Stormwater Management Agencies Association

Prepared by:

OWP AT SACRAMENTO STATE

EOA inc.

SFEI

KINNETIC LABORATORIES INCORPORATED

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BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practices
BSM	Bioretention Soil Media
CW4CB	Clean Watersheds for a Clean Bay
DQO	Data Quality Objective
EPA	Environmental Protection Agency
In/hr	Inches per hour
KLI	Kinnetic Laboratories, Inc.
K_{sat}	Saturated Hydraulic Conductivity
LCS	Laboratory Control Sample
MDD	Maximum Dry Density
MDL	Method Detection Limit
MQO	Measurement Quality Objectives
MRP	Municipal Regional Permit
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MS4	Municipal Separate Storm Sewer System
ND	Non-detect
NPDES	National Pollutant Discharge Elimination System
OWP	Office of Water Programs
PCBs	Polychlorinated Biphenyls
PG&E	Pacific Gas and Electric Company
PMT	Project Management Team
POC	Pollutants of Concern
ppb	parts per billion
ppm	parts per million
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RL	Reporting Limit
RMP	Regional Monitoring Program
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SFEI	San Francisco Estuary Institute
SSC	Suspended Sediment Concentration

TMDL Total Maximum Daily Loads

TOC Total Organic Carbon

EXECUTIVE SUMMARY

The Bay Area Stormwater Management Agencies Association (BASMAA) implemented this regional study to evaluate the effectiveness of biochar-amended bioretention soil media (BSM) to remove polychlorinated biphenyls (PCBs) and mercury from stormwater collected from storm drains within the area covered by the Municipal Regional Permit (MRP; Order R2-2015-0049)[1] that are known to be impacted by diffuse PCB sources. The MRP requires that permittees[2] provide information to support the implementation of the wasteload allocations for mercury and PCB total maximum daily loads (TMDLs) as described in MRP Provisions C.11 and C.12. This study also contributes to implementation of MRP Provision C.8.f (Pollutant of Concern (POC) Monitoring) Priority #3, "Management Action Effectiveness," which focuses on monitoring the effectiveness of specific management actions in reducing or avoiding loads of mercury and PCBs in municipal separate storm sewer system (MS4) discharges.

A prior BASMAA study, the Clean Watershed for a Clean Bay (CW4CB) project, found that BSM amended with biochar substantially improved PCBs removal compared to the standard BSM specified in MRP Provision C.3 at the same location (BASMAA 2017). The BSM contained 60 percent sand and 40 percent compost. The amended BSM contained 75 percent BSM and 25 percent biochar, which equates to 45 percent sand, 30 percent compost, and 25 percent biochar. Only one biochar source was tested, so it was unknown whether there would be substantial performance differences among differing biochar sources.

The goal of this study was to identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs. The primary management question supporting that goal was: "Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?" And the particular purpose of the laboratory testing in this study was: "screen alternative biochar-amended BSM and identify the most promising for further field testing." (Monitoring Study Design, Appendix A)

The study was carried out by a project team comprised of the Office of Water Programs at Sacramento State (OWP), EOA Inc., Kinnetic Laboratories, Inc. (KLI), the San Francisco Estuary Institute (SFEI), and ALS Environmental (ALS). A BASMAA project management team (PMT) consisting of representatives from BASMAA stormwater programs and municipalities provided oversight and guidance to the project team throughout the monitoring study. Stormwater was collected in March and April of 2018, and the BSM testing was conducted in April and May of 2018.

METHODS

This study compared the removal of PCBs and mercury from stormwater in laboratory column tests of five locally-available biochars produced from a variety of feedstock and methods admixed at a 1-to-3 ratio by volume with BSM. The biochars used in this study were compared against each other and against a standard BSM. Due to availability, the BSM contained 65 percent sand and 35 percent

1 http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/Municipal/R2-2015-0049.pdf

2 A total of 76 cities, towns, unincorporated counties, and flood control and water conservation districts covered by the MRP.

compost, which is still within the acceptable range specific in the MRP Provision C.3 and the BASMAA specification (BASMAA 2016). The BSM-biochar blend ratio matched the CW4CB study (75% BSM and 25%). The resulting amended BSM contained 49 percent sand, 26 percent compost, and 25 percent biochar. Each of the test biochars was mixed with the standard BSM and placed in 7.5-inch-diameter glass columns to a depth of 18 inches, typical of standard field installations. One additional column was prepared as a control and filled with 18 inches of standard BSM. The stormwater used for all tests was collected during two storms from two sites that were located in the portion of the San Francisco Bay Area subject to the MRP and that had previously observed elevated levels of PCBs. Four sampling runs were performed on the columns, three runs using undiluted stormwater on all columns and the fourth run using stormwater diluted at a one-to-nine ratio to test removal effectiveness at lower influent concentrations on two[3] columns. Column influent and effluent samples were collected during each test run and analyzed for PCBs, total mercury, total organic carbon (TOC), suspended solids concentration (SSC), and turbidity.

RESULTS

Influent concentrations of PCBs (9,860 to 19,600 picograms/liter or pg/L) were consistent with samples previously taken at the sampling sites during the CW4CB study (BASMAA 2017). The standard BSM control column had effluent concentrations of PCBs similar to the standard BSM tested alongside biochar in the CW4CB study. Two of the five biochar-amended BSM columns, Phoenix and Agrosorb, exhibited lower effluent concentrations of PCBs than the standard BSM column for all test runs. A third column, BioChar Solutions, produced three effluents with lower concentrations and a single effluent sample at a slightly higher concentration than that produced by the standard BSM. The remaining two biochar-amended BSM columns had one or two effluent samples that were much higher than those from the standard BSM, and one sample showed a substantial export of PCBs. However, these high PCB concentrations corresponded to unusually high infiltration rates compared to the testing conditions for all other data, suggesting channelizing or otherwise insufficient compaction of media within the column and so these data are not used in analysis and graphs. The remaining results collected for those two biochars under typical infiltration conditions exhibited PCB removal, and at least half of those results were superior to BSM.

Mercury influent concentrations (9.9-10.2 ng/L) were very similar across all samples. Mercury removal across all test runs occurred in two biochar-amended BSM columns, Phoenix and Agrosorb. The other columns showed variable treatment, including some export of mercury (the worst of which corresponds to a sample removed from the dataset due to abnormally high infiltration rates). The standard BSM column was the only column to export mercury for all test runs.

CONCLUSIONS

All five biochar-BSM blends showed evidence of overall improved PCB and mercury performance compared to the standard BSM. The results support these additional observations:

- Phoenix, Sunriver, BioChar Solutions, and Agrosorb appear to offer improved PCB removal compared to standard BSM and the other biochar-amended BSM.

3 The effluent of one column (CO6) in the dilution run could not be analyzed by the lab at the time of this study report so it is presumed lost.

- Phoenix and Agrosorb appear to offer improved mercury removal compared to standard BSM and the other biochar-amended BSM.
- Biochar may decrease performance variability from variable influent concentrations compared to standard BSM.
- Based on a single run on one column to explore removal at lower influent concentrations, biochar-amended BSM provided removal of PCBs at an influent concentration of 2,100 pg/L. BSM performance at this lower influent concentration could not be reported due to the sample being lost. Neither BSM nor biochar-amended BSM provided removal of mercury at an influent concentration of 3.00 ng/L.
- High initial infiltration rates correlated to poor performance (higher rates are associated with short-circuiting and higher pore velocities).
- Saturated hydraulic conductivity was poorly correlated to the falling head infiltration rates estimated during the water quality sampling runs, so biochars that were eliminated from column testing based on saturated hydraulic conductivity tests may be candidates for future testing.

RECOMMENDATIONS

Based on this study, biochar shows promise in marginally increasing performance; however, increased benefit relative to increased cost was not analyzed. With such limited data, benefit/cost analysis may be more appropriate after collection of substantial field data. Because of the marginal increase in performance, standard BSM should be a component of future side-by-side testing of biochar-amended BSM. If further biochar testing is pursued, the following recommendations should be considered.

If selecting biochar for PCB removal, the best-performing biochars were Phoenix, Sunriver, BioChar Solutions, and Agrosorb. If mercury removal is a design consideration, Phoenix and Agrosorb should be further studied. Because there was no correlation between performance and cost, less costly biochars that were not tested here (including those that were eliminated from this study based on possible inappropriate use of saturated hydraulic conductivity test procedures) might be considered for further field testing alongside one or more biochars from this study.

Site selection should consider the collective experience in this and other studies on irreducible minimum concentrations. This study suggests that value may be around 1,000 pg/L for PCBs. It is unclear for total mercury. Watersheds likely to have concentrations near or below irreducible concentrations should be avoided.

The most substantial enhancement to performance may be the use of outlet controls to increase contact time with biochar-amended BSM. Outlet controls should be considered for further study of both biochar-amended and standard BSM.

And finally, further development of procedures for laboratory tests of hydraulic conductivity or infiltration rate is recommended. Improving correlation between field-measured infiltration rates and laboratory test procedures for hydraulic conductivity may avoid screening out BSM blends and amendments based on tests that do not relate to field conditions.

1 INTRODUCTION

1.1 BACKGROUND

PCBs and mercury are pollutants of concern in the San Francisco Bay Area and removal of both from stormwater runoff using BSM amended with biochar has shown some promise in a previous investigation (BASMAA 2017).

Biochar is a highly porous, granular charcoal produced from a variety of organic materials and primarily marketed as a soil amendment. The majority of biochar research conducted to date has focused on agricultural applications, where biochar has been shown to improve plant growth, soil fertility, and soil water holding, especially in sandier soils. But investigation of stormwater treatment benefit is limited, especially for removal of mercury or PCBs.

A recent laboratory study on the effect of biochar addition to contaminated sediments showed that biochar is one to two orders of magnitude more effective at removing PCBs from soil pore water than natural organic matter, and may be effective at removing methylmercury but not total mercury (Gomez-Eyles et al. 2013). A laboratory column test study to determine treatment effectiveness of 10 media mixtures showed that a mixture of 70% sand/20% coconut coir/10% biochar was one of the top performers and less expensive than similarly effective mixtures using activated carbon (Kitsap County 2015). Liu et al. (2016) tested 36 different biochars for their potential to remove mercury from aqueous solution and found that concentrations of total mercury decreased by >90% for biochars produced at >600°C and by 40–90% for biochars produced at 300°C.

A prior BASMAA study, the CW4CB project (BASMAA 2017), examined whether BSM amended with biochar would substantially improve PCBs removal compared to the standard BSM specified in MRP Provision C.3. In the CW4CB study, the effect of adding a biochar to BSM was evaluated using data collected from two bioretention cells (LAU 3 and LAU 4) that treat roadway runoff just outside the Richmond Pacific Gas and Electric (PG&E) Substation at 1st Street and Cutting Boulevard. At this site, a standard bioretention cell (LAU 3) contains standard BSM (60 percent sand and 40 percent compost) while an enhanced bioretention cell (LAU 4) contains a mix of 75 percent standard BSM and 25 percent pine wood-based biochar (by volume), which equates to 45 percent sand, 30 percent compost, and 25 percent biochar. The results suggest that the addition of biochar to BSM is likely to increase removal of PCBs in bioretention best management practices (BMPs; BASMAA 2017).

Figure 1 shows a cumulative frequency plot of influent and effluent concentrations of PCBs for the two CW4CB bioretention cells. Although influent concentrations at the two cells were generally similar, effluent concentrations were much lower for the biochar enhanced bioretention cell (LAU 4) compared to those for the standard bioretention cell (LAU 3). The results for total mercury were different from those for PCBs, with both cells demonstrating little difference between influent and effluent concentrations. These CW4CB monitoring results suggest that the addition of biochar to BSM may increase removal of PCBs from stormwater. There was little effect on total mercury.

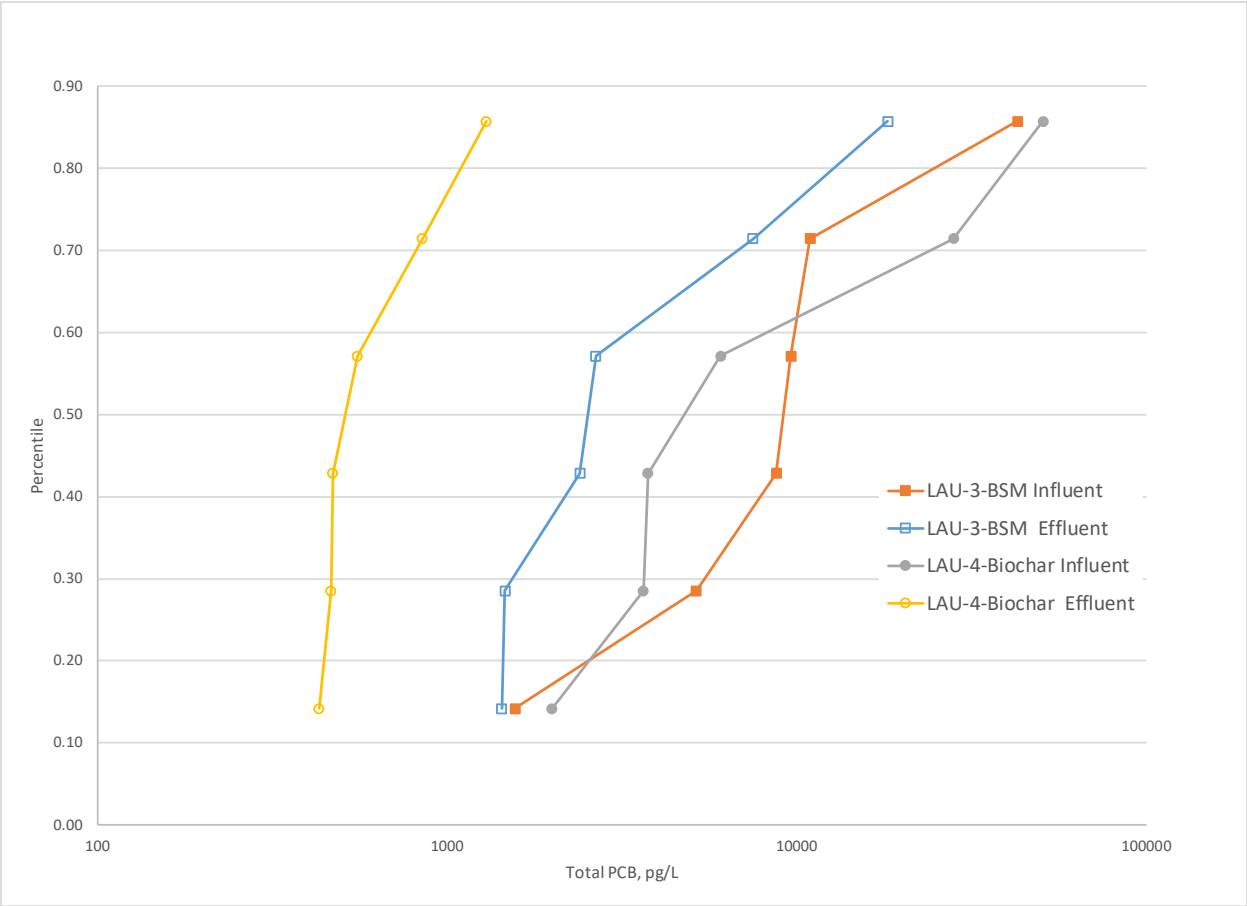

Figure 1. Cumulative Frequency Distribution of Total PCB Influent Concentrations for Bioretention Media with and without Biochar from CW4CB (BASMAA, 2017a)

Monitoring of the two bioretention cells at the CW4CB pilot site showed greater PCBs removal for a biochar-amended BSM than for standard BSM. However, to date, sampling has been limited to one test site and one biochar amendment. Besides the CW4CB study, there are no published literature studies on field PCBs and mercury removal from stormwater using biochars. Additional field testing can confirm the effectiveness of biochar in bioretention, but very little data is available on the selection of biochar for further field study. Laboratory testing of different biochars using actual stormwater from the Bay Area is a cost-effective tool to screen biochar media to identify good candidates for PCBs removal in future field testing.

1.2 Study Goals

The goal of this study, as identified in the Monitoring Study Design (Appendix A), was to identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs. The primary management question supporting that goal was: "Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?" And the particular purpose of the laboratory testing in this study was: "screen alternative biochar-amended BSM and identify the most promising for further field testing."

The MRP requires that permittees provide information to support the implementation of the wasteload allocations for mercury and PCB total maximum daily loads (TMDLs) as described in MRP Provisions C.11 and C.12. This study also contributes to implementation of MRP Provision C.8.f (POC Monitoring) Priority #3, "Management Action Effectiveness," which focuses on monitoring the effectiveness of specific management actions in reducing or avoiding loads of mercury and PCBs in MS4 discharges.

The MRP infiltration rate requirements are described in Provision C.3.c of the MRP. This provision states: "Biotreatment (or bioretention) systems shall be designed to have a surface area no smaller than what is required to accommodate a 5 inches/hour stormwater runoff surface loading rate, infiltrate runoff through biotreatment soil media at a minimum of 5 inches per hour, and maximize infiltration to the native soil during the life of the Regulated Project." In addition to the 5 inches per hour MRP requirement, for any application that uses a non-standard BSM, the recently updated BASMAA specification requires "certification from an accredited geotechnical testing laboratory that the bioretention soil has an infiltration rate between 5 and 12 inches per hour" (BASMAA 2016).

To accomplish the purpose of this study, the following tasks were identified:

1. Collect all readily available west coast biochar;

2. Test each biochar-amended BSM and select those for water quality testing that meet infiltration requirements using saturated hydraulic conductivity tests;

2. Compare performance among select media mixes with biochar using influent-effluent column tests with Bay Area stormwater for PCBs and mercury removal;

3. Estimate whether PCBs and mercury reduction can occur at lower concentrations by using influent-effluent column tests for the best mix with diluted Bay Area stormwater

Because the purpose of the study design is to screen biochars for further field testing, the number of samples was spread out over as many biochars as possible while still producing enough data points for each biochar to distinguish large performance differences between biochars and BSM similar to what was observed in the CW4CB study.

This report presents the results of the BSM testing study conducted from March through May, 2018. The study was implemented by a project team comprised of the Office of Water Programs (OWP), EOA Inc., Kinnetic Laboratories, Inc. (KLI), the San Francisco Estuary Institute (SFEI), and ALS Environmental (ALS). A BASMAA project management team (PMT) consisting of representatives from BASMAA stormwater programs and municipalities provided oversight and guidance to the project team throughout the study.

The Methods section explains the study approach and methods used to complete this study. This is followed by the Results section that includes PCBs and mercury removal data. The Conclusions and Recommendations section summarizes the findings of this study and gives brief recommendations for media selection for future field sites. Appendices include the Monitoring Study Plan, Sampling and Analysis Plan and Quality Assurance Project Plan, Proposed Biochar Selection Factors, Hydraulic Test Results, Biochar Particle Size Distribution, and Water Quality Laboratory Reports.

2 METHODS

2.1 STUDY APPROACH

The study approach called for: 1. Gathering biochar products that are readily available locally (west coast) at the time of the study; 2. Collecting product information, including feedstock, pyrolysis temperature; 3. Testing saturated hydraulic conductivity of each biochar blended into standard BSM at a 1-to-3 ratio; 4. Selecting five biochars; and 5. Performing three runs through side-by-side column tests alongside a standard BSM serving as a control using Bay Area stormwater; and 5. Performing a single run on two columns[4] using diluted Bay Area stormwater. Details and adjustments to this approach are described below.

2.2 INITIAL MEDIA SELECTION AND BLENDS

A total of nine samples from all identified locally available biochar producers were gathered. The samples were mixed at a ratio of one-to-three by volume with standard BSM to match the CW4CB biochar-amended pilot project amendment ratio. All biochars used in this study were unmodified (i.e., the biochars were not sieved, rinsed, or chemically treated in any way; all were used as received from their manufacturers). When blending the biochar-amended BSM, care was taken to use a representative subsample of the biochar. The BSM vendor was L.H.Voss Materials, and the BSM consisted of 65% sand and 35% compost by volume. These percentages are slightly different from the CW4CB study (60% sand and 40% compost), but still within the requirements of the MRP Provision C.3 and BASMAA standard. A precise match could not be accommodated due to the project schedule and approaching stormwater sampling opportunities.

2.3 BIOCHAR SELECTION

Primary biochar selection factors included availability in the Western United States, to ensure any biochar tested would likely be available for use in the San Francisco Bay Area, and acceptable hydraulic conductivity. Initially, the goal of hydraulic testing was to identify biochar-BSM blends that had a hydraulic conductivity in an acceptable range of 5 to 12 in/hr (Appendix C). However, destruction of biochar during the Modified Proctor compaction procedure required adjustments in procedures that made the 5 to 12 in/hr an inappropriate comparison. Instead, biochar-BSM blends that provided the most consistent hydraulic conductivity relative to the standard BSM were selected for testing. Secondary biochar selection factors included a range of pyrolysis temperatures and costs. Up to five biochars could be tested under limitations of timing, resources, and desired minimum samples per column (Appendix A).

2.4 HYDRAULIC TESTING

The BASMAA specification for alternatives to BSM requires testing of saturated hydraulic conductivity (k_{sat}) at a compaction of 85% maximum dry density (MDD) using the Modified Proctor method (BASMAA 2016). Because of the observation that the standard level of compaction was crushing the biochar particles, and thus changing their characteristics, it was decided to compact to 85% MDD using the Standard Proctor method, which uses reduced energy. Before hydraulic testing, a compaction curve was developed by the Standard Proctor method to determine MDD for each biochar-amended BSM.

4 One column was not analyzed due to a sample that is presumed lost after being shipped to the water chemistry laboratory.

Hydraulic testing was used as a screening tool to select the five media for the columns from the nine media tested. This testing, using deionized water that was de-gassed under vacuum and agitation overnight, was performed according to ASTM D2434 Standard Test Method for Permeability of Granular Soils (Constant Head) using a six-inch-diameter permeameter. All test equipment was purchased from the Humboldt Manufacturing Company.

2.5 Column Setup and Seasoning Runs

Six columns were constructed for this study, each column consisting of a 36-inch-long glass pipe with an internal diameter of 7.5 inches (Figure 2). Each column was capped with a Teflon plate that was milled to create a circular channel to nest the pipe in and make a water tight seal. Seven drainage holes were milled through each plate. To create flow paths for draining water to each of the seven drainage holes, each plate had additional drainage veins milled in the top side of each plate. To match each biochar-amended BSM column flow rate to the control BSM flow rate (i.e., outlet control), stainless steel screws were used to block the drainage holes (Figure 3). To create a water tight seal between Teflon cap and glass pipe without an adhesive or caulking (which could adsorb PCBs), ratcheting straps were used to apply force to the top of the glass columns to keep them firmly seated in their Teflon caps. Plugging the drainage holes and filling the empty column with water proved the seal was sufficient. Stainless steel mesh screen (number 40, opening size nominally 0.42 mm) was cut to shape and placed on top of the Teflon cap to keep media from filling the drainage channels and exiting the column. A two-inch layer of sand was placed on top of the stainless steel screen, followed by 18 inches of either the standard BSM control media or one of the five biochar-amended BSM.

Figure 2. Column test setup at Sacramento State showing five of six columns

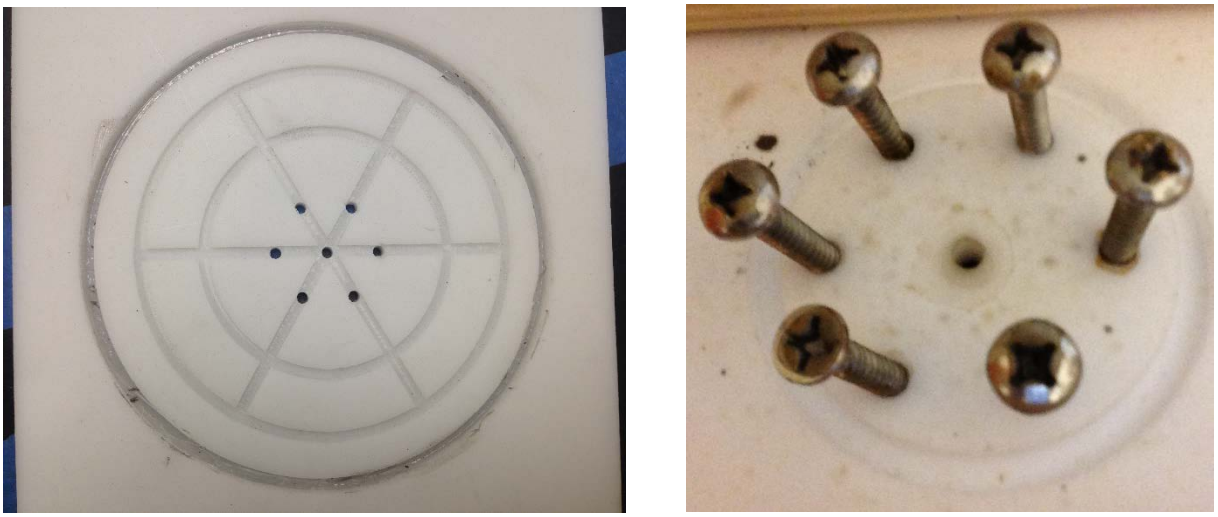

Figure 3. Teflon Column Cap with Drainage Veins and Holes (left) and Stainless Steel Throttling Screws (right)

Initial attempts at media placement and top-down hydro-compaction failed to achieve adequate infiltration rates so a wet placement technique was used to introduce water from the bottom of the column via a water supply cap fitted to the invert column cap. While placing the media in 1- to 2-inch lifts, water was slowly introduced and allowed to flow up through the media. As the previous lift was saturated and water reached the surface, an additional lift of media was placed. This technique allowed the air in the pore space of the media to be pushed out of a relatively thin overlying layer of media. Once all 18 inches of media were placed, the water was allowed to continue rising above the surface of the media until six inches of ponded water was achieved. Once this occurred, the water supply cap at the bottom of the column was removed and the water was allowed to drain. This draining of the six inches of ponded water served to hydraulically compact the media. An additional volume of water—equivalent to a depth of 18 inches of water—was added slowly to the top of the column to maintain the six inches of ponded water until the column was fully drained.

After the columns were filled with media and hydraulically compacted, the media was tested again to verify that infiltration rates were similar to field conditions. Columns were saturated and a falling head test was performed. The standard BSM had the slowest drain time and many of the biochar-amended columns had much faster drain times. Once the drain times had stabilized, a minimum level of outlet control was used on five columns so that the drain time in each column was more consistent with the slowest draining column.

During the first sampling run it was observed that all column effluents had high turbidity. To further stabilize the columns, two "seasoning" runs were performed. Turbidity was the only water quality measurement taken during these seasoning runs. Each run applied 18 inches of stormwater to the column. These seasoning runs were successful in decreasing turbidity in the effluent. Because stormwater was used, additional pollutant loading to the columns occurred during these two runs.

2.6 Stormwater Collection

Stormwater used during the seasoning and sampling runs was collected during storm events at two sites within the area covered by the MRP that were identified in previous studies as having consistently elevated concentrations of PCBs in the runoff (BASMAA 2017). Both sites were tree well locations that

were installed in Oakland, CA, and tested during the CW4CB project. In addition to being previously monitored, tree well 2 (Ettie St and 28th NW) and tree well 6 (Poplar and 26th SW) were considered safe locations to conduct stormwater monitoring. To collect the necessary volume of stormwater for the study, OWP staff accompanied KLI staff to each site during two storm events and pumped stormwater directly from the street gutter into clean five-gallon glass carboys. These were then transported back to OWP in Sacramento, CA, by OWP staff and stored at room temperature until use. Stormwater had to be collected before the columns were ready for experimental runs. Complications in acquiring suitable BSM, hydraulic testing, and preparing columns delayed the experiment for three months, far enough into the wet season that the likelihood of ample rain events was quickly diminishing. To hedge against a lack of late-season rain events, sufficient stormwater was collected from two storm events to perform all sampling runs and seasoning runs. The weather was tracked in hopes of sampling a third storm event, but additional storm events failed to materialize. Nine carboys were filled from each sampling location during each monitored storm event. The preference was to use the stormwater within 72 hours of collection, but additional time was needed to finish the construction and initial seasoning of the columns. The stormwater was stored for four days before the first run. The stormwater for the dilution run was used two weeks after collection. The stormwater for a replacement run (required as a result of bottle breakage during shipping) was used four weeks after collection. This was not a concern for PCB analysis because of the stability of PCBs, though particle agglomeration likely occurred causing associated pollutants to be more easily removed. This was counteracted by using high-sheer mixing as described below.

2.7 Sampling Runs

Following the purpose to screen as many biochars as possible for further study (see Appendix A), only three sampling runs were performed for all six columns using undiluted stormwater. A fourth run was conducted on one biochar-amended BSM column (CO4; BioChar Solutions) and the standard BSM control column[5] (CO6; Control) using stormwater diluted at a one-to-nine ratio. A single replacement run was performed for the first undiluted run for one column (CO1; Sunriver) due to loss of a sample bottle that was damaged in transit between laboratories. A unique influent had to be generated for this replacement run. Each run applied 18 inches of water to each column to simulate the hydraulic loading from storm events near typical water quality design storms. For example, if bioretention is sized to 4 percent of a drainage area that has a volumetric runoff coefficient of 0.8, a 0.9-inch storm size would generate 18 inches of hydraulic loading to the bioretention surface.

A variety of influent concentrations was desired, however, all runs were performed within a period of 30 days so water quality analysis from the first run was not known when performing later runs. Consequently, the selection of which stormwater source (sampling location) and which storm event to use for each run was based on past data from the sampling locations (Table 3). Additionally, each run was sequentially dosed directly from a subset of carboys from each storm. Because all carboys were not used in a run, the visual quality of the stormwater in each carboy was used to select carboys with the most sediment for each run. The dosing sequence is described below.

At the start of each sample run, six cleaned and empty carboys were labeled for effluent collection for all columns and one clean and empty carboy was labeled for influent doses. All sample bottles were labeled to associate them with the collection carboys. Stormwater in the five-gallon storage carboys

5 As previously explained, this sample was not analyzed.

were vigorously agitated before each dose with a stainless steel paddle mixer until all sediment was suspended. A glass beaker marked for the level of a single dose was filled from the carboy and used to dose each column in turn. The dose was sized to be equivalent to one inch of water depth inside the 7.5-inch-diameter column. Each column and the carboy collecting influent received 18 total doses. If the stormwater storage carboy did not have sufficient volume for a complete round of dosing (six column doses and one influent dose), additional water was added to the carboy from the next carboy selected for dosing. This assured that the same batch of stormwater was used for a single dose to each column and influent carboy. Dosing the influent carboy for each round of column dosing allowed a single influent sample from the influent carboy at the end of all 18 doses to represent the composite influent of all columns for that run. If at any time during dosing a column had more than six inches of ponded water the dosing would stop until the water drained to a height of three inches. Figure 4 presents the column test setup.

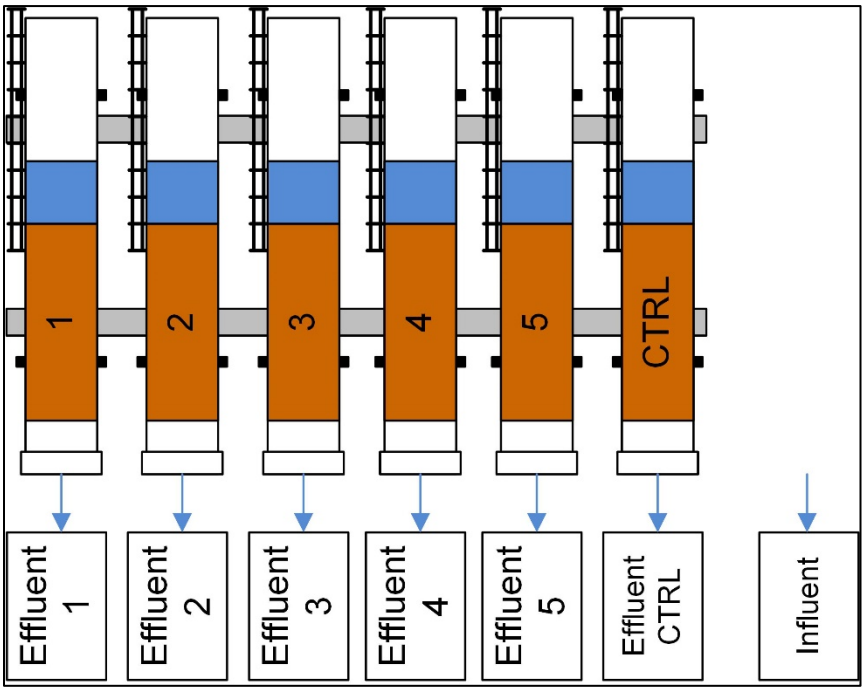

Figure 4. Column Test Setup

Column test observation forms were kept for each column and the time at which each dose was applied and the height of ponded water in the column was recorded. By recording the height of the water in the column at regular time intervals, it was possible to calculate an infiltration rate at each time step over the course of the sampling run. Three times during the dosing of the columns a grab sample was taken from the effluent of each column and tested using on-site meters to measure pH, temperature, and turbidity. At the midpoint of each sampling run, as specified in the sampling protocol to achieve ultra-low detection limits, mercury samples were collected directly from the effluent stream of the column into a preserved sample bottle. Direct collection eliminated losses that would occur if collecting from the effluent carboy. One person was able to handle bottle filling without the aid of a second pair of hands because the sampling person did not have to touch anything while handling the bottle because flow was collected at the air gap as water fell between the column and the effluent carboy.

After all influent water was applied, the columns were allowed to drain until no water was visible in the pore spaces of the soil and the effluent discharge had slowed to a drip. Once the columns drained, the carboy that received influent doses and the effluent carboys of each column were agitated with their own stainless steel paddle mixer before filling all required sample bottles. Sample bottles were refrigerated for up to two days then packed in blue ice and shipped overnight via FedEx to ALS for analysis.

Additional details are presented in Appendix B.

2.8 Constituents and Laboratory Methods

As specified in the study design (Appendix A) and Sampling and Analysis Plan (Appendix B), total PCBs[6] and total mercury were analyzed for all samples. Constituents for analysis of water samples must be consistent with Table 8.3 of the MRP. Table 1 lists the constituents and test methods for this study.

In addition to PCBs and total mercury, the other constituents selected for influent and effluent analysis were suspended solids concentration (SSC), turbidity, and total organic carbon (TOC). Suspended solids concentration was selected for measurement rather than total suspended solids (TSS) because the method more accurately characterizes larger-sized fractions within the sample by avoiding subsampling, while turbidity was selected because it is an inexpensive and quick test to describe treatment efficiency where a strong correlation to other pollutants has been established. As with the SSC analysis, TOC was included because it is a MRP Provision C.8.f POC monitoring parameter and is useful in cases where methylation is a concern.

Table 1. Selected Aqueous Constituents for Media Testing in Laboratory Columns

Constituent	Test Method	Reporting Limit
SSC	ASTM D3977-97	1 mg/L
Turbidity	Field meter	1 NTU
TOC	EPA 9060	2 mg/L
Total Mercury	EPA 1631E	0.5 ng/L
Total PCBs (Sum of RMP 40 congeners) in Water	EPA 1668C	190-220 pg/L

2.9 Analysis and Statistical Testing

Effluent and influent concentrations are presented independently and in chronological order to observe potential trends with loading. Additional analysis was performed for PCBs. Effluent concentration is also presented normalized by influent concentration for comparison to CW4CB study results. Normalization allows caparisons where influent concentrations vary between studies and where effluent concentration is dependent on influent concentration. In addition to traditional graphical or tabular comparisons, statistical testing was performed for PCBs using the Mann-Whitney U test (a rank sum test) on columns showing the greatest differentiation of performance. Correlations between PCB and SSC, and total mercury and TOC were also examined. Comparing total PCBs to suspended solids indicates whether suspended solids have a consistent quantity of associated PCBs.

6 The 40 individual congeners routinely quantified by the Regional Monitoring Program (RMP) for Water Quality in San Francisco Bay include: PCBs 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, 105, 110, 118, 128, 132, 138, 141, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203. The sum of these congeners are referred to as the PCBs or RMP 40 throughout this report.

3 RESULTS

3.1 BIOCHAR CHARACTERISTICS, HYDRAULIC CONDUCTIVITY, AND SELECTION

The study design called for water quality column testing of five biochars. Nine biochars produced in the Western United States were identified as potential candidates (Table 2). Hydraulic tests of the nine biochar-BSM blends produced a wide range of results. More details of the hydraulic conductivity calculations and particle size distributions are presented in Appendices D and E, respectively. Pulverization[7] of biochar during the compaction process could be a contributing factor to the range of the observed results, even when using the lower-energy Standard Proctor method. The five biochar-BSM blends that provided the most consistent hydraulic conductivity compared to the standard BSM were selected for further testing. The selected biochar are highlighted in Table 2, and include Sunriver, Rogue, Phoenix, BioChar Solutions (also used in CW4CB), and Agrosorb. Their associated conductivity measurements were within 4 in/hr of the standard BSM, except for Agrosorb, which was 4.3 in/hr above the value for standard BSM. The selected biochar cover a range of pyrolysis temperatures and costs, but all were manufactured at 500 ˚C or above. Contrary to expectations, cost did not correlate with pyrolysis temperature.

Table 2. Characteristics for Biochar Considered for Water Quality Testing

Biochar[a]	Ksat[b] (in/hr)	Texture[c]	Cost ($/yd³)	Pyrolysis Temp (˚C)	Supplier Location
Blacksorb	2.56	Variable size, 3mm to fines	250	900	CA
Sonoma	5.11	Variable size, 1 cm chips to sand size particles, lots of fines	240	1315	CA
Pacific	5.41	Variable size, 1 cm chips to sand size particles, some fines	90	700	CA
Sunriver	7.67	Variable size, mostly pine needles with some small twigs and chips, 2 cm, little fines	500	500	OR
Rogue	7.85	Uniform size, 4mm, little to no fines	250	700	OR
Phoenix	10.4	chips, 1-.5 cm, little to no fines	254	700	CA
Control – Standard BSM from Voss	10.8	Organics and sand	40	N/A	CA
Biochar Solutions Large	11.0	Chips, 2.5 cm, lots of fines	225	700	CO
Agrosorb	15.1	Large chips, 2 cm, lots of fines	250	900	CA
Biochar Now Medium	17.2	Uniform size, 3mm to 26 mesh, little to no fines	350	600	CO

a. Biochars are sorted by Ksat and the five biochars closest to BSM were selected for column tests (shaded).
b. Ksat values are at 85% maximum dry density using standard Proctor. Computations are presented in Appendix D.
c. Particle Size Distribution of each biochar is presented in Appendix E.

7 Hydraulic compaction was used in the water quality testing columns to avoid pulverization.

3.2 Quality Assurance and Quality Control

Data quality assurance (QA) and quality control (QC) was performed in accordance with the project's SAP/QAPP (Appendix B). The SAP/QAPP established data quality objectives (DQOs) to ensure that data collected are sufficient and of adequate quality for their intended use. These DQOs include both quantitative and qualitative assessments of the acceptability of data. The qualitative goals include representativeness and comparability, and the quantitative goals include completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination. Measurement quality objectives (MQOs) are the acceptance thresholds or goals for the data. The quality assurance summary is presented for PCBs followed by total mercury, TOC, and SSC.

3.2.1 PCBs

The column water dataset included 26 field samples (including 1 field replicate), with 3 blanks, 5 laboratory control samples (LCSs), and one matrix spike/matrix spike duplicate (MS/MSD) pair reported for the RMP 40 PCB analytes (with their coeluters, yielding 38 unique analytes). This met the minimum number of QC samples required. All samples were analyzed within 30 days, less than the recommended hold time of 1 year. Three of the analytes had poor recovery (>70% deviation from target values in MS samples) and were rejected as were 2 analytes that had individual field sample results <3x higher than blanks. Overall 91% of the field sample results were reportable. Two PCBs were non-detect (ND) in 100% of the samples, but all the rest had detects in more than half the samples. However, a large percentage of results were below the lab's reporting limit, and 17 analytes had relative percent differences (RPDs) in the field replicates below 100%, and thus 62% of all results were flagged as estimated. Additionally 25 of the 38 unique analytes had recoveries between 35–70% above target values, so they were flagged as qualified. Nearly half of the data is flagged as estimated (i.e., below the reporting limit (RL) but above the method detection limit (MDL)) or qualified (not compliant with project SAP/QAPP), and approximately 5% of the data were rejected for the reasons mentioned above. Thus individual results are not quantitative at the target levels of confidence (+/- 30%) and thus the data should not be used to draw conclusions regarding attainment of set performance or water quality thresholds. However, the primary management question in this study is answered using the relative comparison of results within this study. Consequently, the data quality is satisfactory for the purpose of this study and all data were used.

3.2.2 Total Mercury (Hg), TOC, and SSC

All field sample results in the Hg/TOC/SSC dataset for water were reportable. The column water dataset included 25 field samples for Hg and SSC, and 1 field replicate for SSC, with 23 samples reported for TOC. All TOC results were analyzed at least in duplicate (some 3 or 4 times). Blanks were reported for all analytes, MS/MSDs for Hg and TOC, and LCSs for SSC and TOC, meeting the minimum number of QC samples required (1 per 20 or per batch of blank, precision, and recovery sample types). Samples were all analyzed within their respective hold times (28 days for Hg and TOC, 7 days for SSC). No results were non-detect, although a few Hg and TOC were DNQ (detected not quantified). Mercury was detected in blanks averaging 2-3x MDL in the two batches, but field sample results were all over 3x higher than blanks, so all results were flagged for blank contamination, but no results were censored. Precision was acceptable, averaging <10% RPD for SSC, <5% for TOC, and <20% for Hg, so no precision qualifiers were added. Similarly, average recovery deviated <10% from target values for all analytes, so no recovery flags were added. Overall, data quality is satisfactory for the purpose of this study and all data were used.

3.3 COLUMN TEST RUNS

Five sampling runs were performed and influent concentrations and stormwater collection characteristics for each run are presented in Table 3. Not all stormwater collected at one location during one storm was used in a single run, so extra water was available for later runs as described in Table 3. In each run, the storage carboys with more sediment (visual judgement) were preferred in early runs. Consequently, water remaining for later runs had less sediment. Infiltration rates and influent and effluent concentrations grouped by column and run are presented in Table 4. Graphical comparisons and discussion is presented in the following sections.

Table 3. Influent Descriptions, PCB and Mercury Concentrations, and Columns Dosed for each Sampling Run

Influent ID	Run Type	Storm ID: No. - Location[a] - Collection Date	Column Run Date	Influent Concentrations				Columns Loaded
				PCB (pg/L)	Total Hg (ng/L)	TOC (mg/L)	SSC (mg/L)	
Influent 1	no dilution	Storm 2 - TW2 - 4/6/18	4/10/2018	19600	9.99	5.39	19.4	all
Influent 2	no dilution	Storm 1 - TW2 - 3/1/18	4/13/2018	18600	10.2	1.71	40.2	all
Influent 3	no dilution	Storm 2 - TW6 - 4/6/18	4/17/2018	9860	9.86	1.64	16.3	all
Influent 4	9X dilution	Storm 1 - TW2 - 3/1/18[b]	4/19/2018	2100	3	NA	1.9	CO4, CO6
Influent 5	no dilution	Mix of Storm 1 and 2 - TW2 - 3/1/18 and 4/6/18[c]	5/9/2018	8160	NA	NA	NA	CO1

a. Stormwater collection locations were at two sites in West Oakland: TW2 is the influent to the Tree Well Site 2 (TW2) on Poplar at 26th and TW6 is the influent to Tree Well Site 6 (TW6) on Ettie St. near 28th

b.TW2 selected because CW4CB indicated it had lower concentrations and was selected to avoid dilution of a high-concentration sample (in this study TW2 had higher concentrations but those results were not available at the time)

c. The dirtiest (visually) of the remaining storage carboys from storms 1 and 2 that were not used in previous runs were selected to get a concentration near what was dosed in Run 1 because this was a makeup for Run 1.

Table 4. Infiltration Rates and PCB, Mercury, TOC, and SSC Results for each Sampling Run

Column ID	Biochar	Test Runs	Inf. Rate (in/hr)	PCBs		Total Mercury		TOC		SSC	
				Influent (pg/L)	Effluent (pg/L)	Influent (ng/L)	Effluent (ng/L)	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)
CO6	Control (BSM only)	Run 1	6.7	19600	2920	9.99	14	5.39	32.9	19.4	118
		Run 2	6.0	18600	4680	10.2	13.1	1.71	15.9	40.2	35
		Run 3	3.7	9860	960	9.86	11.3	1.64	17.2	16.3	26.7
		Run 4	N/A	2100	NA[a]	3	7.41	NA	10.9	1.9	11.1
CO1	Sunriver	Run 1	>20	19600	NA[a]	9.99	24.4[b]	5.39	26.7[b]	19.4	116[b]
		Run 2	>12	18600	32000[b]	10.2	9.68[b]	1.71	12.3[b]	40.2	21.9[b]
		Run 3	5.7	9860	383	9.86	9.74	1.64	12.1	16.3	12.5
		Run 5	N/A	8160	662	NA	NA[c]	NA	NA	NA	NA
CO2	Rogue	Run 1	>20	19600	19400[b]	9.99	16.3[b]	5.39	11[b]	19.4	104[b]
		Run 2	3.2	18600	926	10.2	8.58	1.71	5.72	40.2	13.3
		Run 3	5	9860	4510	9.86	2.17	1.64	5.12	16.3	8.4
CO3	Phoenix	Run 1	8	19600	2000	9.99	6.77	5.39	42	19.4	50.3
		Run 2	7.3	18600	2270	10.2	5.69	1.71	19.1	40.2	14.5
		Run 3	3.8	9860	411	9.86	6.02	1.64	21.6	16.3	19.3
CO4	BioChar Solutions	Run 1	8.5	19600	3270	9.99	15.2	5.39	28.9	19.4	89.1
		Run 2	>12	18600	2310	10.2	11.2	1.71	13.8	40.2	17
		Run 3	3.7	9860	839	9.86	7.58	1.64	14.4	16.3	16.5
		Run 4	5.5	2100	782	3	5.26	NA	NA	1.9	9.7
CO5	Agrosorb	Run 1	8.4	19600	2160	9.99	7.57	5.39	27.7	19.4	78
		Run 2	4.9	18600	2920	10.2	4.53	1.71	12.5	40.2	17.3
		Run 3	5.2	9860	586	9.86	7.36	1.64	12	16.3	11.7

a. Lost sample

b. Values are not used in further analysis due to unusually high initial infiltration rates

c. No Hg for Run 5 because three samples were successfully analyzed and only PCB required a replacement run.

3.3.1 PCBs

Both qualified and estimated influent and effluent PCBs concentrations are presented chronologically in Figure 5. The first two runs had similar influent concentrations and effluent quality was generally similar, despite sediment and turbidity increases in the first run. Effluent concentrations were generally lower for the third run, but influent concentration for the third run was nearly half that of the previous runs. The fourth run is the dilution run for only two columns. The fifth run is the replacement run for the first Sunriver run, which could not be analyzed for PCBs due to a broken sample bottle. All columns reduced concentrations of PCBs. This is expected because PCBs are largely bound to particles and media filters work well to remove these particles. Biochar-amended BSM seems to have improved treatment when compared to the control BSM (CO6), but a more explicit comparison is presented later in this report.

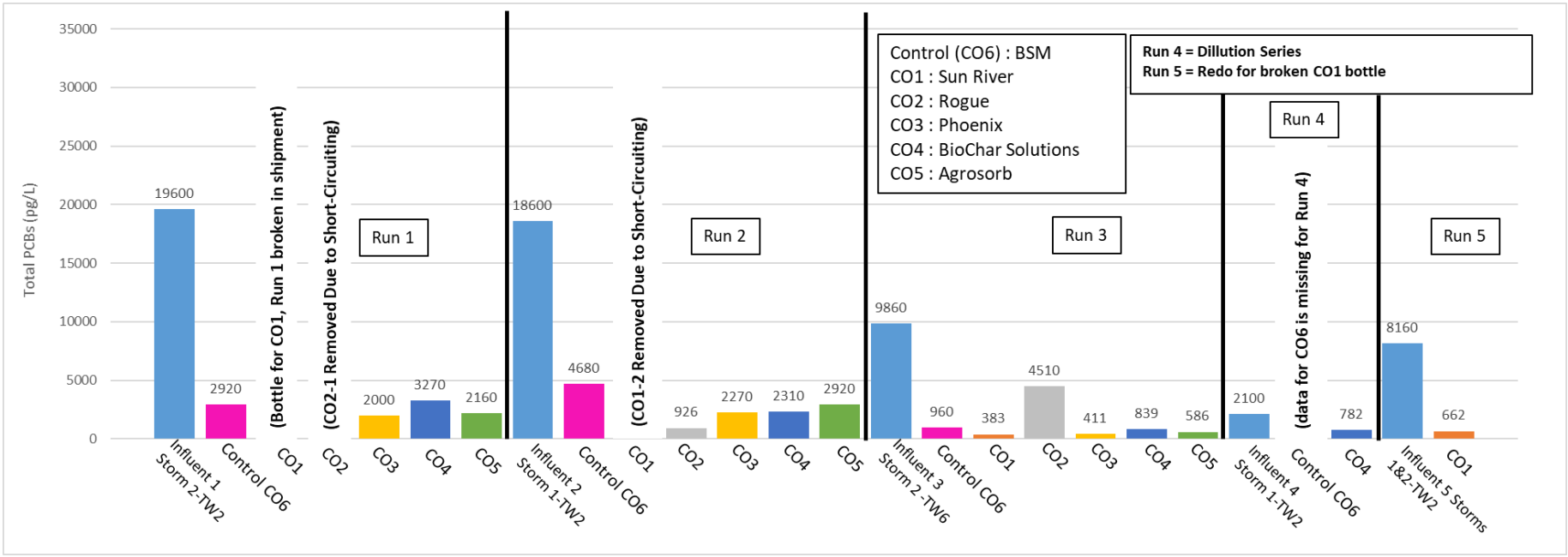

Figure 5. Total PCB Concentrations over Time

The data from Sunriver biochar-amended BSM (CO1) for test runs one and two, and the Rogue biochar-amended BSM (CO2) for test run one have been censored because both of these columns experienced unusually high initial infiltration rates that is indicative of short-circuiting of the media. The infiltration rates were so high that water did not remain in the column at the beginning of a subsequent dose when water level and time would be recorded. To drain this fast, the Sunriver column would have had an infiltration rate above 12 inches per hour and the Rogue column above 20 inches per hour. Because the occurrence of high infiltration rates are not successively repeated for later runs or in the initial runs of other columns, these two measurements have been deemed not representative of a properly compacted media and are not included in further analysis in this report. All other runs had had initial infiltration rates of 3 to 9 in/hr. Run 2 for BioChar Solutions (CO4) exceeded 12 in/hr, but that data was used because the first run was in an acceptable range, signifying that the variation in hydraulic performance could not be attributed to a lack of media seasoning or insufficient compaction. Consequently, later hydraulic variability could be an important longer-term characteristic of the media that would be important to consider in the study.

Despite initial seasoning that fully saturated the media, small air pockets were observed in some columns and it is probable that none of the columns were fully saturated during runs, so infiltration values are not representative of saturated hydraulic conductivity. Air pockets were not fully removed during the sampling runs because, unlike the initial seasoning and hydraulic compaction, water was introduced from the top of the columns.

Figure 6 displays the influent and effluent concentrations for PCBs grouped by column, along with means. There are four influent values because run 5 for Sunriver (CO1) required a unique influent (8,160 pg/L) which replaced the run 1 influent value (19,600 pg/L). Mean effluent concentrations for all biochar-amended BSM are lower than the mean effluent concentration of the control BSM (CO6), with the Rogue biochar-amended BSM (CO2) average just under the control BSM average.

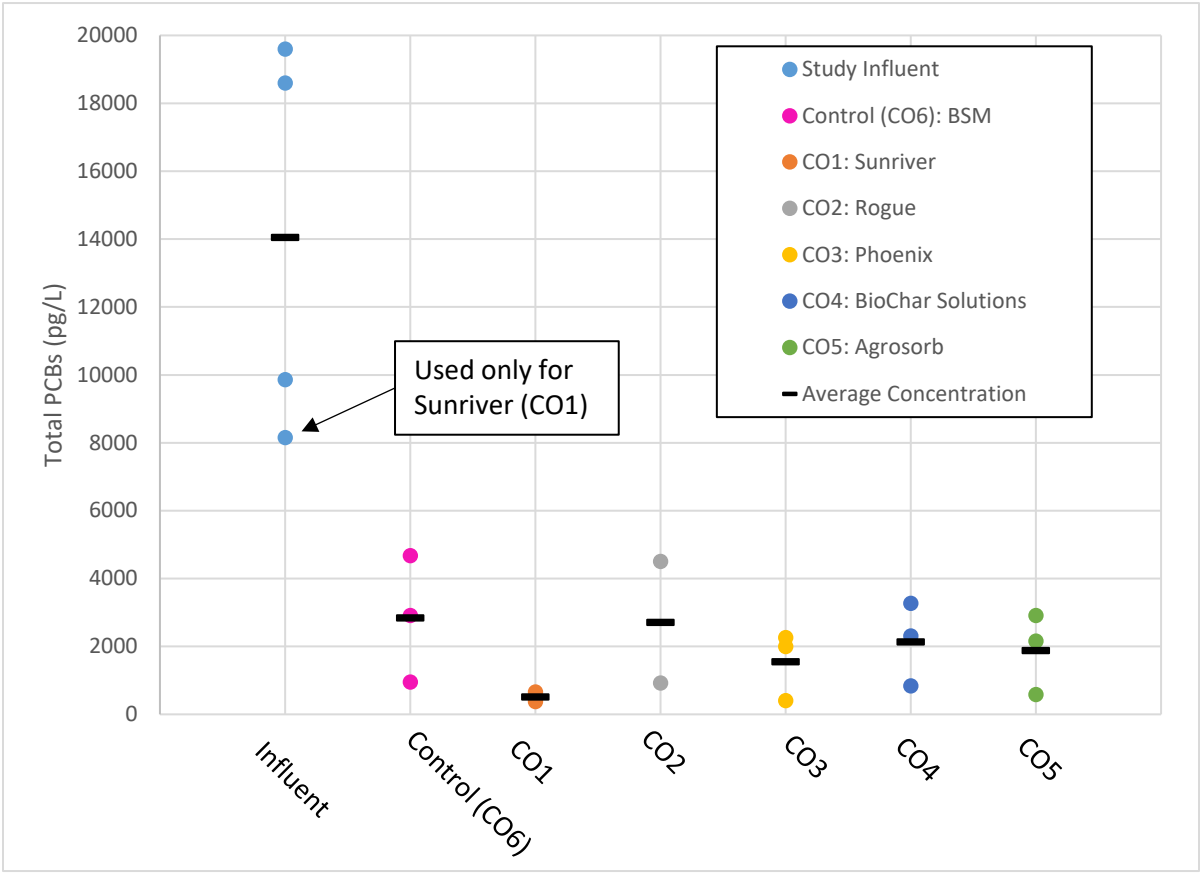

Figure 6. Observed Total PCB Concentrations for Undiluted Influent Runs and Column Test Media Effluent

Dividing each column effluent concentration by the paired influent concentration (Ce/Ci) normalizes the data to the influent and aids in comparison. In Figure 7, a red line has been placed at the mean value for the control BSM data. The noticeable difference between the Ce/Ci graph and the concentrations graph is that Rogue biochar-amended BSM (CO2) now has a higher mean than that of the control, while the average means for all other biochar-amended BSM are below the control. This is because each column had similar effluent values (4,680 and 4,510 pg/L, for the control and Rogue, respectively), but the influent concentration was substantially different (18,600 and 9,860 pg/L). This analysis indicates that all biochar may outperform the standard BSM mix with the possible exception of Rogue, but the data are limited. Further, the duplicate sample of run 3 for Rogue indicates it has better performance than the control but more data would be needed to show the primary sample was an outlier. The dilution run is not included in the analysis presented in Figure 6 because the lower influent concentration was not applied across all columns.

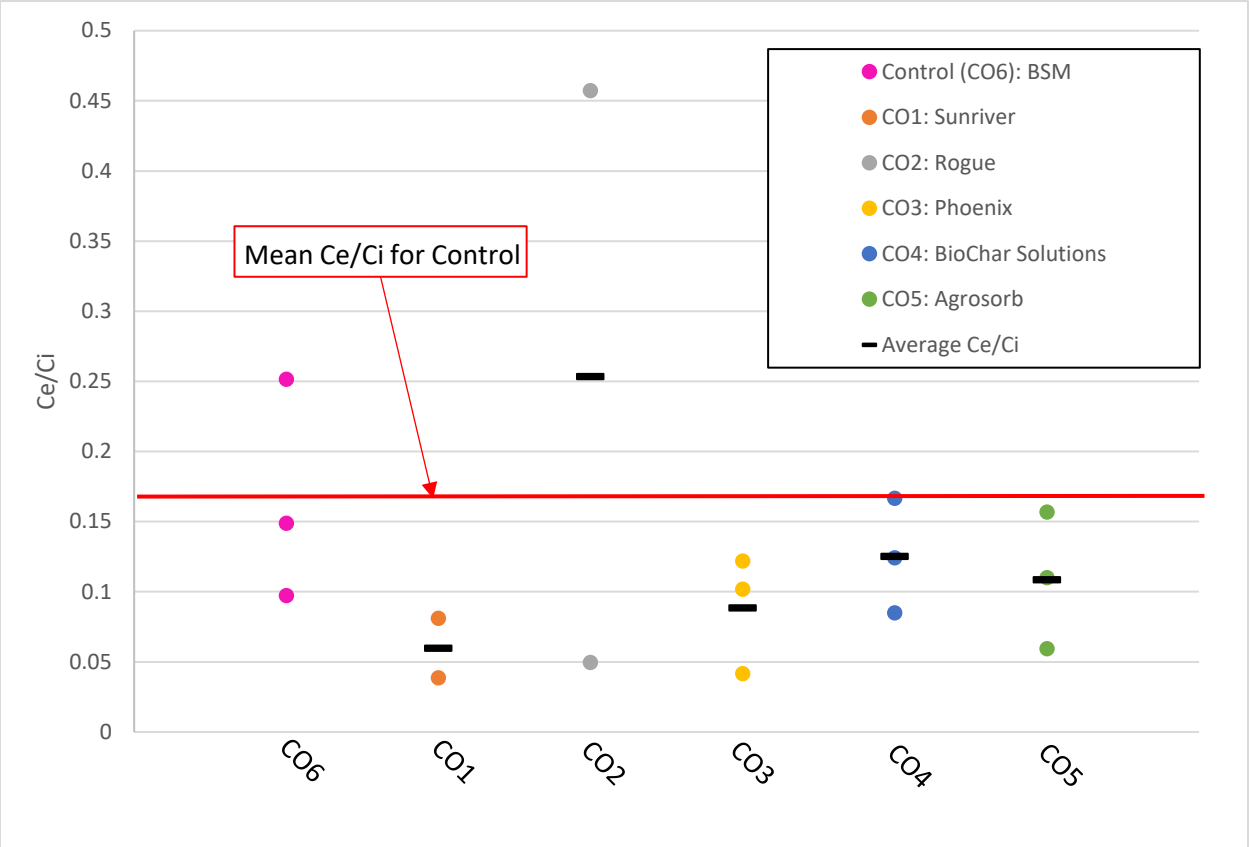

Figure 7. Ce/Ci Total PCB Concentrations for Column Test Media

Figure 8 compares the concentrations from this study to those from the CW4CB pilot site that tested BSM next to BSM with biochar. For ease of comparison, the influent concentrations from both field site influents are combined into one dataset under the label CW4CB Combined Influent. All five of the biochar-amended BSM columns are combined into one dataset under the label Study Biochar.

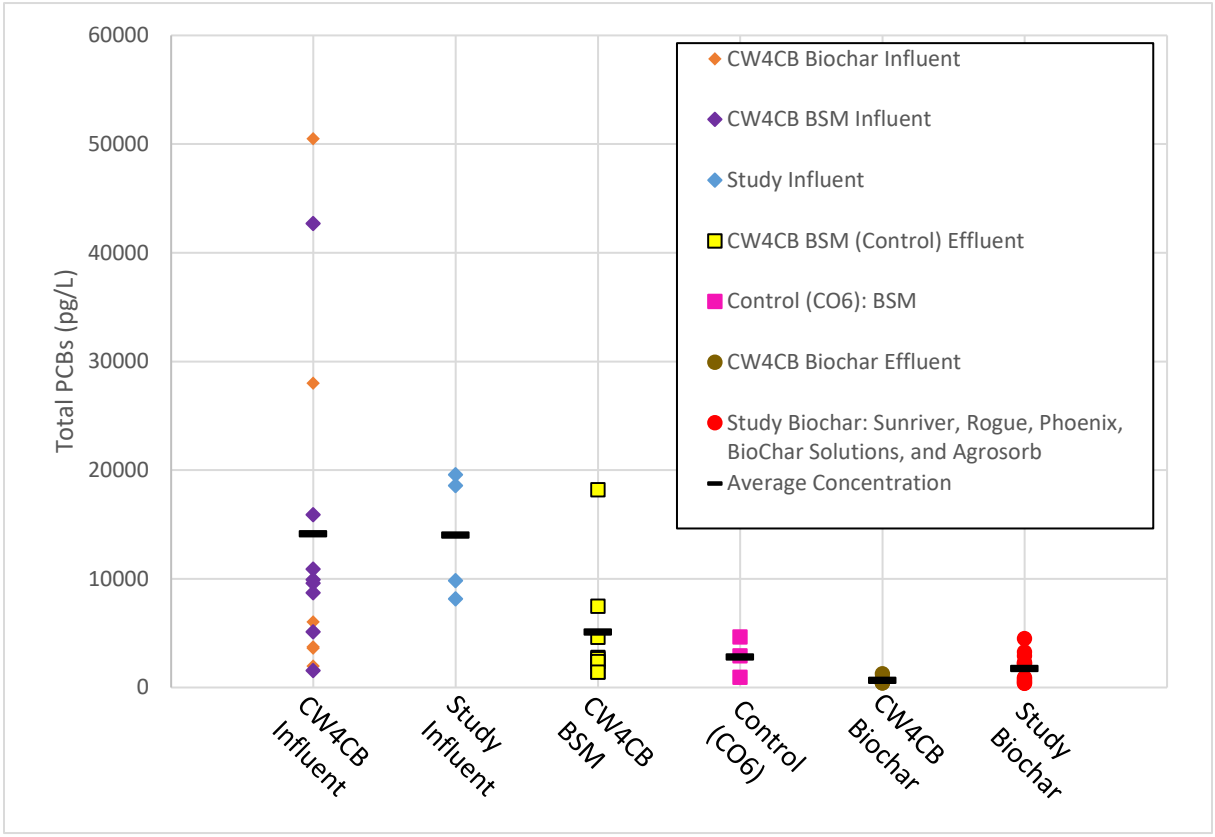

Figure 8. Total PCB Concentrations for CW4CB Pilot Sites Influent, Undiluted Influent Runs, CW4CB BSM Effluent, and Column Test BSM Effluent, CW4CB Biochar-amended Effluent, and Column Test Biochar-amended Effluent

The PCB concentrations in stormwater used in this study were within the range of PCB concentrations in influent at the CW4CB location that compared BSM and biochar-amended BSM. The range of influent concentrations for this study (9,860 pg/L to 19,600 pg/L) was narrower than the ranges of influent concentrations for both the CW4CB BSM site (1,560 pg/L to 42,700 pg/L) and the CW4CB biochar-amended site (1,990 pg/L to 50,500 pg/L). The range of influent concentrations from this study overlapped the middle range of the CW4CB grouped influent concentrations with the influent mean concentration from this study lower by 116 pg/L (less than 1% difference). The Control BSM effluent concentrations of this study were nearly half the concentrations of the CW4CB study BSM effluent concentrations. However, the biochar-amended BSM effluent concentrations from this study were higher than the biochar-amended CW4CB study. As before, normalized effluent is examined for the case that effluent has some dependence on influent.

Figure 9 compares effluent concentrations normalized by their paired influent concentrations for the CW4CB BSM, study BSM, the CW4CB biochar, and all study biochars combined.

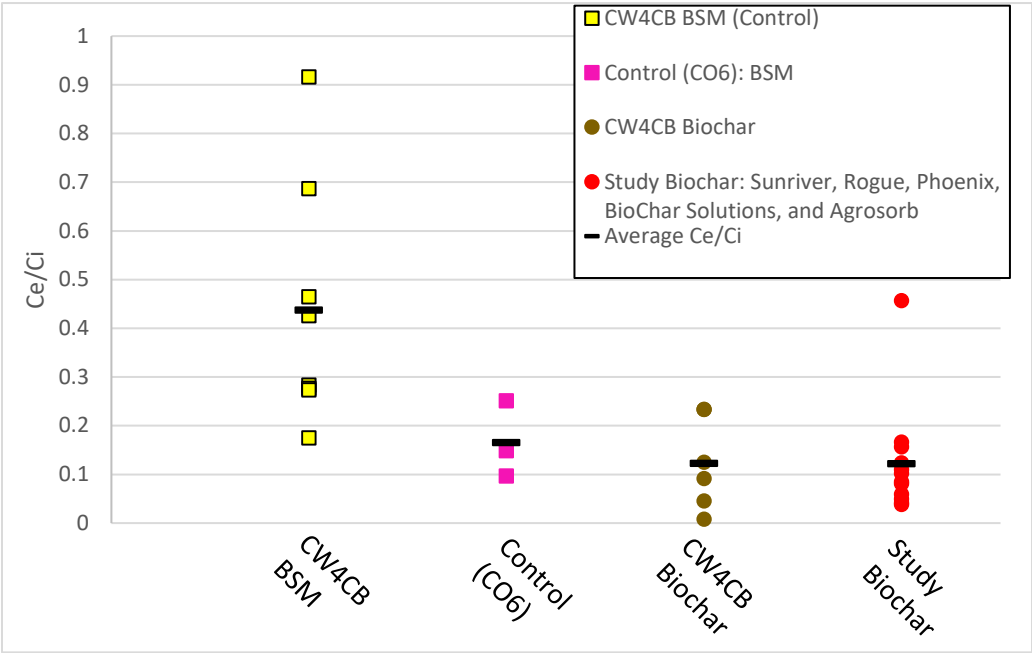

Figure 9. Ce/Ci Total PCB Concentrations for CW4CB Pilot Sites and All Biochar Test Media

Results from both CW4CB and this study indicate that PCB removal by biochar-amended BSM is less sensitive to influent concentrations than standard BSM. The influent-normalized performance (Ce/Ci) for the standard BSM (control) in this study appeared slightly improved compared to the CW4CB control BSM pilot site. In contrast, BioChar Solutions (CO4) influent-normalized performance (Ce/Ci) in this study was similar to the CW4CB biochar-amended pilot site (also using BioChar Solutions).

The improved performance suggests that conditions in the column tests were more ideal, or at least not worse, than field conditions. The normalized biochar data showed better agreement, but a secondary control to the field condition was planned to allow a more direct comparison between the same biochar. This was accomplished by using the same biochar (BioChar Solutions, CO4) as was used at the CW4CB site. The CW4CB biochar site and the column constructed with the same biochar (CO4) are compared in Figure 10, including the dilution run. Though data are limited, it appears that the CW4CB performance is slightly superior, which is in contrast to the comparison of standard BSM. This suggests that there are performance factors influencing the CW4CB site that were not replicated in this study, and there may be differences, besides biochar, contributing to the improvement of performance of the CW4CB biochar over the standard BSM. The CW4CB biochar site also tested a wider range of influent concentrations (Figure 8), which may be another cause for differing results.

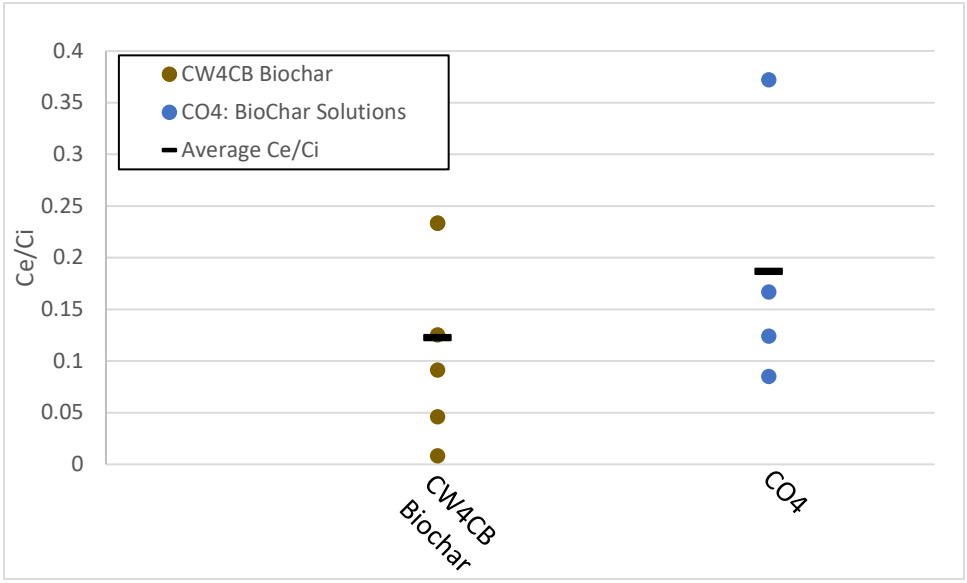

Figure 10. Ce/Ci Total PCB Concentrations for CW4CB Biochar Pilot Site and BioChar Solutions Test Media

All effluent concentrations are plotted against influent concentrations in Figure 11, and all media show removal of PCBs as evidenced by all points appearing under the 1:1 line representing no treatment. The effluent data appears stacked due to the common influent for three of the five runs. Overall, the data may be indicating an irreducible concentration somewhere around 300 pg/L (select Run 3 effluent concentrations) to 800 pg/L (Run 4 dilution effluent concentration), but only a single data point represents the lower end of the influent range.

The dilution run gives a rough estimation of whether biochar-amended BSM would be effective in treatment of concentrations that are lower than the sampled watershed. The single run was performed with stormwater diluted at a one-to-nine ratio to assess one biochar-amended BSM (BioChar Solutions) and the control BSM (The control BSM analysis is not available). The biochar-amended BSM continued to show reduction potential, but the removal relative to influent was not as great, indicating that the influent value may be approaching an irreducible concentration. Even though this analysis is on the most limited basis, the data indicate that biochar may also show benefits at lower concentrations. However, the variation in water column concentration is much larger than that tested in this study. The range of the total PCBs concentration of influent samples was compared to the range found in a summary of water column PCBs concentration data in the Bay Area (McKee et al. 2015). Of 31 locations sampled over several years, seven had concentrations lower than the range of the media study, 16 were within the range, and eight were above. Most of these monitoring locations were in-channel rather than higher upstream in the drainage system where BSM is more traditionally used. Consequently, actual concentrations at upstream BSM locations could vary even more since discrete PCB source areas should get diluted as other cleaner water and sediment combine downstream. Gilbreath et al. (2018) reported a maximum of 160,000 pg/L, a minimum of 533 pg/L, and a median stormwater concentration of 8,923 pg/L, but that is also based on many of the same in-channel monitoring locations. As a result, the biochars that show some promise for further field testing were exposed to a fairly small range of concentrations that would likely be found at random green infrastructure locations.

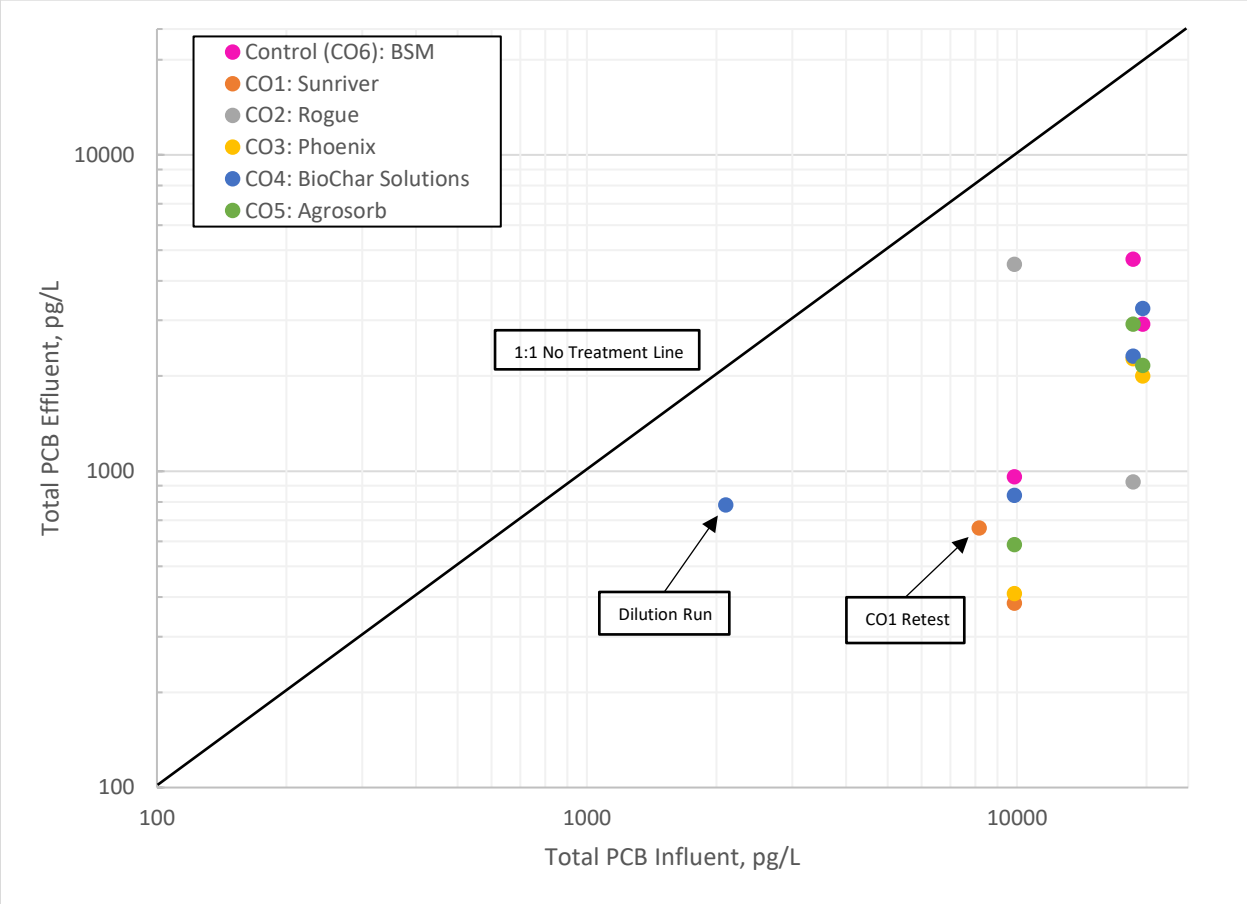

Figure 11. Total PCB Concentrations for all Study Effluent versus Influent

3.3.2 Mercury

Figure 12 shows mercury concentrations for all four test runs in chronological order. Phoenix (CO3) and Agrosorb (CO5) biochar-amended BSM show mercury removal across all three test runs. All biochar-amended BSM shows improved treatment over the standard BSM, except for BioChar Solutions (CO4) in the first and second run.

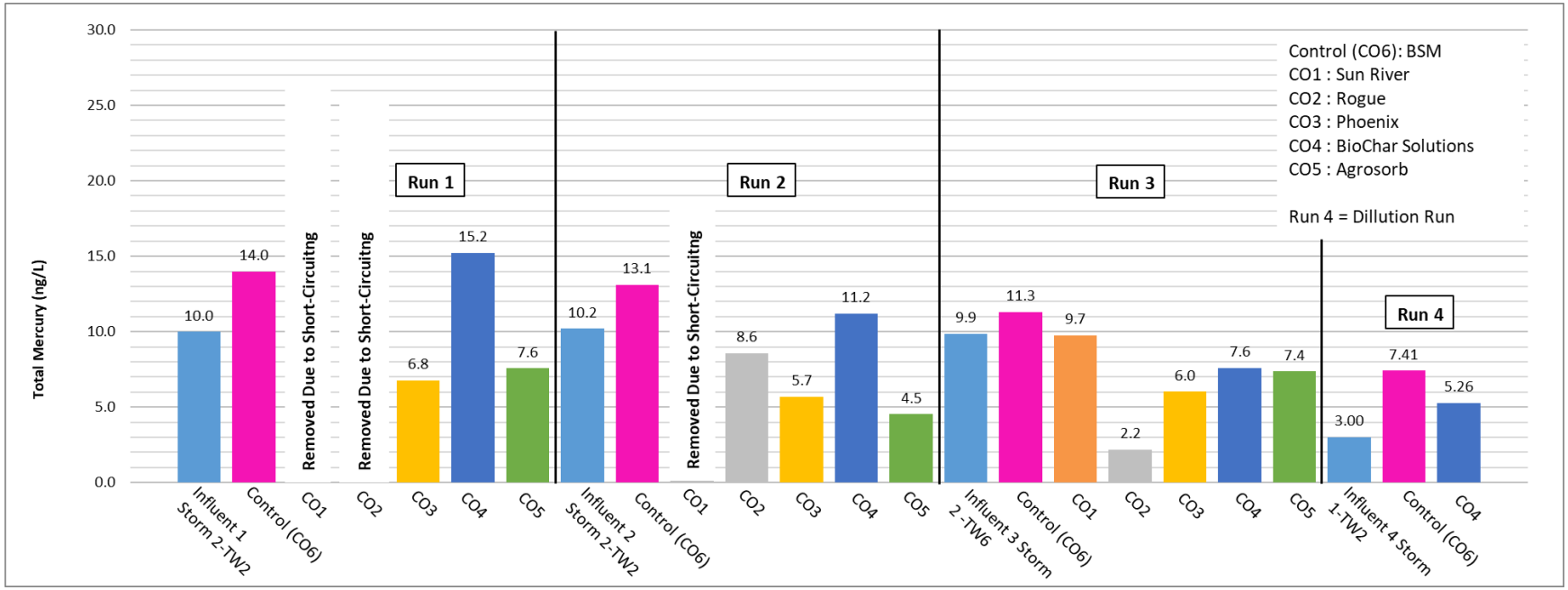

Figure 12. Mercury Concentrations over Time

As stated in the PCB results section, Sunriver biochar-amended BSM (CO1) had unusually high infiltration rates for the first and second test runs and Rogue biochar-amended BSM (CO2) had high rates for the first test run. These data points were removed from the total PCBs dataset for all analyses and were also removed from the mercury dataset.

The mercury export by the control BSM (CO6) for all test runs could indicate that the media itself is releasing mercury. Biochar-amended BSM contain less BSM by volume, which may partially explain the lower mercury concentrations for those columns. Mercury export will likely decrease at locations with higher influent concentrations, and mercury removal is possible if the influent concentration is substantially higher than the export concentration. Gilbreath et al. (2018) reported a median stormwater concentration of 29.2 ng/L, which is almost three times the influent concentration in the three primary test runs.

3.3.3 Other Constituents

Total PCB and mercury concentrations were compared to SSC and TOC respectively. Turbidity was collected during sampling and seasoning runs to provide immediate insight into the performance of the filters throughout the experiment.

Figure 13 shows the relationship between total PCBs and SSC divided into two groups, Influent and Effluent samples.

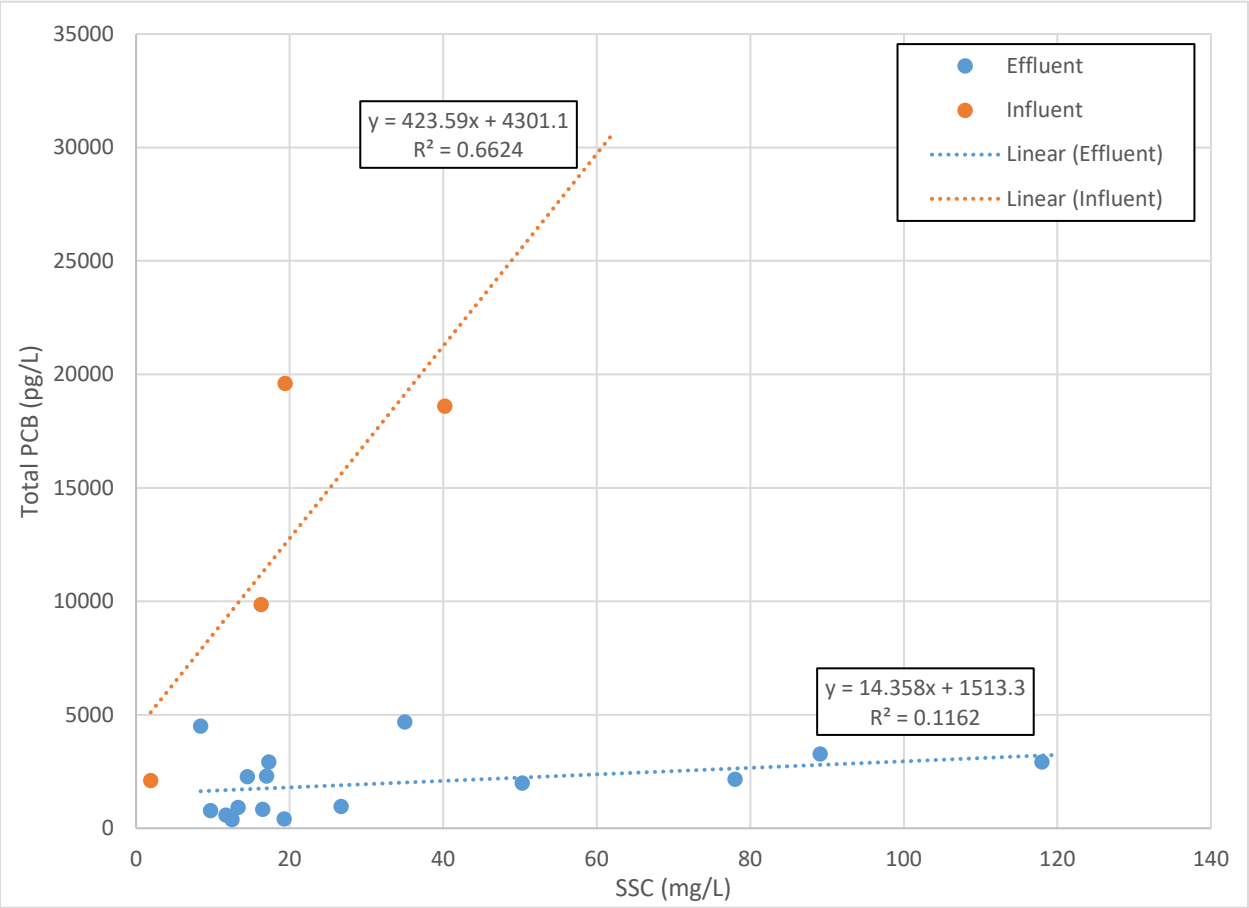

Figure 13. Comparison of Total PCB to SSC Concentrations

Figure 13 confirms the relationship between PCBs and SSC in influent samples (R^2 value of 0.66). The effluent samples have a much shallower regression line with a very low R^2 value of 0.116. This poor correlation is also evidence of contribution of solids from the media rather than the passing of influent solids through the media to the effluent sample, assuming low PCB concentration in the media.

There is no expected correlation between TOC and mercury. It is presented for consideration in cases where methylation is a concern. Figure 14 presents total mercury versus TOC. Normalizing the TOC effluent concentrations by dividing them by influent concentrations shows that TOC at least doubles from influent to effluent, with more typical increases around eight times (Figure 15). This increase is likely from both loss of BSM and leaching of dissolved organic content. Figure 16 shows normalized SSC effluent, which demonstrates substantial export of media, but not as much as TOC. The higher export of TOC is likely due to TOC analysis accounting for particulate and dissolved organic content, while SSC only measures particulates. SSC and TOC increases in these column tests should not be construed as representing field performance. To minimize the concentration reduction in the underdrain, a thin (2-inch) layer of washed coarse sand was used. This underlying coarse sand layer may have exacerbated loss of media solids and consequential increase in TOC and SSC compared to a traditional underdrain with more depth, more fines, and more restriction to infiltration rate.

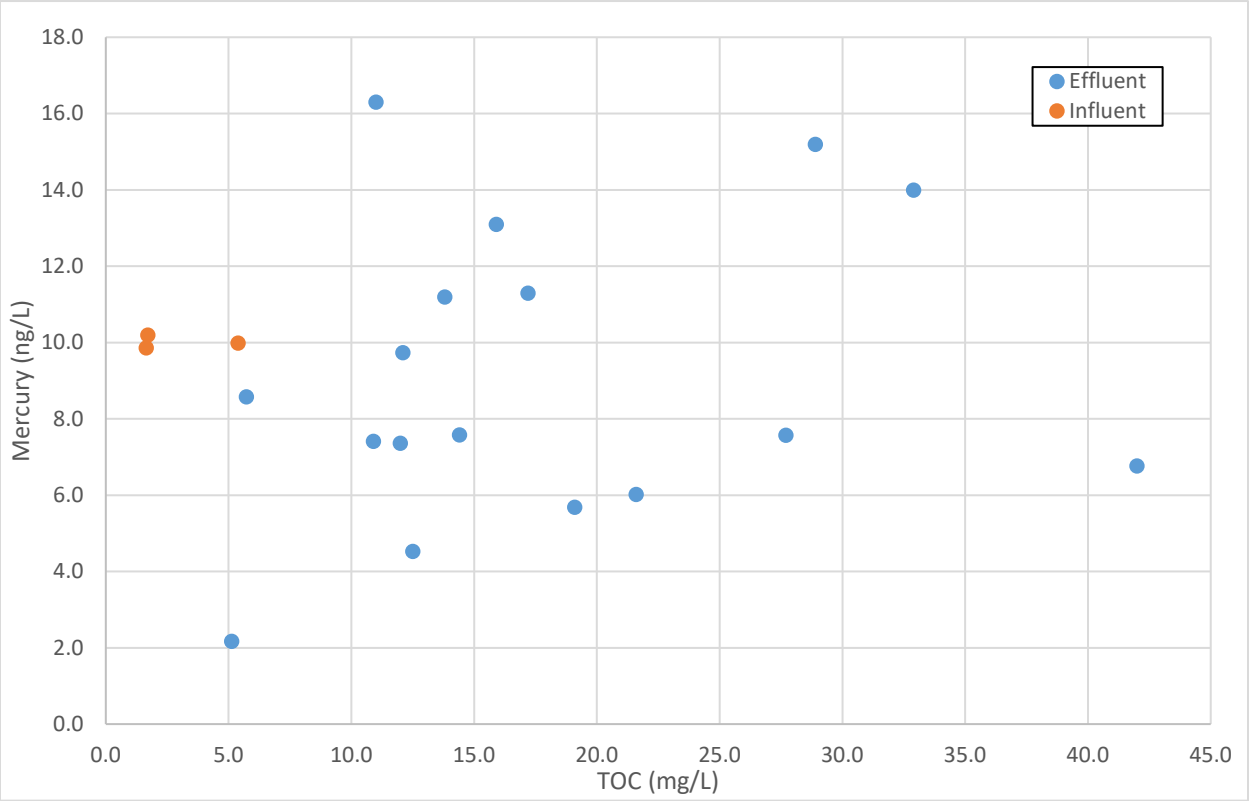

Figure 14. Comparison of Mercury to TOC Concentrations

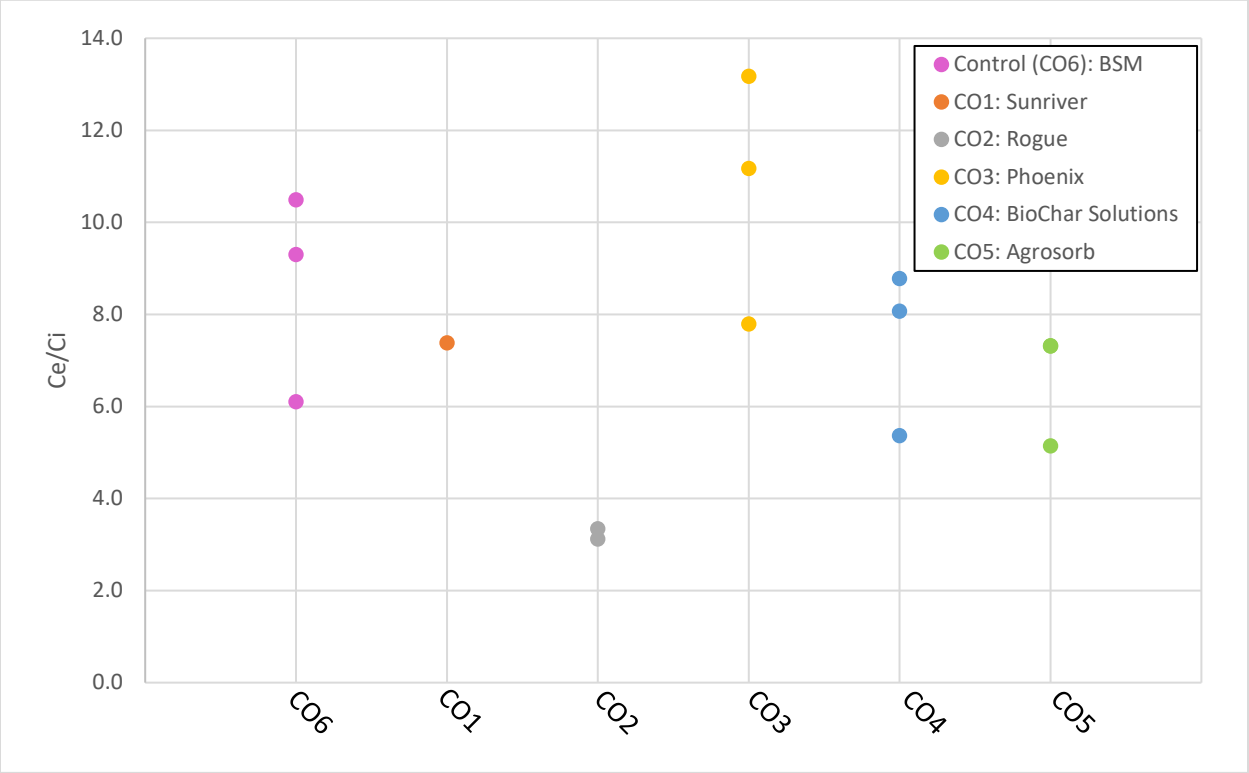

Figure 15. Ce/Ci TOC Concentrations for Column Test Media

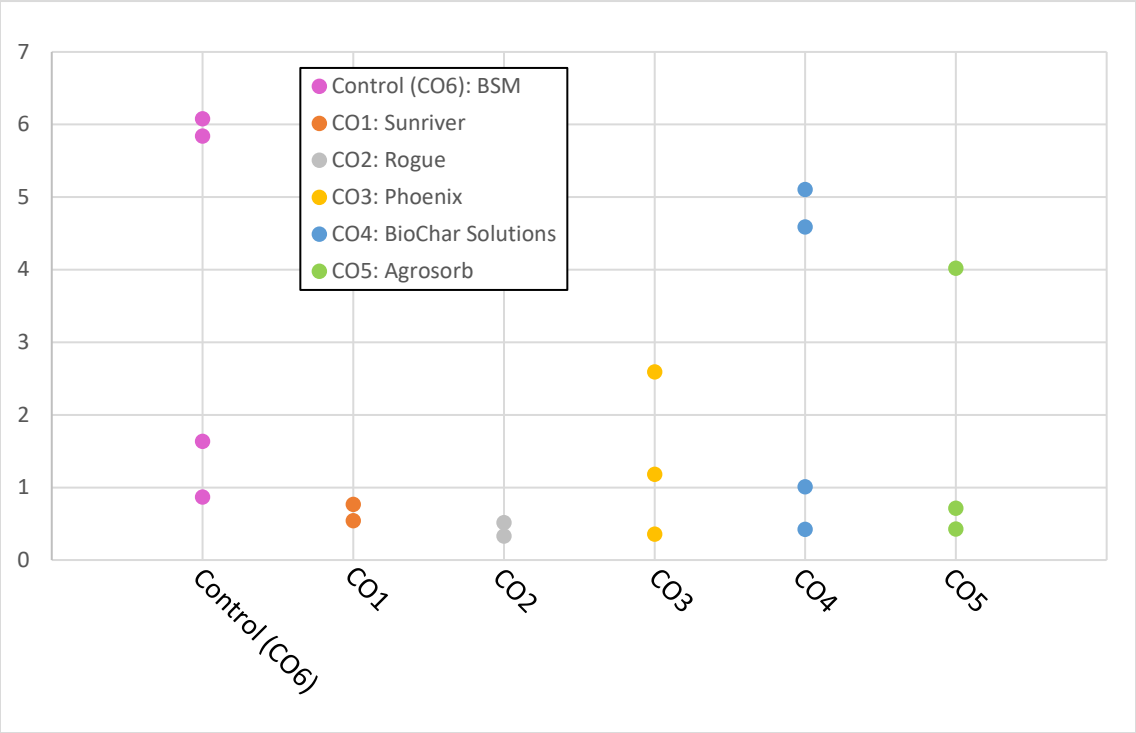

Figure 16. Ce/Ci SSC Concentrations for Column Test Media

Figure 17 shows turbidity measurements for all columns in chronological order over all runs (sampling and seasoning). During the first sampling test run, it was observed that the effluents of all columns had high turbidity and were not representative of a well-established media (see Table 4 for all concentrations). Two seasoning runs were performed next, and the effluent turbidity of all columns stabilized by the end of the second run. Turbidity data is in Appendix F.

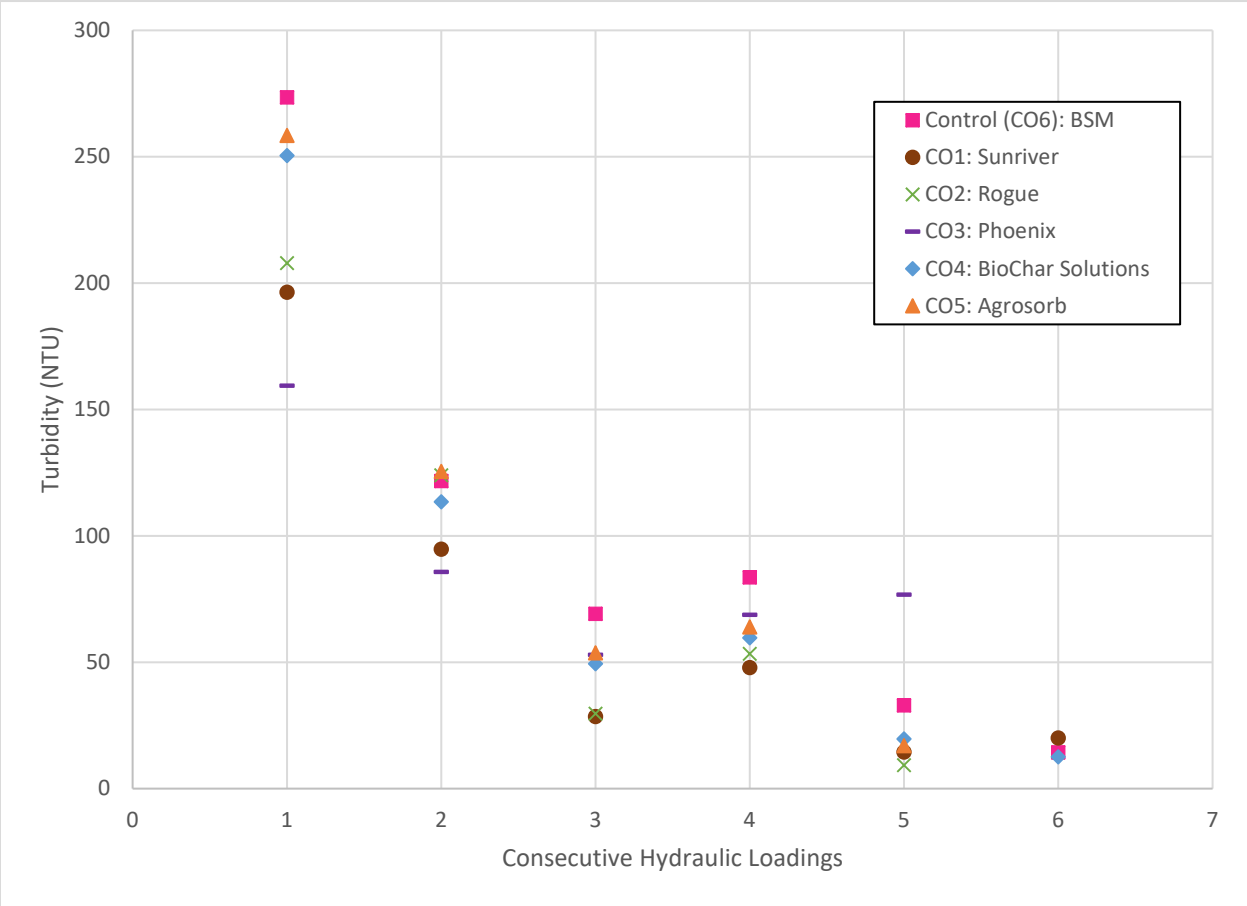

Figure 17. Average Turbidity versus Consecutive Hydraulic Loading (Sampling Runs are labeled 1, 3, 4, 5, and 6 and Seasoning Loading are labeled 2 and 3)

3.4 Statistical Tests

The statistical analysis (Mann-Whitney U test) on normalized effluent PCB concentrations was unable to establish statistical significance at 90% confidence among media type due to the small sample size, even when grouped by class (e.g., with biochar and without). This also held for mercury. Consequently, further statistical tests were not pursued.

4 CONCLUSIONS AND RECOMMENDATIONS

The goal of this study, as identified in the Monitoring Study Design (Appendix A), was to identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs. The primary management question supporting that goal was: "Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?" And the particular purpose of the laboratory testing in this study was: "screen alternative biochar-amended BSM and identify the most promising for further field testing." This study's use of bench scale column testing suggests that there may be some utility in pre-testing materials before use in field applications to ensure that they are likely to meet infiltration requirements

at the project site, as well as provide some preliminary evidence of improved or at least equivalent pollutant removal as standard BSM.

4.1 CONCLUSIONS

Nine biochar were readily available from suppliers in the Western United States, and five were tested in this study to compare their impacts on PCBs and mercury concentrations in effluent. All five biochar-BSM blends showed evidence of overall improved PCB and mercury performance compared to the standard BSM for influent concentrations ranging from 9,860 pg/L to 19,600 pg/L[8]. Though performance varied, no biochars could be conclusively eliminated from consideration in future field study. The results support the following observations:

- Phoenix, Sunriver, BioChar Solutions, and Agrosorb appear to offer improved PCB removal compared to standard BSM and the other biochar-amended BSM.
- Phoenix and Agrosorb appear to offer improved mercury removal compared to standard BSM and the other biochar-amended BSM.
- Based on a single run on one column to explore removal at lower influent concentrations, biochar-amended BSM provided removal of PCBs at an influent concentration of 2,100 pg/L. BSM performance at this lower influent concentration could not be reported due to the sample being lost. Neither BSM nor biochar-amended BSM provided removal of mercury at an influent concentration of 3.00 ng/L.
- High initial infiltration rates (associated with short-circuiting and higher pore velocities) correlated to poor performance. Three of four runs with high infiltration rates correlated with poor reduction of PCBs and mercury. All three runs with poor performance (two of which were on one column) occurred prior to a run with a moderate infiltration rate (< 12 in/hr).
- Saturated hydraulic conductivity had poor correlation to the falling head infiltration rates estimated during the water quality sampling runs so biochar that were eliminated from column testing based on saturated hydraulic conductivity tests may be candidates for future testing.

Because the study was a screening level analysis of biochars for potential further study, the limited data for each biochar did not allow for exploration of several factors that are presented in the following section for consideration in development of future study designs.

4.2 RECOMMENDATIONS

Based on this study, biochar shows promise in marginally increasing performance for PCB and mercury removal, however, increased benefit relative to increased cost was not analyzed. With such limited data, meaningful benefit-cost analysis may require collection of substantial field data. Because of the marginal increase in performance, standard BSM should be a component of future side-by-side testing of biochar-amended BSM. Sample size should be selected to provide suitable statistical power to better understand and qualify the performance differences. Other study considerations include long-term performance, media life expectancy, performance for other pollutants, impacts to plant health and water use, and maintenance ramifications. The study team developed the following recommendations for potential biochar testing.

8 The lowest influent concentration for Sunriver (CO1) was 8,160 pg/L.

4.2.1 Biochar Selection

For enhanced PCB removal, biochar candidates for further field testing are Phoenix, Sunriver, BioChar Solutions, or Agrosorb. If mercury removal is a design consideration, Phoenix and Agrosorb should be selected over Sunriver and BioChar Solutions. All biochar-amended BSM have falling head drain times in the column tests that were faster than the control BSM, so hydraulic performance should not influence selection. Other factors, such as cost and local sourcing should be considered in final biochar selection. Due to a lack of differentiation of performance and a lack of correlation between performance and cost, less expensive biochar that were not tested here may offer higher benefit/cost. Column tests could provide data for an indication of benefit/cost prior to field testing, but more data is recommended to quantify performance than what was specified in this study for screening-level analysis.

4.2.2 Site Selection

The results of this study could also have implications on site selection for future study. As a general principal, study locations should represent concentrations typical of watersheds that will be receiving green infrastructure, unless those concentrations are below the irreducible concentration. The data indicate that irreducible PCBs concentrations may be occurring around 1,000 pg/L. It is unclear for total mercury. Data from other studies in the San Francisco Bay Area should be consulted to develop a better estimate of irreducible concentrations so future study can avoid areas that are too clean for the technology to be effective for these pollutants.

4.2.3 Outlet Control

Outlet control may be the most important factor in performance. Outlet controls minimize short-circuiting (preferential flow paths) and they increase contact time. Elevated outlets can also increase contact time in between storm events, but this may also affect mercury speciation by providing an anoxic environment where methylation may occur. Further study should control for both contact time and presence of biochar to determine which has the greatest effect in field conditions. Further investigation into contact time (i.e., infiltration rates) and underdrain behavior at the CW4CB biochar location may also be helpful in development of future study plans.

4.2.4 Saturated Hydraulic Conductivity Testing Requirements

The representativeness and utility of the saturated hydraulic conductivity test under typical compaction conditions for highly organic and friable material may be a matter worth discussion within the appropriate BASMAA bioretention working groups. Use of outlet control could obviate the verification of the upper-end conductivity. A lower-end conductivity may still be recommended to assure that the outlet control governs flow rather than the media.

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APPENDIX A: MONITORING STUDY DESIGN

POC Monitoring for Management Action Effectiveness

Monitoring Study Design

Final, September 2017

Prepared for:

Bay Area Stormwater Management Agencies Association

Prepared by:

EOA, inc.
1410 Jackson Street
Oakland, California
94612

WATER PROGRAMS
SACRAMENTO STATE
6000 J Street
Sacramento, California
95819

SFEI
4911 Central Avenue
Richmond, California
94804

KINNETIC LABORATORIES INCORPORATED
307 Washington Street
Santa Cruz, California
95060

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1. Introduction

Discharges of PCBs and mercury in stormwater have caused impairment to the San Francisco Bay estuary. In response, the Regional Water Board adopted total maximum daily loads (TMDLs) to address these pollutants of concern (POC) (SFBRWQCB, 2012). Provisions C.11 and C.12 the Municipal Regional Stormwater NPDES Permit, MRP (SFBRWQCB, 2015) implement the Mercury and PCB Total Maximum Daily Loads (TMDLs) for the San Francisco Bay Area. These provisions require mercury and PCB load reductions and the development of a Reasonable Assurance Analysis (RAA) demonstrating that control measures will be sufficient to attain the TMDL waste load allocations within specified timeframes. Provision C.8.f of the MRP supports implementation of the mercury and PCB TMDLs provisions by requiring that Permittees conduct pollutants of concern (POC) monitoring to address the five priority information needs listed below.

1. *Source Identification* – identifying which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff;
2. *Contributions to Bay Impairment* – identifying which watershed source areas contribute most to the impairment of San Francisco Bay beneficial uses (due to source intensity and sensitivity of discharge location);
3. *Management Action Effectiveness* – providing support for planning future management actions or evaluating the effectiveness or impacts of existing management actions;
4. *Loads and Status* – providing information on POC loads, concentrations, and presence in local tributaries or urban stormwater discharges; and
5. *Trends* – evaluating trends in POC loading to the Bay and POC concentrations in urban stormwater discharges or local tributaries over time.

Table 8.2 of Provision C.8.f identifies the minimum number of samples that each MRP Countywide Program (i.e., Santa Clara, San Mateo, Alameda, and Contra Costa) must collect and analyze to address each monitoring priority. Although individual Countywide monitoring programs can meet these monitoring requirements, some requirements can be conducted more efficiently and will likely yield more valuable information if coordinated and implemented on a regional basis. The minimum of eight (8) PCB and mercury samples required by each Program to address information priority #3 is one such example. Findings from a regionally-coordinated monitoring effort would better support development of the RAA.

This Study Design describes monitoring and sample collection activities designed to meet the requirements of information priority #3 of Provision C.8.f of the MRP. The activities planned include field sampling of hydrodynamic separators and laboratory experiments with amended bioretention soils. Study planning is important to ensure that the right type of data are collected and there is a sufficient sample size and power to help address the management questions within the available time and budget constraints. Essential components of the study plan include describing problems, defining study goals, identifying important study parameters, specifying methodologies, and validating and optimizing the study design.

2. Problem Definition

Studies conducted to date have identified PCB source areas in the Bay Area where pollutant management options may be feasible and beneficial. Enhanced municipal operational PCB management options (e.g., street sweeping, storm drain line cleanout) have the advantage of being familiar and well-practiced, address multiple benefits, and the cost-benefit may exceed that for stormwater treatment (BASMAA, 2017a). Site-specific stormwater treatment via bioretention, however, is now commonly implemented to meet new and redevelopment (MRP Provision C.3) requirements. An added benefit of redevelopment is that PCB-laden sediment sources can be immobilized. However, many areas where certain land uses or activities generate higher PCB concentrations in runoff are unlikely to undergo near-term redevelopment, and instead may only be subject to maintenance operations or stormwater BMP retrofit projects implemented by the municipality. Consequently it is valuable to maximize cost effective PCB removal benefit of both operations and maintenance, and stormwater treatment.

Two treatment options that have the potential to reduce PCB discharges include hydrodynamic separators (HDS units) and enhanced bioretention filters. These options were pilot-tested in the Clean Watersheds for a Clean Bay (CW4CB) Project (BASMAA, 2017a). HDS units are being implemented for trash control throughout the Bay Area and collect sediment to some extent along with trash and other debris. Quantifying PCB mass removed by these units will help MRP Permittees account for the associated load reductions. For these and other control measures, an Interim Accounting Methodology has been developed based on relative mercury and PCBs yields from different land use categories (BASMAA, 2017c). Bioretention is a common treatment practice for new development and redevelopment in the San Francisco Bay Area, so enhancing the performance of bioretention is also attractive.

At this time reducing mercury loads in stormwater runoff is a lower priority than PCBs load reduction. The assumption during the MRP 2.0 permit term is that actions taken to reduce PCBs loads in stormwater runoff are generally sufficient to address mercury. Therefore, optimizing stormwater controls for PCBs is the primary focus in this study.

2.1 HDS Units

Limited CW4CB monitoring conducted at two HDS sites was used to calculate the mass of PCBs in trapped sediment (BASMAA, 2017a). The two sites sampled were Leo Avenue in San Jose and City of Oakland Alameda and High Street. The Leo Avenue HDS unit treats runoff from approximately 178 acres of watershed with a long history of industrial land uses, including auto repair and salvage yards, metal recyclers, and historic rail lines. The City of Oakland Alameda and High Street HDS has a tributary drainage area of approximately 35 acres with a high concentration of old industrial and commercial land uses, including historic rail lines.

Sampling of the two CW4CB HDS units was opportunistic and associated with scheduled cleanouts. Two sump cleanout events took place in August 2013, one at the Leo Avenue HDS unit and one at the Alameda and High Street HDS unit. However, due to a lack of captured sediment the samples collected were aqueous phase samples instead of sediment samples. An additional cleanout took place at Leo Avenue in October 2014. A sump sediment sample

collected and analyzed during this cleanout contained total PCB concentrations of 1.5 mg/kg and mercury concentrations of 0.33 mg/kg for sediment less than 2 mm in size, and estimated annual total PCB and mercury removals were 375 mg and 82.4 mg, respectively (Table 2.1). The HDS sediment concentrations are comparable to previous Leo Avenue watershed measurements in sediments from piping assessed via manholes, drop inlets/catch basins, streets/gutters, and private properties (ND to 27 mg/kg for PCBs and 0.089 to 6.2 mg/kg for mercury) (BASMAA, 2014). At the Alameda and High Street HDS unit, tidal influences of Bay water prevented additional monitoring.

Table 2.1 Summary of Data Collected from Leo Avenue HDS during October, 2014 Annual Cleanout Event

Parameter	Result	Units
Volume of Sediment Removed	4	Cubic yards
Total PCBs Concentration	1.5	mg/Kg
Mercury Concentration	0.33	mg/Kg
Bulk density	0.67	g/cm^3
Percent solids	39	%
Particle Size (< 2 mm)	31	%

There are no known published studies characterizing HDS sediment for PCBs or mercury, so the Leo Avenue results are compared to relevant drain inlet/catch basin sediment studies. In the Bay Area, different municipalities have collected and analyzed drain inlet cleaning sediment samples. The analytical results for these drain inlet sediment samples are summarized in Table 2.2 (BASMAA, 2014). As can be seen from Table 2.2, the Leo Avenue sediment PCB concentrations are higher than those measured in Bay Area drain inlet sediment by up to an order-of-magnitude, but mercury concentrations are comparable.

Table 2.2 Summary of Bay Area Drain Inlet Sediment Concentration Data
(Based on readily available data; see BASMAA (2016b) for additional summaries for street and storm drain sediment)

	PCBs			Mercury		
Municipality	No. Drain Inlet Sediment Samples	Mean PCB DI Sediment Concentration (mg/Kg)	Median PCB DI Sediment Concentration (mg/Kg)	No. Drain Inlet Sediment Samples	Mean Mercury DI Sediment Concentration (mg/Kg)	Median Mercury DI Sediment Concentration (mg/Kg)
Fairfield & Suisun	8	0.244	0.055	16	0.510	0.228
San Mateo County Municipalities	29	0.318	0.123	28	0.160	0.147
San Carlos	22	0.267	0.129	25	0.167	0.147
Alameda County Municipalities	47	0.294	0.122	75	0.384	0.204
Berkeley	8	0.147	0.122	11	0.343	0.241
Oakland	24	0.402	0.155	28	0.539	0.297
San Leandro	11	0.219	0.106	21	0.230	0.151
Contra Costa County Municipalities	46	0.515	0.168	48	0.413	0.308
Richmond	31	0.736	0.482	28	0.460	0.349

Notes:
Mean and median drain inlet sediment concentrations were calculated from the SFEI database (SFEI 2010, KLI and EOA 2002; City of San Jose and EOA 2003).

Monitoring by the City of Spokane, Washington, showed total PCBs in catch basin sediment ranged between 0.025 mg/kg and 1.7 mg/kg for an industrial area with known PCB contamination (City of Spokane, 2015). A City of San Diego study characterized sediments in eight catch basins in a 9.5 acre area of downtown San Diego classified as high density mixed use with roads, sidewalks, and parking lots (City of San Diego, 2012). Concentrations of common aroclors in the catch basin sediments varied from about 0.040 to over 0.9 mg/kg. Monitoring by the City of Tacoma showed PCB concentrations in stormwater sediment traps varied from nondetect to a maximum near 2 mg/kg (City of Tacoma, 2015). The highest PCB concentrations in catch basin sediments ranged from 16 mg/kg in downtown Tacoma to 18 mg/kg in East Tacoma. These published drain inlet/catch basin studies show that PCB and mercury concentrations can vary substantially in storm drain sediments depending on the characteristics of the watershed.

Sampling of captured sediment at the Leo Avenue HDS in San Jose highlighted the potential of HDS maintenance as a management practice for controlling PCB and mercury loads. The BASMAA Interim Accounting Methodology that is currently being used to calculate load reductions assumes a default 20% reduction of the area-weighted land-used based pollutant yields for a given catchment. This default value was based on average percent removal of TSS from HDS units based on analysis of paired influent/effluent data. However, significant data gaps remain in determining the effectiveness of this practice and expected load reductions. HDS sediment sampling has been limited to a few samples. PCB concentrations in the Leo Avenue HDS sample were much higher than average concentrations in Bay Area drain inlet sediment. Drain inlet/catch basin sediment sampling by others suggests that sediment PCB and mercury concentrations can vary substantially from watershed to watershed. **The monitoring performed to date is not sufficient to characterize pollutant concentrations of sediment captured in HDS units that drain catchments with different loading scenarios (e.g., land-uses, stormwater volumes, etc.), nor to estimate the percent removal based on the pollutant load captured by the HDS unit. Additional sampling is needed to better quantify the PCB and mercury loads capture by these devices, and calculate the percent removal achieved**. Consequently, quantification of PCBs removed at other HDS locations and evaluation of the percent load reduction achieved is needed to provide better estimates of PCB load reductions from existing HDS unit maintenance practices.

2.2 Bioretention

The results of monitoring the performance of bioretention soil media (BSM) amended with biochar at one CW4CB pilot site suggest that the addition of biochar to BSM is likely to increase removal of PCBs in bioretention BMPs. Biochar is a highly porous, granular material similar to charcoal. In the CW4CB study, the effect of adding biochar to BSM was evaluated using data collected from two bioretention cells (LAU 3 and LAU 4) at the Richmond PG&E Substation 1st and Cutting site. At this site, cell LAU 3 contains standard engineered soil mix (60% sand and 40% compost) while cell LAU 4 contains a mix of 75% standard engineered soil and 25% pine wood-based biochar (by volume).

Figure 2.1 shows a cumulative frequency plot of influent and effluent PCB concentrations for the two bioretention cells. Although influent PCB concentrations at the two cells were generally similar, effluent PCB concentrations were much lower for the enhanced bioretention

cell (LAU 4) compared to those for the standard bioretention cell (LAU 3). The results for total mercury were different from those for PCBs, with both cells demonstrating little difference between influent and effluent concentrations. These CW4CB monitoring results suggest that the addition of biochar to BSM may increase removal of PCBs but not mercury from stormwater. However, analysis of methylmercury indicated that BSM may encourage methylation while biochar may mitigate the effect such that there is no substantial transformation of mercury to methylmercury. Tidal influences at 1st and Cutting also may be a contributing factor that should be controlled in future study.

The majority of biochar research conducted to date has focused on agricultural applications, where biochar has been shown to improve plant growth, soil fertility, and soil water holding, especially in sandier soils. Only a handful of field-scale projects have investigated the effects of biochar in stormwater treatment and no known field studies have investigated removal of mercury or PCBs from stormwater by biochar-amended media.

A recent laboratory study on the effect of biochar addition to contaminated sediments showed that biochar is one to two orders of magnitude more effective at removing PCBs from soil pore water than natural organic matter, and may be effective at removing methylmercury but not total mercury (Gomez-Eyles et al., 2013). A laboratory column testing study to determine treatment effectiveness of 10 media mixtures showed that a mixture of 70% sand/20% coconut coir/10% biochar was one of the top performers and cheaper than similarly effective mixtures using activated carbon (Kitsap County, 2015). Liu et al (2016) tested 36 different biochars for their potential to remove mercury from aqueous solution and found that concentrations of total mercury decreased by >90% for biochars produced at >600◦C but about 40–90% for biochars produced at 300◦C.

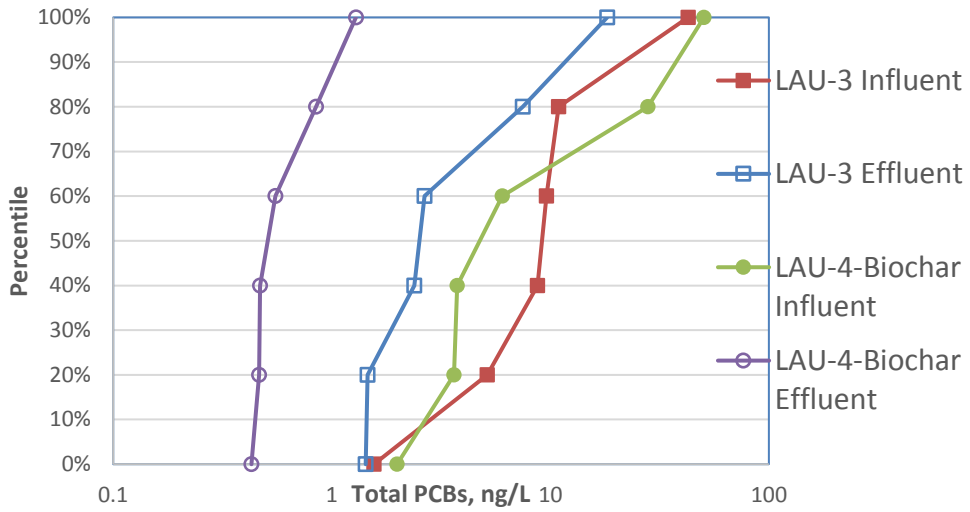

Figure 2.1 Cumulative Frequency Distribution of Total PBCs Influent Concentrations for Bioretention Media with and without Biochar

Monitoring of two bioretention cells at the Richmond PG&E Substation 1st and Cutting pilot site showed greater PCB removal for a biochar-amended BSM than that for standard BSM.

However, to date sampling has been limited to one test site and one biochar amendment, and the operational life of the amended media is unknown. **Besides the CW4CB study, there are no published literature studies on field PCB and mercury removal for biochars. Additional field testing can confirm the effectiveness of bioretention implementation in more typical conditions, and laboratory testing is recommended as an initial screening to help identify potential biochars for field testing**. Laboratory testing using actual stormwater from the Bay Area can be a cost-effective screening tool to identify biochar media that are effective for PCB removal, do not exacerbate mercury problems or even improve mercury removal, and meet operational requirements, including an initial maximum infiltration rate of 12 in/h and a minimum long-term infiltration capacity of 5 in/h.

3. Study Goals

The goals of this study identified from the problem statements are as follows:

1. Quantify annual PCB and mercury load removals during maintenance (cleanout) of HDS units
2. Identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs

To reach these goals, the following management questions are prioritized as primary or secondary management questions.

3.1 Primary Management Questions

A properly conceived study will address the study goals in a manner that supports planning for future management actions or evaluating the effectiveness or impacts of existing management actions. The resulting primary management questions focus on performance and are:

1. What are the average annual PCB and mercury loads captured by existing HDS units in Bay Area urban watersheds?
2. Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?

The MRP infiltration rate requirements are described in Provision C.3.c of the MRP (SFBRWQCB, 2015). This provision states the following: "Biotreatment (or bioretention) systems shall be designed to have a surface area no smaller than what is required to accommodate a 5 inches/hour stormwater runoff surface loading rate, infiltrate runoff through biotreatment soil media at a minimum of 5 inches per hour, and maximize infiltration to the native soil during the life of the Regulated Project. In addition to the 5 inches/hour MRP requirement, for non-standard BSM the recently updated BASMAA specification requires "certification from an accredited geotechnical testing laboratory that the bioretention soil has an infiltration rate between 5 and 12 inches per hour" (BASMAA, 2016a).

3.2 Secondary Management Questions

Secondary management questions are helpful, but they are not critical to the usefulness of the study. Study scope, budget, and schedule constraints limit the extent to which they can be addressed. Possible secondary management questions include the following:

HDS

1. How does sizing of HDS units affect annual PCB and mercury loads captured in HDS sediment?
2. Do design differences between HDS units (e.g., single vs multiple chambers) result in significant differences in pollutant capture?
3. How does the frequency of cleanout of HDS units affect load capture?

4. If present, does washout of HDS sediment depend on remaining sediment volume capacity?
5. Are there significant concentrations of PCBs in the pore (interstitial) water of HDS sediment?
6. Are PCBs and mercury removal correlated to removal of better-studied surrogate constituents, such as TSS?
7. Is there evidence of increased methylation within HDS sediment chambers?

Enhanced Bioretention

1. How does biochar performance vary with feedstock?
2. How does biochar performance vary with manufacturing method?
3. Should the biochar be mixed with the BSM or provided as a separate layer below the standard BSM?
4. Does biochar have leaching issues or require conditioning before use?
5. How long does the improved performance of biochar-amended BSM last?
6. Does the promising media increase methylation of mercury?
7. What is the expected increase in BSM costs due to inclusion of media amendment?
8. Does knowledge of the association of PCBs and mercury to specific particle sizes improve understanding of performance?
9. Is mass removal comparable to that expected from a conceptual understanding of removal mechanisms?

The above secondary management questions are provided as examples, and the questions answered will depend on budget, schedule, and actual data collected.

3.3 Level of Confidence

The level of confidence in the answers to the above management questions depends on sample representativeness and size. Samples are considered representative if they are derived from sites or test conditions that are representative of the watershed or treatment being considered. A power analysis can be used after monitoring commences or at the end of a study to determine if sample size is sufficient to draw statistically valid conclusions at a pre-selected level of confidence. Power analysis can also be used prior to study commencement, but its usefulness in estimating sample size requirements may be limited by lack of knowledge of variability in the biochar-amended BSM data to be collected.

Level of confidence can also be assessed in terms of consistency of treatment (e.g., a particular biochar consistently shows better removals than other biochars for a variety of stormwaters), which can be assessed with non-parametric approaches such as a sign-rank test.

Data analysis approaches are discussed in Section 8.5.

4. Study Design Options

An overview of the available study designs is presented here to understand the methods, value, and constraints of each design. This information is helpful in identifying which study designs are appropriate for the various management questions. To answer the primary management questions, the mass of pollutants captured must be quantified. This is accomplished by monitoring pollutant input and export for each HDS unit or media option, or directly quantifying captured pollutant. For example, the typical input and output pathways for a stormwater treatment measure (i.e., BMP) are illustrated in **Error! Reference source not found.**4.1. This overview describes how data are collected and how they are used to answer the primary study questions.

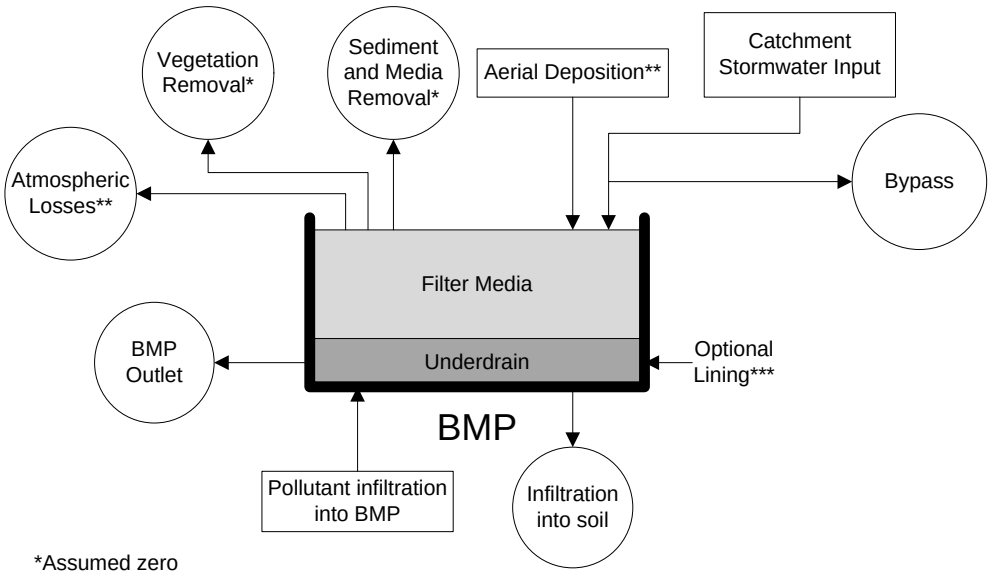

Figure 4.1 Typical BMP system and pollutant pathways

The study designs discussed here address major inputs and losses, but not all. Selection of study design is based on the management questions, the type of BMP(s), the study constraints, and the current and historic conditions of the study area. Each type of study has associated strengths and weaknesses as described below:

- Influent-effluent monitoring
  Influent and effluent monitoring tests water going into and discharging from a selected BMP or treatment option for a particular storm event. This approach is typically used to assess BMP effectiveness. An advantage of this approach is its ability to discern differences in limited data sets. A weakness of this approach is that measured load reductions may not be representative of true load reductions if there is infiltration to the native soil, baseflow entering the BMP, or bypass flows that are not monitored

- Sediment sampling
  Sediment sampling occurs within the BMP or treatment option and is used to estimate cumulative load removed over several storms. Sediment sampling can occur in dry periods.

- Before-after monitoring
  Before-after monitoring occurs at the same location. In the before-after approach, data are collected at some location, a change is made (i.e., a BMP is implemented or modified), and additional data are then collected at the same location. This introduces variability because in field monitoring the storms monitored before BMP implementation may not have the same characteristics as those after implementation.

- Paired watershed monitoring
  Paired watershed attempts to characterize two watersheds that are as similar as possible, except one has BMP treatment (e.g., an HDS unit). The paired watershed approach is typically used when monitoring the influent of the BMP is infeasible. While the storms monitored are the same, inevitable differences in the watersheds often lead to unexplainable variability.

  Paired watershed monitoring is not discussed further because it is not applicable to this study. The scope of work does not require influent monitoring at field sites or monitoring of paired sites without BMPs.

Volume measurement is critical to estimating load removal efficiency for BMPs that have volume losses. Volumes can be measured at influent, effluent, and bypass locations and within the BMP for individual storms or over a longer period.

The following subsections provide more detail on each monitoring approach.

4.1 Influent-Effluent Monitoring

Comparison of influent and effluent water quality and load is the method most often used in studies of treatment BMPs. This method is used to estimate the pollutant removal capability of field devices such as individual BMPs or a series of in-line BMPs (i.e., a treatment train) or laboratory treatment systems such as filter media columns. This type of study results in paired samples. Paired samples are beneficial because fewer samples are needed to show statistically significant levels of pollutant reduction compared to unpaired samples. This can result in substantial cost savings for sample collection and sample analysis.

Comparison of performance among BMPs may not be possible if there are only a limited number of locations because of different influent qualities. This is illustrated in **Error! Reference source not found.** for two non-overlapping BMP data sets, which show confidence intervals for effluent estimates (vertical dashed and dotted lines with arrows) expand as the distance between the hypothetical influent *x*-value and the mean *x*-value of the data increases. Although the effluent estimates at a common influent concentration (solid black square and diamond) may reflect true effluent qualities, confidence in these predictions is low because of this extrapolation and the performance of the two BMPs may not be statistically distinguishable. A better study design is one that selects sites with similar influent

characteristics or ensures collection of a sufficient number of samples at or close to the common influent level.

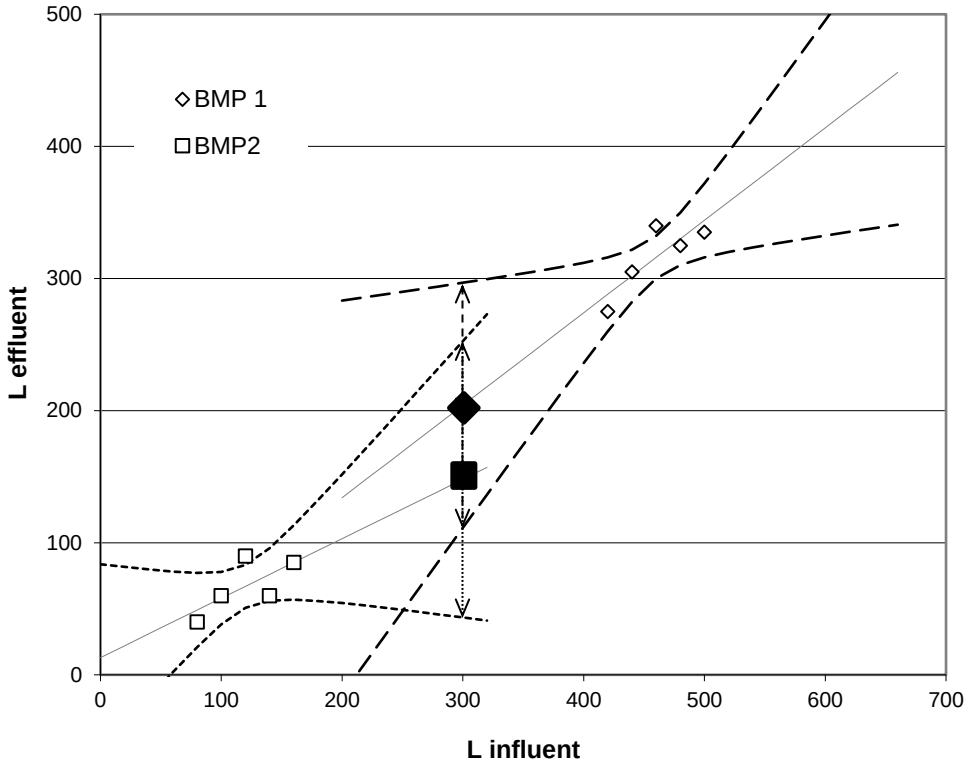

Figure 4.2 Comparison of two hypothetical non-overlapping BMP regressions

4.2 Sediment Sampling

Sediment sampling involves taking samples of actual sediment captured in a BMP in lieu of influent and effluent monitoring. Analysis of the accumulated sediment can provide estimates of the total mass of conservative pollutants removed[1]. An advantage of sediment sampling is reduced cost because expensive storm event sampling is not required. Another advantage is that the measure of pollutants is direct and it is not possible to obtain negative results as in the case of sampling highly variable influent/effluent.

There are a number of limitations to sediment sampling. Annual sediment sampling during a maintenance interval generates fewer data points than influent-effluent sampling throughout a storm season, so comparisons among BMP factors (design, loading, etc.) may require a greater number of monitoring sites. Another limitation is that influent monitoring data are not available to describe how the mass removal estimates may be sensitive to influent loading, and influent monitoring may be required in addition to sediment sampling to

[1] In the context of sediment sampling, "conservative pollutants" are those that are not substantially lost to volatilization or plant uptake in between periods of sediment analysis. Sediment analysis underestimates performance where volatilization or plant uptake is substantial.

characterize pollutant loading. This limitation is addressed in this study during the data analysis by using model estimates of stormwater flows and pollutant loads from each HDS unit catchment to provide estimates of the influent and associated percent removals achieved.

Another limitation of sediment sampling is the potential error resulting in non-homogeneous pollutant distribution within the sediment. Compositing multiple samples will better characterize the sediment, much as the collection of several aliquots throughout a stormwater runoff event can better represent the total volume of water. Mixing the removed sediment before compositing can provide samples that are more homogeneous.

Consequently, the effectiveness of sediment sampling depends on the type of BMP. HDS are the best candidates for sediment sampling. The sumps are cleaned and empty at the start of the study, and the entire mass of retained sediment is removed at each maintenance event (sump cleanout). Conversely, bioretention has background sediment (planting media) that obscure pollutant accumulation. Since pollutants tend to accumulate on the surface of media (typically within the first few inches), surface sediments should be targeted when sampling these systems. Coring these systems and compositing the core sediments will most likely result in further dilution of the PCBs retained in the media, making quantification more difficult. For all systems, larger pieces of litter and vegetation may be difficult to include in the analysis. A conservative approach is to exclude larger material and assume these have little association with PCBs.

4.3 Before-After Monitoring

Pollutant removal can also be estimated by monitoring discharge quality for treatment devices before and after installation. This may be attractive for green street projects that have multiple BMPs with multiple influent and effluent locations. Monitoring all of these individual systems is almost impossible because of space constraints. Note that since the data from before/after implementation are unpaired, variability is expected to be larger and the number of samples required to show significant removal much higher than for paired samples.

Before-after monitoring is also applicable to laboratory test systems in which water quality is measured before and after a change is made. For example, the rate of adsorption or the adsorptive capacity of media can be determined by measuring the water quality before and after addition of a known quantity of media.

5. Primary Data Objectives

The study design options discussed previously are matched to the primary management questions. The primary management questions require two data objectives: determine annual mass captured by HDS units and load removal by biochar-amended BSM. The primary management questions are:

1. What are the **annual PCB and mercury loads captured** by existing HDS units in Bay Area urban watersheds?
2. Are there readily available biochar-amended BSM that provide significantly better **PCB and mercury load reductions** than standard BSM and meet MRP infiltration rate requirements?

Monitoring to address the first management question should at minimum provide the average annual PCB and mercury loads captured by HDS units.

5.1 Data Objective 1: Annual Loads Captured by HDS Units

Determined by influent-effluent monitoring for individual storm events over one or more seasons or filter media/sediment sampling at end of each season.

Options:

- Influent-effluent monitoring. Requires monitoring of as many storms as possible over a season and flow measurement in addition to water quality sampling. Flow measurement is a critical component for estimating stormwater volumes treated, retained, and bypassed, and is often associated with additional measurements such as water depth within a BMP to estimate bypass and retention.
- Filter media/sediment sampling. Requires sampling at end of season but does not require influent/effluent water quality or flow measurement. Sediment sampling has a high value for estimating annual mass removal because a single composite sample of retained sediment over a season can yield an estimate of load removal for the constituents analyzed. However, influent characterization would also help explain mass removal performance. This method is most appropriate when applied to HDS systems because they can isolate retained sediment.

5.2 Data Objective 2: Loads Reduced by Biochar-Amended BSM

Determined by influent-effluent monitoring or filter media/sediment sampling for individual events until sufficient data are available for statistical analysis.

Options:

- Influent-effluent monitoring. Requires monitoring of multiple individual events and flow measurement in addition to water quality sampling. Accurate flow measurement in BMPs is difficult because flows can vary an order of magnitude during individual events and measurements may be required at multiple locations within a device because of bypass, infiltration etc. (see Figure 4.2). This complexity introduces a great degree of variability in the monitored data that can substantially increase the number of data points required to show statistically significant load removals, particularly for BMPs such as HDS units that

show relatively small differences between influent and effluent load reductions. This option is most appropriate for testing filter media, for example in laboratory experiments, in which accurate flow measurements are possible and sampling of accumulated sediment is infeasible.

- Filter media/sediment sampling. Requires sampling after individual events but does not require influent/effluent water quality or flow measurement. This method is not feasible for filter media because the retained sediment cannot be isolated from the filter media.

6. BMP Processes and Key Study Variables

The treatment mechanisms that occur in a BMP help inform selection and control of the study variables. These treatment mechanisms, also called *unit processes*, may include physical, chemical, or biological processes. The primary physical, chemical, and biological processes that are responsible for removing contaminants include the following:

- Sedimentation – The physical process by which suspended solids and other particulate matter are removed by gravity settling. Sedimentation is highly sensitive to many factors, including size of BMP, flow rate/regime, particle size, and particle concentration, and it does not remove dissolved contaminants. Treated water quality is less consistent compared to other mechanisms due to high dependence on flow regime, particle characteristics, and scour potential.
- Flocculation – Flocculation is a process by which colloidal size particles come out of suspension in the form of larger flocs either spontaneously or due to the addition of a flocculating agent. The process of sedimentation can physically remove flocculated particles.
- Filtration – The physical process by which suspended solids and other particulate matter are removed from water by passage through layers of porous media. Filtration provides physical screening of particles and trapping of particles within the porous media. Filtration depends on a number of factors, including hydraulic loading and head, media type and physical properties (composition, media depth, grain size, permeability), and water quality (proportion of dissolved contaminants, particle size, particle size distribution). Compared to sedimentation, filtration provides a more consistent treated quality over a wider range of contaminant concentrations.
- Infiltration – The physical process by which water percolates into underlying soils. Infiltration is similar to filtration except it results in overall volume reduction.
- Screening – The physical process by which suspended solids and other particulate matter are removed by means of a screen. Unlike filtration, screening is used to occlude and remove relatively larger particles and provide little or no removal for particles smaller than the screen opening size and for dissolved contaminants.
- Sorption – The processes of absorption and adsorption occur when water enters a permeable material and contaminants are brought into contact with the surfaces of substrate media, plant roots, and sediments, resulting in short-term retention or long-term immobilization of contaminants. The effectiveness of sorptive processes depends on many factors, including the properties of the water (contaminant concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, pH, particle size and charge), media type (surface charge, absorptive capacity), and contact time.

- Chemical Precipitation – The conversion of contaminants in the influent stream, through contact with the substrate or root zone, to an insoluble solid form that settles out. Consistent performance often depends on controlling other parameters such as pH.
- Aerobic/Anaerobic Biodegradation – The metabolic processes of microorganisms, which play a significant role in removing organic compounds and nitrogen in filters.
- Phytoremediation – The uptake, accumulation, and transpiration of organic and inorganic contaminants, especially nutrients, by plants.

The relative importance of individual treatment mechanisms depend to a large extent on the chemical and physical properties of the contaminant(s) to be removed i.e. the influent quality. The two contaminants of interest in this study are PCBs and mercury. PCBs are relatively inert hydrophobic compounds that have very limited solubility and a strong affinity for organic matter. They are often associated with fine and medium-grained particles in stormwater runoff, making them subject to removal through gravitational settling or filtering through sand, soils, media or vegetation. Most of the mercury in water, soil, and sediments is in the form of inorganic mercury salts and organic forms of mercury such as methylmercury that are strongly adsorbed to organic matter (e.g., humic materials). In general, mercury is most strongly associated with fine particles while PCBs are generally associated with relatively larger and/or heavier particles. It is therefore expected that sedimentation, flocculation, and related processes will be less effective for mercury removal than for removal of PCBs (Yee and McKee, 2010).

The following subsections provide a brief description of the BMP types being evaluated in this study, the unit processes involved in each, and key variables that indicate possible data collection approaches. The final selection of the quantity and type of data to collect is presented in the "Optimized Study Design" section.

6.1 HDS Units

Hydrodynamic separators rely on sedimentation and screening as the primary removal mechanism for sediment and particulate pollutants. Treatment performance is highly dependent on the following:

- Influent quality (contaminant concentration, proportion of dissolved contaminants, particle size, particle size distribution, and particle density)
- BMP design and hydraulic loading/flow regime (size of unit versus catchment area)
- Operational factors (remaining sediment capacity)

HDS effluent quality is highly variable, particularly for contaminants such as mercury that are associated with fine particles that are not as effectively removed in HDS. These devices are expected to require a relatively large number of influent-effluent samples to demonstrate statistically significant reductions in pollutant concentrations. Therefore, analysis of retained sediment is an appropriate alternative to influent-effluent sampling for determining pollutant mass captured. Sediment can be analyzed when the device is cleaned.

6.2 Bioretention

Bioretention is a slow-rate filter bed system. It is planted with macrophytes (typically shrubs and smaller non-woody vegetation). The major sediment removal mechanism is physical filtration through the planting media. When retention time is sufficient, dissolved constituents can be removed by sorption to plant roots in the planting media, which typically contains clays and organics to enhance sorption. Treatment performance is highly dependent on the following variables:

- Influent quality (contaminant concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, particle size distribution)
- BMP design and hydraulic loading rate/head (size of the unit in relation to catchment area and storm character)
- Media type and properties (composition, grain size, grain size distribution, adsorptive properties, and hydraulic conductivity)
- Volume reduction by infiltration
- Operational factors (surface clogging, short-circuiting)

The effluent quality from bioretention and enhanced bioretention is expected to be consistently higher than for sedimentation-type BMPs. These devices are expected to require a relatively fewer number of samples than HDS units to demonstrate statistically significant reduction because of better treatment of fine particles and dissolved contaminants.

It is important to note that laboratory and not field bioretention systems are of interest in this study. These laboratory systems, essentially cylindrical columns filled with the media being tested, attempt to simulate most, but not all, of the chemical, biological, and physical processes that occur in field devices. For example, volume reductions due to infiltration are not simulated in laboratory column experiments. The advantages of using media columns as proxies for field devices include improved control over operation, monitoring, and sample collection in ways that would be impractical in the field. This improved control makes it possible to test a large number of potential media and identify the most promising for future field testing.

7. Monitoring and Sampling Options

Key variables that affect water quality and sediment quality data are identified from knowledge of treatment processes. The following lists the process variables identified through knowledge of the treatment processes:

- Influent quality (contaminant concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, particle size distribution, particle density)
- BMP design and hydraulic loading (flow rate, hydraulic head, flow regime)
- Media type and properties (composition, grain size, grain size distribution, adsorptive properties, and hydraulic conductivity)
- Operational factors (surface clogging, short-circuiting, remaining sediment capacity)

Some of the above variables can be controlled and others are measured to determine their effect on water quality and sediment quality. Inevitably, some variables will be beyond the control of the study but their expected impact should be considered based on theory, past experience, models, or observations from other studies.

7.1 HDS Units

7.1.1 Influent Quality

The location of the BMP can greatly affect influent water quality such as pollutant concentrations and particle characteristics because land use and land cover affect sediment mobilization and pollutant concentrations within the sediments. Land use is often used as an indicator of pollutant loading. The land uses of the areas of interest include industrial, commercial/mixed use, roads/rail, institutional, and residential. Because of past use of PCB and past PCB and mercury handling practices, age of the land use is also important, with generally higher concentrations from older industrial, commercial, and transportation areas, and lower concentrations from newer residential areas. However, PCB analysis by the San Francisco Estuary Institute (SFEI) showed that PCB concentration patterns were patchy within larger urban watersheds with higher concentrations. This finding indicates that mass reductions of PCBs may require site-specific sampling of influent loads or site-specific quantification of mass removed. Mercury data suggest areas with higher mercury concentrations are not as pronounced although generally where there is PCB contamination there is also high to moderate Hg contamination (Yee and McKee, 2010).

Since HDSs are primarily installed for trash capture, their distribution within the study area is assumed to be random. However, the primary interest is in watersheds with relatively high pollutant loads that are most likely to result in significant removal in HDSs (e.g., the Leo Avenue watershed). Land use or land use based pollutant yields can be used to represent average influent water quality when influent monitoring is not conducted.

Figure 7.1 shows the land use based PCB and mercury loadings for key designated land use types. It can be seen that unit PCB loading from watersheds with higher PCB concentrations and mercury loading from old industrial watersheds are substantially higher than the other land uses. Assuming particle size, particle size distribution, and other stormwater characteristics are similar for the different land uses, HDSs in higher concentration watersheds or old industrial watersheds are expected to capture much higher pollutant loads than those in other watersheds.

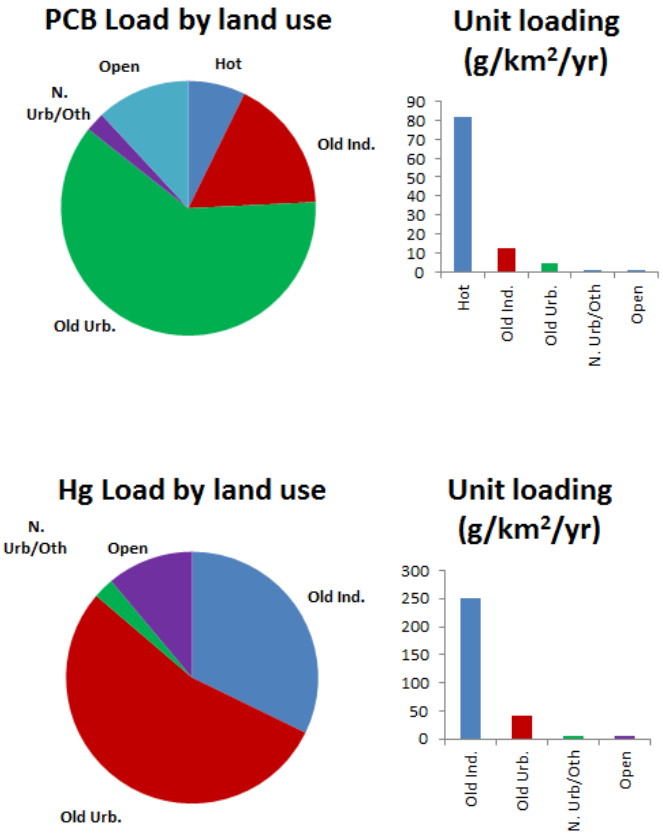

Figure 7.1 Land Use based PCB and Mercury Loading based on BASMAA Integrated Monitoring Reports (SFEI, 2015)

A preliminary land use based study design could categorize HDS sites as show in Table 7.1.

Table 7.1 HDS Sampling Design based on Watershed Land Use

Land Use	HDS Samples
Higher Concentration	X, X, X[1]
Old Industrial	X, X, X[1]
Old Urban	X, X, X[1]

1 – "X" represents a sample from a selected HDS unit in the specified land use category.

The above design is appropriate if HDS units can be categorized easily into one of the three land use categories. A review of the land uses within HDS watersheds indicates that most HDS units are in predominantly old urban watersheds, and it is unclear how many HDSs are within areas with higher PCB concentrations (Table 7.2).

Table 7.2 Percent of Land Use in HDS Watershed Areas
(Based on FY 2015-16 Co-permittee Annual Reports, Section 10 - Trash Load Reduction. Source: Chris Sommers Personal Communication)

HDS Catchment ID	New Urban	Old Industrial	Old Urban	Open Space	Other
287; Sonora Ave		16	84	1	
27A	15	50	34	2	
996; Parkmoor Ave		1	98	1	
1084; Oswego		0	89	0	10
600; Edwards Ave		33	39	28	
611; Balfour		14	55	30	
1082; Melody/33rd		0	97	3	
612; Lewis			93	7	
604; Sunset			96		4
1012; Blossom Hill/Shadowcrest			100	0	
1083; Lucretia		0	98	1	1
1002; Selma Olinder		10	86	5	
995; Dupont St.		9	91	0	
9-A; 73rd Ave and International Blvd		0	94	6	
475; 7th		68	29	3	
509; Coyote	22		77	1	
47			99	1	
8-A; Alameda Ave near Fruitvale		40	57	4	
575; Bulldog		6	93	1	
601; W. Virginia		7	90	3	
1504; Phelps			100	0	
390; Remillard		4	87	10	
Tennyson at Ward Creek		1	97	2	
W Meadow Dr		2	97	1	
Leland and Fair Oaks		1	99		
Ward and Edith			100	0	
5-D; 22nd and Valley		1	99	0	
8-C; High St @ Alameda Bridge		67	32	0	
5-G; Perkins & Bellvue (Nature Center)			100		
999; William		0	95	5	
Main St and Hwy 1			85	15	
Central Expy at Fair Oaks		11	89	0	
393; Wool Creek		18	78	4	
5-C; 27 St & Valdez Ave		2	98		
998; Pierce		1	96	3	
Maple and Ebensburg			98	2	
Ventura Ave			99	1	
Golden Gate and St Patrick			100	0	
5-A; Euclid Ave @ Grand Ave			100		
5-H; Lake Merritt (SD Outfall 11)			100		
5-B; Staten Ave & Bellvue			100		
Central Expy at De la Cruz		33	67		
5-I; Lake Merritt (SD Outfall 26)			100		
Mathilda overpass project CDS2		0	100		
Mathilda overpass project CDS1		10	84	7	

Given the few sites in categories other than old urban, an alternative study design based on mixed land uses may be more appropriate (Table 7.3).

Table 7.3 HDS Sampling Design based on Predominant Land Use

Predominant Land Use	HDS Samples
Higher Concentration/Old Industrial	X, X, X[1]
Old Urban/Old Industrial	X, X, X[1]
New Urban/Old Urban	X, X, X[1]

1 – "X" represents a sample from a selected HDS unit in the specified land use category.

The sampling design in Table 7.3 assumes that at least three HDS units are available for sampling in each PCB land use category. The sampling design may need to be modified further if there are an insufficient number of units available for sampling. For example, any site with more than 30% old industrial may be considered especially if it is a mixed zoned watershed (with industrial, commercial, residential and transportation land uses). The range of values in each land use category can be determined upon review of the most recent information. The design in Table 7.3 assumes that the characteristics of the runoff (e.g., particle sizes) are similar for the different land uses and only the yield is different.

Only sediment sampling is proposed for HDS. Since HDS influent-effluent monitoring is not required, variables such as proportion of dissolved contaminants, particle size, particle size distribution, and particle density are not measured or controlled, but their effect on influent quality and treatment is accounted for by randomly selecting HDSs within each land use category.

7.1.2 BMP Design and Hydraulic Loading

BMP design and hydraulic loading, which depends on the size of the BMP, can have a substantial impact on effluent water quality and the quantity of sediment retained in a BMP. Consequently, a full range of BMP designs and sizes are of interest. Properly sized, BMPs infrequently exceed their design capacity. However, BMPs are not always sized to standard specification, especially in retrofit environments in which typical hydraulic loading is much higher due to space constraints.

HDS units are typically proprietary and designs and sizing vary widely. Sediment capture may vary because of design differences such as number of chambers and design of overflow weirs and baffles, as well as different sizing criteria that can greatly affect both hydraulic loading and flow regime. The purpose of the study is to characterize sediment in HDS units in the study area. Since BMP design and sizing are important factors affecting HDS performance, it is necessary to include a range of HDS units in the study design and not just randomly select HDS units. A randomized blocked study design is therefore considered more appropriate than a completely random one that may result in an insufficient number of HDS units of a certain size.

In a randomized design, one factor or variable is of primary interest (e.g., land use), but there are one or more other confounding variables that may affect the measured result but are not of primary interest (e.g., HDS design, HDS size). Blocking is used to remove the effects of one or more of the most important confounding variables and randomization within blocks is then used to reduce the effects of the remaining confounding variables. An appropriate sampling design could therefore be land use as the primary factor and HDS size as the blocking factor. Since the population of HDS units in the land use categories of interest is limited, only

two size blocks are used (≤ 50th percentile, > 50th percentile), and other variables such as design differences are accounted for by random selection within each block (Table 7.4).

Table 7.4 HDS Sampling Design based on Predominant Land Use and HDS Size

Predominant Land Use	HDS Size	
	≤50th percentile	>50th percentile
Higher Concentration/Old Industrial	X, X, X[1]	X, X, X[1]
Old Urban/Old Industrial	X, X, X[1]	X, X, X[1]
New Urban/Old Urban	X, X, X[1]	X, X, X[1]

1 – "X" represents a sample from a selected HDS unit in the specified land use category.

For the sampling design in Table 7.4, an HDS size factor is required to differentiate the two types of sizes that are of interest. In controlled field study of 4 different proprietary HDS units and laboratory testing of 2 other units, Wilson et al. (2009) developed a *performance function* (treatment factor) that reasonably predicted the removal efficiency of a given hydrodynamic separator. The performance function explained particle removal efficiency in terms of a Péclet number, P_e, which accounts for particle settling and turbulent diffusion. In the following equation, V_s is the particle settling velocity, h is the settling depth in the device, d is the device diameter, and Q is the flow through the device:

$$P_e = \frac{V_s h d}{Q}$$

The above Péclet number (Wilson et al's performance function) can be used in the sampling design as the HDS size factor. For grouping the available HDS units into the two blocks, information is required on the particle diameter and design parameters for each device (settling depth, diameter, and design flow). Particle diameter can be assumed to be 75 µm, which is the critical size used for partitioning PCB fractions in Yee and McKee (2010), and is also approximately the size separating silt and fine sand size particles. The design flow can be calculated from knowledge of the drainage area to the device and a standard design storm. Note that the design flow should not be based on manufacturer guidance because different manufacturers use different sizing criteria and device sizing may not always follow manufacturer guidance.

The final sampling design may need revision depending on the monitoring approach, availability of HDSs, information on watershed land use and sizing, and the level of participation from municipalities.

7.1.3 Operation and Maintenance

Maintenance frequency can greatly impact BMP performance. For sedimentation BMPs such as HDS, sediment levels may exceed the sediment capacity of the BMP, decreasing the volume for sedimentation and increasing scour.

Operation and maintenance (e.g., cleanout frequency) are not of direct interest in this study and their effect on treatment is not being tested. However, these are confounding variables that need to be excluded. In the HDS sediment sampling design, HDS units that are considered at capacity or will reach capacity during the study should be excluded from the population of interest. Field observations are required to make this determination (e.g., whether the screen is blocked). These units can be cleaned out and sampled in a subsequent year. For each selected HDS unit, maintenance schedules (past and current) will need to be reviewed to determine the time period over which sediment accumulated.

7.2 Enhanced Bioretention

7.2.1 Influent Quality

The purpose of the laboratory testing is to screen alternative biochar-amended BSM and identify the most promising for further field testing. The laboratory testing requires influent-effluent monitoring. Influent water characteristics can vary depending on the source of the test water. PCB and mercury loading is largely a result of historic activities that result in accumulation in sediments of pervious areas. Mobilization of these sediments may require exceeding site-specific intensity and volume thresholds. Storm intensity is critical to detach and mobilize particles and storm volume must exceed any depression storage within the pervious areas. However, the precise effect of storm intensity and volume on the mobilization of PCB-contaminated and mercury-contaminated sediments has not been established. Influent water characteristics also depend greatly on drainage area characteristics including traffic and industrial and commercial activity.

Since the purpose of the laboratory study is to screen alternative biochar-amended BSM that can be used throughout the Bay Area, collection and use of stormwater from one or more representative watersheds is preferred. A preliminary review of available Bay Area stormwater runoff monitoring data from 27 sites (Table 7 of SFEI 2015) suggests median PCB concentration is about 9 ng/L. Therefore, one or more previously monitored watersheds with mean PCB concentrations well above 10 ng/L may be appropriate for collection of stormwater for the laboratory testing. Since the relative treatment performance of the various media at even lower concentrations may be different, additional tests with diluted stormwater may be required to confirm study results.

Storms from the representative watershed should be targeted randomly without bias, thereby accounting for the effects of storm intensity and ensuring variability in contaminant concentration, proportion of dissolved contaminants, particle size, particle size distribution, and particle density. To achieve this, minimal mobilization criteria should be used to ensure predicted storm intensity and runoff volume are likely to yield the desired volume.

7.2.2 BMP Design and Hydraulic Loading

The design variables in the enhanced bioretention testing laboratory study include media type, media depth, and media configuration. Media type is a key variable that is discussed further below. Testing the effect of different media depths or media configurations is not a research objective of the laboratory study, so these can be fixed for all experiments. Typical bioretention media depth in the Bay Area is 18 inches, so all column experiments should use 18 inches of BSM. In the Richmond PG&E Substation 1st and Cutting enhanced BSM testing, the biochar was not installed as a separate layer but was instead mixed with the standard BSM. It is unclear how treatment is affected by these two media configurations, but for consistency with previous field work the biochar and standard BSM should be mixed.

Hydraulic loading is a controlled variable that can be kept constant for all columns. Since the laboratory study is attempting to replicate field bioretention, the hydraulic loading can be the design loading for bioretention. Bioretention designs in the Bay Area typically have a maximum ponding depth of 6 inches, so a loading of 6 inches could be used for the column tests. There are two options for loading the columns: pump and manual. Peristaltic pumps are ideal for controlled loading, but in this study manual loading (batch loading) is more appropriate because of the potential for PCBs and mercury to stick to tubing, pump parts, etc. For manual loading, up to 10 inches of stormwater may be needed each time to ensure sufficient sample volume.

7.2.3 Media Type and Properties

Media type and properties have a substantial effect on the treatment performance of filtration devices. This group of variables include composition, grain size, grain size distribution, adsorptive properties such as surface area, and hydraulic conductivity. Media composition is a primary variable that accounts for differences in the biochars used and the proportion of each biochar in the amended BSM mix. The other variables (grain size, grain size distribution, adsorptive properties, and hydraulic conductivity) are not of direct interest in this study and are assumed to vary randomly or are controlled through screening experiments that limit their variability.

Biochar is produced from nearly any biomass feedstock, such as crop residues (both field residues and processing residues such as nut shells, fruit pits, and bagasse); yard, food, and forestry wastes; animal manures, and solid waste. Biochar feedstock and production conditions can vary widely and significantly affect biochar properties and performance in different applications, making it difficult to compare performance results from one study to another (BASMAA, 2017a). A laboratory study that characterized the physical properties of six different waste wood derived biochars found particle sizes ranging from over 20mm to fine powder and surface areas ranging from 0.095 to 155.1 m^2/g (Yargicoglu et al., 2015). The variability in biochar types and properties is expected to result in large variation in treatment efficiency and infiltration rates. Given the large number of potential biochars that could be tested and the need to meet an initial maximum 12 in/h infiltration rate and a minimum long-term infiltration rate of 5 in/h, a phased study design is appropriate. In such a phased study, promising readily available biochars are first identified through a review of the literature, and hydraulic screening experiments are performed on biochar-BSM media mixes to ensure infiltration rates are met

prior to performance testing. This approach is expected to be the most cost-effective because it reduces analytical costs.

There is little information on hydraulic properties of bioretention media amended with biochar, and it is not clear what percentage of the amended BSM should be biochar to maximize treatment benefit. Given the variable physical size of the biochar media, relatively fine biochars could result in a mix that does not meet the initial 12 in/h maximum infiltration rate or minimum 5 in/h long-term infiltration rate. Kitsap County (2015) tested a BSM mix containing 60% sand, 15% Compost, 15% Biochar, and 10% shredded bark, and found that the biochar mix had an infiltration rate of only 6.0 in/h. One conclusion of the study was that the reduction in infiltration rate with the biochar additive was most likely because of fines in the biochar. To overcome this, hydraulic screening experiments are required in which the infiltration rate for each media mix is measured prior to water quality testing to ensure that both the maximum and minimum rates are met. Initially, each biochar can be mixed with standard BSM at a rate of 25% biochar by volume (the same as that at the CW4CB Richmond PG&E Substation 1st and Cutting site). Hydraulic conductivity can be determined using the method stated in the BASMAA soil specification, method ASTM D2434, which requires measurement of water levels and drain times. If a mix does not meet the infiltration requirements, the percentage of biochar is adjusted and the new mix tested. Amended mixes that do not meet the infiltration rate requirements are removed from further consideration (i.e. the effect of hydraulic conductivity is controlled by screening).

The final phase of the laboratory study can be column testing to identify the most effective amended BSM mixes for field testing. An influent-effluent monitoring design is typically used in column testing and media effectiveness is assessed on a storm-to-storm basis with real stormwater collected in the Bay Area. Only media mixes that have passed the hydraulic screening should be tested. All media columns should be sufficiently large or replicated to account for or minimize the impact of variability in media installation and experimental technique. Standard BSM should be used as a control since the primary interest is to identify media mixes that perform significantly better than standard BSM. An example of the column sampling design for 5 new media mixes and one standard BSM control is shown in Table 7.5. The key variable of interest in the sampling design in Table 7.5 is the media mix (composition).

Table 7.5 Example Sampling Design for Laboratory Column Experiments

Biochar/BSM Mix	Column Samples
A Mix	X, X, X[1]
B Mix	X, X, X[1]
C Mix	X, X, X[1]
D Mix	X, X, X[1]
E Mix	X, X, X[1]
Control Mix	X, X, X[1]

1 – "X" represents an influent or effluent sample.

7.2.4 Operation and Maintenance Parameters

Operational life depends on the capacity to pass the minimum required stormwater flows. Like media life, operational life is important because it determines the frequency and cost of maintenance requirements. Maintenance frequency can greatly impact BMP performance, and lack of maintenance can lead to surface clogging and sediment clogging in the inlets which reduces treatment capacity and increases bypass and overflow. Operation and maintenance are not of direct interest in this study and their effect on treatment is not being tested. However, these are confounding variables that need to be excluded.

Media mixes that do not meet the maximum 12 in/h and minimum 5 in/h infiltration rates can be excluded by hydraulic screening experiments (discussed above). As well as meeting the maximum 12 in/h initial infiltration rate requirement, these screening experiments help ensure that the BSM mixes do not fail during the laboratory testing. However, operational performance in laboratory experiments is not expected to be representative of that in the field because of differences in influent quality, variability in loading, effects of vegetation, etc. Therefore, laboratory estimates of long term infiltration rate are of little use and field testing is required to confirm that selected media mixes meet the long-term minimum infiltration rate of 5 in/h. The laboratory testing, however, can provide relative comparisons of hydraulic performance that can be used to decide and screen out media mixes that are likely to hydraulically fail in the field.

7.3 Uncontrolled Variables and Study Assumptions

The following assumptions were adapted from the Caltrans PSGM (Caltrans, 2009):

- Site Assumptions
  - HDS sediment concentrations are representative of the land use within the watershed, i.e. there are no sources of sediment from adjoining watersheds, from illicit discharges, or from construction activities
  - HDS sediment or influent is not affected by base flow, groundwater, or saltwater intrusion
  - Differences in storm patterns throughout the Bay Area are not sufficient to change the HDS performance measurements
  - Water quality of stormwater collected for laboratory testing is representative of that observed in Bay Area urban watersheds
- BMP Operation Assumptions
  - Sampled HDS units operated as designed (e.g., no significant scouring)
  - Volatilization of pollutants is negligible
  - There is no short-circuiting of flows in laboratory column studies
- Media Selection Assumptions
  - The readily available biochars selected are representative of all biochars
  - Selected media do not leach contaminates and media conditioning (e.g., washing) is not required
- Monitoring Assumptions

- Data collected from a few sites over a relatively short time span will accurately represent sediment at all HDS sites over longer time frames
- There are minimal contaminant losses in collecting and transporting water for laboratory experiments
- Water quality of stormwater for laboratory tests does not change significantly during each test
- Stormwater loading of laboratory columns is representative of loading in the field
- Long-term infiltration performance of biochar mixes is to be tested in the field

8. Final Study Design

The study design is optimized to answer the primary management questions within the available budget. The design used prioritizes sampling of HDS units, but allocates sufficient funding for minimum sampling requirements for the laboratory media testing study. Monitoring that does not relate directly to the primary management questions is considered lower priority.

8.1 Statistical Testing & Sample Size

In a traditional test of a treatment, the null hypothesis is that there is no difference between the influent and effluent of a treatment (i.e., the treatment does not work). In the case of HDS sampling, influent-effluent sampling is not required, and interest is only in determining if HDS units remove PCBs and mercury and how the sediment concentrations and load removals vary for different land uses, and for different rainfall and stormwater flow characteristics. Statistical testing in the HDS study is therefore limited to testing if there is a difference in the concentrations and loads captured by HDS units in different watersheds. This testing will require sampling of a sufficient number of HDS units in each land use category associated with differing pollutant load yields.

In the laboratory study, influent-effluent sampling is required and traditional statistical tests can be used depending on sample size.

As well as traditional statistical testing, confidence in the conclusions can be established by comparing total PCB and mercury performance to that for other constituents that directly affect it (e.g., suspended solids, total organic carbon) or have similar chemistry (e.g., other organics). As stated previously, total PCB and mercury concentrations are expected to correlate to some extent with particulates and organics. Comparisons to other constituents are particularly useful for studies in which treatment is expected to be low and the corresponding sample size requirements very high.

Sample size requirements are smaller for paired sampling designs (i.e., influent and effluent sampling for the same storm event) than for independent sampling designs. Paired sampling is not possible for the HDS sampling study that has no influent-effluent monitoring, but is possible in the laboratory media testing study. Additionally, the number of samples required to show significant treatment are generally fewer for filtration-type BMPs than sedimentation-type BMPs because of their better and more consistent treatment.

8.2 Constituents for Sediment Analysis

Constituents selected for HDS sediment analysis must meet the data objectives discussed previously in “Primary Data Objectives”, and be consistent with Table 8.3 of the MRP (SFRWQCB, 2015). Sediment samples will be screened using a 2 mm screen prior to analysis. Table 8.1 lists the constituents for sediment quality analysis. Total organic carbon (TOC) is included because it is a MRP requirement and can be useful for normalizing PCBs data collected for the sediment.

The primary objective of sediment analysis is quantification of the mass of PCBs and mercury accumulating within HDS units. Consequently, PCBs and total mercury are analyzed

for all screened sediment samples. The secondary objective is to establish a relationship between total PCBs, mercury, and particle size. Correlating total PCBs and mercury to particle sizes will complement past studies and provide insight into the type of BMPs that are appropriate to achieve the most cost-effective mass removal.

Analysis of PCBs at the CW4CB Leo Avenue HDS showed that PCBs in the water above the sediment may be minor when compared to sediment-associated PCBs (BASMAA, 2017b). PCB concentrations in overlying water are expected to be low and sampling of this water is not included in this study design.

Table 8.1 Selected Constituents for HDS Sediment Monitoring

Constituent
TOC
Total Mercury[1]
PCBs (40 congeners) in Sediment
Particle Size Distribution
Bulk Density

1 – Only total mercury analyzed. Methyl mercury is not relevant for SF Bay TMDL.

8.3 Constituents for Water Quality Analysis

Constituents for analysis of water samples must meet the data objectives discussed previously in "Primary Data Objectives", and be consistent with Table 8.3 of the MRP (SFRWQCB, 2015). Table 8.2 lists the constituents for the laboratory media testing studies. The list of water quality constituents must provide data to address the primary management question to quantify total PCB and mercury reduction, so PCBs and total mercury are analyzed for all samples. Secondary management questions relate to understanding removal performance for total PCB and mercury.

In addition to PCBs and total mercury, the other constituents selected for influent and effluent analysis are SSC, turbidity, and TOC. SSC was selected because it more accurately characterizes larger size fractions within the water column, while turbidity was selected because it is an inexpensive and quick test to describe treatment efficiency where strong correlation to other pollutants has been established. As with the sediment analysis, TOC is included because it is a MRP requirement and can be useful for normalizing PCBs data collected for water samples.

Table 8.2 Selected Aqueous Constituents for Media Testing in Laboratory Columns

Constituent
SSC
Turbidity
TOC
Total Mercury[1]
PCBs (40 congeners) in Water

1 – Only total mercury analyzed. Methyl mercury is not relevant for SF Bay TMDL.

8.4 Budget and Schedule

The monitoring budget for the study is approximately $200,000. A contingency of 10 percent of the water quality monitoring budget is recommended to account for unforeseen costs such as equipment failure. Another constraint is that all sampling will occur in one wet season.

8.5 Optimized Study Design

The optimized study designs are presented in Tables 8.3 and 8.4 for the HDS Monitoring and Enhanced Bioretention studies, respectively. Several iterations were analyzed and the study designs shown are based on best professional judgment to allocate the budget to the various data collection options.

The final design for the HDS monitoring study is based on selection and sampling of 9 HDS units in key land use areas. The number of units that can be sampled is limited because sampling is expected to be opportunistic as part of regular maintenance programs. Therefore, a simple design with 9 units is appropriate. The data analysis will evaluate the percent removal achieved for each HDS unit during the time period of interest (i.e., the time period between the date of the previous cleanout, and the current cleanout date for each HDS unit sampled) by incorporating modeled estimates of stormwater volumes and associated pollutant loads for each HDS unit catchment. Because HDS units are sized to treat stormwater runoff from storms of a given size and intensity, excess flows for storms exceeding the design capacity will bypass the unit and are not treated. Storm by storm analysis of rainfall data during the time period of interest will allow estimation of the total stormwater volume and pollutant load to the catchment during each storm, as well as the volume and pollutant load that bypassed the HDS unit and was not treated. This information will then be combined with the measured pollutant mass captured by each HDS unit to quantify the percent removal of PCBs and mercury from the total catchment flow, and the percent removal of PCBs and mercury from the treated flow. For each HDS unit sampled in the study, the total and treated pollutant mass removed will be calculated using the following equations.

(1) Total Pollutant Mass Removed (%) = $[M_{HDS\text{-}i}/M_{Catchment\text{-}i}] \times 100\%$

(2) Treated Pollutant Mass Removed (%) = $[M_{HDS\text{-}i}/(M_{Catchment\text{-}i} - M_B)] \times 100\%$

Where:

M_{HDS-i}	the total POC mass captured in the sump of HDS Unit i over the time period of interest
$M_{Catchment-i}$	the total POC mass discharged from Catchment-A (the catchment draining to HDS unit A) over the time period of interest
M_B	the total POC mass that bypassed HDS unit A over the time period of interest

The following inputs will be measured or modeled for the time period of interest for use in the equations above:

- Total PCBs and mercury mass captured by a given HDS unit. This is the mass measured in each HDS unit during this project.
- The total stormwater volume and associated PCBs and mercury load from the HDS unit catchment. This will be modeled on a storm by storm basis using available rainfall data, catchment runoff coefficients, and assumed pollutant stormwater concentrations.
- The stormwater volume and associated PCBs and mercury load that bypassed the HDS unit. The bypass volume (and associated pollutant load) during each storm (if any) will be calculated based on the design criteria for a given HDS unit.
- The total PCBs and mercury load treated by a given HDS unit. This will be determined by subtracting the bypass load (if any) from the total pollutant load for the catchment.

The corresponding design for the enhanced BSM study is based on testing of readily available biochars in hydraulic screening experiments followed by column testing of up to five promising BSM mixes as well as a standard BSM control mix. The final number of BSM mixes will depend on availability and media properties (e.g., expected hydraulic conductivity). The optimized designs will yield 33 data points for the key data objectives, 9 from the HDS monitoring study and 24 from the enhanced BSM media testing column study.

Table 8.3 HDS Monitoring Study Design

<table>
<tr><td>Primary Management Question(s)</td><td>What are the annual PCB and mercury loads captured by existing HDS units in Bay Area urban watersheds and the associated percent removal?</td></tr>
<tr><td>Type of Study</td><td>Sediment monitoring; modeling stormwater volume and pollutant load</td></tr>
<tr><td>Data Objective(s)</td><td>Annual PCB and mercury mass captured in HDS units and percent removal</td></tr>
<tr><td>Description of Key Treatment Processes</td><td>Sedimentation, Flocculation & Screening
• Removal by gravity settling and physical screening of particulates
• Effectiveness depends on water quality, BMP design and hydraulic loading/flow regime, and operational factors</td></tr>
<tr><td>Key Variables</td><td>• Sediment quality and quantity
• Influent quantity and quality (contaminant concentration,)
• BMP design and hydraulic loading/flow regime
• BMP maintenance (remaining sediment capacity)</td></tr>
<tr><td>Monitoring Needs</td><td>Monitored variables: sediment quality, sediment mass
Controlled variables: influent quality, BMP maintenance (remaining sediment capacity)
Uncontrolled variables: HDS design, hydraulic loading, flow regime</td></tr>
<tr><td>Monitoring Approach</td><td>Influent quantity and quality: based on rainfall/runoff characteristics and on land use pollutant yield (old urban, new urban, etc.)
Hydraulic loading: base on HDS size (diameter and settling depth) and flow (design flow for known watershed size)
BMP maintenance: base on remaining sump capacity</td></tr>
<tr><td>Sampling Design</td><td>Sampling expected to be opportunistic as part of regular maintenance programs.
Targeted predominant land uses for HDS selection and corresponding data generation:
<table><tr><th>Predominant Land Use</th><th>HDS Samples</th><th>No. Samples (Total 9)</th></tr><tr><td>Higher Concentration/Old Industrial</td><td>X, X, X[1]</td><td>3</td></tr><tr><td>Old Urban/Old Industrial</td><td>X, X, X[1]</td><td>3</td></tr><tr><td>New Urban/Old Urban</td><td>X, X, X[1]</td><td>3</td></tr></table>1 – “X” represents a sample from a selected HDS unit. Yield categories will be determined during site selection.
• Exclude units at full sump capacity (cleanout and monitor subsequent year if possible)</td></tr>
<tr><td>Constituent List</td><td>TOC, total mercury, PCBs (40 congeners) in sediment, particle size distribution, and bulk density</td></tr>
<tr><td>Data Analysis</td><td>Independent (unpaired) samples. Present range of total PCB and mercury concentrations measured and mass removed/area treated. Analyze using ANOVA. Model estimates of catchment stormwater volumes and PCB and mercury stormwater loads combined with the measured mass captured in the unit to calculate the percent removal.</td></tr>
</table>

Table 8.4 Enhanced BSM Testing Study Design

<table>
<tr><td>Primary Management Question(s)</td><td>Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?</td></tr>
<tr><td>Type of Study</td><td>Influent-effluent monitoring</td></tr>
<tr><td>Data Objective(s)</td><td>PCB and mercury load removal</td></tr>
<tr><td>Description of Key Treatment Processes</td><td>Filtration and Adsorption
• Removal by physical screening, trapping in media, and retention on media surface
• Effectiveness depends on influent water quality, BMP design and hydraulic loading/flow regime, media type and properties, and operational factors</td></tr>
<tr><td>Key Variables</td><td>• Influent and effluent quality (PCB concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, particle size distribution)
• BMP design (media depth) and hydraulic loading/head
• Media type and properties (composition, grain size/size distribution, adsorptive properties, hydraulic conductivity)
• BMP maintenance (surface clogging, short-circuiting)</td></tr>
<tr><td>Monitoring Needs</td><td>Monitored variables: Influent and effluent quality contaminant concentration, particle concentration, organic matter, surface clogging
Controlled variables: media depth, hydraulic loading/head, media composition and adsorptive properties, hydraulic conductivity
Uncontrolled variables: Influent and effluent proportion of dissolved contaminants, particle size, particle size distribution, short-circuiting</td></tr>
<tr><td>Monitoring Approach</td><td>Phased approach because of number of media/need to ensure MRP infiltration rates
1. Hydraulic tests to ensure amended media meet infiltration requirements
2. Influent-effluent column tests for select mixes with Bay Area stormwater
3. Influent-effluent column tests for best mix with Bay Area stormwater at lower concentrations</td></tr>
<tr><td>Sampling Design</td><td>Phase I Hydraulic Tests:
- Determine infiltration rates for media mixes with 25% biochar by volume
- If MRP infiltration rates not met, adjust biochar proportion and retest
- Target infiltration rate of 5 - 12 in/h for all mixes, attempt to control rate to +/- 1 in/hr.

Phase II Influent-Effluent Column Tests with Bay Area Stormwater (up to 5 mixes)
<table>
<tr><th>Biochar/BSM Mix</th><th>Column Samples</th><th>No. Samples (Total 21)</th></tr>
<tr><td>A Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>B Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>C Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>D Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>E Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>Control Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>Influent</td><td>X, X, X</td><td>3</td></tr>
</table>
Phase III Influent-Effluent Column Tests for Select Mix with Diluted Bay Area Stormwater
- Perform tests with diluted stormwater, if necessary, to confirm effectiveness at concentrations representative of New Urban and New Industrial land
- Test at one dilution (1 influent and 1 mix and 1 control effluent) (3 samples)</td></tr>
<tr><td>Constituent List</td><td>SSC, turbidity, TOC, total mercury, PCBs (40 congeners) in water</td></tr>
<tr><td>Data Analysis</td><td>Dependent (paired) samples. Present range of total PCB and mercury concentrations measured and mass removal efficiencies. Analyze using ANOVA and regressions of influent/effluent quality. Perform sign-rank test to compare consistency in relative performance among the columns.</td></tr>
</table>

8.6 Adequacy of Study Design

The primary management questions are reviewed in this section in light of the budgeted data collection efforts. The primary management questions are restated and followed by an analysis of the adequacy of the data collection effort.

1. *What are the annual PCB and mercury loads captured by existing HDS units in Bay Area urban watersheds?*

Table 8.3 lists the number of data points that are anticipated for the HDS monitoring study.

This selected design will provide 9 data points for each of the following: PCB sediment concentration, mercury sediment concentration, and sediment mass. This design will not be able to assess the effect of HDS size and hydraulic loading on pollutant removal, and may not be able to statistically differentiate load capture between different land uses because of the small sample count for each land use (3). However, this design is selected because of the lack of information available on HDS sizing and the opportunistic nature of the sampling which limits the number of HDS units that can be sampled. The effect of maintenance is eliminated by ensuring that samples are not collected from units that have no remaining sump capacity.

The HDS study design collects independent (unpaired) samples since each HDS unit is sampled independently and there is no relationship between the various HDS units. This limits ability to discern differences due to land use or HDS size, especially when sample size is relatively low and there is considerable variability in the data collected. Although the study design yields 9 data points for each data objective, it may not be sufficient to draw statistically-based conclusions. However, the study will provide point estimates of loads removed during cleanouts and how they vary for different land uses (e.g., X g of PCBs are removed per unit area of Y land use). This is the metric used for effectiveness of HDS cleanouts, so the study will provide a practical improvement in knowledge that can be applied to future HDS effectiveness estimates.

In addition, modeled stormwater flows and associated POC loads to each HDS unit catchment during the time period between cleanouts will be developed. These modeled estimates will be used along with the measured mass captured in the HDS unit between cleanouts to quantify the percent removal for each unit during the study.

2. *Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?*

Table 8.4 lists the number of data points that are anticipated for the enhanced BSM testing study. The sampling design will yield 19 data points for each of the following: effluent PCB concentration, effluent mercury concentration. Including influent analysis, a total of 24 samples will be analyzed. The purpose of this study is to identify the best biochar amended BSM mixes for field testing and not test the effect of confounding variables such as influent quality and hydraulic loading on load removals. The study design accounts for these confounding variables by either ensuring their effect is randomized (e.g., influent water quality) or keeps them fixed (e.g., hydraulic loading). To ensure influent stormwater concentrations are representative of typical Bay Area concentrations, an additional column test with diluted

stormwater is performed on an effective media mix. Standard BSM controls are used for each column run so that removal by biochar amended mixes can be compared directly to removal by standard BSM. Infiltration experiments are performed prior to the column testing to ensure media selected for final column testing will meet the MRP infiltration rate requirements.

The enhanced BSM column study design collects dependent (paired) samples since each effluent sample is related to a corresponding influent sample. Additionally, standard BSM controls are used for each run which makes it possible to directly compare effluent quality for each amended BSM to standard BSM. The paired sampling design, use of standard BSM controls, and ability to control or fix many of the variables that effect load removal increase the ability to discern differences in treatment. Therefore, only 3 column runs are proposed, and available budget is instead used in initial hydraulic screening experiments to ensure selected media mixes meet MRP infiltration rate requirements. The study design may not be sufficient to draw statistically-based conclusions because it yields only 3 data points for each biochar mix tested. However, the study will enable direct comparisons of effluent quality and treatment between mixes for individual events and consistency of treatment between events. The information provided by the study is expected to be sufficient to identify the most promising biochar mixes for field testing.

The study designs for the HDS monitoring and enhanced bioretention studies meet MRP sample collection requirements. The sampling design for the HDS monitoring study will yield a minimum of 9 PCB and mercury data points, while the sampling design for the enhanced bioretention laboratory study will yield 24 PCB and mercury data points (including influent analysis). The minimum number of PCB samples for this study plan is 33 (9+24). Because 3 of the 32 BMP effectiveness samples required by the current MRP have already been collected, the minimum number required for this project is 29. This study must yield 29 of the 32 permit-required samples, per Provision C.8.f of the MRP. To ensure that at least 29 samples are collected to meet the MRP requirement, additional samples will be collected during the laboratory media testing runs if fewer than 5 HDS units are available for sampling.

9. Recommendations for Sampling and Analysis Plans

This section presents specific recommendations for the development of SAPs. More detailed information is available in Section 6 of the Caltrans Monitoring Guidance Manual (Caltrans, 2015) and in the Urban Stormwater BMP Performance Monitoring (WERF 2009). Analysis of constituents should follow the CW4CB Quality Assurance Project Plan (BASMAA 2013).

9.1 HDS Monitoring

The following SAP recommendations are based on the lessons learned from sampling the Leo Avenue HDS site (BASMAA, 2017b):

- Include equipment to determine sump capacity before sampling. The study design does not require sampling of units that are full (i.e., have no remaining sump capacity). The depth of the unit can make it difficult to inspect for sump basin contents, and use of a "sludge judge" or other similar equipment may not be possible because of difficulty penetrating through compacted organic materials.
- The sampling is expected to be opportunistic sampling during regular cleanouts. Since it coincides with regular maintenance patterns, the occurrence of a clean and empty vactor truck from which samples of the sediment can be taken is unlikely. To obtain representative samples, multiple grab samples that extend from the top of the sediment layer to the bottom of the sump will need to be collected and composited prior to analyses.
- Sediment samples will require screening to remove coarse particles, trash, etc. In the CW4CB study (BASMAA, 2007b), only sediment less than 2 mm in size was analyzed.

It is unclear how samples of the HDS sediment were taken in the Leo Avenue HDS sampling. Appropriate sampling methods should be developed to ensure the samples collected are representative of the sediment in the HDS units.

HDS sediment sampling is not expected to require additional handling/safety precautions beyond normal drain cleaning safety procedures. Human health criteria for PCBs are for exposure via ingestion or vapor intake and not for contact. OSHA directive STD 01-04-002 state that "repeated skin contact hazards with all PCB's could be addressed by the standards 1910.132 and 1910.133". Both 1910.132 and 1910.133 OSHA standards require use of personal protective equipment, including eye and face protection.

9.2 Enhanced Bioretention Media Testing

The following SAP recommendations are based on past experience and specific guidance provided in DEMEAU (2014):

- The enhanced BSM testing will use real stormwater for the column experiments to account for the effect of influent water quality on load removal. A stormwater

collection site will need to be identified in a watershed with typical PCB concentrations to ensure PCB concentrations are representative of those expected in Bay Area urban watersheds. Also, guidance will need to be developed on mobilization to ensure storms are targeted randomly.

- Stormwater properties are known to change significantly with time due to natural flocculation and settling of particles. Appropriate procedures should be developed to ensure collected stormwater is well mixed at all times, and experiments are performed in a timely manner to insure the stormwater used is representative.
- PCBs can readily attach to test equipment, including the inside of tubing that may be used for pumps and the inside of PVC columns. Alternatives should be considered that eliminate the need for pumping equipment and reduce attachment within columns (e.g., by use of glass columns).
- The results of column experiments can be affected by channeling and wall effects. Use a column diameter to particle diameter ratio greater than about 40 to minimize these.
- How media is packed in columns will affect infiltration rates and treatment performance. Therefore, detailed procedures should be developed for the packing of media in columns to ensure consistency between columns and between experiments.

9.3 Data Quality Objectives

Data quality objectives (DQOs) should follow standard stormwater monitoring protocols and be described in detail in individual SAPs. Both sampling and laboratory data quality objectives should be included. For sampling, the SAP should specify sediment and water collection procedures and equipment as well as sample volume and handling requirements. For laboratories, numeric DQOs are appropriate for sample blanks, duplicates (or field splits), and matrix spike recovery.

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APPENDIX B: SAMPLING AND ANALYSIS PLAN AND QUALITY ASSURANCE PROJECT PLAN

BASMAA
Regional Monitoring Coalition

Pollutants of Concern Monitoring for Source Identification and Management Action Effectiveness, 2017-2018

Sampling and Analysis Plan and Quality Assurance Project Plan

Prepared for:

The Bay Area Stormwater Management Agencies Association (BASMAA)

Prepared by:

EOA inc.
1410 Jackson Street
Oakland, CA
94612

WATER PROGRAMS
SACRAMENTO STATE
6000 J Street
Sacramento, CA
95819

SFEI
4911 Central Avenue
Richmond, CA
94804

KINNETIC LABORATORIES INCORPORATED
307 Washington Street
Santa Cruz, CA
95060

Version 2
September 29, 2017

Title and Approval Sheet

Program Title	Pollutants of Concern (POC) Monitoring for Source Identification and Management Action Effectiveness
Lead Organization	Bay Area Stormwater Management Agencies Association (BASMAA) P.O. Box 2385, Menlo Park, CA 94026, 510-622-2326 info@basmaa.org
Primary Contact	Geoff Brosseau
Effective Date	September 29, 2017
Revision Number	Version 2

Approval Signatures:

A signature from the BASMAA Executive Director approving the BASMAA POC Monitoring for Source Identification and Management Action Effectiveness is considered approval on behalf of all Program Managers.

Geoff Brosseau _____ Date _____

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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
ALS	ALS Environmental Laboratory
BASMAA	Bay Area Stormwater Management Agencies Association
BSM	Bioretention Soil Media
CCCWP	Contra Costa Clean Water Program
CCV	continuing calibration verification
CEDEN	California Environmental Data Exchange Network
CEH	Center for Environmental Health
COC	Chain of Custody
Consultant-PM	Consultant Team Project Manager
CRM	Certified Reference Material
CSE	Confined Space Entry
ECD	Electron capture detection
EDD	Electronic Data Deliverable
EOA	Eisenberg, Olivieri & Associates, Inc.
EPA	Environmental Protection Agency (U.S.)
FD	Field duplicate
Field PM	Field Contractor Project Manager
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GC-MS	Gas Chromatography-Mass Spectroscopy
IDL	Instrument Detection Limits
ICV	initial calibration verification
KLI	Kinnetic Laboratories Inc.
LCS	Laboratory Control Samples
Lab-PM	Laboratory Project Manager
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MDL	Method Detection Limit
MQO	Measurement Quality Objective
MRL	Method Reporting Limit
MRP	Municipal Regional Permit
NPDES	National Pollutant Discharge Elimination System
OWP-CSUS	Office of Water Programs at California State University Sacramento
PCB	Polychlorinated Biphenyl
PM	Project Manager
PMT	Project Management Team
POC	Pollutants of Concern
QA	Quality Assurance
QA Officer	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	Quality Control
ROW	Right-of-way
RPD	Relative Percent Difference
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program for Water Quality in the San Francisco Estuary
SFRWQCB	San Francisco Regional Water Quality Control Board (Regional Water Board)
SAP	Sampling and Analysis Plan
SCCVURPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SCVWD	Santa Clara Valley Water Department
SFEI	San Francisco Estuary Institute

SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Procedure
SWAMP	California Surface Water Ambient Monitoring Program
TOC	Total Organic Carbon
TMDL	Total Maximum Daily Load
VSFCD	Vallejo Sanitation and Flood Control District

1. Problem Definition/Background

The Bay Area Stormwater Management Agencies Association (BASMAA) member agencies will implement a regional monitoring program for Pollutants of Concern (POC) Monitoring for Source Identification and Management Action Effectiveness (Monitoring Program). The Monitoring Program is intended to fulfill components of the Municipal Regional Stormwater NPDES Permit (MRP; Order No. R2-2015-0049), which implements the polychlorinated biphenyls (PCBs) and Mercury Total Maximum Daily Loads (TMDLs) for the San Francisco Bay Area. Monitoring for Source Identification and Management Action Effectiveness are two of five monitoring priorities for POCs identified in the MRP. Source identification monitoring is conducted to identify the sources or watershed source areas that provide the greatest opportunities for reductions of POCs in urban stormwater runoff. Management action effectiveness monitoring is conducted to provide support for planning future management actions or to evaluate the effectiveness or impacts of existing management actions.

BASMAA developed two study designs to implement each component of the Monitoring Program. The ***Evaluation of PCBs Presence in Public Roadway and Storm Drain Infrastructure Caulk and Sealants Study Design*** (BASMAA 2017a) addresses the source identification monitoring requirements of Provision C.8.f, as well as requirements of Provision C.12.e to investigate PCBs in infrastructure caulk and sealants. The ***POC Monitoring for Management Action Effectiveness Study Design*** (BASMAA 2017b) addresses the management action effectiveness monitoring requirements of Provision C.8.f. The results of the Monitoring Program will contribute to ongoing efforts by MRP Permittees to identify PCB sources and improve the PCBs and mercury treatment effectiveness of stormwater control measures in the Phase I permittee area of the Bay Area. This Sampling and Analysis Plan and Quality Assurance Project Plan (SAP/QAPP) was developed to guide implementation of both components of the Monitoring Program.

1.1. Problem Statement

Fish tissue monitoring in San Francisco Bay (Bay) has revealed bioaccumulation of PCBs and mercury. The measured fish tissue concentrations are thought to pose a health risk to people consuming fish caught in the Bay. As a result of these findings, California has issued an interim advisory on the consumption of fish from the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act "Section 303(d) list" due to PCBs and mercury. In response, the California Regional Water Quality Control Board, San Francisco Bay Region (Regional Water Board) has developed TMDL water quality restoration programs targeting PCBs and mercury in the Bay. The general goals of the TMDLs are to identify sources of PCBs and mercury to the Bay and implement actions to control the sources and restore water quality.

Since the TMDLs were adopted, Permittees have conducted a number of projects to provide information that supports implementation of management actions designed to achieve the wasteload allocations described in the Mercury and PCBs TMDL, as required by Provisions of the MRP. The Clean Watersheds for a Clean Bay project (CW4CB) was a collaboration among BASMAA member agencies that pilot tested various stormwater control measures and provided estimates of the PCBs and mercury load reduction effectiveness of these controls (BASMAA, 2017c). However, the results of the CW4CB project identified a number of remaining data gaps on the load reduction effectiveness of the control measures

that were tested. In addition, MRP Provisions C.8.f. and C.12.e require Permittees to conduct further source identification and management action effectiveness monitoring during the current permit term.

1.2. Outcomes

The Monitoring Program will allow Permittees to satisfy MRP monitoring requirements for source identification and management action effectiveness, while also addressing some of the data gaps identified by the CW4CB project (BASMAA, 2017c). Specifically, the Monitoring Program is intended to provide the following outcomes:

1. Satisfy MRP Provision C.8.f. requirements for POC monitoring for source identification; and Satisfy MRP Provision C.12.e.ii requirements to evaluate PCBs presence in caulks/sealants used in storm drain or roadway infrastructure in public ROWs;
    a. Report the range of PCB concentrations observed in 20 composite samples of caulk/sealant collected from structures installed or rehabilitated during the 1970's;
2. Satisfy MRP Provision C.8.f. requirements for POC monitoring for management action effectiveness;
    a. Quantify the annual mass of mercury and PCBs captured in HDS Unit sumps during maintenance; and
    b. Identify bioretention soil media (BSM) mixtures for future field testing that provide the most effective mercury and PCBs treatment in laboratory column tests.

The information generated from the Monitoring Program will be used by MRP Permittees and the Regional Water Board to better understand potential PCB sources and better estimate the load reduction effectiveness of current and future stormwater control measures.

2. Distribution List and Contact Information

The distribution list for this BASMAA SAP/QAPP is provided in Table 2-1.

Table 2-1. BASMAA SAP/QAPP Distribution List.

Project Group	Title	Name and Affiliation	Telephone No.
BASMAA Project Management Team	BASMAA Project Manager, Stormwater Program Specialist	Reid Bogert, SMCWPPP	650-599-1433
	Program Manager	Jim Scanlin, ACCWP	510-670-6548
	Watershed Management Planning Specialist	Lucile Paquette, CCCWP	925-313-2373
	Program Manager	Rachel Kraai, CCCWP	925-313-2042
	Technical Consultant to ACCWP and CCCWP	Lisa Austin, Geosyntec Inc. CCCWP	510-285-2757
	Supervising Environmental Services Specialist	James Downing, City of San Jose	408-535-3500
	Senior Environmental Engineer	Kevin Cullen, FSURMP	707-428-9129
	Pollution Control Supervisor	Doug Scott, VSFCD	707-644-8949 x269
Consultant Team	Project Manager	Bonnie de Berry, EOA Inc.	510-832-2852 x123
	Assistant Project Manager SAP/QAPP Author and Report Preparer	Lisa Sabin, EOA Inc.	510-832-2852 x108
	Technical Advisor	Chris Sommers, EOA Inc.	510-832-2852 x109
	Study Design Lead and Report Preparer	Brian Currier, OWP-CSUS	916-278-8109
	Study Design Lead and Report Preparer	Dipen Patel, OWP-CSUS	
	Technical Advisor	Lester McKee, SFEI	415-847-5095
	Quality Assurance Officer	Don Yee, SFEI	510-746-7369
	Data Manager	Amy Franz, SFEI	510-746-7394
	Field Contractor Project Manager	Jonathan Toal, KLI	831-457-3950
Project Laboratories	Laboratory Project Manager	Howard Borse, ALS	360-430-7733
	XRF Laboratory Project Manager	Matt Nevins, CEH	510-655-3900 x318

3. Program Organization

3.1. Involved Parties and Roles

BASMAA is a 501(c)(3) non-profit organization that coordinates and facilitates regional activities of municipal stormwater programs in the San Francisco Bay Area. BASMAA programs support implementation of the MRP (Order No. R2-2015-0049), which implements the PCBs and Mercury TMDLs for the San Francisco Bay Area. BASMAA is comprised of all 76 identified MRP municipalities and special districts, the Alameda Countywide Clean Water Program (ACCWP), Contra Costa Clean

Water Program (CCCWP), the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), the Fairfield-Suisun Urban Runoff Management Program (FSURMP), the City of Vallejo and the Vallejo Sanitation and Flood Control District (VSFCD) (Table 3-1).

MRP Permittees have agreed to collectively implement this Monitoring Program via BASMAA. The Program will be facilitated through the BASMAA Monitoring and Pollutants of Concern Committee (MPC). BASMAA selected a consultant team to develop and implement the Monitoring Program with oversight and guidance from a BASMAA Project Management Team (PMT), consisting of representatives from BASMAA stormwater programs and municipalities (Table 3-1).

Table 3-1. San Francisco Bay Area Stormwater Programs and Associated MRP Permittees Participating in the BASMAA Monitoring Program.

Stormwater Programs	MRP Permittees
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and, Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and, Zone 7 Water District
Contra Costa Clean Water Program (CCCWP)	Cities of, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, , Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, Danville, and Moraga; Contra Costa County; and, Contra Costa County Flood Control and Water Conservation District
San Mateo County Wide Water Pollution Prevention Program (SMCWPPP)	Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees (VSFCD)	City of Vallejo and Vallejo Sanitation and Flood Control District

3.2. BASMAA Project Manager (BASMAA-PM)

The BASMAA Project Manager (BASMAA-PM) will be responsible for directing the activities of the below-described PMT, and will provide oversight and managerial level activities, including reporting status updates to the PMT and BASMAA, and acting as the liaison between the PMT and the Consultant Team. The BASMAA PM will oversee preparation, review, and approval of project deliverables, including the required reports to the Regional Water Board.

3.3. BASMAA Project Management Team (PMT)

The BASMAA PMT will assist the BASMAA-PM and the below described Consultant Team with the design and implementation of all project activities. PMT members will assist the BASMAA-PM and Consultant Team to complete project activities within scope, on-time, and within budget by having specific responsibility for planning and oversight of project activities within the jurisdiction of the BASMAA agency that they represent. In addition, the PMT will coordinate with the municipal project partners and key regional agencies, including the Regional Water Board. The PMT is also responsible for reviewing and approving project deliverables (e.g., draft and final project reports).

3.4. Consultant Team Project Manager (Consultant-PM)

The Consultant Team Project Manager (Consultant-PM) will be responsible for ensuring all work performed during the Monitoring Program is consistent with project goals, and provide oversight of all day-to-day operations associated with implementing all components of the Monitoring Program, including scheduling, budgeting, reporting, and oversight of subcontractors. The Consultant-PM will ensure that data generated and reported through implementation of the Monitoring Program meet measurement quality objectives (MQOs) described in this SAP/QAPP. The Consultant -PM will work with the Quality Assurance Officer as required to resolve any uncertainties or discrepancies. The Consultant -PM will also be responsible for overseeing development of draft and final reports for the Monitoring Program, as described in this SAP/QAPP.

3.5. Quality Assurance Officer (QA Officer)

The role of the Quality Assurance Officer (QA Officer) is to provide independent oversight and review of the quality of the data being generated. In this role, the QA Officer has the responsibility to require data that is of insufficient quality to be flagged, or not used, or for work to be redone as necessary so that the data meets specified quality measurements. The QA Officer will oversee the technical conduct of the field related components of the Monitoring Program, including ensuring field program compliance with the SAP/QAPP for tasks overseen at the programmatic level.

3.6. Data Manager (DM)

The Data Manager will be responsible for receipt and review of all project related documentation and reporting associated with both field efforts and laboratory analysis. The Data Manager will also be responsible for storage and safekeeping of these records for the duration of the project.

3.7. Field Contractor Project Manager (Field-PM)

The Field Contractor Project Manager (Field-PM) will be responsible for conduct and oversight of all field monitoring- and reporting-related activities, including completion of field datasheets, chain of custodies, and collection of field measurements and field samples, consistent with the monitoring methods and procedures in the SAP/QAPP. The Field-PM will also be responsible for ensuring that personnel conducting monitoring are qualified to perform their responsibilities and have received appropriate training. The Field-PM will be responsible for initial receipt and review of all project related documentation and reporting associated with both field efforts and laboratory analysis.

The Field-PM will also be responsible for receiving all samples collected opportunistically by participating municipalities, including all caulk/sealant samples, initial review of sample IDs to ensure there are no duplicate sample IDs, and shipping the samples under COC to the appropriate laboratory (CEH for the caulk/sealant samples; ALS for all other samples). Participating municipalities should ship all samples they collect to the Field PM at the following address:

Jon Toal
Kinnetic Laboratories, Inc.
307 Washington Street
Santa Cruz, CA 95060
Reference: BASMAA POC Monitoring Project
(831)457-3950

3.8. Laboratory Project Manager (Lab-PM)

The Laboratory Project Manager (Lab-PM) and chemists at each analytical laboratory will be responsible for ensuring that the laboratory's quality assurance program and standard operating procedures (SOPs) are consistent with this SAP/QAPP, and that laboratory analyses meet all applicable requirements or explain any deviations. Each Lab-PM will also be responsible for coordinating with the Field-PM and other staff (e.g., Consultant -PM, Data Manager, QA Officer) and facilitating communication between the Field-PM, the Consultant -PM, and analytical laboratory personnel, as required for the project.

The Center for Environmental Health (CEH) will provide chlorine content screening of all caulk/sealant samples collected using X-Ray Fluorescence (XRF) technology to assist in selection of samples for further laboratory analysis of PCBs. This XRF-screening will also provide additional information on the utility of XRF in prioritizing samples for chemical PCBs analyses.

All other laboratory analyses will be provided by ALS Environmental.

3.1. Report Preparer

The Report Preparer (RP) will be responsible for developing draft and final reports for each of the following components of the Monitoring Program: (1) Source identification; and (2) Management action effectiveness. All draft reports will be submitted to the PMT for review and input prior to submission for approval by the BASMAA Board of Directors (BOD).

4. Monitoring Program Description

4.1. Work Statement and Program Overview

The Monitoring Program consists of the following three major tasks, each of which has a field sampling component:

- **Task 1. Evaluate presence and possible concentrations of PCBs in roadway and storm drain infrastructure caulk and sealants**. This task involves analysis of 20 composite samples of caulk/sealant collected from public roadway and storm drain infrastructure throughout the permit

area to investigate PCB concentrations. The goal of this task is to evaluate, at a limited screening level, whether and in what concentrations PCBs are present in public roadway and storm drain infrastructure caulk and sealants in the portions of the Bay Area under the jurisdiction of the Phase I Permittees identified in Table 3-1 (Bay Area).

- **Task 2. Evaluate Annual mass of PCBs and mercury captured in Hydrodynamic Separator (HDS) Unit sumps during maintenance.** This task involves collecting sediment samples from the sumps of public HDS unit during maintenance cleanouts to evaluate the mass of PCBs and mercury captured by these devices. The goal of this task is to provide data to better characterize the concentrations of POCs in HDS Unit sump sediment and improve estimates of the mass captured and removed from these units during current maintenance practices for appropriate TMDL load reduction crediting purposes.

- **Task 3. Bench-scale testing of the mercury and PCBs removal effectiveness of selected BSM mixtures enhanced with biochar.** This task involves collecting stormwater from the Bay Area that will then be used to conduct laboratory column tests designed to evaluate the mercury and PCBs treatment effectiveness of various biochar-amended BSM mixtures. Real stormwater will be used for the column tests to account for the effect of influent water quality on load removal. The goal of this task is to identify BSM mixtures amended with biochar that meet operational infiltration requirements and are effective for PCBs and mercury removal for future field testing.

All monitoring results and interpretations will be documented in BASMAA reports for submission to the Regional Water Board according to the schedule in the MRP.

4.2. Sampling Detail

The Monitoring Program includes three separate sampling tasks that involve collection and analysis of the following types of samples: caulk/sealants (Task 1); sediment from HDS units (Task 2); and stormwater collected and used for column tests in the lab (Task 3). Additional details specific to the sampling design for each task are provided below.

4.2.1. Task 1 - Caulk/Sealant samples

The PMT will recruit municipal partners from within each stormwater program to participate in this task. All caulk/sealant samples will be collected from locations within public roadway or storm drain infrastructure in the participating municipalities. Exact sample sites will be identified based on available information for each municipal partner, including: age of public infrastructure; records of infrastructure repair or rehabilitation (aiming for the late 1960s through the 1970s); and current municipal staff knowledge about locations that meet the site selection criteria identified in the study design (BASMAA, 2017a). Field crews led by the Field-PM and/or municipal staff will conduct field reconnaissance to further identify specific sampling locations and if feasible, will collect caulk/sealant samples during these initial field visits. Follow-up sampling events will be conducted for any sites that require additional planning or equipment for sample collection (e.g., confined space entry, parking controls, etc.). Sample locations will include any of the following public infrastructure where caulk/sealant are present: roadway or sidewalk surfaces, between expansion joints for roadways, parking garages, bridges, dams, or storm drain pipes, and/or in pavement joints (e.g., curb and gutter). Sampling will only occur during periods of dry weather when urban runoff flows through any structures that will be sampled are minimal, and do not

present any safety hazards or other logistical issues during sample collection. Sample collection methods are described further in Section 9.

As opportunities arise, municipal staff will also collect samples following the methods and procedures described in this SAP/QAPP during ongoing capital projects that provide access to public infrastructure locations with caulk/sealant that meet the sample site criteria. All samples collected by participating municipal staff will be delivered to the Field PM under COC. The Field-PM will be responsible for storing all caulk/sealant samples and shipping the samples under COC to CEH for XRF screening analysis.

All caulk/sealant samples collected will be screened for chlorine content using XRF technology described in Section 9. Samples will be grouped for compositing purposes as described in the study design (BASMAA, 2017a). Up to three samples will be included per composite and a total of 20 composite caulk/sealant samples will be analyzed for the RMP 40 PCB congeners[1]. All compositing and PCBs analysis will be conducted blind to the location where each sample was collected. Laboratory analysis methods must be able to detect a minimum PCBs concentration of 200 parts per billion (ppb, or µg/Kg). Laboratory analytical methods are described further in Section 12. The range of PCB concentrations found in caulk based on this documented sampling design will be reported to the Regional Water Board within the Permittees' 2018 Annual Reports.

4.2.2. Task 2 - Sediment samples from HDS Units

The PMT will recruit municipal partners that maintain public HDS units to participate in this task. All sediment samples will be collected from the sump of selected HDS units during scheduled cleaning and maintenance. Selection of the HDS units for sampling will be opportunistic, based on the units that are scheduled for maintenance by participating municipalities during the project period. Field crews led by the Field-PM and municipal maintenance staff will coordinate sampling with scheduled maintenance events. As needed, municipal staff will dewater the HDS unit sumps prior to sample collection, and provide assistance to field crews with access to the sump sediment as needed (e.g., confined space entry, parking controls, etc.). All sump sediment samples will be collected following the methods and procedures described in this SAP/QAPP. Sampling will only occur during periods of dry weather when urban runoff flows into the HDS unit sumps are minimal, and do not present any safety hazards or other logistical issues during sample collection. Sample collection methods are described further in Section 9.

All sediment samples collected will be analyzed for the RMP 40 PCB congeners, total mercury, total organic carbon (TOC), particle size distribution (PSD), and bulk density. Laboratory analytical methods are described further in Section 12. The range of PCB and mercury concentrations observed in HDS Unit sump sediments and the annual pollutant masses removed during cleanouts will be reported to the Regional Water Board in March 2019.

4.2.3. Task 3 - Storm Water and Column Test Samples

This task will collect stormwater from Bay Area locations that will then be used as the influent for column tests of biochar-amended BSM. Bay Area stormwater samples will be collected from locations

[1] The 40 individual congeners routinely quantified by the Regional Monitoring Program (RMP) for Water Quality in the San Francisco Estuary include: PCBs 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, l05, 110, 118, 128, 132, 138, 141, 149, l51, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203

within public roadway or storm drain infrastructure in participating municipalities. Field personnel lead by the Field PM will collect stormwater samples during three qualifying storm events and ensure all samples are delivered to the lab of OWP at CSUS within 24-hours of collection. Stormwater will be collected from one watershed that has a range of PCB concentrations and is considered representative of Bay Area watersheds (e.g. the West Oakland Ettie Street Pump Station watershed). Storms from the representative watershed should be targeted randomly without bias, thereby accounting for the effects of storm intensity and ensuring variability in contaminant concentration, proportion of dissolved contaminants, particle size, particle size distribution, and particle density. To achieve this, minimal mobilization criteria should be used to ensure predicted storm intensity and runoff volume are likely to yield the desired volume. Sample collection methods are described further in Section 9.

The stormwater collected will be used as the influent for column tests of various BSM mixtures amended with biochar. These tests will be implemented in three phases. First, hydraulic screening tests will be performed to ensure all amended BSM mixtures meet the MRP infiltration rate requirements of 12 in/h initial maximum infiltration or minimum 5 in/h long-term infiltration rate. Second, column tests will be performed using Bay Area stormwater to evaluate pollutant removal. Third, additional column tests will be performed using lower concentration (e.g., diluted) Bay Area stormwater to evaluate relative pollutant removal performance at lower concentrations. Further details about the column testing are provided in Section 9.3.

All influent and effluent water samples collected will be analyzed for the RMP 40 PCB congeners, total mercury, suspended sediment concentrations (SSC), TOC, and turbidity. Laboratory analytical methods are described further in Section 12. The range of PCB and mercury concentrations observed in influent and effluent water samples and the associated pollutant mass removal efficiencies for each BSM mixture tested will be reported to the Regional Water Board in March 2019.

4.3. Schedule

Caulk/sealant sampling (Task 1) will be conducted between July 2017 and December 2017. HDS Unit sampling (Task 2) will be conducted between July 2017 and May 2018. Stormwater sample collection and BSM column tests (Task 3) will occur between October 2017 – April 2018.

4.4. Geographical Setting

Field operations will be conducted across multiple Phase I cities in the San Francisco Bay region within the counties of San Mateo, Santa Clara, Alameda, and Contra Costa, and the City of Vallejo.

4.5. Constraints

Caulk/sealant sampling and HDS unit sampling will only be conducted during dry weather, when urban runoff flows through the sampled structures are minimal and do not present safety hazards or other logistical concerns. Caulk/sealant sampling will be limited to the caulk/sealant available and accessible at sites that meet the project site criteria (described in the Study Design, BASMAA 2017a). HDS unit sampling will be limited by the number of public HDS units that are available for maintenance during the project period. Extreme wet weather may pose a safety hazard to sampling personnel and may therefore impact wet season sampling.

5. Measurement Quality Objectives (MQO)

The quantitative measurements that estimate the true value or concentration of a physical or chemical property always involve some level of uncertainty. The uncertainty associated with a measurement generally results from one or more of several areas: (1) natural variability of a sample; (2) sample handling conditions and operations; (3) spatial and temporal variation; and (4) variations in collection or analytical procedures. Stringent Quality Assurance (QA) and Quality Control (QC) procedures are essential for obtaining unbiased, precise, and representative measurements and for maintaining the integrity of the sample during collection, handling, and analysis, as well and for measuring elements of variability that cannot be controlled. Stringent procedures also must be applied to data management to assure that accuracy of the data is maintained.

MQOs are established to ensure that data collected are sufficient and of adequate quality for the intended use. MQOs include both quantitative and qualitative assessment of the acceptability of data. The qualitative goals include representativeness and comparability, and the quantitative goals include completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination.

MQOs associated with representativeness, comparability, completeness, sensitivity, precision, accuracy, and contamination are presented below in narrative form.

5.1. Representativeness and Comparability

The representativeness of data is the ability of the sampling locations and the sampling procedures to adequately represent the true condition of the sample sites. The comparability of data is the degree to which the data can be compared directly between all samples collected under this SAP/QAPP. Field personnel, including municipal personnel that collect samples, will strictly adhere to the field sampling protocols identified in this SAP/QAPP to ensure the collection of representative, uncontaminated, comparable samples. The most important aspects of quality control associated with chemistry sample collection are as follows:

- Field personnel will be thoroughly trained in the proper use of sample collection equipment and will be able to distinguish acceptable versus unacceptable samples in accordance with pre-established criteria.
- Field personnel are trained to recognize and avoid potential sources of sample contamination (e.g., dirty hands, insufficient field cleaning).
- Samplers and utensils that come in direct contact with the sample will be made of non-contaminating materials, and will be thoroughly cleaned between sampling stations.
- Sample containers will be pre-cleaned and of the recommended type.
- All sampling sites will be selected according to the criteria identified in the project study design (BASMAA, 2017a)

Further, the methods for collecting and analyzing PCBs in infrastructure caulk and sealants will be comparable to other studies of PCBs in building material and infrastructure caulk (e.g., Klosterhaus et al., 2014). This SAP/QAPP was also developed to be comparable with the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP, SWAMP 2013). All sediment

and water quality data collected during the Monitoring Program will be performed in a manner so that data are SWAMP comparable [2].

5.2. Completeness

Completeness is defined as the percentage of valid data collected and analyzed compared to the total expected to being obtained under normal operating conditions. Overall completeness accounts for both sampling (in the field) and analysis (in the laboratory). Valid samples include those for analytes in which the concentration is determined to be below detection limits.

Under ideal circumstances, the objective is to collect 100 percent of all field samples desired, with successful laboratory analyses on 100% of measurements (including QC samples). However, circumstances surrounding sample collections and subsequent laboratory analysis are influenced by numerous factors, including availability of infrastructure meeting the required sampling criteria (applies to both infrastructure caulk sampling and HDS Unit sampling), flow conditions, weather, shipping damage or delays, sampling crew or lab analyst error, and QC samples failing MQOs. An overall completeness of greater than 90% is considered acceptable for the Monitoring Program.

5.3. Sensitivity

Different indicators of the sensitivity of an analytical method to measure a target parameter are often used including instrument detection limits (IDLs), method detection limits (MDLs), and method reporting limits (MRLs). For the Monitoring Program, MRL is the measurement of primary interest, consistent with SWAMP Quality Assurance Project Plan (SWAMP 2013). Target MRLs for all analytes by analytical method provided in Section 13.

5.4. Precision

Precision is used to measure the degree of mutual agreement among individual measurements of the same property under prescribed similar conditions. Overall precision usually refers to the degree of agreement for the entire sampling, operational, and analysis system. It is derived from reanalysis of individual samples (laboratory replicates) or multiple collocated samples (field replicates) analyzed on equivalent instruments and expressed as the relative percent difference (RPD) or relative standard deviation (RSD). Analytical precision can be determined from duplicate analyses of field samples, laboratory matrix spikes/matrix spike duplicates (MS/MSD), laboratory control samples (LCS) and/or reference material samples. Analytical precision is expressed as the RPD for duplicate measurements:

$$RPD = ABS([X1 - X2] / [(X1 + X2) / 2])$$

Where: X1 = the first sample result
X2 = the duplicate sample result.

[2] SWAMP data templates and documentation are available online at http://waterboards.ca.gov/water_issues/programs/swamp/data_management_resources/templates_docs.shtml

Precision will be assessed during the Monitoring Program by calculating the RPD of laboratory replicate samples and/or MS/MSD samples, which will be run at a frequency of 1 per analytical batch for each analyte. Target RPDs for the Monitoring Program are identified in Section 13.

5.5. Accuracy

Accuracy describes the degree of agreement between a measurement (or the average of measurements of the same quantity) and its true environmental value, or an acceptable reference value. The "true" values of the POCs in the Monitoring Program are unknown and therefore "absolute" accuracy (and representativeness) cannot be assessed. However, the analytical accuracy can be assessed through the use of laboratory MS samples, and/or LCS. For MS samples, recovery is calculated from the original sample result, the expected value (EV = native + spike concentration), and the measured value with the spike (MV):

$$\% \text{ Recovery} = (MV-N) \times 100\% / (EV-N)$$

Where: MV = the measured value
EV = the true expected (reference) value
N = the native, unspiked result

For LCS, recovery is calculated from the concentration of the analyte recovered and the true value of the amount spiked:

$$\% \text{ Recovery} = (X/TV) \times 100\%$$

Where: X = concentration of the analyte recovered
TV = concentration of the true value of the amount spiked

Surrogate standards are also spiked into samples for some analytical methods (i.e., PCBs) and used to evaluate method and instrument performance. Although recoveries on surrogates are to be reported, control limits for surrogates are method and laboratory specific, and no project specific recovery targets for surrogates are specified, so long as overall recovery targets for accuracy (with matrix spikes) are achieved. Where surrogate recoveries are applicable, data will not be reported as surrogate-corrected values.

Analytical accuracy will be assessed during the Monitoring Program based on recovery of the compound of interest in matrix spike and matrix spike duplicates compared with the laboratory's expected value, at a frequency of 1 per analytical batch for each analyte. Recovery targets for the Monitoring Program are identified in Section 13.

5.6. Contamination

Collected samples may inadvertently be contaminated with target analytes at many points in the sampling and analytical process, from the materials shipped for field sampling, to the air supply in the analytical laboratory. When appropriate, blank samples evaluated at multiple points in the process chain help assure that compound of interest measured in samples actually originated from the target matrix in the sampled environment and are not artifacts of the collection or analytical process.

Method blanks (also called laboratory reagent blanks, extraction blanks, procedural blanks, or preparation blanks) are used by laboratory personnel to assess laboratory contamination during all stages of sample preparation and analysis. The method blank is processed through the entire analytical procedure in a manner identical to the samples. A method blank concentration should be less than the RL or should not exceed a concentration of 10% of the lowest reported sample concentration. A method blank concentration greater than 10% of the lowest reported sample concentration will require corrective action to identify and eliminate the source(s) of contamination before proceeding with sample analysis. If eliminating the blank contamination is not possible, all impacted analytes in the analytical batch shall be flagged. In addition, a detailed description of the likely contamination source(s) and the steps taken to eliminate/minimize the contaminants shall be included in narrative of the data report. If supporting data is presented demonstrating sufficient precision in blank measurement that the 99% confidence interval around the average blank value is less than the MDL or 10% of the lowest measured sample concentration, then the average blank value may be subtracted.

A field blank is collected to assess potential sample contamination levels that occur during field sampling activities. Field blanks are taken to the field, transferred to the appropriate container, preserved (if required by the method), and treated the same as the corresponding sample type during the course of a sampling event. The inclusion of field blanks is dependent on the requirements specified in the relevant MQO tables or in the sampling method.

6. Special Training Needs / Certification

All fieldwork will be performed by contractor staff that has appropriate levels of experience and expertise to conduct the work, and/or by municipal staff that have received the appropriate instruction on sample collection, as determined by the Field PM and/or the PMT. The Field-PM will ensure that all members of the field crew (including participating municipal staff) have received appropriate instructions based on methods described in this document (Section 9) for collecting and transporting samples. As appropriate, sampling personnel may be required to undergo or have undergone OSHA training / certification for confined space entry in order to undertake particular aspects of sampling within areas deemed as such.

Analytical laboratories are to be certified for the analyses conducted at each laboratory by ELAP, NELAP, or an equivalent accreditation program as approved by the PMT. All laboratory personal will follow methods described in Section 13 for analyzing samples.

7. Program Documentation and Reporting

The Consultant Team in consultation with the PMT will prepare draft and final reports of all monitoring data, including statistical analysis and interpretation of the data, as appropriate, which will be submitted to the BASMAA BOD for approval. Following approval by the BASMAA BOD, Final project reports will be available for submission with each stormwater program's Annual Report in 2018 (Task 1) or in the March 31, 2019 report to the Regional Water Board (Tasks 2 and 3). Procedures for overall management of project documents and records and report preparation are summarized below.

7.1. Field Documentation

All field data gathered for the project are to be recorded in field datasheets, and scanned or transcribed to electronic documents as needed to permit easy access by the PMT, the consultant team, and other appropriate parties.

7.1.1. Sampling Plans, COCs, and Sampling Reports

The Field-PM will be responsible for development and submission of field sampling reports to the Data Manager and Consultant-PM. Field crews will collect records for sample collection, and will be responsible for maintaining these records in an accessible manner. Samples sent to analytical laboratories will include standard Chain of Custody (COC) procedures and forms; field crews will maintain a copy of originating COCs at their individual headquarters. Analytical laboratories will collect records for sample receipt and storage, analyses, and reporting. All records, except lab records, generated by the Monitoring Program will be stored at the office of the Data Manager for the duration of the project, and provided to BASMAA at the end of the project.

7.1.2. Data Sheets

All field data gathered by the Monitoring Program will be recorded on standardized field data entry forms. The field data sheets that will be used for each sampling task are provided in Appendix A.

7.1.3. Photographic Documentation

Photographic documentation is an important part of sampling procedures. An associated photo log will be maintained documenting sites and subjects associated with photos. If an option, the date function on the camera shall be turned on. Field Personnel will be instructed to take care to avoid any land marks when taking photographs, such as street signs, names of buildings, road mile markers, etc. that could be used later to identify a specific location. A copy of all photographs should be provided at the conclusion of sampling efforts and maintained for project duration.

7.2. Laboratory Documentation

The Monitoring Program requires specific actions to be taken by contract laboratories, including requirements for data deliverables, quality control, and on-site archival of project-specific information. Each of these aspects is described below.

7.2.1. Data Reporting Format

Each laboratory will deliver data in electronic formats to the Field-PM, who will transfer the records to the Data Manager, who is responsible for storage and safekeeping of these records for the duration of the project. In addition, each laboratory will deliver narrative information to the QA Officer for use in data QA and for long-term storage.

The analytical laboratory will report the analytical data to the Field-PM via an analytical report consisting of, at a minimum:

1. Letter of transmittal
2. Chain of custody information
3. Analytical results for field and quality control samples (Electronic Data Deliverable, EDD)
4. Case narrative

5. Copies of all raw data.

The Field-PM will review the data deliverables provided by the laboratory for completeness and errors. The QA Officer will review the data deliverables provided by the laboratory for review of QA/QC. In addition to the laboratory's standard reporting format, all results meeting MQOs and results having satisfactory explanations for deviations from objectives shall be reported in tabular format on electronic media. SWAMP-formatted electronic data deliverable (EDD) templates are to be agreed upon by the Data Manager, QA Officer, and the Lab-PM prior to onset of any sampling activities related to that laboratory.

Documentation for analytical data is kept on file at the laboratories, or may be submitted with analytical results. These may be reviewed during external audits of the Monitoring Program, as needed. These records include the analyst's comments on the condition of the sample and progress of the analysis, raw data, and QC checks. Paper or electronic copies of all analytical data, field data forms and field notebooks, raw and condensed data for analysis performed on-site, and field instrument calibration notebooks are kept as part of the Monitoring Program archives for a minimum period of eight years.

7.2.2. Other Laboratory QA/QC Documentation

All laboratories will have the latest version of this Monitoring Program SAP/QAPP in electronic format. In addition, the following documents and information from the laboratories will be current, and they will be available to all laboratory personnel participating in the processing of samples:

1. Laboratory QA plan: Clearly defines policies and protocols specific to a particular laboratory, including personnel responsibilities, laboratory acceptance criteria, and corrective actions to be applied to the affected analytical batches, qualification of data, and procedures for determining the acceptability of results.

2. Laboratory Standard Operation Procedures (SOPs): Contain instructions for performing routine laboratory procedures, describing exactly how a method is implemented in the laboratory for a particular analytical procedure. Where published standard methods allow alternatives at various steps in the process, those approaches chosen by the laboratory in their implementation (either in general or in specific analytical batches) are to be noted in the data report, and any deviations from the standard method are to be noted and described.

3. Instrument performance information: Contains information on instrument baseline noise, calibration standard response, analytical precision and bias data, detection limits, scheduled maintenance, etc.

4. Control charts: Control charts are developed and maintained throughout the Program for all appropriate analyses and measurements for purposes of determining sources of an analytical problem or in monitoring an unstable process subject to drift. Control charts serve as internal evaluations of laboratory procedures and methodology and are helpful in identifying and correcting systematic error sources. Control limits for the laboratory quality control samples are ±3 standard deviations from the certified or theoretical concentration for any given analyte.

Records of all quality control data, maintained in a bound notebook at each workstation, are signed and dated by the analyst. Quality control data include documentation of standard calibrations, instrument

maintenance and tests. Control charts of the data are generated by the analysts monthly or for analyses done infrequently, with each analysis batch. The laboratory quality assurance specialist will review all QA/QC records with each data submission, and will provide QA/QC reports to the Field-PM with each batch of submitted field sample data.

7.3. Program Management Documentation

The BASMAA-PM and Consultant-PM are responsible for managing key parts of the Monitoring Program's information management systems. These efforts are described below.

7.3.1. SAP/QAPP

All original SAP/QAPPs will be held by the Consultant-PM. This SAP/QAPP and its revisions will be distributed to all parties involved with the Monitoring Program. Copies will also be sent to the each participating analytical laboratory's contact for internal distribution, preferably via electronic distribution from a secure location.

Associated with each update to the SAP/QAPP, the Consultant-PM will notify the BASMAA-PM and the PMT of the updated SAP/QAPP, with a cover memo compiling changes made. After appropriate distributions are made to affected parties, these approved updates will be filed and maintained by the SAP/QAPP Preparers for the Monitoring Program. Upon revision, the replaced SAP/QAPPs will be discarded/deleted.

7.3.2. Program Information Archival

The Data Manager and Consultant-PM will oversee the actions of all personnel with records retention responsibilities, and will arbitrate any issues relative to records retention and any decisions to discard records. Each analytical laboratory will archive all analytical records generated for this Program. The Consultant-PM will be responsible for archiving all management-level records.

Persons responsible for maintaining records for this Program are shown in Table 7-1.

Table 7-1. Document and Record Retention, Archival, and Disposition

Type	Retention (years)	Archival	Disposition
Field Datasheets	8	Data Manager	Maintain indefinitely
Chain of Custody Forms	8	Data Manager	Maintain indefinitely
Raw Analytical Data	8	Laboratory	Recycling
Lab QC Records	8	Laboratory	Recycling
Electronic data deliverables	8	Data Manager	Maintain indefinitely
Reports	8	Consultant-PM	Maintain indefinitely

As discussed previously, the analytical laboratory will archive all analytical records generated for this Program. The Consultant-PM will be responsible for archiving all other records associated with implementation of the Monitoring Program.

All field operation records will be entered into electronic formats and maintained in a dedicated directory managed by the BASMAA-PM.

7.4. Reporting

The Consultant team will prepare draft and final reports for each component of the Monitoring Program. The PMT will provide review and input on draft reports and submit to the BASMAA BOD for approval. Once approved by the BASMAA BOD, the Monitoring Program reports will be available to each individual stormwater program for submission to the Regional Water Board according to the schedule outlined in the MRP and summarized in Table 7.2.

Table 7-2. Monitoring Program Final Reporting Due Dates.

Monitoring Program Component	Task	MRP Reporting Due Date
Source Identification	Task 1 - Evaluation of PCB concentrations in roadway and storm drain infrastructure caulk and sealants	September 30, 2018
Management Action Effectiveness	Task 2 - Evaluation of the annual mass of PCBs and mercury captured in HDS Unit sump sediment	March 31, 2019
	Task 3 - Bench-scale testing of the mercury and PCBs removal effectiveness of selected BSM mixtures.	

8. Sampling Process Design

All information generated through conduct of the Monitoring Program will be used to inform TMDL implementation efforts for mercury and PCBs in the San Francisco Bay region. The Monitoring Program will implement the following tasks: (1) evaluate the presence and concentrations of PCB in caulk and sealants from public roadway and stormdrain infrastructure; (2) evaluate mass of PCBs and mercury removed during HDS Unit maintenance; and (3) evaluate the mercury and PCBs treatment effectiveness of various BSM mixtures in laboratory column tests using stormwater collected from Bay Area locations. Sample locations and the timing of sample collection will be selected using the directed sampling design principle. This is a deterministic approach in which points are selected deliberately based on knowledge of their attributes of interest as related to the environmental site being monitored. This principle is also known as "judgmental," "authoritative," "targeted," or "knowledge-based." Individual monitoring aspects are summarized further under Field Methods (Section 9) and in the task-specific study designs (BASMAA 2017a,b).

8.1. Caulk/Sealant Sampling

Caulk/sealant sampling will support the Monitoring Program's Task 1 to evaluate PCBs in roadway and stormdrain infrastructure caulk/sealant, as described previously (see Section 4). Further detail on caulk/sealant sampling methods and procedures are provided under Field Methods (Section 9).

8.2. Sediment Quality Sampling

Sediment sampling will support the Monitoring Program's Task 2 to evaluate the mass of mercury and PCBs removed during HDS unit maintenance, as described previously (see Section 4). Further detail on

sediment sampling methods and procedures are provided under Field Methods (Section 9).

8.3. Water Quality Sampling

Water sampling will support the Monitoring Program's Task 3 to evaluate the mercury and PCBs treatment effectiveness of various BSM mixtures, as described previously (see Section 4). Further detail on water sampling methods and procedures are provided under Field Methods (Section 9).

8.4. Sampling Uncertainty

There are multiple sources of potential sampling uncertainty associated with the Monitoring Program, including: (1) measurement error; (2) natural (inherent) variability; (3) undersampling (or poor representativeness); and (4) sampling bias (statistical meaning). Measures incorporated to address these areas of uncertainty are discussed below:

(1) Measurement error combines all sources of error related to the entire sampling and analysis process (i.e., to the measurement system). All aspects of dealing with uncertainty due to measurement error have been described elsewhere within this document.

(2) Natural (inherent) variability occurs in any environment monitored, and is often much wider than the measurement error. Prior work conducted by others in the field of stormwater management have demonstrated the high degree of variability in environmental media, which will be taken into consideration when interpreting results of the various lines of inquiry.

(3) Under- or unrepresentative sampling happens at the level of an individual sample or field measurement where an individual sample collected is a poor representative for overall conditions encountered given typical sources of variation. To address this situation, the Monitoring Program will be implementing a number of QA-related measures described elsewhere within this document, including methods refined through implementation of prior, related investigations.

(4) Sampling bias relates to the sampling design employed and whether the appropriate statistical design is employed to allow for appropriate understanding of environmental conditions. To a large degree, the sampling design required by the Monitoring Program is judgmental, which will therefore incorporate an unknown degree of sampling bias into the Project. There are small measures that have been built into the sampling design to combat this effect (e.g., homogenization of sediments for chemistry analyses), but overall this bias is a desired outcome designed to meet the goals of this Monitoring Program, and will be taken into consideration when interpreting results of the various investigations.

Further detail on measures implemented to reduce uncertainty through mobilization, sampling, sample handling, analysis, and reporting phases are provided throughout this document.

9. Sampling Methods

The Monitoring Program involves the collection of three types of samples: Caulk/sealants; sediment from HDS unit sumps; and water quality samples. Field collection will be conducted by field contractors or municipal staff using a variety of sampling protocols, depending on the media and parameter monitored. These methods are presented below. In addition, the Monitoring Program will utilize several field

sampling SOPs previously developed by the BASMAA Regional Monitoring Coalition identified in Table 9-3 (RMC, BASMAA, 2016).

9.1. Caulk/Sealant Sampling (Task 1)

Procedures for collecting caulk and sealant samples are not well established. Minimal details on caulk or sealant sample collection methodologies are available in peer-reviewed publications. The caulk/sealant sampling procedures described here were adapted from a previous study examining PCBs in building materials conducted in the Bay Area (Klosterhaus et al., 2014). The methods described by Klosterhaus et al. (2014) were developed through consultation with many of the previous authors of caulk literature references therein, in addition to field experience gained during the Bay Area study. It is anticipated that lessons will also be learned during the current study.

9.1.1. Sample Site Selection

Once a structure has been identified as meeting the selection criteria and permission is granted to perform the testing or collection of sealant samples, an on-site survey of the structure will be used to identify sealant types and locations on the structure to be sampled. It is expected that sealants from a number of different locations on each structure may sampled; however, inconspicuous locations on the structure will be targeted.

9.1.2. Initial Equipment Cleaning

The sampling equipment that is pre-cleaned includes:

- Glass sample jars
- Utility knife, extra blades
- Stainless-steel forceps

Prior to sampling, all equipment will be thoroughly cleaned. Glass sample containers will be factory pre-cleaned (Quality Certified™, ESS Vial, Oakland, CA) and delivered to field team at least one week prior to the start of sample collection. Sample containers will be pre-labeled and kept in their original boxes, which will be transported in coolers. Utility knife blades, forceps, stainless steel spoons, and chisels will be pre-cleaned with Alconox, Liquinox, or similar detergent, and then rinsed with deionized water and methanol. The cleaned equipment will then be wrapped in methanol-rinsed aluminum foil and stored in clean Ziploc bags until used in the field.

9.1.3. Field Cleaning Protocol

Between each use the tool used (utility knife blade, spoon or chisel) and forceps will be rinsed with methanol and then deionized water, and inspected to ensure all visible sign of the previous sample have been removed. The clean tools, extra blades, and forceps will be kept in methanol-rinsed aluminum foil and stored in clean Ziploc bags when not in use.

9.1.4. Blind Sampling Procedures

The intention of this sampling is to better determine whether sealants in road and storm drain infrastructure contain PCBs at concentrations of concern, and to understand the relative importance of PCBs in this infrastructure among the other known sources of PCBs that can affect San Francisco Bay. At this phase of the project, we are not seeking to identify specific facilities requiring mitigation (if PCBs are

identified, this could be a future phase). Therefore, in this initial round of sampling, we are not identifying sample locations, but instead implementing a blind sampling protocol, as follows:

- All samples will be collected without retaining any information that would identify structure locations. The information provided to the contractor on sampling locations will not be retained. Structure location information will not be recorded on any data sheets or in any data spreadsheets or other electronic computer files created for the Project. Physical sealant samples collected will be identified only by a sample identification (ID) designation (Section 4). Physical sealant sample labels will contain only the sample ID (see Section 4 and example label in Appendix A). Samples will be identified only by their sample ID on the COC forms.
- As an added precaution and if resources allow, oversampling will occur such that more samples will be collected than will be sent to the laboratory for compositing and analysis. In this case, the Project team would select a subset of samples for PCB analysis based on factors such as application type and/or chlorine content, but blind to the specific location where each sample was collected.
- Up to three individual sealant samples will be composited by the laboratory prior to analysis for PCBs, following instructions from the Consultant PM. This further ensures a blind sampling approach because samples collected at different locations will be analyzed together.

9.1.5. Caulk/Sealant Collection Procedures

At each sample location, the Field-PM, and/or municipal staff, will make a final selection of the most accessible sampling points at the time of sampling. From each point sampled, a one inch strip (aiming for about 10 g of material) of caulk or sealant will be removed from the structure using one of the following solvent-rinsed tools: a utility knife with a stainless-steel blade, stainless steel spoon to scrape off the material, or a stainless steel chisel. The Field-PM or municipal staff at the site will select the appropriate tool based on the conditions of the caulk/sealant at each sample point. Field personnel will wear nitrile gloves during sample collection to reduce potential sample contamination. The sample will then be placed in a labeled, factory-cleaned glass jar. For each caulk sample collected, field personnel will fill out a field data sheet at the time of sample collection, which includes the following information:

- Date and time of sample collection,
- sample identification designation,
- qualitative descriptions of relevant structure or caulk/sealant features, including use profile, color and consistency of material collected, surface coating (paint, oily film, masonry residues etc.)
- crack dimensions, the length and/or width of the caulk bead sampled, spacing of expansion joints in a particular type of application, and
- a description of any unusual occurrences associated with the sampling event (especially those that could affect sample or data quality).

Appendix A contains an example field data sheet. All samples will be kept in a chilled cooler in the field (i.e., at 4 ºC ± 2 ºC), and kept refrigerated pending delivery under COC to the Field PM at KLI. Further, the field data sheets will remain with the samples when they are shipped to KLI, and will then be maintained by the Field PM at KLI.

As needed, the procedure for replacement of the caulk/sealant will be coordinated with the appropriate municipal staff to help ensure that the sampling does not result in damage to the structure.

9.1.6. Sample ID Designation

Every sample must have a unique sample ID to ensure analytical results from each sample can be differentiated from every other sample. This information should follow the sample through the COC, analytical, and interpretation and reporting processes. For the infrastructure caulk/sealant samples, the sample ID must not contain information that can be used to identify where the sample was collected. The following 2-step process will be followed to assign sample IDs to the caulk/sealant samples.

1. Upon collection, the sample will be labeled according to the following naming convention:

   MMDDYYYY-TTTT-##

   Where:

MM	2 digit month of collection
DD	2 digit date of collection
YYYY	4 digit year of collection
TTTT	4 digit time of collection (military time)
##	Sequential 2-digit sample number (i.e., 01, 02, 03…etc.)

   For example, a sample collected on September 20, 2017 at 9 AM could be assigned the following sample ID: 09202017-0900-01.

2. This second step was added to avoid issues that could arise due to duplicate sample IDs, while maintaining the blind sampling approach. While the sample naming system identified above is unlikely to produce duplicate sample IDs, there is a chance that different groups may collect samples simultaneously. This second step will be implemented by the Field PM at KLI upon receipt of caulk/sealant samples from participating municipalities. The Field PM at KLI will review the sample IDs on the COC forms for all samples and compare the sample IDs to all caulk samples for this project already in storage at KLI. If any two samples have the same sample IDs, the Field PM will add a one-digit number to the end of one of the sample IDs, selected at random. This extra number will be added to the sample container label, the field data sheet, and the COC form for that sample.

9.2. HDS Unit Sampling Procedures (Task 2)

9.2.1. Sample Site Selection

Sample site selection will be opportunistic, based on the public HDS units that participating municipalities schedule for cleaning during the project. The project team will coordinate with participating municipalities to schedule sampling during HDS unit cleanouts.

9.2.2. Field Equipment and Cleaning

A list of potential sampling equipment for soil/sediment is presented in Table 5. The equipment list should be reviewed and tailored by field contractors to meet the needs of each individual sampling site. Appropriate sampling equipment is prepared in the laboratory a minimum of four days prior to sampling. Prior to sampling, all equipment will be thoroughly cleaned. Equipment is soaked (fully immersed) for three days in a solution of Alconox, Liquinox, or similar phosphate-free detergent and deionized water. Equipment is then rinsed three times with deionized water. Equipment is next rinsed with a dilute solution

(1-2%) of hydrochloric acid, followed by a rinse with reagent grade methanol, followed by another set of three rinses with deionized water. All equipment is then allowed to dry in a clean place. The cleaned equipment is then wrapped in aluminum foil or stored in clean Ziploc bags until used in the field.

Table 9-1 Field Equipment for HDS Unit Sampling.

Description of Equipment	Material (if applicable)
Sample scoops	Stainless steel or Kynar coated
Sample trowels	Stainless steel or Kynar coated
Compositing bucket	Stainless steel or Kynar coated
Ekman Dredge (as needed)	Stainless steel
Sample containers (with labels)	As coordinated with lab(s)
Methanol, Reagent grade (Teflon squeeze bottle with refill)	
Hydrochloric acid, 1-2%, Reagent grade (Teflon squeeze bottle)	
Liquinox detergent (diluted in DI within Teflon squeeze bottle)	
Deionized / reverse osmosis water	
Plastic scrub brushes	
Container for storage of sampling derived waste, dry	
Container for storage of sampling derived waste, wet	
Wet ice	
Coolers, as required	
Aluminum foil (heavy duty recommended)	
Protective packaging materials	Bubble / foam bags
Splash proof eye protection	
PPE for sampling personnel, including traffic mgmt as required	
Gloves for dry ice handling	Cotton, leather, etc.
Gloves for sample collection, reagent handling	Nitrile
Field datasheets	
COC forms	
Custody tape (as required)	
Shipping materials (as required)	
GPS	

9.2.3. Soil / Sediment Sample Collection

Field sampling personnel will collect sediment samples from HDS unit sumps using methods that minimize contamination, losses, and changes to the chemical form of the analytes of interest. The samples will be collected in the field into pre-cleaned sample containers of a material appropriate to the analysis to be conducted. Pre-cleaned sampling equipment is used for each site, whenever possible and/or when necessary. Appropriate sampling technique and measuring equipment may vary depending on the location, sample type, sampling objective, and weather. Additional safety measures may be necessary in some cases; for example, if traffic control or confined space entry is required to conduct the sampling.

Ideally and where a sufficient volume of soil/sediment allows, samples are collected into a composite container, where they are thoroughly homogenized, and then aliquoted into separate jars for chemical analysis. Sediment samples for metals and organics are submitted to the analytical laboratories in separate jars, which have been pre-cleaned according to laboratory protocol. It is anticipated that soil / solid media will be collected for laboratory analysis using one of two techniques: (1) Remote grab of submerged sediments within HDS unit sumps using Ekman dredge or similar; or (2) direct grab sampling of

sediments after dewatering HDS unit sumps using individual scoops, push core sampling, or similar. Each of these techniques is described briefly below.

- Soil and Sediment Samples, Submerged. Wet soil and sediment samples may be collected from within HDS unit sumps. Sample crews must exercise judgment on whether submerged samples can be collected in a manner that does not substantially change the character of the soil/sediment collected for analysis (e.g., loss of fine materials). It is anticipated that presence of trash within the sumps may interfere with sample collection by preventing complete grab closure and loss of significant portion of the sample. Field crews will have the responsibility to determine the best method for collection of samples within each HDS Unit sump. If sampling personnel determine that sample integrity cannot be maintained throughout collection process, it is preferable to cancel sampling operations rather than collect samples with questionable integrity. This decision making process is more fully described in Section 11, Field Variances.

- Soil and Sediment Samples, Dry. Soils / sediments may be collected from within the HDS unit sump after dewatering. Field crews will have the responsibility to identify areas of sediment accumulation within areas targeted for sampling and analysis, and determine the best method for collection of samples with minimal disturbance to the sampling media.

After collection, all soil/sediment samples for PCBs and mercury analyses will be homogenized and transferred from the sample-dedicated homogenization pail into factory-supplied wide-mouth glass jars using a clean trowel or scoop. The samples will be transferred to coolers containing double-bagged wet ice and chilled to 6°C immediately upon collection.

For each sample collected, field personnel will fill out a field data sheet at the time of sample collection. Appendix A contains an example field data sheet. All samples will be kept in a chilled cooler in the field, and kept refrigerated pending delivery under COC to the field-PM. The Field PM will be responsible for sending the samples in a single batch to CEH for XRF analysis under COC. Following XRF analysis, CEH will deliver the samples under COC to the Consultant-PM. The Consultant-PM will be responsible for working with the project team to group samples for compositing, and sending those samples to the analytical laboratory under COC.

9.2.4. Sample ID Designation

Every sample must have a unique sample ID so that the analytical results from each sample can be differentiated from every other sample. This information should follow the sample through the COC, analytical, and interpretation and reporting processes. Each sediment/soil sample collected from HDS units will be labeled according to the following naming convention:

MMM-UUU-##

where:

MMM	Municipal Abbreviation (i.e., SJC=San Jose; OAK=Oakland; SUN=Sunnyvale).
UUU	HDS Unit Catchment ID; this is the number provided by the municipality for a specific HDS unit.
##	Sequential Sample Number (i.e., 01, 02, 03…etc.)

9.3. Water Quality Sampling and Column Testing Procedures (Task 3)

For this task, monitoring will be conducted during three storm events. The stormwater collected during these events will then be used as the influent for the laboratory column tests of amended BSM mixtures. Four influent samples (i.e., one sample of Bay Area stormwater from each of the three monitored storm events plus one diluted stormwater sample) and 20 effluent samples from the column tests that includes 3 tests for each of the six columns, plus one test with the diluted stormwater in two columns (one test column and one control column) will be collected and analyzed for pollutant concentrations.

9.3.1. Sample Site Selection

Two stormwater collection sites have been selected based on influent PCB concentrations measured during CW4CB (BASMAA, 2017c). Both sites are near tree wells located on Ettie Street in West Oakland. The first site is the influent to tree well #6 (station code = TW6). During CW4CB, influent stormwater concentrations at this location were average to high, ranging from 30 ng/L to 286 ng/L. Stormwater collected from this site will be used as the influent for one of the main column tests and some water will be reserved for the dilution series column tests. The amount of dilution will be determined after results are received from the lab from the first run. The second site is the influent to tree well #2 (station code=TW2). During CW4CB, influent stormwater concentrations at this location were low to average, ranging from 6 ng/L to 39 ng/L. Stormwater collected from this site will be used for the remaining two main column tests..

9.3.2. Field Equipment and Cleaning

Field sampling equipment includes:

1. Borosilicate glass carboys
2. Glass sample jars
3. Peristaltic pump tubing

Prior to sampling, all equipment will be thoroughly cleaned. Glass sample containers and peristaltic pump tubing will be factory pre-cleaned. Prior to first use and after each use, glass carboys (field carboys and effluent collection carboys) will be washed using phosphate-free laboratory detergent and scrubbed with a plastic brush. After washing the carboy will be rinsed with methylene chloride, then de-ionized water, then 2N nitric acid, then again with de-ionized water. Glass carboys will be cleaned after each sample run before they are returned to the Field PM for reuse in the field.

9.3.3. Water Sampling Procedures

During each storm event, stormwater will be collected in six, five-gallon glass carboys. To fill the carboys, the Field PM will create a backwater condition in the gutter before the drain inlet at each site and use a peristaltic pump to pump the water into glass carboys. Field personnel will wear nitrile gloves during sample collection to prevent contamination. Carboys will be stored and transported in coolers with either wet ice or blue ice, and will be delivered to OWP within 24 hours of collection.

9.3.4. Hydraulic Testing

Based on the literature review and availability, the best five biochars will be mixed with the standard BSM to create biochar amended BSMs. Initially, each biochar will be mixed with standard BSM at a rate of 25% biochar by volume (the same as that at the CW4CB Richmond PG&E Substation 1st and Cutting

site). Hydraulic conductivity can be determined using the method stated in the BASMAA soil specification, method ASTM D2434.

1. Follow the directions for permeability testing in ASTM D2434 for the BSM.
2. Sieve enough of the sample biochar to collect at least 15 in^3 on a no. 200 sieve.
3. Mix the sieved biochar with standard BSM at a 1 to 4 ratio.
4. Thoroughly mix the soil.
5. Follow the directions for permeability testing in ASTM D2434.
6. If the soil mix is more than 1 in/hr different from the BSM, repeat steps 1-4 but on step 3, adjust the ratio as estimated to achieve the same permeability as the BSM.
7. Repeat steps 2-6 for each biochar.

9.3.5. Column Testing Procedures

Column Setup: Up to five biochar amended BSMs and one standard BSM will be tested (based on performance and availability of biochars). Six glass columns with a diameter of eight inches and a height of three feet will be mounted to the wall with sufficient height between the bottom of the columns and the floor to allow for effluent sample collection. Each column will be capped at the bottom and fitted with a spigot to facilitate sampling. Soil depth for all columns will be 18" after compaction, which is a standard depth used in bay area bioretention installations (see Figure 9-1 below). To retain soil the bottom of the soil layer will be contained by a layer of filter fabric on top of structural backing. Behind each column, a yardstick will be mounted to the wall so that the depth of water in the column can be monitored.

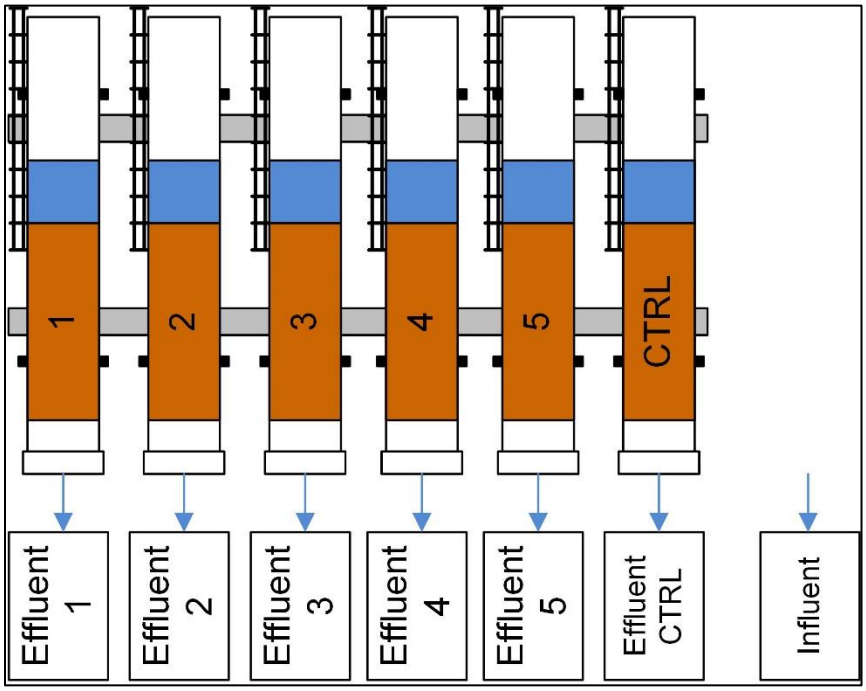

Figure 9-1. Column Test Setup

Dilution Run Column Setup: One of the existing biochar-amended BSM column and the standard BSM will be tested using diluted stormwater.

Testing procedure pre run setup: Before a sampling run begins a clean glass carboy will be placed under each soil column and labeled to match, this carboy will be sized to collect the full effluent volume

of the sample run. A glass beaker will also be assigned and labeled for each column of sufficient volume to accurately measure a single influent dose equivalent to 1 inch of depth in the column. An additional beaker will be prepared and labeled influent.

Media conditioning: Within 24 to 72 hours prior to the first column test run, pre-wet each column with a stormwater matrix collected from the CSUS campus by filling each column from the invert until water ponds above the media. Drain the water after 3 hours.

Sampling run: When the six glass carboys are delivered:

1. Inspect each carboy and fill out the Sample Receiving worksheet.
2. The runs will begin within 72 hours of delivery.
3. Select one carboy at random and fully mix it using a portable lab mixer for five minutes.
4. Turn off and remove the mixer, allow the sample to rest for one minute to allow the largest particles to settle to the bottom.
5. Fill each of the six dosing beakers and the one influent sample jar.
6. Pour each aliquot beaker into its respective column; record the time and height of water in each column.
7. Repeat steps 3-6 for each of the remaining carboys until a total of 18 inches of water is applied to each column. Before pouring an aliquot record the height of water in each column and the time. Pour each successive aliquot from the carboy when all columns have less than three inches of water above the soil surface. The water level should never be above 6 inches in any column at any time (6 inches is a standard ponding depth used in the bay area). Pour all aliquots from a single carboy into the columns at the same time.
8. Collect turbidity samples from the effluent of each column at the beginning, middle, and end of the sampling run. Fill the cuvettes for turbidity measurement directly from the effluent stream of each column and dispose of them after testing.
9. Collect mercury samples from the effluent of each column at the middle of the sample run using pre-labeled sample containers provided by the lab for that purpose.
10. Fill a pre-labeled sample jar from each columns effluent. The jar will be obtained from the laboratory performing the PCB analysis.
11. Pack each jar in ice and complete the lab COCs.
12. Ship the samples to the lab for analysis.

9.3.6.Sample ID Designations

Every sample must have a unique sample identification to ensure analytical results from each sample can be differentiated from every other sample. This information should follow the sample through the COC, analytical, and interpretation and reporting processes. Each influent and effluent water quality sample will be labeled according to the following naming convention:

SSS-TT-MMDDYYYY-##

Where:

SSS	Station code (see Table 9-2 for station codes)
TT	Sample Type (IN=influent; EF=Effluent)
MM	2 digit month of collection
DD	2 digit date of collection
YYYY	4 digit year of collection
##	Sequential 2-digit sample number (i.e., 01, 02, 03…etc.)

For example, a sample collected at the West Oakland Tree Well #2 site on October 20, 2017 and used for the influent sample for run #3 could be assigned the following sample ID: TW2-IN-09202017-03.

Table 9-2 Station Codes for Stormwater Influent Samples and Column Tests.

Station Code	Station Description
TW2	Stormwater sample collected from the West Oakland Tree Well #2
TW6	Stormwater sample collected from the West Oakland Tree Well #6
CO1	Effluent sample collected from column number 1
CO2	Effluent sample collected from column number 2
CO3	Effluent sample collected from column number 3
CO4	Effluent sample collected from column number 4
CO5	Effluent sample collected from column number 5
CO6	Effluent sample collected from column number 6

9.4. Collection of Samples for Archiving

Archive samples will not be collected for this Monitoring Program. The sample size collected will be enough to support additional analyses if QA/QC issues arise. Once quality assurance is certified by the QA Officer, the laboratory will be instructed to dispose of any leftover sample materials.

9.5. Waste Disposal

Proper disposal of all waste is an important component of field activities. At no time will any waste be disposed of improperly. The proper methods of waste disposal are outlined below:

9.5.1. Routine Garbage

Regular garbage (paper towels, paper cups, etc.) is collected by sampling personnel in garbage bags or similar. It can then be disposed of properly at appropriate intervals.

9.5.2. Detergent Washes

Any detergents used or detergent wash water should be collected in the field in a water-tight container and disposed of appropriately.

9.5.3. Chemicals

Methanol, if used, should be disposed of by following all appropriate regulations. It should always be collected when sampling and never be disposed in the field.

9.1. Responsibility and Corrective Actions

If monitoring equipment fails, sampling personnel will report the problem in the comments section of their field notes and will not record data values for the variables in question. Actions will be taken to replace or repair broken equipment prior to the next field use.

9.2. Standard Operating Procedures

SOPs associated with sampling and sample handling expected to be used as part of implementation of The Monitoring Program are identified in Table 9-3. Additional details on sample container information, required preservation, holding times, and sample volumes for all Monitoring Program analytes are listed

in Table 10-1 of Section 10.

Table 9-3. List of BASMAA RMC SOPs Utilized by the Monitoring Program.

RMC SOP #	RMC SOP	Source
FS-2	Water Quality Sampling for Chemical Analysis, Pathogen Indicators, and Toxicity	BASMAA 2016
FS-3	Field Measurements, Manual	BASMAA 2016
FS-4	Field Measurements, Continuous General Water Quality	BASMAA 2016
FS-5	Temperature, Automated, Digital Logger	BASMAA 2016
FS-6	Collection of Bedded Sediment Samples for Chemical Analysis and Toxicity	BASMAA 2016
FS-7	Field Equipment Cleaning Procedures	BASMAA 2016
FS-8	Field Equipment Decontamination Procedures	BASMAA 2016
FS-9	Sample Container, Handling, and Chain of Custody Procedures	BASMAA 2016
FS-10	Completion and Processing of Field Datasheets	BASMAA 2016
FS-11	Site and Sample Naming Convention	BASMAA 2016

In addition, contractor-specific plans and procedures may be required for specific aspects of the Monitoring Program implementation (e.g., health and safety plans, dry ice shipping procedures).

10. Sample Handling and Custody

Sample handling and chain of custody procedures are described in detail in RMC SOP FS-9 (Table 9-3) (BASMAA 2016). The Field-PM or designated municipal staff on site during sample collection will be responsible for overall collection and custody of samples during field sampling. Field crews will keep a field log, which will consist of sampling forms for each sampling event. Sample collection methods described in this document and the study designs (BASMAA 2017a, b) will be followed for each sampling task. Field data sheets will be filled out for each sample collected during the project. Example field data sheets are provided in Appendix A, and described further in Section 9.

The field crews will have custody of samples during field sampling, and COC forms will accompany all samples from field collection until delivery to the analyzing laboratory. COC procedures require that possession of samples be traceable from the time the samples are collected until completion and submittal of analytical results. Each laboratory will follow sample custody procedures as outlined in its QA plans.

Information on sampling containers, preservation techniques, packaging and shipping, and hold times is described below and summarized in Table 10.1.

10.1. Sampling Containers

Collection of all sample types require the use of clean containers. Factory pre-cleaned sample containers of the appropriate type will be provided by the contracted laboratory and delivered to field team at least one week prior to the start of sample collection. Individual laboratories will be responsible for the integrity of containers provided. The number and type of sample containers required for all analytes by media type for each sampling task are provided in Table 10.1.

10.2. Sample Preservation

Field Crews will collect samples in the field in a way that neither contaminates, loses, or changes the chemical form of the analytes of interest. The samples will be collected in the field into pre-cleaned sample containers of a material appropriate to the analysis to be conducted. Pre-cleaned sampling equipment is used for each site, whenever possible and/or when necessary. Appropriate sampling technique and measurement equipment may vary depending on the location, sample type, sampling objective, and weather.

In general, all samples will be packed in sufficient wet ice or frozen ice packs during shipment, so that they will be kept between 2 and 4º C (Table 10.1). When used, wet ice will be double bagged in Zip-top bags to prevent contamination via melt water. Where appropriate, samples may be frozen to prevent degradation. If samples are to be shipped frozen on dry ice, then appropriate handling procedures will be followed, including ensuring use of appropriate packaging materials and appropriate training for shipping personnel.

10.3. Packaging and Shipping

All samples will be handled, prepared, transported, and stored in a manner so as to minimize bulk loss, analyte loss, contamination, or biological degradation. Sample containers will be clearly labeled with an indelible marker. All caps and lids will be checked for tightness prior to shipping. Ice chests will be sealed with packing tape before shipping. Samples will be placed in the ice chest with enough ice or frozen ice packs to maintain between 2 and 4º C. Additional packing material will be added as needed. COC forms will be placed in a zip-top bag and placed inside of the ice chest.

10.4. Commercial Vehicle Transport

If transport of samples to the contracted laboratories is to be by commercial carriers, pickup will be pre-arranged with the carrier and all required shipping forms will be completed prior to sample pickup by the commercial carrier.

10.5. Sample Hold Times

Sample hold times for each analyte by media type are presented in Table 10-1.

Table 10-1 Sample Handling for the Monitoring Program Analytes by media type.

Analyte	Sample Media	Sample Container	Minimum Sample / Container Size[a]	Preservative	Hold Time (at 6º C)
PCBs (40-RMP Congeners)	Caulk or sealant	Pre-cleaned 250-mL glass sample container (e.g., Quality Certified™, ESS Vial, Oakland, CA)	10 g	Cool to 6° C within 24 hours, then freeze to ≤-20° C	1 year at -20º C; Samples must be analyzed within 14 days of collection or thawing.
	Sediment	Pre-cleaned 250-mL I-Chem 200 Series amber glass jar with Teflon lid liner	500 mL (two jars)	Cool to 6° C within 24 hours, then freeze to ≤-20° C	1 year at -20º C; Samples must be analyzed within 14 days of collection or thawing.
	Water	1000-mL I-Chem 200-Series amber glass bottle, with Teflon lid-liner	1000 mL/per individual analyses	Cool to 6º C in the dark.	1 year until extraction, 1 year after extraction
Total Mercury	Sediment	Pre-cleaned 250-mL I-Chem 200 Series amber glass jar with Teflon lid liner	100 g	Cool to 6º C and in the dark	1 year at -20º C; Samples must be analyzed within 14 days of collection or thawing.
	Water	250-mL glass or acid-cleaned Teflon bottle	250 mL	Cool to 6º C in the dark and acidify to 0.5% with pre-tested HCl within 48 hours	6 months at room temperature following acidification
Bulk Density	Sediment	250-mL clear glass jar; pre-cleaned	250 mL	Cool to 6º C	7 days
Grain Size and TOC	Sediment	250-mL clear glass jar; pre-cleaned	250 mL	Cool to 6º C, in the dark up to 28 days[2]	28 days at ≤6 ◦C; 1 year at ≤-20 ◦C
SSC	Water	125-mL amber glass jar or Polyethylene Bottles	125 mL	Cool to 6º C and store in the dark	7 days
Turbidity	Water				
Total Solids	Water	1 L HDPE	1 L	Cool to ≤6 ◦C	7 days
TOC	Water	40-mL glass vial	40 mL	Cool to 6º C and store in the dark. If analysis is to occur more than two hours after sampling, acidify (pH < 2) with HCl or H_2SO_4.	28 days
Particle Size Distribution	Water	1 L HDPE	2 L	Cool to 6º C and store in the dark	7 days

[a]QC samples or other analytes require additional sample bottles.

11. Field Health and Safety Procedures

All field crews will be expected to abide by their employer's (i.e., the field contractor's) health and safety programs. Additionally, prior to the fieldwork, field contractors are required to develop site-specific Health and Safety plans that include the locations of the nearest emergency medical services.

Implementation of the Monitoring Program activities may require confined space entry (CSE) to accomplish sampling goals. Sampling personnel conducting any confined space entry activities will be expected to be certified for CSE and to abide by relevant regulations.

12. Laboratory Analytical Methods

12.1. Caulk/Sealant Samples (Task 1)

12.1.1. XRF Chlorine analysis

XRF technology will be used in a laboratory setting to rank samples for chlorine content before sending the samples to the project laboratory for chemical analysis. Procedures for testing caulk or sealants using X-Ray fluorescence (XRF) and collecting caulk and sealant samples are not well described, and minimal detail on caulk or sealant sample collection is available in peer-reviewed publications. Sealant sampling procedures were adapted from the previous study examining PCBs in building materials (Klosterhaus et al., 2014).

An XRF analyzer will be used at the Center for Environmental Health (CEH) as a screening tool to estimate the concentration of chlorine (Cl) in collected caulk and sealant samples from various structures. Settings for the analyzer will be 'standardized' using procedures developed/ recommended by CEH each time the instrument is turned on and prior to any measurement. European plastic pellet reference materials (EC680 and EC681) will be used as 'check' standards upon first use to verify analyzer performance. A 30 second measurement in 'soil' mode will be used. CEH personnel will inspect the caulk/sealant surfaces and use a stainless steel blade to scrape off any paint, concrete chips, or other visible surface residue. The caulk/sealant surface to be sampled will then be wiped with a laboratory tissue to remove any remaining debris that may potentially interfere with the XRF analysis. At least two XRF readings will be collected from each sample switching the orientation or position of the sample between readings. If Cl is detected, a minimum of four additional readings will be collected on the same material to determine analytical variability. Each individual Cl reading and its detection limit will be recorded on the data sheet. After XRF analysis, all samples will be returned to their original sample container. Results of the XRF analysis will be provided to the project team as a table of ranked Cl screening results for possible selection for chemical (PCBs) analysis.

12.1.2. Selection of Samples for PCB analysis and Compositing

Once samples have been ranked for their chlorine content, primarily samples with the highest Cl will preferentially be selected for chemical analysis. About 75% of samples to be analyzed should be selected from samples with the top quartile Cl content. The remaining 25% should be selected from samples with medium (25 to 75th percentile) Cl, as the previous study using XRF screening showed inconsistent correlation between total Cl and PCB. Although samples with very low Cl seldom had much PCBs, samples with medium Cl on occasion had higher PCBs than samples with high Cl, and within the high Cl group, Cl content was not a good predictor of their ranks of PCB concentration.

In addition to Cl content, other factors about each sample that were recorded on the field data sheets at the time of sample collection, including the color or consistency of the sample, the type and/or age of the structure that was sampled, or the type of caulk or sealant application will be considered in selecting the samples that will be sent to the laboratory for PCBs analysis, as well as how the samples will be grouped for compositing purposes. Those factors are described in more detail in the study design (BASMAA, 2017a).

The Consultant PM will work with the project team to identify up to three samples for inclusion in each composite. A common composite ID will then be assigned to each sample that will be composited together (i.e., all samples the lab should composite together will be identified by the common composite ID). The composite ID will consist of a single letter designation and will be identical for all samples (up to 3 total) that will be composited together. The Consultant PM will add the composite ID to each sample container label, to each sample ID on all COC forms, and to each field data sheet for all samples prior to sending the samples to the laboratory for PCBs analysis.

12.1.3. Sample Preparation

The project laboratory will composite the samples prior to extraction and PCBs analysis according to the groupings identified by the common composite ID. Sample preparation will include removal of any paint, concrete chips, or other surface debris, followed by homogenization of the caulk/sealant material and compositing up to three samples per composite. Each sample will have a composite ID that will be used to identify which samples should be composited together. Samples with the same composite ID will be combined into a single composite sample. For example, all samples with composite ID = "A" will be composited together; all samples with composite ID = "B" will be composited together, etc. Sample preparation and compositing will follow the procedures outlined in the laboratory SOPs (Appendix B). After compositing, each composite sample will be assigned a new sample ID using the following naming convention:

X-MMDDYYYY

Where:

X	the single letter Composite ID that is common to all samples included in a given composite.
MM	2 digit month of composite preparation
DD	2 digit date of composite preparation
YYYY	4 digit year of composite preparation

For example, if three samples with the composite ID= "A" are combined into a single composite sample on December 12, 2017, the new (composite) sample ID would be the following: A-12122017.

12.1.4. PCBs Analysis

All composite caulk/sealant samples will be extracted by Method 3540C, and analyzed for the RMP-40 PCB congeners[3] using a modified EPA Method 8270C (GC/MS-SIM), in order to obtain positive

[3] The 40 individual congeners routinely quantified by the Regional Monitoring Program (RMP) for Water Quality in the San Francisco Estuary include: PCBs 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, l05, 110, 118, 128, 132, 138, 141, 149, l51, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203

identification and quantitation of PCBs. PCB content of these material covers an extremely wide range, so the subsampling of material should include sufficient material for quantification assuming that the concentration is likely to be around the median of previous results. There may be samples with much higher concentrations, which can be reanalyzed on dilution as needed. Method Reporting Limits (MRLs) for each of the RMP-40 PCB Congeners are 0.5 µg/Kg.

12.2. Sediment Samples Collected from HDS Units (Task 2)

All sediment samples collected from HDS units under Task 2 will be analyzed for TOC, grain size, bulk density, total mercury, and PCBs (RMP 40 Congeners1) by the methods identified in Table 12-1. All sediment samples (with the exception of grain size) will be sieved by the laboratory at 2 mm prior to analysis.

Table 12-1. Laboratory Analytical Methods for Analytes in Sediment

Analyte	Sampling Method	Recommended Analytical Method	Reporting Units
Total Organic Carbon (TOC)	Grab	EPA 415.1, 440.0, 9060, or ASTM D4129M	%
Grain Size	Grab	ASTM D422M/PSEP	%
Bulk Density	Grab	ASTM E1109-86	g/cm3
Mercury	Grab	EPA 7471A, 7473, or 1631	µg/kg
PCBs (RMP 40 Congeners)	Grab	EPA 1668	µg/kg

12.3. Water Samples – Stormwater and Column Tests (Task 3)

All water samples submitted to the laboratory will be analyzed for SSC, TOC, total mercury and PCBs (RMP-40 congeners) according to the methods identified in Table 12-2.

Table 12-2. Laboratory Analytical Methods for Analytes in Water

Analyte	Sampling Method	Recommended Analytical Method	Reporting Units
Suspended Sediment Concentration (SSC)	Grab	ASTM D3977-97 (Method C)	mg/L
Total Organic Carbon (TOC)	Grab	EPA 415.1 or SM 5310B	%
Mercury (Total)	Grab	EPA 1631	µg/L
PCBs (RMP 40 Congeners)	Grab	EPA 1668	ng/L

12.4. Method Failures

The QA Officer will be responsible for overseeing the laboratory implementing any corrective actions that may be needed in the event that methods fail to produce acceptable data. If a method fails to provide acceptable data for any reason, including analyte or matrix interferences, instrument failures, etc., then the involved samples will be analyzed again if possible. The laboratory in question's SOP for handling these types of problems will be followed. When a method fails to provide acceptable data, then the laboratory's

SOP for documenting method failures will be used to document the problem and what was done to rectify it.

Corrective actions for chemical data are taken when an analysis is deemed suspect for some reason. These reasons include exceeding accuracy or precision ranges and/or problems with sorting and identification. The corrective action will vary on a case-by-case basis, but at a minimum involves the following:

- A check of procedures.
- A review of documents and calculations to identify possible errors.
- Correction of errors based on discussions among analysts.
- A complete re-identification of the sample.

The field and laboratory coordinators shall have systems in place to document problems and make corrective actions. All corrective actions will be documented to the FTL and the QA Officer.

12.5. Sample Disposal

After analysis of the Monitoring Program samples has been completed by the laboratory and results have been accepted by QA Officer and the Field-PM, they will be disposed by laboratory staff in compliance with all federal, state, and local regulations. The laboratory has standard procedures for disposing of its waste, including left over sample materials

12.6. Laboratory Sample Processing

Field samples sent to the laboratories will be processed within their recommended hold time using methods agreed upon method between the Lab-PM and Field-PM. Each sample may be assigned unique laboratory sample ID numbers for tracking processing and analyses of samples within the laboratory. This laboratory sample ID (if differing from the field team sample ID) must be included in the data submission, within a lookup table linking the field sample ID to that assigned by the lab.

Samples arriving at the laboratory are to be stored under conditions appropriate for the planned analytical procedure(s), unless they are processed for analysis immediately upon receipt. Samples to be analyzed should only be removed from storage when laboratory staff are ready to proceed.

13. Quality Control

Each step in the field collection and analytical process is a potential source of contamination and must be consistently monitored to ensure that the final measurement is not adversely affected by any processing steps. Various aspects of the quality control procedures required by the Monitoring Program are summarized below.

13.1. Field Quality Control

Field QC results must meet the MQOs and frequency requirements specified in Tables 13-1 – 13-4 below.

13.1.1. Field Blanks

A field blank is collected to assess potential sample contamination levels that occur during field sampling activities. Field blanks are taken to the field, transferred to the appropriate container, preserved (if required by the method), and treated the same as the corresponding sample type during the course of a sampling event. The inclusion of field blanks is dependent on the requirements specified in the relevant MQO tables or in the sampling method or SOP.

Collection of caulk or sealant field blank samples has been deemed unnecessary due to the difficulty in collection and interpretation of representative blank samples and the use of precautions that minimize contamination of the samples. Additionally, PCBs have been reported to be present in percent concentrations when used in sealants; therefore any low level contamination (at ppb or even ppm level) due to sampling equipment and procedures is not expected to affect data quality because it would be many orders of magnitude lower than the concentrations deemed to be a positive PCB signal.

For stormwater samples, field blanks will be generated using lab supplied containers and clean matrices. Sampling containers will be opened as though actual samples were to be collected, and clean lab-supplied matrix (if any) will be transferred to sample containers for analysis.

13.1.2. Field Duplicates

Field samples collected in duplicate provide precision information as it pertains to the sampling process. The duplicate sample must be collected in the same manner and as close in time as possible to the original sample. This effort is to attempt to examine field homogeneity as well as sample handling, within the limits and constraints of the situation. These data are evaluated in the data analysis/assessment process for small-scale spatial variability.

Field duplicates will not be collected for caulk/sealant samples (Task 1), as assessment of within-structure variability of PCB concentrations in sealants is not a primary objective of the Project. Due to budget limitations, PCBs analysis of only one caulk/sealant sample per application will be targeted to maximize the number of Bay Area structures and structure types that may be analyzed in the Project. The selected laboratory will conduct a number of quality assurance analyses (see Section 13), including a limited number of sample duplicates, to evaluate laboratory and method performance as well as variability of PCB content within a sample.

For all sediment and water samples, 5% of field duplicates and/or column influent/effluent duplicates will be collected along with primary samples in order to evaluate small scale spatial or temporal variability in sample collection without specifically targeting any apparent or likely bias (e.g. different sides of a seemingly symmetrical unit, or offset locations in making a composite, or immediately following collection of a primary water sample would be acceptable, whereas collecting one composite near an inlet and another near the outlet, or intentionally collecting times with vastly different flow rates, would not be desirable).

13.1.3. Field Corrective Action

The Field PM is responsible for responding to failures in their sampling and field measurement systems. If monitoring equipment fails, personnel are to record the problem according to their documentation protocols. Failing equipment must be replaced or repaired prior to subsequent sampling events. It is the combined responsibility of all members of the field organization to determine if the performance

requirements of the specific sampling method have been met, and to collect additional samples if necessary. Associated data is to be flagged accordingly. Specific field corrective actions are detailed in Table 13-8.

13.2. Laboratory Quality Control

Laboratories providing analytical support to the Monitoring Program will have the appropriate facilities to store, prepare, and process samples in an ultra-clean environment, and will have appropriate instrumentation and staff to perform analyses and provide data of the required quality within the time period dictated by the Monitoring Program. The laboratories are expected to satisfy the following:

1. Demonstrate capability through pertinent certification and satisfactory performance in inter-laboratory comparison exercises.
2. Provide qualification statements regarding their facility and personnel.
3. Maintain a program of scheduled maintenance of analytical balances, laboratory equipment and instrumentation.
4. Conduct routine checking of analytical balances using a set of standard reference weights (American Society of Testing and Materials Class 3, NIST Class S-1, or equivalents). Analytical balances are serviced at six-month intervals or when test weight values are not within the manufacturer's instrument specifications, whichever occurs first.
5. Conduct routine checking and recording the composition of fresh calibration standards against the previous lot. Acceptable comparisons are within 2% of the precious value.
6. Record all analytical data in bound (where possible) logbooks, with all entries in ink, or electronically.
7. Monitor and document the temperatures of cold storage areas and freezer units on a continuous basis.
8. Verify the efficiency of fume/exhaust hoods.
9. Have a source of reagent water meeting specifications described in Section 8.0 available in sufficient quantity to support analytical operations.
10. Label all containers used in the laboratory with date prepared, contents, initials of the individual who prepared the contents, and other information as appropriate.
11. Date and safely store all chemicals upon receipt. Proper disposal of chemicals when the expiration date has passed.
12. Have QAPP, SOPs, analytical methods manuals, and safety plans readily available to staff.
13. Have raw analytical data readily accessible so that they are available upon request.

In addition, laboratories involved in the Monitoring Program are required to demonstrate capability continuously through the following protocols:

1. Strict adherence to routine QA/QC procedures.
2. Regular participation in annual certification programs.
3. Satisfactory performance at least annually in the analysis of blind Performance Evaluation Samples and/or participation in inter-laboratory comparison exercises.

Laboratory QC samples must satisfy MQOs and frequency requirements. MQOs and frequency requirements are listed in Tables 13-1 – 13-3. Frequency requirements are provided on an analytical batch

level. The Monitoring Program defines an analytical batch as 20 or fewer samples and associated quality control that are processed by the same instrument within a 24-hour period (unless otherwise specified by method). Target Method Reporting Limits are provided in Tables 13.4 – 13.8. Details regarding sample preparation are method- or laboratory SOP-specific, and may consist of extraction, digestion, or other techniques.

13.2.1. Calibration and Working Standards

All calibration standards must be traceable to a certified standard obtained from a recognized organization. If traceable standards are not available, procedures must be implemented to standardize the utilized calibration solutions (*e.g.*, comparison to a CRM – see below). Standardization of calibration solutions must be thoroughly documented, and is only acceptable when pre-certified standard solutions are not available. Working standards are dilutions of stock standards prepared for daily use in the laboratory. Working standards are used to calibrate instruments or prepare matrix spikes, and may be prepared at several different dilutions from a common stock standard. Working standards are diluted with solutions that ensure the stability of the target analyte. Preparation of the working standard must be thoroughly documented such that each working standard is traceable back to its original stock standard. Finally, the concentration of all working standards must be verified by analysis prior to use in the laboratory.

13.2.2. Instrument Calibration

Prior to sample analysis, utilized instruments must be calibrated following the procedures outlined in the relevant analytical method or laboratory SOP. Each method or SOP must specify acceptance criteria that demonstrate instrument stability and an acceptable calibration. If instrument calibration does not meet the specified acceptance criteria, the analytical process is not in control and must be halted. The instrument must be successfully recalibrated before samples may be analyzed.

Calibration curves will be established for each analyte covering the range of expected sample concentrations. Only data that result from quantification within the demonstrated working calibration range may be reported unflagged by the laboratory. Quantification based upon extrapolation is not acceptable; sample extracts above the calibration range should be diluted and rerun if possible. Data reported below the calibration range must be flagged as estimated values that are Detected not Quantified.

13.2.3. Initial Calibration Verification

The initial calibration verification (ICV) is a mid-level standard analyzed immediately following the calibration curve. The source of the standards used to calibrate the instrument and the source of the standard used to perform the ICV must be independent of one another. This is usually achieved by the purchase of standards from separate vendors. Since the standards are obtained from independent sources and both are traceable, analyses of the ICV functions as a check on the accuracy of the standards used to calibrate the instrument. The ICV is not a requirement of all SOPs or methods, particularly if other checks on analytical accuracy are present in the sample batch.

13.2.4. Continuing Calibration Verification

Continuing calibration verification (CCV) standards are mid-level standards analyzed at specified intervals during the course of the analytical run. CCVs are used to monitor sensitivity changes in the instrument during analysis. In order to properly assess these sensitivity changes, the standards used to perform CCVs must be from the same set of working standards used to calibrate the instrument. Use of a

second source standard is not necessary for CCV standards, since other QC samples are designed to assess the accuracy of the calibration standards. Analysis of CCVs using the calibration standards limits this QC sample to assessing only instrument sensitivity changes. The acceptance criteria and required frequency for CCVs are detailed in Tables 13-1 through 13-3. If a CCV falls outside the acceptance limits, the analytical system is not in control, and immediate corrective action must be taken.

Data obtained while the instrument is out of control is not reportable, and all samples analyzed during this period must be reanalyzed. If reanalysis is not an option, the original data must be flagged with the appropriate qualifier and reported. A narrative must be submitted listing the results that were generated while the instrument was out of control, in addition to corrective actions that were applied.

13.2.5. Laboratory Blanks

Laboratory blanks (also called extraction blanks, procedural blanks, or method blanks) are used to assess the background level of a target analyte resulting from sample preparation and analysis. Laboratory blanks are carried through precisely the same procedures as the field samples. For both organic and inorganic analyses, a minimum of at least one laboratory blank must be prepared and analyzed in every analytical batch or per 20 samples, whichever is more frequent. Some methods may require more than one laboratory blank with each analytical run. Acceptance criteria for laboratory blanks are detailed in Tables 13-1 through 13-3. Blanks that are too high require corrective action to bring the concentrations down to acceptable levels. This may involve changing reagents, cleaning equipment, or even modifying the utilized methods or SOPs. Although acceptable laboratory blanks are important for obtaining results for low-level samples, improvements in analytical sensitivity have pushed detection limits down to the point where some amount of analyte will be detected in even the cleanest laboratory blanks. The magnitude of the blanks must be evaluated against the concentrations of the samples being analyzed and against project objectives.

13.2.6. Reference Materials and Demonstration of Laboratory Accuracy

Evaluation of the accuracy of laboratory procedures is achieved through the preparation and analysis of reference materials with each analytical batch. Ideally, the reference materials selected are similar in matrix and concentration range to the samples being prepared and analyzed. The acceptance criteria for reference materials are listed in Tables 13-1 – 13-3. The accuracy of an analytical method can be assessed using CRMs only when certified values are provided for the target analytes. When possible, reference materials that have certified values for the target analytes should be used. This is not always possible, and often times certified reference values are not available for all target analytes. Many reference materials have both certified and non-certified (or reference) values listed on the certificate of analysis. Certified reference values are clearly distinguished from the non-certified reference values on the certificate of analysis.

13.2.7. Reference Materials vs. Certified Reference Materials

The distinction between a reference material and a certified reference material does not involve how the two are prepared, rather with the way that the reference values were established. Certified values are determined through replicate analyses using two independent measurement techniques for verification. The certifying agency may also provide “non-certified or “reference” values for other target analytes. Such values are determined using a single measurement technique that may introduce bias. When available, it is preferable to use reference materials that have certified values for all target analytes. This is not always an option, and therefore it is acceptable to use materials that have reference values for these

analytes. Note: Standard Reference Materials (SRMs) are essentially the same as CRMs. The term "Standard Reference Material" has been trademarked by the National Institute of Standards and Technology (NIST), and is therefore used only for reference materials distributed by NIST.

13.2.8. Laboratory Control Samples

While reference materials are not available for all analytes, a way of assessing the accuracy of an analytical method is still required. LCSs provide an alternate method of assessing accuracy. An LCS is a specimen of known composition prepared using contaminant-free reagent water or an inert solid spiked with the target analyte at the midpoint of the calibration curve or at the level of concern. The LCS must be analyzed using the same preparation, reagents, and analytical methods employed for regular samples. If an LCS needs to be substituted for a reference material, the acceptance criteria are the same as those for the analysis of reference materials..

13.2.9. Prioritizing Certified Reference Materials, Reference Materials, and Laboratory Control Samples

Certified reference materials, reference materials, and laboratory control samples all provide a method to assess the accuracy at the mid-range of the analytical process. However, this does not mean that they can be used interchangeably in all situations. When available, analysis of one certified reference material per analytical batch should be conducted. Certified values are not always available for all target analytes. If no certified reference material exists, reference values may be used. If no reference material exists for the target analyte, an LCS must be prepared and analyzed with the sample batch as a means of assessing accuracy. The hierarchy is as follows: analysis of a CRM is favored over the analysis of a reference material, and analysis of a reference material is preferable to the analysis of an LCS. Substitution of an LCS is not acceptable if a certified reference material or reference material is available, contact the Project Manager and QAO for approval before relying exclusively on an LCS as a measure of accuracy.

13.2.10. Matrix Spikes

A MS is prepared by adding a known concentration of the target analyte to a field sample, which is then subjected to the entire analytical procedure. The MS is analyzed in order to assess the magnitude of matrix interference and bias present. Because these spikes are often analyzed in pairs, the second spike is called the MSD. The MSD provides information regarding the precision of measurement and consistency of the matrix effects. Both the MS and MSD are split from the same original field sample. In order to properly assess the degree of matrix interference and potential bias, the spiking level should be approximately 2-5x the ambient concentration of the spiked sample. To establish spiking levels prior to sample analysis, if possible, laboratories should review any relevant historical data. In many instances, the laboratory will be spiking samples blind and will not meet a spiking level of 2-5x the ambient concentration. In addition to the recoveries, the relative percent difference (RPD) between the MS and MSD is calculated to evaluate how matrix affects precision. The MQO for the RPD between the MS and MSD is the same regardless of the method of calculation. These are detailed in Tables 13-1 – 13-3. Recovery data for matrix spikes provides a basis for determining the prevalence of matrix effects in the samples collected and analyzed. If the percent recovery for any analyte in the MS or MSD is outside of the limits specified in Tables 13-1 – 13-3, the chromatograms (in the case of trace organic analyses) and raw data quantitation reports should be reviewed. Data should be scrutinized for evidence of sensitivity shifts (indicated by the results of the CCVs) or other potential problems with the analytical process. If associated QC samples (reference materials or LCSs) are in control, matrix effects may be the source of

the problem. If the standard used to spike the samples is different from the standard used to calibrate the instrument, it must be checked for accuracy prior to attributing poor recoveries to matrix effects.

13.2.11.Laboratory Duplicates

In order to evaluate the precision of an analytical process, a field sample is selected and prepared in duplicate. Specific requirements pertaining to the analysis of laboratory duplicates vary depending on the type of analysis. The acceptance criteria for laboratory duplicates are specified in Tables 13-1 – 13-3.

13.2.12.Laboratory Duplicates vs. Matrix Spike Duplicates

Although the laboratory duplicate and matrix spike duplicate both provide information regarding precision, they are unique measurements. Laboratory duplicates provide information regarding the precision of laboratory procedures at actual ambient concentrations. The matrix spike duplicate provides information regarding how the matrix of the sample affects both the precision and bias associated with the results. It also determines whether or not the matrix affects the results in a reproducible manner. MS/MSDs are often spiked at levels well above ambient concentrations, so thus are not representative of typical sample precision. Because the two concepts cannot be used interchangeably, it is unacceptable to analyze only an MS/MSD when a laboratory duplicate is required.

13.2.13.Replicate Analyses

The Monitoring Program will adopt the same terminology as SWAMP in defining replicate samples, wherein replicate analyses are distinguished from duplicate analyses based simply on the number of involved analyses. Duplicate analyses refer to two sample preparations, while replicate analyses refer to three or more. Analysis of replicate samples is not explicitly required.

13.2.14.Surrogates

Surrogate compounds accompany organic measurements in order to estimate target analyte losses or matrix effects during sample extraction and analysis. The selected surrogate compounds behave similarly to the target analytes, and therefore any loss of the surrogate compound during preparation and analysis is presumed to coincide with a similar loss of the target analyte. Surrogate compounds must be added to field and QC samples prior to extraction, or according to the utilized method or SOP. Surrogate recovery data are to be carefully monitored. If possible, isotopically labeled analogs of the analytes are to be used as surrogates.

13.2.15.Internal Standards

To optimize gas chromatography mass spectrometry (GC-MS) analysis, internal standards (also referred to as "injection internal standards") may be added to field and QC sample extracts prior to injection. Use of internal standards is particularly important for analysis of complex extracts subject to retention time shifts relative to the analysis of standards. The internal standards can also be used to detect and correct for problems in the GC injection port or other parts of the instrument. The analyst must monitor internal standard retention times and recoveries to determine if instrument maintenance or repair or changes in analytical procedures are indicated. Corrective action is initiated based on the judgment of the analyst. Instrument problems that affect the data or result in reanalysis must be documented properly in logbooks and internal data reports, and used by the laboratory personnel to take appropriate corrective action. Performance criteria for internal standards are established by the method or laboratory SOP.

13.2.16.Dual-Column Confirmation

Due to the high probability of false positives from single-column analyses, dual column confirmation should be applied to all gas chromatography and liquid chromatography methods that do not provide definitive identifications. It should not be restricted to instruments with electron capture detection (ECD).

13.2.17.Dilution of Samples

Final reported results must be corrected for dilution carried out during the process of analysis. In order to evaluate the QC analyses associated with an analytical batch, corresponding batch QC samples must be analyzed at the same dilution factor. For example, the results used to calculate the results of matrix spikes must be derived from results for the native sample, matrix spike, and matrix spike duplicate analyzed at the same dilution. Results derived from samples analyzed at different dilution factors must not be used to calculate QC results.

13.2.18.Laboratory Corrective Action

Failures in laboratory measurement systems include, but are not limited to: instrument malfunction, calibration failure, sample container breakage, contamination, and QC sample failure. If the failure can be corrected, the analyst must document it and its associated corrective actions in the laboratory record and complete the analysis. If the failure is not resolved, it is conveyed to the respective supervisor who should determine if the analytical failure compromised associated results. The nature and disposition of the problem must be documented in the data report that is sent to the Consultant-PM. Suggested ccorrective actions are detailed in Table 13-9.

Table 13-1. Measurement Quality Objectives - PCBs.

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Tuning[2]	Per analytical method	Per analytical method
Calibration	Initial method setup or when the calibration verification fails	• Correlation coefficient (r^2 >0.990) for linear and non-linear curves • If RSD<15%, average RF may be used to quantitate; otherwise use equation of the curve • First- or second-order curves only (not forced through the origin) • Refer to SW-846 methods for SPCC and CCC criteria[2] • Minimum of 5 points per curve (one of them at or below the RL)
Calibration Verification	Per 12 hours	• Expected response or expected concentration ±20% • RF for SPCCs=initial calibration[4]
Laboratory Blank	Per 20 samples or per analytical batch, whichever is more frequent	<RL for target analytes
Reference Material	Per 20 samples or per analytical batch	70-130% recovery if certified; otherwise, 50-150% recovery
Matrix Spike	Per 20 samples or per analytical batch, whichever is more frequent	50-150% or based on historical laboratory control limits (average±3SD)
Matrix Spike Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	50-150% or based on historical laboratory control limits (average±3SD); RPD<25%
Surrogate	Included in all samples and all QC samples	Based on historical laboratory control limits (50-150% or better)
Internal Standard	Included in all samples and all QC samples (as available)	Per laboratory procedure
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	5% of total Project sample count (sediment and water samples only)	RPD<25% (n/a if concentration of either sample<RL)
Field Blank	Not required for the Monitoring Program	<RL for target analytes

Table 13-2. Measurement Quality Objectives – Inorganic Analytes.

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Calibration Standard	Per analytical method or manufacturer's specifications	Per analytical method or manufacturer's specifications
Continuing Calibration Verification	Per 10 analytical runs	80-120% recovery
Laboratory Blank	Per 20 samples or per analytical batch, whichever is more frequent	<RL for target analyte
Reference Material	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery ; RPD<25%
Laboratory Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	RPD<25% (n/a if concentration of either sample<RL)
Internal Standard	Accompanying every analytical run when method appropriate	60-125% recovery
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	5% of total Project sample count	RPD<25% (n/a if concentration of either sample<RL), unless otherwise specified by method
Field Blank, Equipment Field, Eqpt Blanks	Not required for the Monitoring Program	Blanks<RL for target analyte

Table 13-3. Measurement Quality Objectives – Conventional Analytes.

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Calibration Standard	Per analytical method or manufacturer's specifications	Per analytical method or manufacturer's specifications
Laboratory Blank	Total organic carbon only: one per 20 samples or per analytical batch, whichever is more frequent (n/a for other parameters)	80-120% recovery
Reference Material	One per analytical batch	RPD<25% (n/a if native concentration of either sample<RL)
Laboratory Duplicate	(TOC only) one per 20 samples or per analytical batch, whichever is more frequent (n/a for other parameters)	80-120% recovery
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	5% of total Project sample count	RPD<25% (n/a if concentration of either sample<RL)
Field Blank, Travel Blank, Field Blanks	Not required for the Monitoring Program analytes	NA

Consistent with SWAMP QAPP and as applicable, percent moisture should be reported with each batch of sediment samples. Sediment data must be reported on a dry weight basis.

Table 13-4. Target MRLs for Sediment Quality Parameters.

Analyte	MRL
Sediment Total Organic Carbon	0.01% OC
Bulk Density	n/a
%Moisture	n/a
%Lipids	n/a
Mercury	30 µg/kg

Table 13-5. Target MRLs for PCBs in Water, Sediment and Caulk

Congener	Water MRL (µg/L)	Sediment MRL (µg/kg)	Caulk/Sealant MRL (µg/kg)
PCB 8	0.002	0.2	0.5
PCB 18	0.002	0.2	0.5
PCB 28	0.002	0.2	0.5
PCB 31	0.002	0.2	0.5
PCB 33	0.002	0.2	0.5
PCB 44	0.002	0.2	0.5
PCB 49	0.002	0.2	0.5
PCB 52	0.002	0.2	0.5
PCB 56	0.002	0.2	0.5
PCB 60	0.002	0.2	0.5
PCB 66	0.002	0.2	0.5
PCB 70	0.002	0.2	0.5
PCB 74	0.002	0.2	0.5
PCB 87	0.002	0.2	0.5
PCB 95	0.002	0.2	0.5
PCB 97	0.002	0.2	0.5
PCB 99	0.002	0.2	0.5
PCB 101	0.002	0.2	0.5
PCB 105	0.002	0.2	0.5
PCB 110	0.002	0.2	0.5
PCB 118	0.002	0.2	0.5
PCB 128	0.002	0.2	0.5
PCB 132	0.002	0.2	0.5
PCB 138	0.002	0.2	0.5
PCB 141	0.002	0.2	0.5
PCB 149	0.002	0.2	0.5
PCB 151	0.002	0.2	0.5
PCB 153	0.002	0.2	0.5
PCB 156	0.002	0.2	0.5
PCB 158	0.002	0.2	0.5
PCB 170	0.002	0.2	0.5
PCB 174	0.002	0.2	0.5
PCB 177	0.002	0.2	0.5
PCB 180	0.002	0.2	0.5
PCB 183	0.002	0.2	0.5
PCB 187	0.002	0.2	0.5
PCB 194	0.002	0.2	0.5
PCB 195	0.002	0.2	0.5
PCB 201	0.002	0.2	0.5
PCB 203	0.002	0.2	0.5

Table 13-6. Size Distribution Categories for Grain Size in Sediment

Wentworth Size Category	Size	MRL
Clay	<0.0039 mm	1%
Silt	0.0039 mm to <0.0625 mm	1%
Sand, very fine	0.0625 mm to <0.125 mm	1%
Sand, fine	0.125 mm to <0.250 mm	1%
Sand, medium	0.250 mm to <0.5 mm	1%
Sand, coarse	0.5 mm to < 1.0 mm	1%
Sand, very coarse	1.0 mm to < 2 mm	1%
Gravel	2 mm and larger	1%

Table 13-7. Target MRLs for TOC, SSC, and Mercury in Water

Analyte	MRL
Total Organic Carbon	0.6 mg/L
Suspended Sediment Concentration	0.5 mg/L
Mercury	0.0002 µg/L

Table 13-8. Corrective Action – Laboratory and Field Quality Control

Laboratory Quality Control	Recommended Corrective Action
Calibration	Recalibrate the instrument. Affected samples and associated quality control must be reanalyzed following successful instrument recalibration.
Calibration Verification	Reanalyze the calibration verification to confirm the result. If the problem continues, halt analysis and investigate the source of the instrument drift. The analyst should determine if the instrument must be recalibrated before the analysis can continue. All of the samples not bracketed by acceptable calibration verification must be reanalyzed.
Laboratory Blank	Reanalyze the blank to confirm the result. Investigate the source of contamination. If the source of the contamination is isolated to the sample preparation, the entire batch of samples, along with the new laboratory blanks and associated QC samples, should be prepared and/or re-extracted and analyzed. If the source of contamination is isolated to the analysis procedures, reanalyze the entire batch of samples. If reanalysis is not possible, the associated sample results must be flagged to indicate the potential presence of the contamination.
Reference Material	Reanalyze the reference material to confirm the result. Compare this to the matrix spike/matrix spike duplicate recovery data. If adverse trends are noted, reprocess all of the samples associated with the batch.
Matrix Spike	The spiking level should be near the midrange of the calibration curve or at a level that does not require sample dilution. Reanalyze the matrix spike to confirm the result. Review the recovery obtained for the matrix spike duplicate. Review the results of the other QC samples (such as reference materials) to determine if other analytical problems are a potential source of the poor spike recovery.
Matrix Spike Duplicate	The spiking level should be near the midrange of the calibration curve or at a level that does not require sample dilution. Reanalyze the matrix spike duplicate to confirm the result. Review the recovery obtained for the matrix spike. Review the results of the other QC samples (such as reference materials) to determine if other analytical problems are a potential source of the poor spike recovery.
Internal Standard	Check the response of the internal standards. If the instrument continues to generate poor results, terminate the analytical run and investigate the cause of the instrument drift.
Surrogate	Analyze as appropriate for the utilized method. Troubleshoot as needed. If no instrument problem is found, samples should be re-extracted and reanalyzed if possible.
Field Quality Control	**Recommended Corrective Action**
Field Duplicate	Visually inspect the samples to determine if a high RPD between results could be attributed to sample heterogeneity. For duplicate results due to matrix heterogeneity, or where ambient concentrations are below the reporting limit, qualify the results and document the heterogeneity. All failures should be communicated to the project coordinator, who in turn will follow the process detailed in the method.
Field Blank	Investigate the source of contamination. Potential sources of contamination include sampling equipment, protocols, and handling. The laboratory should report evidence of field contamination as soon as possible so corrective actions can be implemented. Samples collected in the presence of field contamination should be flagged.

14. Inspection/Acceptance for Supplies and Consumables

Each sampling event conducted for the Monitoring Program will require use of appropriate consumables to reduce likelihood of sample contamination. The Field-PM will be responsible for ensuring that all supplies are appropriate prior to their use. Inspection requirements for sampling consumables and supplies are summarized in Table 14-1.

Table 14-1. Inspection / Acceptance Testing Requirements for Consumables and Supplies

Project-related Supplies	Inspection / Testing Specifications	Acceptance Criteria	Frequency	Responsible Person Sampling Containers
Sampling supplies	Visual	Appropriateness; no evident contamination or damage; within expiration date	Each purchase	Field Crew Leader

15. Non Direct Measurements, Existing Data

No data from external sources are planned to be used with this project.

16. Data Management

As previously discussed, the Monitoring Program data management will conform to protocols dictated by the study designs (BASMAA 2017a, b). A summary of specific data management aspects is provided below.

16.1. Field Data Management

All field data will be reviewed for legibility and errors as soon as possible after the conclusion of sampling. All field data that is entered electronically will be hand-checked at a rate of 10% of entries as a check on data entry. Any corrective actions required will be documented in correspondence to the QA Officer.

16.2. Laboratory Data Management

Record keeping of laboratory analytical data for the proposed project will employ standard record-keeping and tracking practices. All laboratory analytical data will be entered into electronic files by the instrumentation being used or, if data is manually recorded, then it will be entered by the analyst in charge of the analyses, per laboratory standard procedures.

Following the completion of internal laboratory quality control checks, analytical results will be forwarded electronically to the Field-PM. The analytical laboratories will provide data in electronic format, encompassing both a narrative and electronic data deliverable (EDD).

17. Assessments and Response Actions

17.1. Readiness Reviews

The Field-PM will review all field equipment, instruments, containers, and paperwork to ensure that everything is ready prior to each sampling event. All sampling personnel will be given a brief review of the goals and objectives of the sampling event and the sampling procedures and equipment that will be used to achieve them. It is important that all field equipment be clean and ready to use when it is needed. Therefore, prior to using all sampling and/or field measurement equipment, each piece of equipment will be checked to make sure that it is in proper working order. Equipment maintenance records will be checked to ensure that all field instruments have been properly maintained and that they are ready for use. Adequate supplies of all preservatives, bottles, labels, waterproof pens, etc. will be checked before each field event to make sure that there are sufficient supplies to successfully support each sampling event, and, as applicable, are within their expiration dates. It is important to make sure that all field activities and measurements are properly recorded in the field. Therefore, prior to starting each field event, necessary paperwork such as logbooks, chain of custody record forms, etc. will be checked to ensure that sufficient amounts are available during the field event. In the event that a problem is discovered during a readiness review it will be noted in the field log book and corrected before the field crew is deployed. The actions taken to correct the problem will also be documented with the problem in the field log book. This information will be communicated by the Field-PM prior to conducting relevant sampling. The Field-PM will track corrective actions taken.

17.2. Post Sampling Event Reviews

The Field-PM will be responsible for post sampling event reviews. Any problems that are noted will be documented along with recommendations for correcting the problem. Post sampling event reviews will be conducted following each sampling event in order to ensure that all information is complete and any deviations from planned methodologies are documented. Post sampling event reviews will include field sampling activities and field measurement documentation in order to help ensure that all information is complete. The reports for each post sampling event will be used to identify areas that may be improved prior to the next sampling event.

17.3. Laboratory Data Reviews

The Field-PM will be responsible for reviewing the laboratory's data for completeness and accuracy. The data will also be checked to make sure that the appropriate methods were used and that all required QC data was provided with the sample analytical results. Any laboratory data that is discovered to be incorrect or missing will immediately be reported to the both the laboratory and Consultant-PM. The laboratory's QA manual details the procedures that will be followed by laboratory personnel to correct any invalid or missing data. The Consultant-PM has the authority to request re-testing if a review of any of the laboratory data is found to be invalid or if it would compromise the quality of the data and resulting conclusions from the proposed project.

18. Instrument/Equipment Testing, Inspection and Maintenance

18.1. Field Equipment

Field measurement equipment will be checked for operation in accordance with manufacturer's specifications. All equipment will be inspected for damage when first employed and again when returned from use. Maintenance logs will be kept and each applicable piece of equipment will have its own log that documents the dates and description of any problems, the action(s) taken to correct problem(s), maintenance procedures, system checks, follow-up maintenance dates, and the person responsible for maintaining the equipment.

18.2. Laboratory Equipment

All laboratories providing analytical support for chemical or biological analyses will have the appropriate facilities to store, prepare, and process samples. Moreover, appropriate instrumentation and staff to provide data of the required quality within the schedule required by the program are also required. Laboratory operations must include the following procedures:

- A program of scheduled maintenance of analytical balances, microscopes, laboratory equipment, and instrumentation.
- Routine checking of analytical balances using a set of standard reference weights (American Society of Testing and Materials (ASTM) Class 3, NIST Class S-1, or equivalents).
- Checking and recording the composition of fresh calibration standards against the previous lot, wherever possible. Acceptable comparisons are < 2% of the previous value.
- Recording all analytical data in bound (where possible) logbooks, with all entries in ink, or electronic format.
- Monitoring and documenting the temperatures of cold storage areas and freezer units once per week.
- Verifying the efficiency of fume hoods.
- Having a source of reagent water meeting ASTM Type I specifications (ASTM, 1984) available in sufficient quantity to support analytical operations. The conductivity of the reagent water will not exceed 18 megaohms at 25°C. Alternately, the resistivity of the reagent water will exceed 10 mmhos/cm.
- Labeling all containers used in the laboratory with date prepared, contents, initials of the individual who prepared the contents, and other information, as appropriate.
- Dating and safely storing all chemicals upon receipt. Proper disposal of chemicals when the expiration date has passed.
- Having QAPP, SOPs, analytical methods manuals, and safety plans readily available to staff.
- Having raw analytical data, such as chromatograms, accessible so that they are available upon request.

Laboratories will maintain appropriate equipment per the requirements of individual laboratory SOPs and will be able to provide information documenting their ability to conduct the analyses with the required level of data quality. Such information might include results from interlaboratory comparison studies, control charts and summary data of internal QA/QC checks, and results from certified reference material analyses.

19. Instrument/Equipment Calibration and Frequency

19.1. Field Measurements

Any equipment used should be visually inspected during mobilization to identify problems that would result in loss of data. As appropriate, equipment-specific SOPs should be consulted for equipment calibration.

19.2. Laboratory Analyses

19.2.1. In-house Analysis – XRF Screening

A portable XRF analyzer will be used as a screening tool to estimate the chlorine concentration in each caulk sample. Since caulk often contains in excess of 1% PCBs and detection limits of portable XRF may be in the ppm range, the portable XRF may be able to detect chlorine within caulk containing PCBs down to about 0.1%. The analysis will be performed on the field samples using a test stand. The analyzer will be calibrated for chlorine using plastic pellet European reference materials (EC680 and EC681) upon first use, and standardized each time the instrument is turned on and prior to any caulk Cl analysis. The standardization procedure will entail a calibration analysis of the materials provided/recommended with the XRF analyzer. Analyses will be conducted in duplicate on each sample and notes kept. The mean will be used for comparison to GC–MS results.

19.2.2. Contract Laboratory Analyses

The procedures for and frequency of calibration will vary depending on the chemical parameters being determined. Equipment is maintained and checked according to the standard procedures specified in each laboratory's instrument operation instruction manual.

Upon initiation of an analytical run, after each major equipment disruption, and whenever on-going calibration checks do not meet recommended DQOs (see Section 13), analytical systems will be calibrated with a full range of analytical standards. Immediately after this procedure, the initial calibration must be verified through the analysis of a standard obtained from a different source than the standards used to calibrate the instrumentation and prepared in an independent manner and ideally having certified concentrations of target analytes of a CRM or certified solution. Frequently, calibration standards are included as part of an analytical run, interspersed with actual samples.

Calibration curves will be established for each analyte and batch analysis from a calibration blank and a minimum of three analytical standards of increasing concentration, covering the range of expected sample concentrations. Only those data resulting from quantification within the demonstrated working calibration range may be reported by the laboratory.

The calibration standards will be prepared from reference materials available from the EPA repository, or from available commercial sources. The source, lot number, identification, and purity of each reference material will be recorded. Neat compounds will be prepared weight/volume using a calibrated analytical balance and Class A volumetric flasks. Reference solutions will be diluted using Class A volumetric glassware. Individual stock standards for each analyte will be prepared. Combination working standards will be prepared by volumetric dilution of the stock standards. The calibration standards will be stored at -20º C. Newly prepared standards will be compared with existing standards prior to their use. All solvents

used will be commercially available, distilled in glass, and judged suitable for analysis of selected chemicals. Stock standards and intermediate standards are prepared on an annual basis and working standards are prepared every three months.

Sampling and analytical logbooks will be kept to record inspections, calibrations, standard identification numbers, the results of calibrations, and corrective action taken. Equipment logs will document instrument usage, maintenance, repair and performance checks. Daily calibration data will be stored with the raw sample data

20. Data Review, Verification, and Validation

Defining data review, verification, and validation procedures helps to ensure that Monitoring Plan data will be reviewed in an objective and consistent manner. Data review is the in-house examination to ensure that the data have been recorded, transmitted, and processed correctly. The Field-PM will be responsible for initial data review for field forms and field measurements; QA Officer will be responsible for doing so for data reported by analytical laboratories. This includes checking that all technical criteria have been met, documenting any problems that are observed and, if possible, ensuring that deficiencies noted in the data are corrected.

In-house examination of the data produced from the proposed Monitoring Program will be conducted to check for typical types of errors. This includes checking to make sure that the data have been recorded, transmitted, and processed correctly. The kinds of checks that will be made will include checking for data entry errors, transcription errors, transformation errors, calculation errors, and errors of data omission.

Data generated by Program activities will be reviewed against MQOs that were developed and documented in Section 13. This will ensure that the data will be of acceptable quality and that it will be SWAMP-comparable with respect to minimum expected MQOs.

QA/QC requirements were developed and documented in Sections 13.1 and 13.2, and the data will be checked against this information. Checks will include evaluation of field and laboratory duplicate results, field and laboratory blank data, matrix spike recovery data, and laboratory control sample data pertinent to each method and analytical data set. This will ensure that the data will be SWAMP-comparable with respect to quality assurance and quality control procedures.

Field data consists of all information obtained during sample collection and field measurements, including that documented in field log books and/or recording equipment, photographs, and chain of custody forms. Checks of field data will be made to ensure that it is complete, consistent, and meets the data management requirements that were developed and documented in Section 13.1.

Lab data consists of all information obtained during sample analysis. Initial review of laboratory data will be performed by the laboratory QA/QC Officer in accordance with the lab's internal data review procedures. However, upon receipt of laboratory data, the Lab-PM will perform independent checks to ensure that it is complete, consistent, and meets the data management requirements that were developed and documented in Section 13.2. This review will include evaluation of field and laboratory QC data and also making sure that the data are reported in compliance with procedures developed and documented in Section 7.

Data verification is the process of evaluating the completeness, correctness, and conformance / compliance of a specific data set against the method, procedural, or contractual specifications. The Lab-PM and Data Manager will conduct data verification, as described in Section 13 on Quality Control, in order to ensure that it is SWAMP-comparable with respect to completeness, correctness, and conformance with minimum requirements.

Data will be separated into three categories for use with making decisions based upon it. These categories are: (1) data that meets all acceptance requirements, (2) data that has been determined to be unacceptable for use, and (3) data that may be conditionally used and that is flagged as per US EPA specifications.

21. Verification and Validation Methods

Defining the methods for data verification and validation helps to ensure that Program data are evaluated objectively and consistently. For the proposed Program many of these methods have been described in Section 20. Additional information is provided below.

All data records for the Monitoring Program will be checked visually and will be recorded as checked by the checker's initials as well as with the dates on which the records were checked. Consultant Team staff will perform an independent re-check of at least 10% of these records as the validation methodology.

All of the laboratory's data will be checked as part of the verification methodology process. Each contract laboratory's Project Analyst will conduct reviews of all laboratory data for verification of their accuracy.

Any data that is discovered to be incorrect or missing during the verification or validation process will immediately be reported to the Consultant-PM. If errors involve laboratory data then this information will also be reported to the laboratory's QA Officer. Each laboratory's QA manual details the procedures that will be followed by laboratory personnel to correct any invalid or missing data. The laboratory's QA Officer will be responsible for reporting and correcting any errors that are found in the data during the verification and validation process.

If there are any data quality problems identified, the QA Officer will try to identify whether the problem is a result of project design issues, sampling issues, analytical methodology issues, or QA/QC issues (from laboratory or non-laboratory sources). If the source of the problems can be traced to one or more of these basic activities then the person or people in charge of the areas where the issues lie will be contacted and efforts will be made to immediately resolve the problem. If the issues are too broad or severe to be easily corrected then the appropriate people involved will be assembled to discuss and try to resolve the issue(s) as a group. The QA Officer has the final authority to resolve any issues that may be identified during the verification and validation process.

22. Reconciliation with User Requirements

The purpose of the Monitoring Program is to comply with Provisions of the MRP and provide data that can be used to identify sources of PCBs to urban runoff, and to evaluate management action effectiveness in removing POCs from urban runoff in the Bay Area. The objectives of the Monitoring Program are to provide the following outcomes:

1. Satisfy MRP Provision C.8.f. requirements for POC monitoring for source identification;

2. Satisfy MRP Provision C.12.e.ii requirements to evaluate PCBs presence in caulks/sealants used in storm drain or roadway infrastructure in public ROWs;
3. Report the range of PCB concentrations observed in 20 composite samples of caulk/sealant collected from structures installed or rehabilitated during the 1970's;
4. Satisfy MRP Provision C.8.f. requirements for POC monitoring for management action effectiveness;
5. Quantify the annual mass of mercury and PCBs captured in HDS Unit sumps during maintenance; and
6. Identify BSM mixtures for future field testing that provide the most effective mercury and PCBs treatment in laboratory column tests.

Information from field data reports (including field activities, post sampling events, and corrective actions), laboratory data reviews (including errors involving data entry, transcriptions, omissions, and calculations and laboratory audit reports), reviews of data versus MQOs, reviews against QA/QC requirements, data verification reports, data validation reports, independent data checking reports, and error handling reports will be used to determine whether or not the Monitoring Program's objectives have been met. Descriptions of the data will be made with no extrapolation to more general cases.

Data from all monitoring measurements will be summarized in tables. Additional data may also be represented graphically when it is deemed helpful for interpretation purposes.

The above evaluations will provide a comprehensive assessment of how well the Program meets its objectives. The final project reports will reconcile results with project MQOs.

23. References

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BASMAA 2017a. The Evaluation of PCBs Presence in Public Roadway and Storm Drain Infrastructure Caulk and Sealants Study Design. Prepared by EOA Inc. and the San Francisco Estuary Institute (SFEI). June 2017.

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Surface Water Ambient Monitoring Program Quality Assurance Team, 2013. *SWAMP Quality Assurance Project Plan.* Prepared for the California State Water Quality Control Board. 2013.

24. Appendix A: Field Documentation

Caulk/Sealant Sampling Field Data Sheet	Composite ID:		Contractor:	Pg of Pgs
Sample ID:	Date (mm/dd/yyyy):		Personnel:	Failure Reason
Photos (Y / N)	ArrivalTime:	DepartureTime:		
Photo Log Identifier	**Land-Use at the Sample Location:**		Commercial (pre-1980; post 1980)	Open Space
	Industrial (pre-1980; post-1980)		Residential (pre 1980; post 1980)	Other:

Description of Structure: (Do not include any information on the location of the structure)							**Diagram of Structure (if needed) to identify where caulk/sealants were located in/on structure**
Structure Type:	Storm Drain Catch Basin	Roadway Surface		Sidewalk	Curb/Gutter	Bridge	
	Other:						
Structure Material:	Concrete	Asphalt	Other:				
Condition of Structure:	Good	Fair	Poor	Other:			
Year of Strucutre Construction							
Year of Repair							

Description of Caulk or Sealant Sample Collected:							
Application or Usage	Caulk	caulk between adjoing surfaces of same material (e.g., concrete-concrete); Describe:					
		caulk between adjoining surfaces of different types of material (e.g., concrete-asphalt); Describe:					
		Other:					
	Sealant	Crack Repair (describe):					
		Other:					
Color							
Texture	Hard/brittle	Soft/pliable	Other:				
Condition	Good (intact/whole)		Poor (crumbling/disintegrating)	Other:			
Location	Surface	Between Joints	Submerged	Exposed	At street level	Below street level	Other:
Amount of Caulk/Sealant observed on structure	Crack dimensions:				Spacing of expansion joints		
	Length&width of caulk bead sampled:				Other:		

Samples Taken	
COLLECTION DEVICE:	Equiptment type used:
SITE/SAMPLING DESCRIPTION AND COMMENTS:	

HDS Unit Sampling Field Data Sheet (Sediment Chemistry)			Contractor:	Pg of Pgs
City:	Date (mm/dd/yyyy):	/ /	*Contractor:	
HDS Catchment ID:	ArrivalTime:	DepartureTime:	*SampleTime (1st sample):	Failure Reason
	Personnel:			

Photos (Y / N)	*GPS/DGPS	**Lat (dd.ddddd)**	**Long (ddd.ddddd)**	Address, Location, and Sketches (if needed)
Photo Log Identifier	**Target (if known):**			
	***Actual:**			
	GPS Device:			

Estimate of Volume of Sediment in the HDS unit sump prior to cleanout:	
Estimate of Volume of Sediment REMOVED from the HDS unit sump during the cleanout:	

Env. Conditions		WIND DIRECTION (from):	N W E S	
SITE ODOR:	None,Sulfides,Sewage,Petroleum,Smoke,Other_____			
SKY CODE:	Clear, Partly Cloudy, Overcast, Fog, Smoky, Hazy			
PRECIP:	None, Fog, Drizzle, Rain			
PRECIP (last 24 hrs):	Unknown, <1", >1", None			
SOILODOR:	None, Sulfides, Sewage, Petroleum, Mixed, Other_____			
SOILCOLOR:	Colorless, Green, Yellow, Brown			
SOILCOMPOSITION:	Silt/Clay, Sand, Gravel, Cobble, Mixed, Debris			
SOILPOSITION	Submerged, Exposed			

Samples Taken (3 digit ID nos. of containers filled)	**Field Dup at Site? YES / NO:** (create separate datasheet for FDs, with unique IDs (i.e., blind samples)
COLLECTION DEVICE:	Equiptment type used: Scoop (SS / PC / PE), Core (SS / PC / PE), Grab (Van Veen / Eckman / Petite Ponar), Broom (nylon, natural fiber)

Sample ID (City-Catchment ID-Sample	DepthCollec (cm)	Composite / Grab (C / G)	Grain Size	PCBs	Hg	Bulk Density	TOC	OTHER		

SITE/SAMPLING DESCRIPTION AND COMMENTS:

Stormwater Field Data Sheet (Water Chemistry)						Entered in d-base (initial/date)				Pg of Pgs
***Station Code:**		*Date (mm/dd/yyyy):	/ /					*PurposeFailure:		*Agency:
Personnel:		ArrivalTime:	DepartureTime:							*Protocol:
		*GPS/DGPS	**Lat (dd.ddddd)**	**Long (ddd.ddddd)**		OCCUPATION METHOD: Walk-in Bridge R/V _____ Other				
GPS Device:		**Target:**		-						
Datum: NAD83	Accuracy (ft / m):	***Actual:**		-		Sampling Location (e.g., gutter at SW corner of 10th Street)				
Habitat Observations (CollectionMethod = Habitat_generic)			WADEABILITY: Y / N / Unk	BEAUFORT SCALE (see attachment)						
SITE ODOR:	None,Sulfides,Sewage,Petroleum,Smoke,Other____									
SKY CODE:	Clear, Partly Cloudy, Overcast, Fog, Smoky, Hazy		WIND DIRECTION (from):	N W E S		**PHOTOS** (RB & LB assigned when facing downstream; RENAME to StationCode_yyyy_mm_dd_uniquecode):				1: (RB / LB / BB / US / DS / ##)
OTHER PRESENCE:	Vascular,Nonvascular,OilySheen,Foam,Trash,Other_									
DOMINANT SUBSTRATE:	Bedrock, Concrete, Cobble, Boulder, Gravel, Sand, Mud, Unk, Other_____									
WATERCLARITY:	Clear (see bottom), Cloudy (>4" vis), Murky (<4" vis)		PRECIPITATION:	None, Fog, Drizzle, Rain, Snow						2: (RB / LB / BB / US / DS / ##)
WATERODOR:	None, Sulfides, Sewage, Petroleum, Mixed, Other___		PRECIPITATION (last 24 hrs):	Unknown, <1", >1", None						
WATERCOLOR:	Colorless, Green, Yellow, Brown									3: (RB / LB / BB / US / DS / ##)
OVERLAND RUNOFF (Last 24 hrs):	none, light, moderate / heavy, unknown									
OBSERVED FLOW:	NA, Dry Waterbody Bed, No Obs Flow, Isolated Pool, Trickle (<0.1cfs), 0.1-1cfs, 1-5cfs, 5-20cfs, 20-50cfs, 50-200cfs, >200cfs									

Field Samples (Record Time Sample Collected)

Carboy ID #	Start Sample Time	End Sample Time	Sample Type (Grab=G; Integrated = I)	Collection Depth (m)	Field Dup (Yes/No)	Indiv bottle (by hand, by pole, by bucket); Teflon tubing; Kemmer; Pole & Beaker; Other

COMMENTS:

Stormwater Influent Samples – Office of Water Programs

Sample Receiving							
Date (mm/dd/yy):		Time (24 hr) :			Team Member's Initial:		
Carboy	Temperature	pH	Observations				
1							
2							
3							
4							
5							
6							
7							

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID:

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

25. Appendix B: Laboratory Standard Operating Procedures (SOPs)

APPENDIX C: PROPOSED BIOCHAR SELECTION FACTORS

The primary goal of this study is to select a biochar and bioretention soil mix (BSM) for field testing which will be conducted to assess improved removal of PCBs and mercury. The selection for field tests will be informed by column tests performed by this study. This memorandum contains a review of known biochar available in the Western United States. Five biochars are needed for column tests; nine biochars will be obtained and mixed with BSM at a ratio of 75 percent BSM and 25 percent biochar. These mixes will be tested hydraulically according to the alternative BSM specification to see which mixes pass the hydraulic requirement of an infiltration rate of 5-12 inches per hour. If more than five biochar mixes pass the hydraulic test then five will be chosen based on probable treatment efficiency and cost. Factors that will be used to determine probable treatment efficiency are pH, surface area, source material, pyrolysis method, and hydrophobicity.

Feasibility Criteria

Three criteria were chosen to screen potential biochars for sample gathering. All nine of the biochars selected for initial hydraulic testing have met reasonable expectations of cost, availability, and consistency.

Cost

Generally, biochar is a byproduct of the lumber industry or more recently household yard waste and tree trimmings. This byproduct is cheap and plentiful in certain regions especially when compared to more costly adsorbents commonly used to treat stormwater such as zeolite, activated alumina, activated carbon, or proprietary engineered media. Because even a relatively expensive biochar can be considered inexpensive when compared to other soil additives, biochars will not be excluded based solely on cost.

Availability

The selection process for the different biochars ensures that local soil suppliers have consistent access to the tested biochar in commercial quantities. To ensure availability, producers that are well established and offer biochar in commercial quantities in stock year round were prioritized.

Consistency

Biochar can be made from a variety of feedstocks and processed at various temperatures, which will produce biochars with varying properties and treatment capacities. To ensure that the biochars tested in this study will be available with the same properties, only suppliers who use a consistent feedstock and process will be considered.

Performance Criteria

Hydraulic Conductivity

A current requirement of alternative BSM is to have an infiltration rate between 5 and 12 inches per hour with a long-term infiltration rate of at least 5 inches per hour. In a previous study, the hydraulic conductivity of a biochar was studied before and after having the fines removed by sieving. The sample with fines removed had a hydraulic conductivity nearly four times higher than the one with fines (Yargicoglu et al., 2015). Any biochar amended BSM that does not achieve 5 to 12 inches per hour infiltration rate will be removed from the study.

Soil pH

There is a correlation between increased pyrolysis temperatures and increased pH, though there is a large variation between feedstocks (Cantrell et al., 2012). If the pH is raised enough it could affect plant health as several key nutrients required by plants can be immobilized in high pH soils. Ideally the biochars chosen should have a pH as close to seven as possible.

Surface Area

Surface area is arguably the most important characteristic for treatment performance. Adsorption capacity is directly related to available surface area of the adsorbent. Some biochars have been lab tested to measure surface area via N_2 adsorption but not many. From literature, a correlation between pyrolysis temperature and surface area is established, pyrolysis temperatures of 600-700 C show much higher surface areas than those produced at 500 C or less (Ahmad et al., 2014).

Hydrophobicity

Hydrophobicity is important to our study because hydrophobic substances, like PCBs, in a water solution are attracted to hydrophobic surfaces like biochar where they are adsorbed and removed from the water. Hydrophobicity is a difficult characteristic to measure, requiring either specialized equipment or lengthy experimentation. However, it has been well documented that hydrophobicity in biochar decreases as pyrolysis temperature increases (Zimmerman, 2010). The hydrophobicity in biochar is likely due to hydrophobic substances that are not completely volatilized at lower temperatures (Gray et al., 2014). Hydrophobicity in biochar will decline over time as these hydrophobic substances are consumed by microbes or oxidized, eventually making the biochar hydrophilic (Zimmerman, 2010). This is a concern for long-term treatment effectiveness if treatment depends on hydrophobicity.

Source Material and Pyrolysis Method

Many studies have compared the physical and chemical properties of biochar produced using different feedstocks and different methods of pyrolysis. However, because we have chosen to only study biochars that meet our availability requirements we do not have the option to make source material a primary selection criteria. Most of the biochars that meet our selection requirements are produced from woodchips and other industrial forestry residues. Consequently, biochars will be ordered by pyrolysis temperature. A range of pyrolysis temperatures are recommended since low temperatures tend to produce more hydrophobic biochars and higher temperatures produce biochars with more surface area (Zimmerman, 2010).

Probable Treatment Efficiency

From literature there are many factors that will affect overall treatment efficiency in a biochar. To simplify the selection process, pyrolysis temperature was chosen as the factor to represent treatment efficiency. Because pyrolysis temperature affects both surface area and hydrophobicity directly, biochars will be chosen that are produced at a wide range of temperatures. This will ensure biochars with the greatest surface area, the greatest hydrophobicity, and combinations of the two will be tested.

Table 1. Biochar Selection Table

Biochar Name	Cost ($/yd³)	Pyrolysis Temp (Degrees C)
1. Pacific	$ 90.00	700
2. Sonoma Biochar	$ 240.00	1315
3. Rogue Biochar	$ 249.50	700
4. BioChar Now - Medium	$ 350.00	600
5. Sunriver High Porosity Biochar	$ 500.00	500
6. Biochar Solutions (CW4CB)	$ 225.00	700
7. Agrosorb	$ 250.00	900
8. BlackSorb	$ 250.00	900
9. Cool Terra CF-11	$ 700.00	600
10. Phoenix	$ 254.00	700

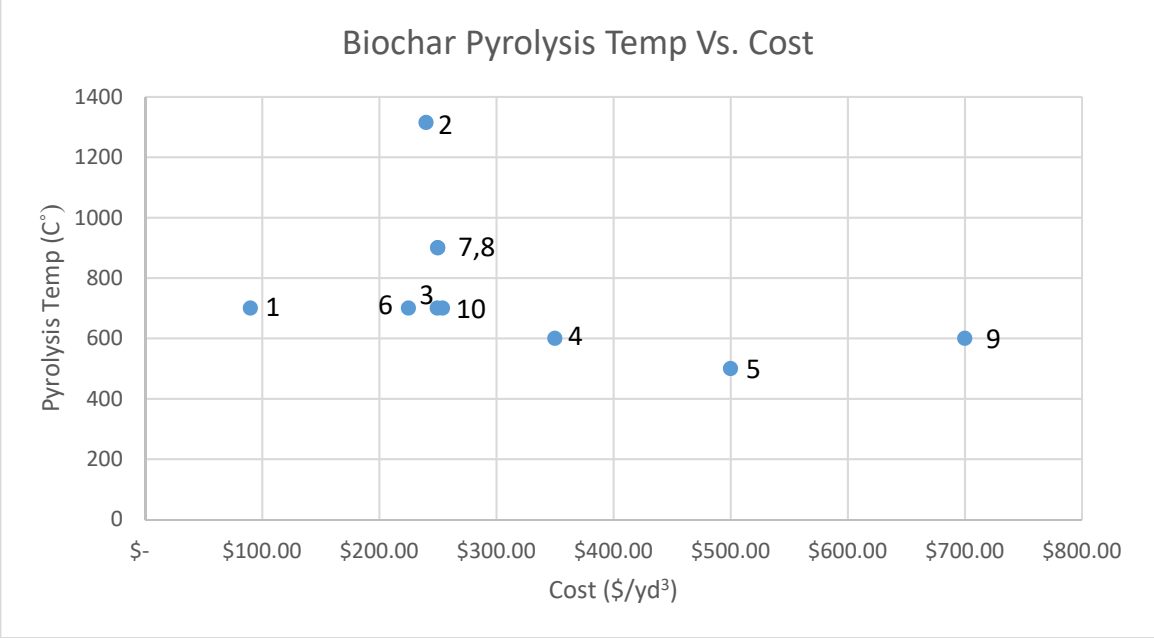

Figure 1. Biochar Pyrolysis Temperature Vs. Cost

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APPENDIX D: HYDRAULIC TEST RESULTS

Blacksorb biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
43.7	35.1	8.6	46	240	0.001051	0.565789	19.9	0.001858	0.00186303	2.640514
42.75	27.6	15.15	49.5	150	0.00181	0.996711	19.9	0.001816	0.00182084	2.580724
42.3	24.7	17.6	49.5	135	0.002011	1.157895	19.9	0.001737	0.00174153	2.468306
									Average K	2.563181

Sonoma biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
43.98	37.1	6.88	48.8	165	0.001622	0.452632	20	0.003584	0.00358473	5.080723
43.25	32.3	10.95	48	100	0.002633	0.720395	20	0.003655	0.00365541	5.1809
42.65	28.05	14.6	47	75	0.003437	0.960526	20	0.003578	0.00357926	5.072965
									Average K	5.111529

Pacific biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
42.2	38.1	4.1	43.5	225	0.00106	0.269737	20.5	0.003931	0.0038846	5.505762
42.1	38	4.1	43	225	0.001048	0.269737	20.5	0.003886	0.00384	5.442478
40.4	34.2	6.2	43	150	0.001572	0.407895	20.5	0.003855	0.003809	5.398587
35.2	24.15	11.05	45	90	0.002742	0.726974	20.5	0.003772	0.0037276	5.283264
									Average K	5.407523

Sunriver biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
43.2	40.7	2.5	47	280	0.000921	0.164474	21.5	0.005598	0.005399934	7.65345
42.8	39.6	3.2	47.5	210	0.001241	0.210526	21.5	0.005893	0.005684771	8.057156
41.7	36.6	5.1	46	128	0.001971	0.335526	21.5	0.005875	0.005667171	8.032211
39.85	32.2	7.65	48	90	0.002925	0.503289	21.5	0.005812	0.00560694	7.946844
39.4	31.8	7.6	46.5	90	0.002834	0.5	21.5	0.005668	0.005467458	7.749154
34.5	22.5	12	200	255	0.004302	0.789474	21.5	0.005449	0.005256507	7.450167
33.4	22.3	11.1	200	255	0.004302	0.730263	21.5	0.005891	0.00568271	8.054234
33.1	22.2	10.9	200	305	0.003597	0.717105	21.5	0.005015	0.004838294	6.857425
32.5	22.15	10.35	200	305	0.003597	0.680921	21.5	0.005282	0.005095402	7.221829
									Average K	7.669163

Rogue biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm		viscosity at 20		1.0034
Area	182.3222	cm2		viscosity at 22		0.955
				Ratio		0.951764

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.65	42.5	2.15	40	270	0.000813	0.141447	22	0.005745	0.005476319	7.761713
43.5	35.75	7.75	48.5	90	0.002956	0.509868	22	0.005797	0.005526225	7.832444
43.3	34.75	8.55	45	75	0.003291	0.5625	22	0.00585	0.005577199	7.904691
42.6	31.5	11.1	46.5	60	0.004251	0.730263	22	0.005821	0.005548936	7.864634
42	28.75	13.25	41.7	45	0.005083	0.871711	22	0.005831	0.005558258	7.877845
43	34.95	8.05	50.5	90	0.003078	0.529605	22	0.005811	0.005539671	7.851503
									Average K	7.848805

Phoenix biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
42.58	39.9	2.68	49	210	0.00128	0.176316	19.5	0.007258	0.007349893	10.41717
40.3	34.9	5.4	47.5	100	0.002605	0.355263	19.5	0.007333	0.007425726	10.52465
38.9	31.65	7.25	49.2	80	0.003373	0.476974	19.5	0.007072	0.007161041	10.14951
									Average K	10.36378

Voss Compacted to 85% MDD of Standard Proctor

Length	15.2	cm		viscosity at 20		1.0034
Area	182.3222	cm2		viscosity at 21		0.979
				Ratio		0.975683

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
40.2	37.35	2.85	44.5	165	0.001479	0.1875	21	0.007889	0.007702247	10.91657
39.81	33.45	6.36	43	75	0.003145	0.418421	21	0.007515	0.007337301	10.39932
39.55	30.8	8.75	46	58	0.00435	0.575658	21	0.007557	0.00737748	10.45627
39	27.5	11.5	203	176	0.006326	0.756579	21	0.008362	0.008163413	11.57019
									Average K	10.83559

BioChar Solutions biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.2	41.7	2.5	49.5	220	0.001234	0.164474	20	0.007503	0.00750502	10.63704
43.5	39.05	4.45	49.5	120	0.002262	0.292763	20	0.007728	0.00772989	10.95575
42.7	36.48	6.22	49.5	85	0.003194	0.409211	20	0.007805	0.00780738	11.06558
42.3	35.4	6.9	46.5	70	0.003643	0.453947	20	0.008026	0.00802814	11.37847
41.45	32.7	8.75	47.8	58	0.00452	0.575658	20	0.007852	0.00785419	11.13192
									Average K	11.03375

Agrosorb biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm		viscosity at 20		1.0034
Area	182.3222	cm2		viscosity at 22		0.955
				Ratio		0.951764

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.23	40.58	3.65	47	100	0.002578	0.240132	20.4	0.010735	0.0106337	15.07137
43.09	36.4	6.69	45.2	50	0.004958	0.440132	20.4	0.011265	0.0111589	15.81576
43.05	36.3	6.75	45.4	50	0.00498	0.444079	20.4	0.011215	0.0111086	15.74453
41.82	32.2	9.62	51.2	40	0.007021	0.632895	20.4	0.011093	0.0109879	15.57337
41.82	32.09	9.73	38	30	0.006947	0.640132	20.4	0.010853	0.0107505	15.23692
40.85	28.58	12.27	39.1	25	0.008578	0.807237	20.4	0.010627	0.0105262	14.91901
40.85	28.5	12.35	39	25	0.008556	0.8125	20.4	0.010531	0.0104313	14.78446
44	39.9	4.1	41.8	85	0.002697	0.269737	20.4	0.009999	0.009905	14.03852
									Average K	15.14799

Biochar Now biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.3	40.8	3.5	48	90	0.002925	0.230263	21	0.012704	0.01240272	17.57866
44	39.3	4.7	49	70	0.003839	0.309211	21	0.012417	0.01212234	17.18127
43.5	36.85	6.65	49.5	50	0.00543	0.4375	21	0.012411	0.01211713	17.17389
42.85	34.25	8.6	45.1	35	0.007068	0.565789	21	0.012491	0.01219541	17.28483
42.15	31.35	10.8	200	128	0.00857	0.710526	21	0.012061	0.01177559	16.68981
									Average K	17.18169

APPENDIX E: BIOCHAR PARTICLE SIZE DISTRIBUTION

Sieve Analysis Data Sheet

ASTM D422-63(2007)

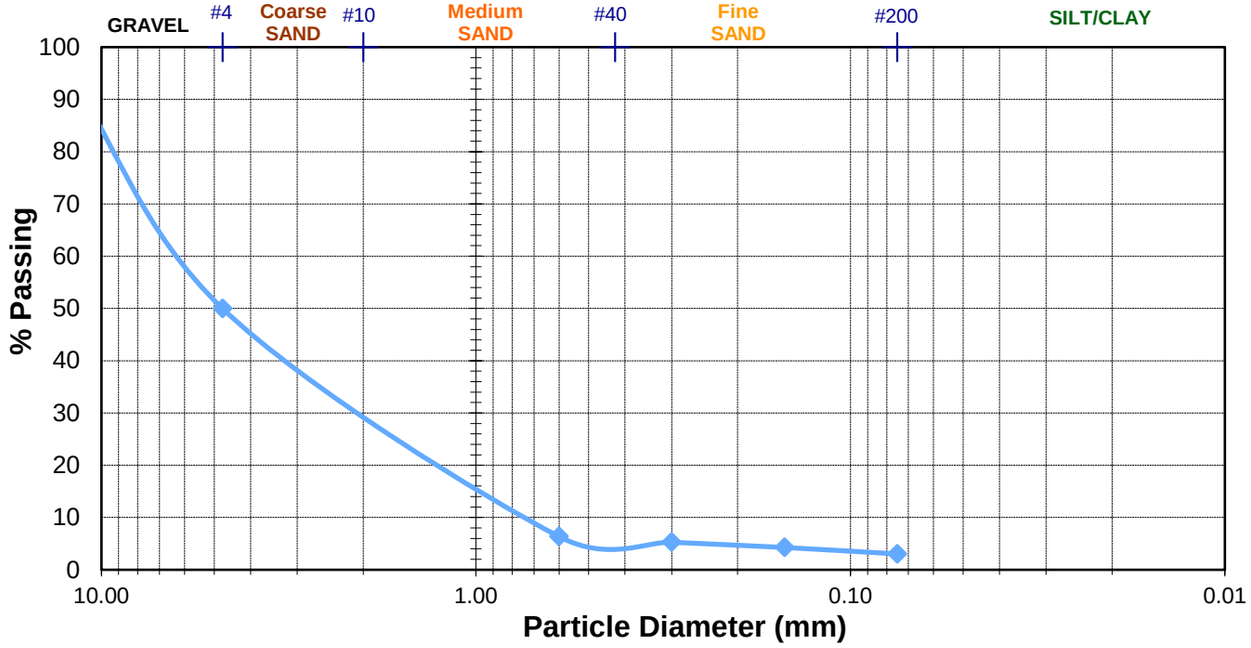
Project Name:		**Tested By:**	RH & JB	**Date:**	7/10/2018
Location:		**Checked By:**		**Date:**	
Boring No:		**Test Number:**			
Sample Depth:		**Gnd Elev.:**			

Biochar Type: BioChar Solutions

Weight of Container (g): 52.4 **Weight of Container & Soil (g):** 97.0

Weight of Dry Sample (g): 44.6

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	13.9837	15.1551	1.2	2.6	97.4
4	4.75	13.9837	35.5409	21.6	47.4	50.0
30	0.60	13.9837	33.8176	19.8	43.6	6.4
50	0.30	13.9837	14.4764	0.5	1.1	5.3
100	0.15	13.9837	14.4401	0.5	1.0	4.3
200	0.075	0.7018	1.2622	0.6	1.2	3.0
Pan		0.7018	2.0797	1.4	3.0	0.0
			TOTAL:	**45.4**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel:	2.6	**D_{10}:**	0.72	**C_u:**	8.61
% Sand:	94.4	**D_{30}:**	2.05	**C_c:**	0.94
% Fines:	3	**D_{60}:**	6.2		

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name: _____ **Tested By:** RH & JB **Date:** 7/10/2018

Location: _____ **Checked By:** _____ **Date:** _____

Boring No: _____ **Test Number:** _____

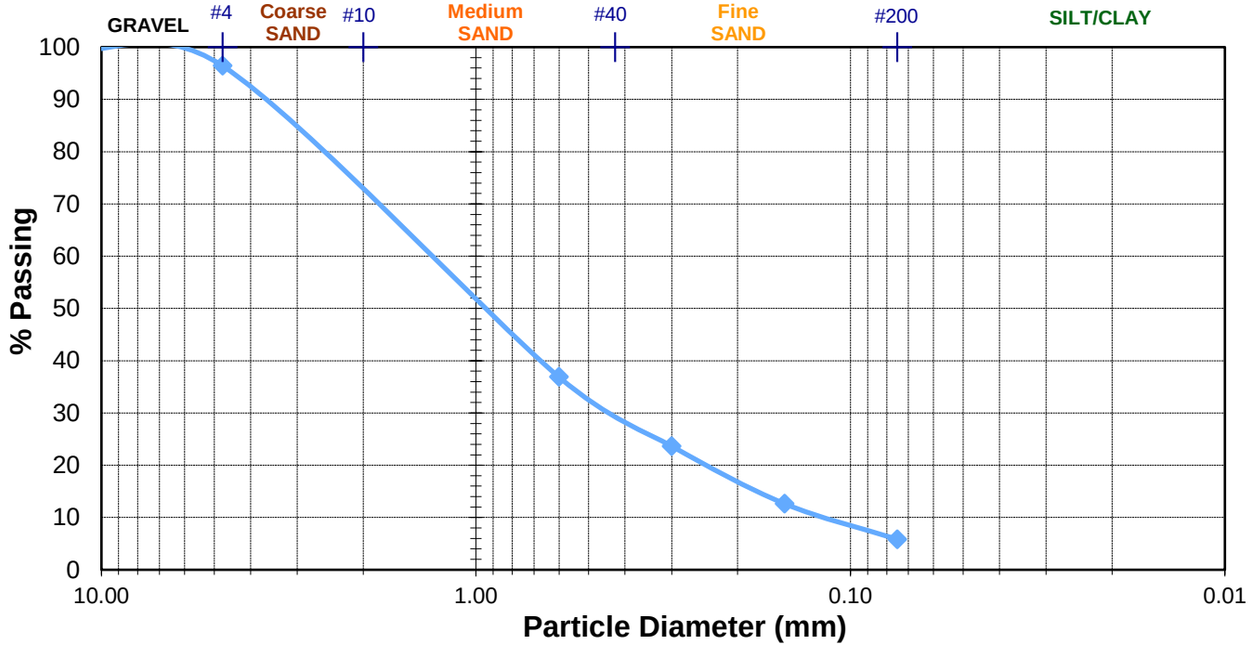
Sample Depth: _____ **Gnd Elev.:** _____

Biochar Type: Agrosorb

Weight of Container (g): 3.2 **Weight of Container & Soil (g):** 175.3

Weight of Dry Sample (g): 172.1

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	1.5896	3.1261	1.5	0.9	99.1
4	4.75	1.5896	6.1437	4.6	2.7	96.4
30	0.60	3.1792	104.6093	101.4	59.6	36.9
50	0.30	1.5896	24.1144	22.5	13.2	23.6
100	0.15	1.5896	20.3184	18.7	11.0	12.7
200	0.075	1.5896	13.1978	11.6	6.8	5.8
Pan		1.5896	11.5284	9.9	5.8	0.0
			TOTAL:	**170.3**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: 0.9 **D_{10}:** 0.11 **C_u:** 10.9

% Sand: 93.3 **D_{30}:** 0.43 **C_c:** 1.40

% Fines: 5.8 **D_{60}:** 1.2

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name: _____ **Tested By:** RH & JB **Date:** 7/10/2018

Location: _____ **Checked By:** _____ **Date:** _____

Boring No: _____ **Test Number:** _____

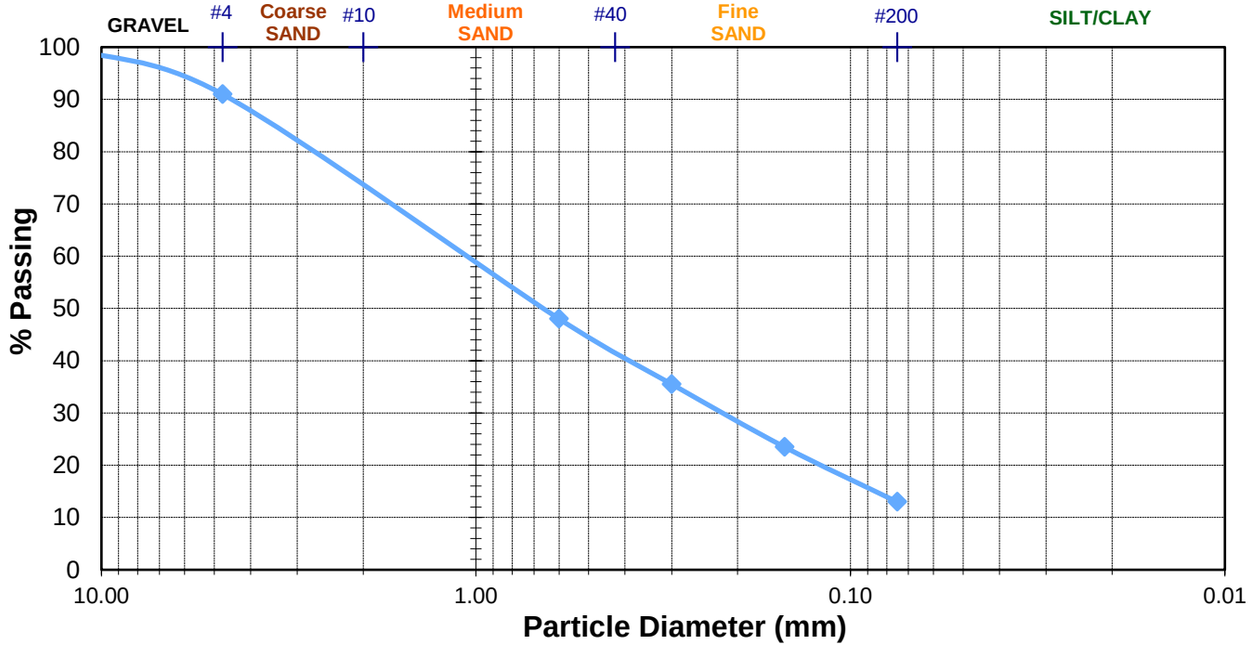
Sample Depth: _____ **Gnd Elev.:** _____

Biochar Type: Phoenix

Weight of Container (g): 2.8 **Weight of Container & Soil (g):** 241.2

Weight of Dry Sample (g): 238.4

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	0.7018	0.7018	0.0	0.0	100.0
4	4.75	0.7018	23.5505	22.8	9.0	91.0
30	0.60	13.9837	122.8911	108.9	43.0	48.0
50	0.30	1.5896	33.2888	31.7	12.5	35.5
100	0.15	1.5896	32.0522	30.5	12.0	23.5
200	0.075	1.5896	28.2517	26.7	10.5	13.0
Pan		1.5896	34.4933	32.9	13.0	0.0
			TOTAL:	**253.5**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: 0 **D_{10}:** _____ **C_u:** _____

% Sand: 87 **D_{30}:** 0.21 **C_c:** _____

% Fines: 13 **D_{60}:** 1.03

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name: _____ **Tested By:** RH & JB **Date:** 7/10/2018

Location: _____ **Checked By:** _____ **Date:** _____

Boring No: _____ **Test Number:** _____

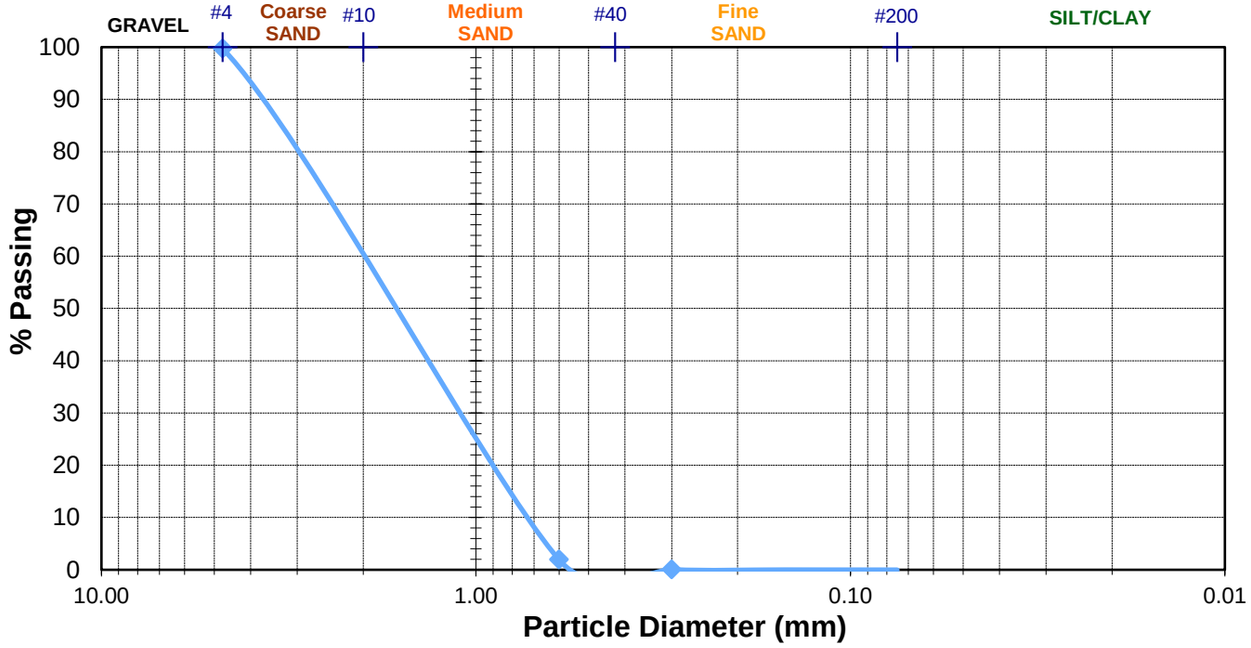
Sample Depth: _____ **Gnd Elev.:** _____

Biochar Type: Rogue

Weight of Container (g): 52.3 **Weight of Container & Soil (g):** 173.8

Weight of Dry Sample (g): 121.5

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	1.5896	1.5896	0.00	0.00	100.00
4	4.75	1.5896	1.9089	0.32	0.27	99.73
30	0.60	3.1792	119.5292	116.35	97.79	1.94
50	0.30	1.5896	3.8304	2.24	1.88	0.05
100	0.15	1.5896	1.6583	0.07	0.06	0.00
200	0.075	1.5896	1.6115	0.02	0.02	-0.02
Pan		1.5896	1.5635	-0.03	-0.02	0.00
			TOTAL:	**119.0**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: _____ D_{10}: _____ C_u: _____

% Sand: _____ D_{30}: _____ C_c: _____

% Fines: _____ D_{60}: _____

Sieve Analysis Data Sheet

ASTM D422-63(2007)

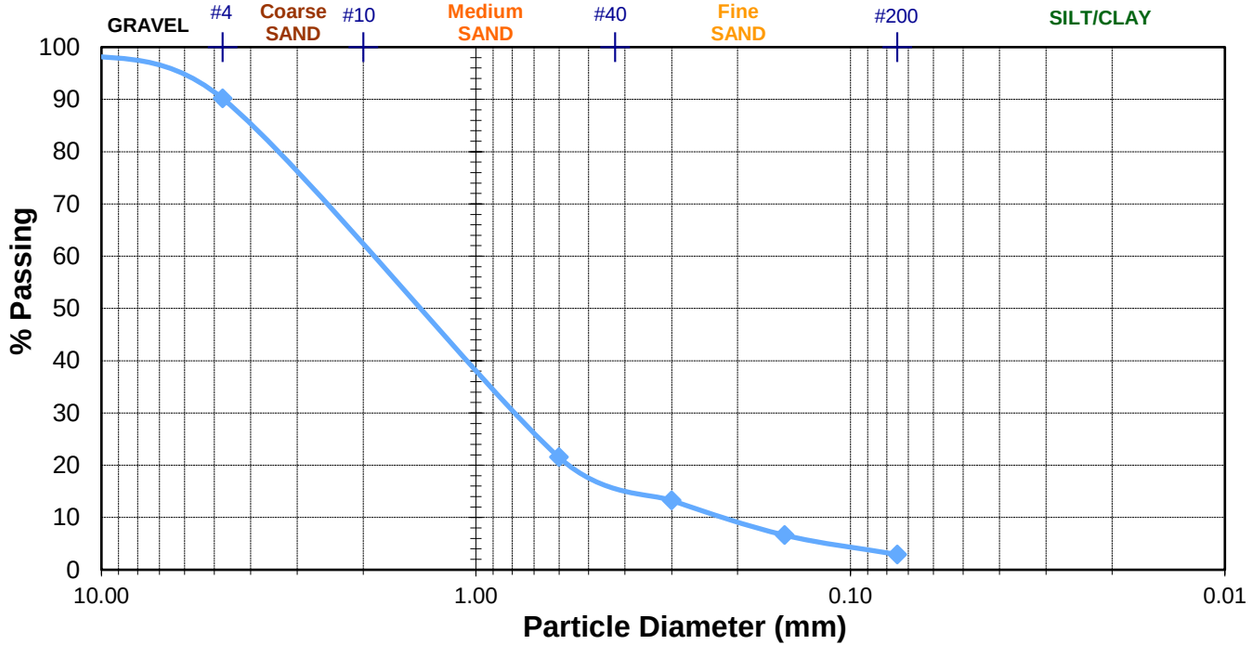
Project Name:		**Tested By:**	RH & JB	**Date:**	7/10/2018
Location:		**Checked By:**		**Date:**	
Boring No:		**Test Number:**			
Sample Depth:		**Gnd Elev.:**			

Biochar Type: Sun River

Weight of Container (g): 52.3 **Weight of Container & Soil (g):** 153.2

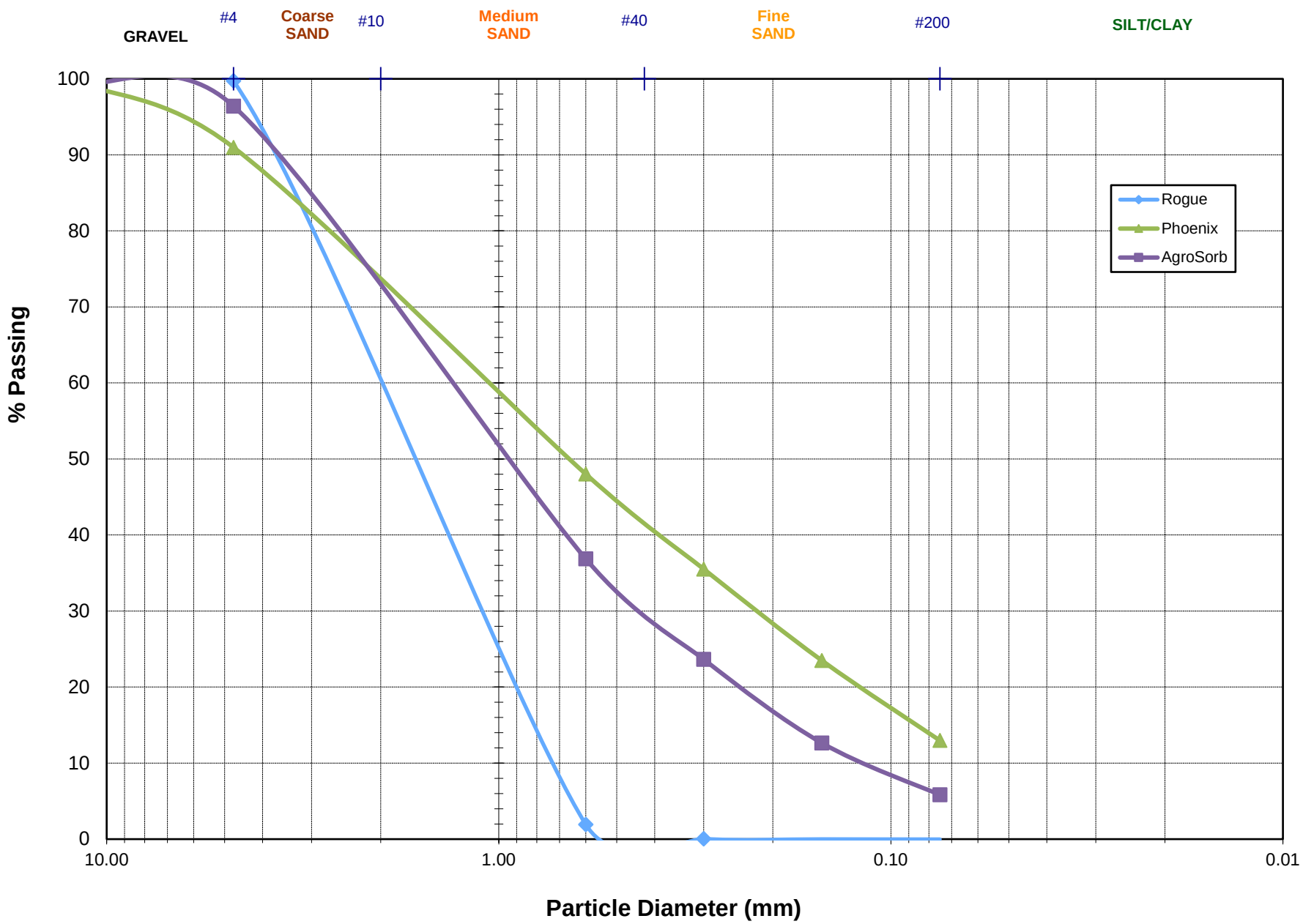
Weight of Dry Sample (g): 100.9

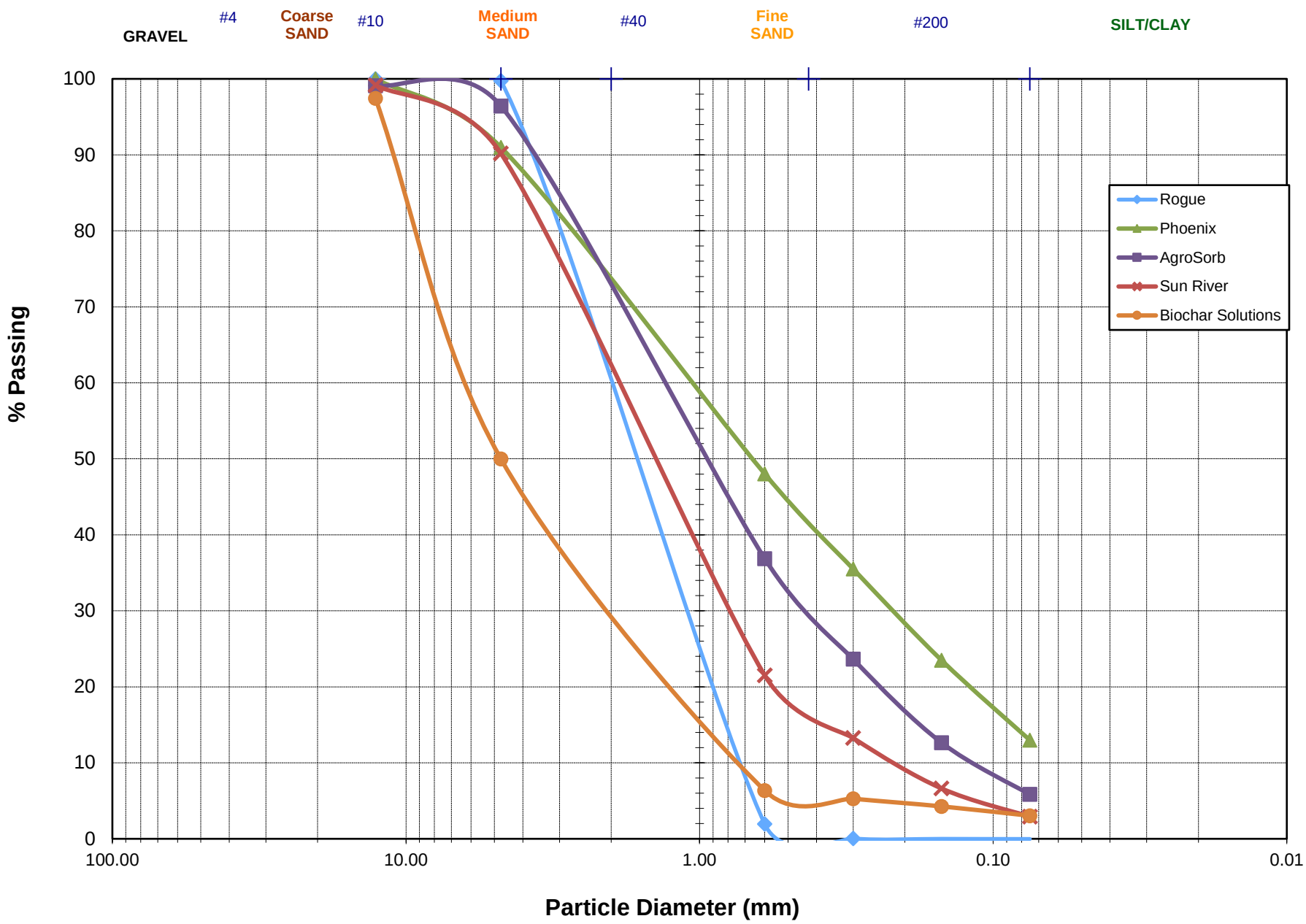
Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	1.5896	2.4228	0.8	0.8	99.2
4	4.75	1.5896	10.6182	9.0	9.0	90.2
30	0.60	1.5896	70.5872	69.0	68.7	21.5
50	0.30	1.5896	9.8777	8.3	8.2	13.3
100	0.15	1.5896	8.2566	6.7	6.6	6.6
200	0.075	1.5896	5.3083	3.7	3.7	2.9
Pan		1.5896	4.5286	2.9	2.9	0.0
			TOTAL:	**100.5**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel:	0.8	**D_{10}:**	0.22	**C_u:**	8.18
% Sand:	96.3	**D_{30}:**	0.78	**C_c:**	1.54
% Fines:	2.9	**D_{60}:**	1.8		


GRAVEL
#4
Coarse SAND
#10
Medium SAND
#40
Fine SAND
#200
SILT/CLAY
100
90
80
70
60
50
40
30
20
10
0
% Passing
10.00
1.00
0.10
0.01
Particle Diameter (mm)
Rogue
Phoenix
AgroSorb


GRAVEL
#4
Coarse SAND
#10
Medium SAND
#40
Fine SAND
#200
SILT/CLAY
100
90
80
70
60
50
40
30
20
10
0
% Passing
100.00
10.00
1.00
0.10
0.01
Particle Diameter (mm)
Rogue
Phoenix
AgroSorb
Sun River
Biochar Solutions

APPENDIX F: COLUMN TEST OBSERVATION FORMS

OCC 13.7

4/10/18 First Run

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: CO

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:25	11	20.6			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:19	11	18.7			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: CO2

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:28	0"	210			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:49	0"	206			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C05

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:26	11"	138			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:01	4"	181			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: COC1

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:28	0"	289			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:42	1"	212			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C05

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:31	1"	283			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:52	2"	234			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C06

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
1128	1"	218			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
1155	3"	335			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: CN Flume 7

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:18	–	24			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:56	–	21.4			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Technician_____ Sampling Sheet Column ID: TW2 Date: 4/10/18

Column Description Influent

Sample Run 1 Water 1-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	X			
2	X			
3	X	→ Start of Sampling		
4	X			
5	X			
6	X			
7	X			
8	3:41			
9	3:58			
10	4:18	Turb		
11	4:46			
12	5:22			
13	6:29			
14	X			
15	5:36			
16	5:11			
17	5:46			
18	5:55			

Observations:

Technician_____ **Sampling Sheet** Column ID: C02 Date: 4/10/18

Column Description Rogue

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	3:45			
2	3:48			
3	3:20			
4	3:21			
5	3:30			
6	3:34			
7	3:41			
8	3:44			
9	3:48			
10	4:15			
11	4:20	Turb		
12	4:42			
13	4:50	Mercury		
14	5:21			
15	5:31			
16	5:31	.5?		
17	5:41			
18	5:51			

Observations:

Technician _____ **Sampling Sheet** Column ID: C01 Date: 4/10/18

Column Description Gunnison River

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	2:45			
2	2:48			
3	3:19			
4	3:26	Start Alternating		
5	3:30	11 → dry before next flow		
6	3:33	3 11		
7	3:40	2 11		
8	3:41	1 5"		
9	3:47	1 11 → dry before next flow		
10	4:15			
11	4:19	40rb		
12	4:41			
13	4:48	Mercury grab		
14	5:20			
15	5:30			
16	5:36	.75		
17	5:40			
18	5:50			

Observations:

Technician_____ Sampling Sheet Column ID: C03 Date: 6/10/18

Column Description Phoenix

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	3:45			
2	3:49			
3	3:20	Binding		
4	3:27			
5	3:30	1.5"		
6	3:34	2.0"		
7	3:41	2.0"		
8	3:45	2.5		
9	3:49	2.75		
10	4:15	1"		
11	4:20	1.5	Torn	
12	4:43	1"		
13	4:52	[illegible]		
14	5:25	1		
15	5:30	1"		
16	5:38	1		
17	5:41	1.5"		
18	5:51			

Observations:

Column Description Biochar Solutions

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	3:45			
2	3:49			
3	3:21			
4	3:28			
5	3:31	1"		
6	3:34	1.5"		
7	3:42	1"		
8	3:45	1.5"		
9	3:50	2"		
10	4:16	3"		
11	4:21	Turb		
12	4:44	.5"		
13	4:58	normal	✓	
14	5:26	1"		
15	5:33	.5"		
16	5:38			
17	5:42	2"		
18	5:52			

Observations:

Technician_____ **Sampling Sheet** Column ID: C05 Date: 4/10/18

Column Description Black Sorb

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	3:45			
2	3:50			
3	3:22	Ponding		
4	3:28	1"		
5	3:31	1.25		
6	3:34	1.75"		
7	3:42	1.5		
8	3:46	2"		
9	3:50	2.75		
10	4:17	1"		
11	4:22	1.5"	Turb	
12	4:24	1"		
13	5:02	"		
14	5:26	.75"		
15	5:34	1.5"		
16	5:38			
17	5:43	3"		
18	5:53	1.5"		

Observations:

Technician_____ Appendix F: Column Test Observation Forms **Sampling Sheet** Column ID: C06 Date: 4/10/18

Column Description Control

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	2:45			
2	2:51			
3	3:20	Yandry		
4	3:28			
5	3:32	1.75"		
6	3:35	2.5"		
7	3:43	2.75"		
8	3:46	3.5"		
9	3:50	4"		
10	4:18	1.75"		
11	4:22	2"	Turb →	dropped to 0" before next Sample
12	4:45	1"		
13	5:03	1"		
14	5:29	1		
15	5:34	1.5"		
16	5:40			
17	5:44	2.5"		
18	5:54	3.5"		

Observations:

Technician Michelle

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: 6 Date: 4/11/18

Column Description

Media flushing w/2-2 & 2-1

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	1:06	1			
2	"	1			
3	"	1			
4	"	2			
5	"	2.5			
6	"	2		88.5	
7	2:02	1			site 2 storm 1
8	"	2			
9	"	2.5			
10	"	3			
11	"	4			
12	"	5			
13	"	3.5			Break @ 2:35
14	3:08	1			
15	"	2			
16	"	2.5			
17	3:31	2.5			Mix of 2-1 & 2-2
18	3:40	2		155	half dose

Observations:

Technician Michelle Sampling Sheet Column ID: 5 Date: 4/11/18

Column Description

Media flushing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	1:05	Ø			
2	"	1			
3	"	1			
4	"	1.5			
5	"	2			
6	"	2		91.1	
7	2:01	1			Site 2 Storm 1
8	"	2			
9	"	2.5			
10	"	3			
11	"	4			
12	"	4.5			
13	"	3			Break @ 2:35
14	3:07	0			
15	"	1			
16	"	2			
17	3:29	1			Mix of 2-1 & 2-2
18	3:39	0		160	half dose

(9

Observations:

Technician Michelle Appendix F: Sampling Sheet Column Test Observation Forms Column ID: 4 Date: 9/11/18

Column Description

Media flushing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	1:04	ø			
2	"	1			
3	"	1			
4	"	1			
5	"	1			
6	"	1		105	
7	2:00	1			site 2 storm 1
8	"	1.5			
9	"	2.5			
10	"	3			
11	"	4			
12	"	5			
13	"	5			Break @ 2:35
14	3:06	1			
15	"	1.5			
16	"	2			
17	3:28	1			Mix of 2-1 & 2-2
18	3:38	0.5		122	half dose

Observations:

Technician Michelle

Sampling Sheet Column ID: 3 Date: 4/11/18

Column Description

Media Fishing 2/2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	12:56	~~0~~			
2	–	1			
3	/	1			
4	/	1.5			
5	/	1.5			
6	/	1		75.4	
7	2:00	1			Site 2 Storm 1
8	–	1.5			
9	/	2.5			
10	–	3			
11	/	4			
12	/	5			
13	/	5			Break @ 2:35
14	3:05	1			
15	/	1.5			
16	/	2.5			
17	3:27	2			Mix of 2-1 & 2-2
18	3:38	1.5		96.1	half dose

jA

Observations:

Technician Michelle Appendix F: Column Test Observation Forms **Sampling Sheet** Column ID: 2 Date: 4/11/18

Column Description

2:2 Flushing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	12:55	~~0~~ 1			
2	—	1			
3	—	1			
4	—	1			
5	—	1			
6	—	1		105	
7	1:59	1			Site 2 Storm 1
8	—	1			
9	—	2			
10	—	2.5			
11	—	3			
12	—	~~4~~			
13	—	4			Break @ 2:35
14	3:05	1			
15	—	1			
16	—	1			
17	3:27	1			Mix of 2-1 & 2-2
18	3:37	0		143	Half dose

17 X

Observations:

Technician Michele Appendix F: Sampling Sheet Column Test Observation Forms Column ID: 1 Date: 4/11/18

Column Description

Media flushing w/ 2-2 Site 2 Storm 2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	12:54				
2					
3					
4					
5					
6				87.5	
7	1:58				Site 2 Storm 1
8					
9					
10					
11					
12					
13					Break @ 2:35
14	3:05				
15					
16					
17	3:25				Mix of 2-1 & 2-2
18	3:34			~~98.5~~ 102	half dose

Observations:

Technician Jessica/Audrey Sampling Sheet Column ID: C01 Date: 4/12/18

Column Description Media flushing

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	"			
3	"	1		
4	"	2		
5	"	2.2		
6	1:14	2.8		16.5
7	1:33	1.9		
8	"	2.8		
9	"	3		
10	"	4		
11	"	4.4		21.6
12	2:31	"		
13	"	1		
14	"	1		
15	"	2		
16	"	2.4		
17	"	2.4		
18	"	4		47.7

3:14

CLEAR

Observations:

Technician Jessica/Audrey **Sampling Sheet** **Column ID:** C12 **Date:** 4/10/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	"	1		
3	"	1.5		
4	"	2.2		
5	"	2.5		
6	1:15	3		15.4
7	1:34	2		
8	"	2.2		
9	"	3		
10	"	4		
11	"	4.3		28.3
12	2:31	"		
13	"	1.75		
14	"	2.5		
15	"	3.4		
16	"	4.0		
17	"	4.9		
18	3:14	4		45.6

BREAK

Observations:

Technician Jessica / Aubrey **Sampling Sheet** Column ID: C0.3 Date: 4/11/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:46			
2	/	1		
3	/	1		
4	/	1		
5	/	1.5		
6	1:15	1.6		34.4
7	1:34	1		
8	/	1.8		
9	/	1.5		
10	/	1.8		
11	/	2.2		61.1
12	2:31	1		
13	—	1.5		
14	—	2		
15	—	3		
16	—	3.4		
17	—	3.4		
18	3:14	1.7		63.7

BREAK

Observations:

Technician Jessica / Audrey **Sampling Sheet** Column ID: C04 Date: 4/10/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	/			
3	/	1		
4	/	1.2		
5	/	1.7		
6	1:16	2		33.1
7	1:36	2		
8	/	1.2		
9	/	2		
10	/	2.5		
11	/	2.9		48.0
12	2:32	–		
13	–	1		
14	–	1.3		
15	–	2		
16	–	2.8		
17	–	2.8		
18	3:14	1		67.2

BREAK

Observations:

Technician Jessica/Andrey **Sampling Sheet** Column ID: C05 Date: 4/10/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	"			
3	"	1.5		
4	"	2		
5	"	2.8		
6	1:16	3.3		32.4
7	1:36	2		
8	"	2.5		
9	"	3		
10	"	3.3		
11	"	4.2		48.3
12	2:32	"		
13	"	1.2		
14	"	1.8		
15	"	2.3		
16	"	2.5		
17	"	>		
18	3:15	1		80.5

BREAK

Observations:

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	"	1		
3	"	1.5		
4	"	1.75		
5	"	2		
6	1:17	2.75		29.3
7	1:37	1		
8	"	1.8		
9	"	2.1		
10	"	3		
11	1:53	3.6		76.5
12	2:32	1		
13	"	1.75		
14	"	2		
15	"	3		
16	"	3.5		
17	"	4		
18	"	2.8		102

— BREAK

Observations:

Technician Joe L

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: Inf Date: 4/13/18

Column Description

Sample Run 2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:05			
2	9:10			✓
3	9:30			
4	9:40		21	
5	9:48			
6	9:57			
7	10:33			
8	10:37			
9	10:42			✓
10	10:56			
11	11:32			
12	11:49			
13	11:53			
14	11:57			→ pending
15	[illegible]			
16	12:03			
17	1:09			
18	4:12		20°C	

Observations: pH: 6.80 Temp: 20.2°C

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:01			
2	9:08			✓
3	9:21			
4	9:38			
5	9:46			
6	9:49	.5-1		
7	10:29			
8	10:31			
9	10:40			✓
10	10:46			
11	11:15			
12	11:42			
13	11:50			
14	11:55			
15	12:05			No ponding
16	12:59			
17	1:04			
18	1:11	1.25		

Observations: 19.20°C & pH = 7.66

Technician Dave F

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: C02 Date: 4/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:05			
2	9:09	1"		Stopped draining, no turb sample
3	9:27	1.25"		✓
4	9:38	2"		
5	9:46	2.75		
6	9:49	3.25"		→ removed screws → Abu Sk / Zn Mg-A
7	10:29	1.1"		
8	10:35	1.75		
9	10:40	2.5		✓
10	10:49	3.25		
11	11:30	0		
12	11:40			
13	11:50			
14	11:55			
15	12:00p			→ pumping
16	1:00			
17	1:05	1.5"		
18	1:17	2.25		

Observations: Very slow flow rate, Very clear effluent

pH=7.97 Temp=19.2°C

Technician JDC

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: ~~C3~~ C03 Date: 4/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:04			
2	9:09			√
3	9:28			
4	9:39	1"		
5	9:47	1.25"		
6	9:59	1.75		
7	10:31			
8	10:35	?		
9	10:41	1.75		√
10	10:50	2.1		
11	11:31			
12	11:43			
13	11:51			
14	11:55			
15	12:09			→ ponding
16	1:09			
17	1:06	1.25"		
18	1:13	1.75"		

Observations:

pH = 7.65 Temp: 19.2°C

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:04			
2	9:09			✓
3	9:28			
4	9:39	0.75		
5	9:48	— ?		
6	9:49	1.5		
7	10:31			
8	10:32			
9	10:41	1		✓
10	10:53	1 11		
11	11:32			
12	11:43			
13	11:51			
14	11:56			
15	12:02p			→ ponding
16	1:01			
17	1:06			
18	1:21	~~1~~ 1.75		

Observations: pH= [redacted] 7.78 temp: 19.2°C

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:01			
2	9:10			✓
3	9:28			
4	9:40			
5	9:48	4"		
6	9:50	1.75		
7	10:31			
8	10:36	1"		
9	10:40	1.25		✓
10	10:55	1.75		
11	11:35			
12	11:44			
13	11:52			
14	11:56			
15	12:02			
16	1:02			
17	1:07	1"		
18	1:15	2"		

→ removed 3 screws

→ Ponding

Observations: pH = 7.77 Temp = 19.5°C

Technician Joel

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: C06 Date: 4/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:14			
2	9:10			✓
3	9:29			
4	9:40	.75"		
5	9:48	1.5"		
6	9:50	2"		
7	10:32			
8	10:36	1"		
9	10:42	1.5"		✓
10	10:56	1.5"		
11	11:36			
12	11:44			
13	11:53			
14	11:57			
15	12:03p			
16	1:03			
17	1:08	1"		
18	1:12	1.5"		

Observations: pH: 7.94 Temp: 19.5°C

Technician Joel **Sampling Sheet** Column ID: C04 Date: 4/17/18

Column Description

Sample Run 3

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:14			
2	10:16			
3	10:20	0.50		10.5
4	10:36			
5	10:45			
6	11:27			
7	11:32	0.50		
8	11:35	1.25		
9	11:40	1.75	✓	✓
10	12:18			
11	12:25	0.75		
12	12:35	1.25		
13	12:39	2.25		
14	12:47	2.75		
15	12:58	3.50		
16	10:53	4.25		
17	1:02	4.00		
18	1:06	4.50		

Observations:

Technician Joel **Sampling Sheet** Column ID: CO2 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:14	0.25		
2	10:16	0.75		
3	10:20	1.5		
4	10:36	1.75		
5	10:45	2.50		2.27
6	11:27	0.75		
7	11:32	1.5		
8	11:35	2.25		
9	11:41	2.75	✓	✓
10	12:18	1.50		
11	12:25	2.00		
12	12:36	2.50		
13	12:39	3.25		
14	12:47	3.75		
15	12:50	4.00		
16	12:54	5.25		
17	1:02	5.25		
18	1:06	5.75		

Observations:

Technician Joel Sampling Sheet Column ID: C03 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:14			
2	10:17			
3	10:20	0.25		14.5
4	10:42			
5	10:45			
6	11:27			
7	11:33	0.50		
8	11:35	1.00		
9	11:42	1.25		/
10	12:18			
11	12:25	0.25		
12	12:36	0.50		
13	12:40	1.50		
14	12:47	2.50		
15	12:50	3.50		
16	12:54	4.00		
17	1:03	3.75		
18	1:06	4.50		

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Observations:

Technician Seel Sampling Sheet Column ID: C04 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:17	0.25		
3	10:20	0.50		8.02
4	10:42			
5	10:46	0.50		
6	11:28	0.25		
7	11:33	1.75		
8	11:36	1.75		
9	11:44	2.00	✓	✓
10	12:19	0.25		
11	12:26	0.50		
12	12:37	0.75		
13	12:40	1.75		
14	12:48	2.25		
15	12:50	3.00		
16	12:54	3.75		
17	1:03	4.00		
18	1:07	4.75		

14

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Observations:

Technician Joel Sampling Sheet Column ID: C05 Date: 4/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:18	0.5		
3	10:21	1		6.27
4	10:42			
5	10:46	0.50		
6	11:28			
7	11:33	0.25		
8	11:36	0.75		
9	11:44	0.75	✓	✓
10	12:19	0.25		
11	12:26	0.50		
12	12:37	1.00		
13	12:40	1.75		
14	12:48	2.25		
15	12:50	3.00		
16	12:55	4.00		
17	1:03	4.00		
18	1:07	4.50		

22

22

Observations:

Technician Joel **Sampling Sheet** Column ID: C6 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:18	0.25		
3	10:21	0.25		11.7
4	10:43			
5	10:46	0.50		
6	11:29	0.50		
7	11:34	1.00		
8	11:37	1.75		
9	11:45	2.00	✓	✓
10	12:19	0.50		
11	12:27	0.50		
12	12:38	0.75		
13	12:40	1.75		
14	12:48	2.25		
15	12:52	3.00		
16	12:55	4.00		
17	1:04	4.00		
18	1:07	4.75		

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Observations:

Technician Joel

Appendix F: Column Test Observation Forms **Sampling Sheet**

Column ID: INF TW6 Date: 4/17/18

Column Description Storm 2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:18			
3	10:22			5.51
4	10:43			
5	10:46			
6	11:28			
7	11:34			
8	11:37			
9	11:41		✓	✓
10	12:20			
11	12:38			
12	12:40			
13	12:48			
14	12:52			
15	12:55			
16	1:04			
17	1:08			
18				

12:27 → shift down

Observations: Missed 12:27 time record
shift Dose 11 through Dose 17 down one cell & insert 12:27 for Dose 11

Column Description

Dilution Run

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:43			
2	9:48			
3	9:44			
4	9:55			
5	9:56		✓	✓
6	10:15			
7	10:17			
8	10:19			
9	10:22			
10	10:24			
11	10:26		✓	✓
12	11:04			
13	11:05			
14	11:06			
15	11:07			
16	11:08			
17	11:10			
18	11:16			

Graduated

Observations:

Technician Joel Sampling Sheet Column ID: C06 Date: 4/19/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	9:41				
2	9:43	0.5			
3	9:49	0.75			
4	9:54	~~1.0~~			→ Start effluent collection
5	9:56	1.5	✓	✓	
6	10:15	1.5			
7	10:16	1.5			
8	10:18	2.25			
9	10:22	3.00			
10	10:23	4			
11	10:26	5	✓	✓	Grab Meas
12	11:04	1			
13	11:05	2			
14	11:06	2.5			
15	11:07	3.75			
16	11:08	4.85			
17	11:10	5.5			
18	11:16	5.8			

Observations:

Technician Joel **Sampling Sheet** Column ID: C04 Date: 4/19/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:40			
2	9:42	1		
3	9:45	1.75		
4	9:54	2.0		
5	9:56	3.75	✓	✓
6	10:14	1		
7	10:15	2		
8	10:18	2.75		
9	10:21	3.5		
10	10:23	4.25		
11	10:25	5	✓	✓
12	11:04			
13	11:05	2		
14	11:06	2.75		
15	11:07	3.75		
16	11:08	4.75		
17	11:10	5.5		
18	11:16	5.9		

Start → Effluent Collecting

Grab Mark

Observations:

4/19/18 — GAC Columns

Sample ID	Turb	Time	pH	Temp
~~C05~~ C0C	15.6	10:02	6.99	18.7
C04	6.46	10:03	7.09	19.3
C06	7.75	10:06	6.96	18.9
Influent	2.02	10:10	7.63	19.1
C01	9.75	1029	6.89	19.4
C06	13.8	1034	7.08	19.2
Influent	1.93	1036	7.77	19.3
C06	21.8	11:18	6.55	19.1°C
C01	21.7	11:22	6.93	19.2°C
Influent	2.08	11:24	7.68	18.8°C

Technician Joel S.

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: ~~INF~~ Date: 5/9/18

Retest

Column Description TW2 influent

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	10:02a				
2	10:03a				
3	10:04a				→ Turb
4	10:05a				
5	10:17a				
6	10:18a				
7	10:19a				
8	10:20a				→ Mercury Grab
9	10:29a				
10	10:30a				
11	10:31a				
12	10:32a				→ Grab taken
13	10:41a				
14	10:42a				
15	10:43a				
16	10:45a				
17	10:46a				
18	10:50a				→ Grab taken

Replacement Storm.
2-1 used for majority of influent
2-2 mixed in for last part

Observations:

Technician Joel G

Sampling Sheet
Appendix F: Column Test Observation Forms

Column ID: C01 Date: 5/9/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	10:02a				
2	10:03a				
3	10:04a				
4	10:05a			✓	→ grab taken
5	10:17a				
6	10:18a				
7	10:19a				
8	10:19a	3"			→ Mercury grab
9	10:28a				
10	10:29a				
11	10:31a	3.5			
12	10:32a			✓	→ Grab taken
13	10:41a				
14	10:42a				
15	10:43a				
16	10:45a				
17	10:46a				
18	10:50a	6"			

Observations:

Joe I

4/13/18	Turb / POC	Column
DOC	13.6	9:11
Influent	17.1	9:13
C01	27.0	9:14
C03	69.5	9:15
C04	48.9	9:17
C05	55.3	9:17
C06	46.0	9:20
C02	63.3	9:36

Round 2

C01	59.8	10:44am
C02	22.5	10:44am
C03	52.3	10:46am
C04	47.8	10:47am
C05	54.0	10:51am
C06	82.8	10:54am
Influent	13.2	10:55am

Round 3

C01	56.9	1:14pm
C02	74.3	1:20pm
C03	84.2	1:21pm
C04	82.4	1:22pm
C05	81.9	1:23pm
C06	122	1:24pm
Influent	18.0	

4/17/18 POC Columns

Sample ID		Turb	Time	pH	temp
COC		13.6	9:47		
TW6		5.51	10:23am	6.10	19°C
C06		11.7	10:24am	6.86	19.2°C
C03		14.5	10:27am	7.01	19.1°C
C04		8.02	10:28am	6.83	19.3°C
C05		6.27	10:30am	7.05	18.9°C
C01		10.5	10:36am	6.95	19.2°C
C02	(Dose 5)	2.27	10:57am	7.26	18.1°C
Round 2 (Dose 4)	TW6	7.95	11:46am	6.04	20.1°C
	C01	13.0	11:56am	6.88	19.4°C
	C02	4.05	12:00pm	7.23	19.3°C
	C03	27.6	11:58am	6.98	19.1°C
	C04	14.9	12:01pm	7.16	19.2°C
	C05	22.8	12:11pm	7.02	19.1°C
	C06	26.1	12:15pm	7.03	19.4°C
Round 3	TW6	6.66	1:27pm	6.40	20.2°C
	C01	20.0	1:42pm	7.13	19.2°C
	C02	21.5	1:38pm	7.30	19.3°C
	C03	57.7	1:32	7.06	19.6°C
	C04	36.4	1:35	7.19	19.5°C
	C05	22.2	1:28	6.90	19.5°C
	C06	61.4	1:25pm	6.90	19.4°C

4/19/18 — for Columns

Sample ID	Turb	Time	pH	Temp
~~COC~~ COC	15.6	10:02	6.99	18.7
CO4	6.46	10:03	7.09	19.3
CO6	7.75	10:06	6.96	18.9
Influent	2.02	10:10	7.63	19.1
CO1	9.75	1029	6.89	19.4
CO6	13.8	1034	7.08	19.2
Influent	1.93	1036	7.77	19.3
CO6	21.8	11:18	6.55	19.1°C
CO4	21.7	11:22	6.93	19.2°C
Influent	2.08	11:24	7.68	18.8°C

5/9/18

	Turb	time	pH	temp
~~Column Effluent~~				
①				
OCV	14.5	10:09	~~3.28~~	22.8 °C
Col	14.0	~~10:14~~ 10:15	7.54	
Influent	16.8	10:10	6.59	22.0 °C
②				
Col	22.0	10:35a	6.84	22.7 °C
Influent	16.0	10:34a	6.08	22°C
Col	24.3	10:54a	6.59	22.3°C
Influent	18.4	10:54a	6.28	22°C

APPENDIX G: WATER QUALITY Data

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04102018-01	PCB 008	pg/L	76.2	18.3	48	NBC,VIL,VJ
CO2-EF-04102018-01	PCB 018/30	pg/L	69.5	28.6	48	NBC
CO2-EF-04102018-01	PCB 020/28	pg/L	90	42.2	48	JA,NBC
CO2-EF-04102018-01	PCB 021/33	pg/L	69.1	44.7	48	NBC
CO2-EF-04102018-01	PCB 031	pg/L	87.8	40.1	48	NBC
CO2-EF-04102018-01	PCB 044/47/65	pg/L	206	38.5	97	NBC,VIU
CO2-EF-04102018-01	PCB 049/69	pg/L	167	35.9	97	NBC,VIU
CO2-EF-04102018-01	PCB 052	pg/L	370	36.1	48	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 056	pg/L		35.5	48	NBC
CO2-EF-04102018-01	PCB 060	pg/L		34.6	48	NBC
CO2-EF-04102018-01	PCB 066	pg/L	67.3	30.5	48	NBC,VIU
CO2-EF-04102018-01	PCB 070/61/74/76	pg/L	131	32.9	193	J,NBC,VIL,VIU,VJ
CO2-EF-04102018-01	PCB 083/99	pg/L	519	23.3	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	209	20.3	193	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 090/101/113	pg/L	424	20.3	193	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 093/95/100	pg/L	362	23.2	193	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 105	pg/L	63.6	27.7	28	NBC,VIU
CO2-EF-04102018-01	PCB 110/115	pg/L	162	18.4	97	NBC
CO2-EF-04102018-01	PCB 118	pg/L	191	25.8	26	NBC,VIL
CO2-EF-04102018-01	PCB 128/166	pg/L	113	14.4	97	JA,NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 129/138/163	pg/L	1440	19.6	193	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 132	pg/L	116	17.8	48	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 135/151/154	pg/L	1050	10.6	97	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 141	pg/L	116	15.1	48	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 147/149	pg/L	670	15.1	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 153/168	pg/L	5360	12.9	97	VIP,NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 156/157	pg/L	62	18	39	NBC,VIU
CO2-EF-04102018-01	PCB 158	pg/L	78.2	11.2	48	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 170	pg/L	525	29.1	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 174	pg/L	163	23.8	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 177	pg/L	262	25.6	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 180/193	pg/L	1960	22.8	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 183/185	pg/L	626	24.3	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 187	pg/L	2270	14.1	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 194	pg/L	734	28.4	48	NBC,VIL,VJ
CO2-EF-04102018-01	PCB 195	pg/L	172	25.9	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 201	pg/L	79.1	14.9	48	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 203	pg/L	317	22.3	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	Total DiCB	pg/L	76.2	18.3	19	NBC,VIL,VJ
CO2-EF-04102018-01	Total HeptaCB	pg/L	5170	14.1	19	NBC,VIL,VJ
CO2-EF-04102018-01	Total HexaCB	pg/L	9000	10.6	19	VIP,NBC,VIL,VJ
CO2-EF-04102018-01	Total MonoCB	pg/L		19.3	19	NBC
CO2-EF-04102018-01	Total NonaCB	pg/L		19.3	19	NBC
CO2-EF-04102018-01	Total OctaCB	pg/L	1300	14.9	19	NBC,VIL,VJ
CO2-EF-04102018-01	Total PCBs	pg/L	19400	10.6	193	VIP,NBC,VIL,VJ
CO2-EF-04102018-01	Total PentaCB	pg/L	1930	18.4	193	NBC,VIL

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04102018-01	Total TetraCB	pg/L	941	30.5	193	NBC,VIL
CO2-EF-04102018-01	Total TriCB	pg/L	316	28.6	48	NBC,VIL
CO3-EF-04102018-01	PCB 008	pg/L	76.3	2.87	49	NBC,VIL,VJ
CO3-EF-04102018-01	PCB 018/30	pg/L	62.3	6.37	49	NBC
CO3-EF-04102018-01	PCB 020/28	pg/L	114	7.02	49	NBC
CO3-EF-04102018-01	PCB 021/33	pg/L	56.1	7	49	NBC
CO3-EF-04102018-01	PCB 031	pg/L	91.5	6.49	49	NBC
CO3-EF-04102018-01	PCB 044/47/65	pg/L	78.7	6.23	98	J,NBC,VIU
CO3-EF-04102018-01	PCB 049/69	pg/L	41.8	5.86	98	J,NBC,VIU
CO3-EF-04102018-01	PCB 052	pg/L	107	6.17	49	NBC,VIL,VIU
CO3-EF-04102018-01	PCB 056	pg/L	23.8	7.96	49	J,JA,NBC
CO3-EF-04102018-01	PCB 060	pg/L	16.8	7.8	49	J,NBC
CO3-EF-04102018-01	PCB 066	pg/L	47.5	4.83	49	J,NBC,VIU
CO3-EF-04102018-01	PCB 070/61/74/76	pg/L	108	5.19	197	J,NBC,VIL,VIU,VJ
CO3-EF-04102018-01	PCB 083/99	pg/L	50.1	4.37	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	63.1	3.83	197	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 090/101/113	pg/L	91.5	3.78	197	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 093/95/100	pg/L	66.3	3	197	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 105	pg/L	37.2	3.04	20	NBC,VIU
CO3-EF-04102018-01	PCB 110/115	pg/L	102	3.49	98	NBC
CO3-EF-04102018-01	PCB 118	pg/L	68.4	2.83	20	NBC,VIL
CO3-EF-04102018-01	PCB 128/166	pg/L	14.6	2.84	98	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 129/138/163	pg/L	133	3.7	197	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 132	pg/L	29.6	3.38	49	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 135/151/154	pg/L	28.9	2.59	98	VRIU,J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 141	pg/L	18.5	2.85	49	VRIU,J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 147/149	pg/L	60.1	2.8	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 153/168	pg/L	92.8	2.44	98	VIP,J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 156/157	pg/L	11.1	8.04	39	J,JA,NBC,VIU
CO3-EF-04102018-01	PCB 158	pg/L	10.3	2.14	49	VRIU,J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 170	pg/L	28.8	5.59	49	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 174	pg/L	25.8	4.2	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 177	pg/L	16.3	4.54	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 180/193	pg/L	81	4.19	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 183/185	pg/L	21.7	4.11	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 187	pg/L	45.1	3.29	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 194	pg/L	36	4.35	49	J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 195	pg/L	11.9	3.71	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 201	pg/L	3.28	1.86	49	VRIU,J,JA,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 203	pg/L	28.2	3.07	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	Total DiCB	pg/L	76.3	2.87	20	NBC,VIL,VJ
CO3-EF-04102018-01	Total HeptaCB	pg/L	197	3.29	20	NBC,VIL,VJ
CO3-EF-04102018-01	Total HexaCB	pg/L	399	2.14	20	VIP,NBC,VIL,VJ
CO3-EF-04102018-01	Total MonoCB	pg/L		19.7	20	NBC
CO3-EF-04102018-01	Total NonaCB	pg/L		19.7	20	NBC
CO3-EF-04102018-01	Total OctaCB	pg/L	79.4	1.86	20	NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO3-EF-04102018-01	Total PCBs	pg/L	2000	1.86	197	VIP,NBC,VIL,VJ
CO3-EF-04102018-01	Total PentaCB	pg/L	479	2.83	197	NBC,VIL
CO3-EF-04102018-01	Total TetraCB	pg/L	424	4.83	197	NBC,VIL
CO3-EF-04102018-01	Total TriCB	pg/L	324	6.37	49	NBC,VIL
CO4-EF-04102018-01	PCB 008	pg/L	104	4.41	48	NBC,VIL,VJ
CO4-EF-04102018-01	PCB 018/30	pg/L	105	8.46	48	NBC
CO4-EF-04102018-01	PCB 020/28	pg/L	162	10.8	48	NBC
CO4-EF-04102018-01	PCB 021/33	pg/L	98.2	10.8	48	NBC
CO4-EF-04102018-01	PCB 031	pg/L	130	9.97	48	NBC
CO4-EF-04102018-01	PCB 044/47/65	pg/L	127	6.12	96	NBC,VIU
CO4-EF-04102018-01	PCB 049/69	pg/L	75.6	5.75	96	J,NBC,VIU
CO4-EF-04102018-01	PCB 052	pg/L	161	6.05	48	NBC,VIL,VIU
CO4-EF-04102018-01	PCB 056	pg/L	44.7	8.87	48	J,JA,NBC
CO4-EF-04102018-01	PCB 060	pg/L	29.9	8.69	48	J,NBC
CO4-EF-04102018-01	PCB 066	pg/L	80.2	4.74	48	NBC,VIU
CO4-EF-04102018-01	PCB 070/61/74/76	pg/L	185	5.09	192	J,NBC,VIL,VIU,VJ
CO4-EF-04102018-01	PCB 083/99	pg/L	84.1	5.33	96	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	130	4.67	192	J,NBC,VIL,VIU
CO4-EF-04102018-01	PCB 090/101/113	pg/L	146	4.61	192	J,NBC,VIL,VIU
CO4-EF-04102018-01	PCB 093/95/100	pg/L	112	5.15	192	J,NBC,VIL,VIU
CO4-EF-04102018-01	PCB 105	pg/L	64.5	8.66	19	NBC,VIU
CO4-EF-04102018-01	PCB 110/115	pg/L	186	4.26	96	NBC
CO4-EF-04102018-01	PCB 118	pg/L	114	8.16	19	NBC,VIL
CO4-EF-04102018-01	PCB 128/166	pg/L	34.1	4.91	96	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 129/138/163	pg/L	226	6.41	192	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 132	pg/L	54.8	5.85	48	NBC,VIL,VIU
CO4-EF-04102018-01	PCB 135/151/154	pg/L	50.3	3.6	96	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 141	pg/L	31.8	4.94	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 147/149	pg/L	104	4.85	96	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 153/168	pg/L	138	4.22	96	VIP,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 156/157	pg/L	28.1	9.81	38	J,NBC,VIU
CO4-EF-04102018-01	PCB 158	pg/L	20.2	3.7	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 170	pg/L	45	8.2	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 174	pg/L	45.6	6.17	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 177	pg/L	24.3	6.65	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 180/193	pg/L	118	6.15	96	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 183/185	pg/L	38.6	6.03	96	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 187	pg/L	65.4	3.19	48	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 194	pg/L	49.5	6.04	48	NBC,VIL,VJ
CO4-EF-04102018-01	PCB 195	pg/L	16.3	5.15	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 201	pg/L	9.17	2.59	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 203	pg/L	34.6	4.26	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	Total DiCB	pg/L	104	4.41	19	NBC,VIL,VJ
CO4-EF-04102018-01	Total HeptaCB	pg/L	298	3.19	19	NBC,VIL,VJ
CO4-EF-04102018-01	Total HexaCB	pg/L	687	3.6	19	VIP,NBC,VIL,VJ
CO4-EF-04102018-01	Total MonoCB	pg/L		19.2	19	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04102018-01	Total NonaCB	pg/L		19.2	19	NBC
CO4-EF-04102018-01	Total OctaCB	pg/L	110	2.59	19	NBC,VIL,VJ
CO4-EF-04102018-01	Total PCBs	pg/L	3270	2.59	192	VIP,NBC,VIL,VJ
CO4-EF-04102018-01	Total PentaCB	pg/L	837	4.26	192	NBC,VIL
CO4-EF-04102018-01	Total TetraCB	pg/L	704	4.74	192	NBC,VIL
CO4-EF-04102018-01	Total TriCB	pg/L	496	8.46	48	NBC,VIL
CO5-EF-04102018-01	PCB 008	pg/L	135	48	48	NBC,VIL,VJ
CO5-EF-04102018-01	PCB 018/30	pg/L	117	97.6	98	JA,NBC
CO5-EF-04102018-01	PCB 020/28	pg/L	206	116	116	NBC
CO5-EF-04102018-01	PCB 021/33	pg/L		116	116	NBC
CO5-EF-04102018-01	PCB 031	pg/L	149	107	107	JA,NBC
CO5-EF-04102018-01	PCB 044/47/65	pg/L	137	80.3	96	NBC,VIU
CO5-EF-04102018-01	PCB 049/69	pg/L	129	75.4	96	NBC,VIU
CO5-EF-04102018-01	PCB 052	pg/L	306	79.4	79	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 056	pg/L		89.9	90	NBC
CO5-EF-04102018-01	PCB 060	pg/L		88	88	NBC
CO5-EF-04102018-01	PCB 066	pg/L		62.2	62	NBC,VIU
CO5-EF-04102018-01	PCB 070/61/74/76	pg/L	139	66.8	191	J,NBC,VIL,VIU,VJ
CO5-EF-04102018-01	PCB 083/99	pg/L		70.6	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L		61.8	191	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 090/101/113	pg/L		61	191	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 093/95/100	pg/L		87.1	191	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 105	pg/L		57.5	58	NBC,VIU
CO5-EF-04102018-01	PCB 110/115	pg/L	121	56.4	96	NBC
CO5-EF-04102018-01	PCB 118	pg/L	78.3	53.8	54	NBC,VIL
CO5-EF-04102018-01	PCB 128/166	pg/L		44	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 129/138/163	pg/L	182	57.4	191	J,NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 132	pg/L		52.4	52	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 135/151/154	pg/L		48.9	96	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 141	pg/L		44.2	48	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 147/149	pg/L	76.7	43.4	96	J,NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 153/168	pg/L	219	37.7	96	VIP,NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 156/157	pg/L		78.7	79	NBC,VIU
CO5-EF-04102018-01	PCB 158	pg/L		33.1	48	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 170	pg/L		129	129	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 174	pg/L		96.7	97	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 177	pg/L		105	105	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 180/193	pg/L	103	96.4	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 183/185	pg/L		94.5	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 187	pg/L	61.8	46	48	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 194	pg/L		106	106	NBC,VIL,VJ
CO5-EF-04102018-01	PCB 195	pg/L		89.9	90	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 201	pg/L		45.1	48	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 203	pg/L		74.4	74	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	Total DiCB	pg/L	135	48	48	NBC,VIL,VJ
CO5-EF-04102018-01	Total HeptaCB	pg/L	165	46	46	NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO5-EF-04102018-01	Total HexaCB	pg/L	478	33.1	33	VIP,NBC,VIL,VJ
CO5-EF-04102018-01	Total MonoCB	pg/L		19.1	19	NBC
CO5-EF-04102018-01	Total NonaCB	pg/L		19.1	19	NBC
CO5-EF-04102018-01	Total OctaCB	pg/L		45.1	45	NBC,VIL,VJ
CO5-EF-04102018-01	Total PCBs	pg/L	2160	33.1	191	VIP,NBC,VIL,VJ
CO5-EF-04102018-01	Total PentaCB	pg/L	199	53.8	191	NBC,VIL
CO5-EF-04102018-01	Total TetraCB	pg/L	711	62.2	191	NBC,VIL
CO5-EF-04102018-01	Total TriCB	pg/L	473	97.6	98	NBC,VIL
CO6-EF-04102018-01	PCB 008	pg/L	99.7	1.26	48	NBC,VIL,VJ
CO6-EF-04102018-01	PCB 018/30	pg/L	125	5.01	48	NBC
CO6-EF-04102018-01	PCB 020/28	pg/L	164	7.93	48	NBC
CO6-EF-04102018-01	PCB 021/33	pg/L	86.3	7.9	48	NBC
CO6-EF-04102018-01	PCB 031	pg/L	130	7.33	48	NBC
CO6-EF-04102018-01	PCB 044/47/65	pg/L	133	3.68	96	NBC,VIU
CO6-EF-04102018-01	PCB 049/69	pg/L	70.8	3.46	96	J,NBC,VIU
CO6-EF-04102018-01	PCB 052	pg/L	169	3.64	48	NBC,VIL,VIU
CO6-EF-04102018-01	PCB 056	pg/L	40.8	7.08	48	J,NBC
CO6-EF-04102018-01	PCB 060	pg/L	24.5	6.93	48	J,NBC
CO6-EF-04102018-01	PCB 066	pg/L	74.2	2.85	48	NBC,VIU
CO6-EF-04102018-01	PCB 070/61/74/76	pg/L	167	3.07	192	J,NBC,VIL,VIU,VJ
CO6-EF-04102018-01	PCB 083/99	pg/L	67.3	2.9	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	102	2.54	192	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 090/101/113	pg/L	135	2.51	192	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 093/95/100	pg/L	113	2.35	192	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 105	pg/L	49.3	4.61	19	NBC,VIU
CO6-EF-04102018-01	PCB 110/115	pg/L	159	2.32	96	NBC
CO6-EF-04102018-01	PCB 118	pg/L	106	4.17	19	NBC,VIL
CO6-EF-04102018-01	PCB 128/166	pg/L	23.3	2.94	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 129/138/163	pg/L	187	3.84	192	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 132	pg/L	45.1	3.5	48	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 135/151/154	pg/L	42	2.57	96	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 141	pg/L	24.2	2.96	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 147/149	pg/L	96.5	2.91	96	NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 153/168	pg/L	115	2.52	96	VIP,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 156/157	pg/L	16.9	5.34	39	J,NBC,VIU
CO6-EF-04102018-01	PCB 158	pg/L	15.3	2.22	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 170	pg/L	35.9	5.28	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 174	pg/L	33.8	3.97	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 177	pg/L	21.2	4.29	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 180/193	pg/L	84.8	3.96	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 183/185	pg/L	27.2	3.88	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 187	pg/L	51.6	2.29	48	NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 194	pg/L	35.8	4.57	48	J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 195	pg/L	14.6	3.9	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 201	pg/L	5.85	1.96	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 203	pg/L	27.3	3.23	48	J,JA,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO6-EF-04102018-01	Total DiCB	pg/L	99.7	1.26	19	NBC,VIL,VJ
CO6-EF-04102018-01	Total HeptaCB	pg/L	227	2.29	19	NBC,VIL,VJ
CO6-EF-04102018-01	Total HexaCB	pg/L	565	2.22	19	VIP,NBC,VIL,VJ
CO6-EF-04102018-01	Total MonoCB	pg/L		19.2	19	NBC
CO6-EF-04102018-01	Total NonaCB	pg/L		19.2	19	NBC
CO6-EF-04102018-01	Total OctaCB	pg/L	83.6	1.96	19	NBC,VIL,VJ
CO6-EF-04102018-01	Total PCBs	pg/L	2920	1.26	192	VIP,NBC,VIL,VJ
CO6-EF-04102018-01	Total PentaCB	pg/L	732	2.32	192	NBC,VIL
CO6-EF-04102018-01	Total TetraCB	pg/L	680	2.85	192	NBC,VIL
CO6-EF-04102018-01	Total TriCB	pg/L	506	5.01	48	NBC,VIL
TW2-IN-04102018-01	PCB 008	pg/L	130	10.7	49	NBC,VIL,VJ
TW2-IN-04102018-01	PCB 018/30	pg/L	218	37.4	49	NBC
TW2-IN-04102018-01	PCB 020/28	pg/L	489	44.4	49	NBC
TW2-IN-04102018-01	PCB 021/33	pg/L	337	47	49	NBC
TW2-IN-04102018-01	PCB 031	pg/L	397	42.2	49	NBC
TW2-IN-04102018-01	PCB 044/47/65	pg/L	545	52.3	98	NBC,VIU
TW2-IN-04102018-01	PCB 049/69	pg/L	275	48.7	98	NBC,VIU
TW2-IN-04102018-01	PCB 052	pg/L	508	49	49	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 056	pg/L	223	32.4	49	NBC
TW2-IN-04102018-01	PCB 060	pg/L	128	31.6	49	NBC
TW2-IN-04102018-01	PCB 066	pg/L	322	41.4	49	NBC,VIU
TW2-IN-04102018-01	PCB 070/61/74/76	pg/L	717	44.7	195	NBC,VIL,VIU,VJ
TW2-IN-04102018-01	PCB 083/99	pg/L	367	27.3	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 086/87/97/109/119/125	pg/L	443	23.8	195	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 090/101/113	pg/L	527	23.8	195	JA,NBC,VIL,VIU
TW2-IN-04102018-01	PCB 093/95/100	pg/L	470	31.8	195	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 105	pg/L	325	21.3	21	NBC,VIU
TW2-IN-04102018-01	PCB 110/115	pg/L	822	21.5	98	NBC
TW2-IN-04102018-01	PCB 118	pg/L	554	19.5	20	NBC,VIL
TW2-IN-04102018-01	PCB 128/166	pg/L	186	23.9	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 129/138/163	pg/L	1690	32.5	195	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 132	pg/L	368	29.6	49	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 135/151/154	pg/L	584	16.6	98	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 141	pg/L	213	25	49	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 147/149	pg/L	963	25.1	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 153/168	pg/L	1710	21.3	98	VIP,NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 156/157	pg/L	145	44.6	45	NBC,VIU
TW2-IN-04102018-01	PCB 158	pg/L	110	18.6	49	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 170	pg/L	540	36.4	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 174	pg/L	608	29.8	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 177	pg/L	361	32	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 180/193	pg/L	1550	28.6	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 183/185	pg/L	529	30.4	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 187	pg/L	1100	17.1	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 194	pg/L	560	35.7	49	NBC,VIL,VJ
TW2-IN-04102018-01	PCB 195	pg/L	192	32.6	49	JA,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04102018-01	PCB 201	pg/L	69.4	18.8	49	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 203	pg/L	365	28	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	Total DiCB	pg/L	130	10.7	20	NBC,VIL,VJ
TW2-IN-04102018-01	Total HeptaCB	pg/L	4160	17.1	20	NBC,VIL,VJ
TW2-IN-04102018-01	Total HexaCB	pg/L	5970	16.6	20	VIP,NBC,VIL,VJ
TW2-IN-04102018-01	Total MonoCB	pg/L		19.5	20	NBC
TW2-IN-04102018-01	Total NonaCB	pg/L		19.5	20	NBC
TW2-IN-04102018-01	Total OctaCB	pg/L	1190	18.8	20	NBC,VIL,VJ
TW2-IN-04102018-01	Total PCBs	pg/L	19600	10.7	195	VIP,NBC,VIL,VJ
TW2-IN-04102018-01	Total PentaCB	pg/L	3510	19.5	195	NBC,VIL
TW2-IN-04102018-01	Total TetraCB	pg/L	2720	31.6	195	NBC,VIL
TW2-IN-04102018-01	Total TriCB	pg/L	1440	37.4	49	NBC,VIL
CO1-EF-04132018-01	PCB 008	pg/L	74.8	2.31	48	NBC,VIL,VJ
CO1-EF-04132018-01	PCB 018/30	pg/L	60.3	5.02	48	NBC
CO1-EF-04132018-01	PCB 020/28	pg/L	84.8	12	48	NBC
CO1-EF-04132018-01	PCB 021/33	pg/L	50.6	12	48	NBC
CO1-EF-04132018-01	PCB 031	pg/L	65.8	11.1	48	NBC
CO1-EF-04132018-01	PCB 044/47/65	pg/L	105	5.15	96	NBC,VIU
CO1-EF-04132018-01	PCB 049/69	pg/L	74.9	4.84	96	J,NBC,VIU
CO1-EF-04132018-01	PCB 052	pg/L	160	5.09	48	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 056	pg/L	38.2	27.4	48	J,NBC
CO1-EF-04132018-01	PCB 060	pg/L		26.8	48	NBC
CO1-EF-04132018-01	PCB 066	pg/L	52.8	3.99	48	NBC,VIU
CO1-EF-04132018-01	PCB 070/61/74/76	pg/L	111	4.28	192	J,NBC,VIL,VIU,VJ
CO1-EF-04132018-01	PCB 083/99	pg/L	531	4.87	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	184	4.26	192	J,NBC,VIL,VIU
CO1-EF-04132018-01	PCB 090/101/113	pg/L	405	4.21	192	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 093/95/100	pg/L	211	3.39	192	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 105	pg/L	82.7	12	19	NBC,VIU
CO1-EF-04132018-01	PCB 110/115	pg/L	147	3.89	96	NBC
CO1-EF-04132018-01	PCB 118	pg/L	277	10.9	19	NBC,VIL
CO1-EF-04132018-01	PCB 128/166	pg/L	224	5.47	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 129/138/163	pg/L	2450	7.14	192	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 132	pg/L	142	6.51	48	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 135/151/154	pg/L	1360	3.39	96	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 141	pg/L	176	5.5	48	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 147/149	pg/L	980	5.4	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 153/168	pg/L	9440	4.69	96	VIP,NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 156/157	pg/L	115	14.9	38	NBC,VIU
CO1-EF-04132018-01	PCB 158	pg/L	125	4.12	48	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 170	pg/L	1160	8.02	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 174	pg/L	308	6.03	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 177	pg/L	520	6.5	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 180/193	pg/L	4090	6.01	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 183/185	pg/L	1250	5.89	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 187	pg/L	4380	3.23	48	NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04132018-01	PCB 194	pg/L	1480	6.25	48	NBC,VIL,VJ
CO1-EF-04132018-01	PCB 195	pg/L	348	5.33	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 201	pg/L	152	2.68	48	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 203	pg/L	622	4.41	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	Total DiCB	pg/L	74.8	2.31	19	NBC,VIL,VJ
CO1-EF-04132018-01	Total HeptaCB	pg/L	10500	3.23	19	NBC,VIL,VJ
CO1-EF-04132018-01	Total HexaCB	pg/L	15000	3.39	19	VIP,NBC,VIL,VJ
CO1-EF-04132018-01	Total MonoCB	pg/L		19.2	19	NBC
CO1-EF-04132018-01	Total NonaCB	pg/L		19.2	19	NBC
CO1-EF-04132018-01	Total OctaCB	pg/L	2610	2.68	19	NBC,VIL,VJ
CO1-EF-04132018-01	Total PCBs	pg/L	32000	2.31	192	VIP,NBC,VIL,VJ
CO1-EF-04132018-01	Total PentaCB	pg/L	1840	3.39	192	NBC,VIL
CO1-EF-04132018-01	Total TetraCB	pg/L	542	3.99	192	NBC,VIL
CO1-EF-04132018-01	Total TriCB	pg/L	261	5.02	48	NBC,VIL
CO2-EF-04132018-01	PCB 008	pg/L	19.4	1.28	48	J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 018/30	pg/L	21.6	3.12	48	J,NBC
CO2-EF-04132018-01	PCB 020/28	pg/L	33.3	3.86	48	J,NBC
CO2-EF-04132018-01	PCB 021/33	pg/L	21.6	3.94	48	J,NBC
CO2-EF-04132018-01	PCB 031	pg/L	28.7	3.6	48	J,NBC
CO2-EF-04132018-01	PCB 044/47/65	pg/L	46.5	2.79	96	J,NBC,VIU
CO2-EF-04132018-01	PCB 049/69	pg/L	24.9	2.65	96	J,NBC,VIU
CO2-EF-04132018-01	PCB 052	pg/L	73.3	2.72	48	NBC,VIL,VIU
CO2-EF-04132018-01	PCB 056	pg/L	8.37	4.63	48	J,NBC
CO2-EF-04132018-01	PCB 060	pg/L	5.01	4.55	48	J,NBC
CO2-EF-04132018-01	PCB 066	pg/L	15	2.26	48	J,NBC,VIU
CO2-EF-04132018-01	PCB 070/61/74/76	pg/L	37.5	2.42	191	J,NBC,VIL,VIU,VJ
CO2-EF-04132018-01	PCB 083/99	pg/L	19.8	2.74	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	28.1	2.39	191	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 090/101/113	pg/L	39.5	2.36	191	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 093/95/100	pg/L	39.8	1.83	191	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 105	pg/L	11.3	3.41	19	J,JA,NBC,VIU
CO2-EF-04132018-01	PCB 110/115	pg/L	39.6	2.17	96	J,NBC
CO2-EF-04132018-01	PCB 118	pg/L	23.1	3.13	19	NBC,VIL
CO2-EF-04132018-01	PCB 128/166	pg/L	8.08	2.45	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 129/138/163	pg/L	69.7	3.24	191	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 132	pg/L	14.9	2.83	48	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 135/151/154	pg/L	19.9	1.26	96	VRIU,J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 141	pg/L	8.4	2.45	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 147/149	pg/L	31.7	2.33	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 153/168	pg/L	60.6	2.07	96	VIP,J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 156/157	pg/L	9.15	5.15	38	J,JA,NBC,VIU
CO2-EF-04132018-01	PCB 158	pg/L	5.91	1.83	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 170	pg/L	18.2	4.4	48	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 174	pg/L	12.8	3.11	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 177	pg/L	9.24	3.44	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 180/193	pg/L	42.4	3.33	96	J,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04132018-01	PCB 183/185	pg/L	16.2	3.24	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 187	pg/L	26.9	1.6	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 194	pg/L	17.5	2.9	48	J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 195	pg/L	6.09	2.5	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 201	pg/L	2.47	1.28	48	VRIU,J,JA,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 203	pg/L	9.22	2.1	48	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	Total DiCB	pg/L	19.4	1.28	19	NBC,VIL,VJ
CO2-EF-04132018-01	Total HeptaCB	pg/L	109	1.6	19	NBC,VIL,VJ
CO2-EF-04132018-01	Total HexaCB	pg/L	228	1.26	19	VIP,NBC,VIL,VJ
CO2-EF-04132018-01	Total MonoCB	pg/L		19.1	19	NBC
CO2-EF-04132018-01	Total NonaCB	pg/L		19.1	19	NBC
CO2-EF-04132018-01	Total OctaCB	pg/L	35.3	1.28	19	NBC,VIL,VJ
CO2-EF-04132018-01	Total PCBs	pg/L	926	1.26	191	VIP,NBC,VIL,VJ
CO2-EF-04132018-01	Total PentaCB	pg/L	201	1.83	191	NBC,VIL
CO2-EF-04132018-01	Total TetraCB	pg/L	211	2.26	191	NBC,VIL
CO2-EF-04132018-01	Total TriCB	pg/L	105	3.12	48	NBC,VIL
CO3-EF-04132018-01	PCB 008	pg/L	40.9	0.85	48	J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 018/30	pg/L	45.7	3.09	48	J,NBC
CO3-EF-04132018-01	PCB 020/28	pg/L	52.3	5.23	48	NBC
CO3-EF-04132018-01	PCB 021/33	pg/L	30.9	5.34	48	J,NBC
CO3-EF-04132018-01	PCB 031	pg/L	46.2	4.88	48	J,NBC
CO3-EF-04132018-01	PCB 044/47/65	pg/L	68	2.8	96	J,NBC,VIU
CO3-EF-04132018-01	PCB 049/69	pg/L	39.8	2.66	96	J,NBC,VIU
CO3-EF-04132018-01	PCB 052	pg/L	108	2.73	48	NBC,VIL,VIU
CO3-EF-04132018-01	PCB 056	pg/L	12.4	4.81	48	J,NBC
CO3-EF-04132018-01	PCB 060	pg/L	8.03	4.72	48	J,NBC
CO3-EF-04132018-01	PCB 066	pg/L	24.9	2.27	48	J,NBC,VIU
CO3-EF-04132018-01	PCB 070/61/74/76	pg/L	56.7	2.43	191	J,NBC,VIL,VIU,VJ
CO3-EF-04132018-01	PCB 083/99	pg/L	62.8	1.89	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	41.9	1.65	191	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 090/101/113	pg/L	70.9	1.63	191	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 093/95/100	pg/L	65.8	2.54	191	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 105	pg/L	17.5	3.94	19	J,JA,NBC,VIU
CO3-EF-04132018-01	PCB 110/115	pg/L	53.2	1.5	96	J,NBC
CO3-EF-04132018-01	PCB 118	pg/L	46.1	3.55	19	NBC,VIL
CO3-EF-04132018-01	PCB 128/166	pg/L	15.2	3.6	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 129/138/163	pg/L	169	4.77	191	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 132	pg/L	20.8	4.16	48	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 135/151/154	pg/L	69.5	1.6	96	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 141	pg/L	17.7	3.6	48	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 147/149	pg/L	59.4	3.43	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 153/168	pg/L	427	3.05	96	VIP,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 156/157	pg/L	11	5.5	38	J,JA,NBC,VIU
CO3-EF-04132018-01	PCB 158	pg/L	9.79	2.69	48	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 170	pg/L	51.1	3.92	48	JA,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 174	pg/L	24.7	2.77	48	J,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO3-EF-04132018-01	PCB 177	pg/L	24.4	3.07	48	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 180/193	pg/L	166	2.96	96	NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 183/185	pg/L	53.5	2.88	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 187	pg/L	166	2.02	48	NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 194	pg/L	48.3	5	48	NBC,VIL,VJ
CO3-EF-04132018-01	PCB 195	pg/L	15.8	4.31	48	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 201	pg/L	6.08	2.21	48	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 203	pg/L	22.3	3.63	48	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	Total DiCB	pg/L	40.9	0.85	19	NBC,VIL,VJ
CO3-EF-04132018-01	Total HeptaCB	pg/L	432	2.02	19	NBC,VIL,VJ
CO3-EF-04132018-01	Total HexaCB	pg/L	799	1.6	19	VIP,NBC,VIL,VJ
CO3-EF-04132018-01	Total MonoCB	pg/L		19.1	19	NBC
CO3-EF-04132018-01	Total NonaCB	pg/L		19.1	19	NBC
CO3-EF-04132018-01	Total OctaCB	pg/L	92.4	2.21	19	NBC,VIL,VJ
CO3-EF-04132018-01	Total PCBs	pg/L	2270	0.85	191	VIP,NBC,VIL,VJ
CO3-EF-04132018-01	Total PentaCB	pg/L	358	1.5	191	NBC,VIL
CO3-EF-04132018-01	Total TetraCB	pg/L	318	2.27	191	NBC,VIL
CO3-EF-04132018-01	Total TriCB	pg/L	175	3.09	48	NBC,VIL
CO4-EF-04132018-01	PCB 008	pg/L	47.3	1.41	50	J,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 018/30	pg/L	65.4	3.95	50	NBC
CO4-EF-04132018-01	PCB 020/28	pg/L	75	4.57	50	NBC
CO4-EF-04132018-01	PCB 021/33	pg/L	42.4	4.67	50	J,NBC
CO4-EF-04132018-01	PCB 031	pg/L	59.7	4.27	50	NBC
CO4-EF-04132018-01	PCB 044/47/65	pg/L	82.9	2.72	101	J,NBC,VIU
CO4-EF-04132018-01	PCB 049/69	pg/L	40.7	2.57	101	J,NBC,VIU
CO4-EF-04132018-01	PCB 052	pg/L	108	2.64	50	NBC,VIL,VIU
CO4-EF-04132018-01	PCB 056	pg/L	18.8	7.34	50	J,NBC
CO4-EF-04132018-01	PCB 060	pg/L	11.4	7.21	50	J,NBC
CO4-EF-04132018-01	PCB 066	pg/L	38	2.2	50	J,NBC,VIU
CO4-EF-04132018-01	PCB 070/61/74/76	pg/L	79.6	2.36	201	J,NBC,VIL,VIU,VJ
CO4-EF-04132018-01	PCB 083/99	pg/L	36.2	4.47	101	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	58.2	3.91	201	J,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 090/101/113	pg/L	78.9	3.86	201	J,JA,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 093/95/100	pg/L	76.2	2.89	201	J,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 105	pg/L	25.4	8.33	20	JA,NBC,VIU
CO4-EF-04132018-01	PCB 110/115	pg/L	88.3	3.55	101	J,NBC
CO4-EF-04132018-01	PCB 118	pg/L	52.6	7.21	20	NBC,VIL
CO4-EF-04132018-01	PCB 128/166	pg/L	15.3	3.12	101	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 129/138/163	pg/L	202	4.13	201	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 132	pg/L	43.2	3.6	50	J,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 135/151/154	pg/L	57	2.64	101	VRIU,J,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 141	pg/L	36	3.12	50	VRIU,J,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 147/149	pg/L	126	2.97	101	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 153/168	pg/L	151	2.64	101	VIP,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 156/157	pg/L	17.2	6.85	40	J,NBC,VIU
CO4-EF-04132018-01	PCB 158	pg/L	15.7	2.33	50	VRIU,J,NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04132018-01	PCB 170	pg/L	66.3	5.84	50	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 174	pg/L	65.4	4.13	50	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 177	pg/L	39	4.57	50	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 180/193	pg/L	166	4.41	101	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 183/185	pg/L	51.6	4.29	101	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 187	pg/L	80.7	2.88	50	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 194	pg/L	41.1	8.32	50	J,JA,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 195	pg/L	19.2	7.16	50	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 201	pg/L	5.22	3.67	50	VRIU,J,JA,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 203	pg/L	32.6	6.03	50	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	Total DiCB	pg/L	47.3	1.41	20	NBC,VIL,VJ
CO4-EF-04132018-01	Total HeptaCB	pg/L	417	2.88	20	NBC,VIL,VJ
CO4-EF-04132018-01	Total HexaCB	pg/L	663	2.33	20	VIP,NBC,VIL,VJ
CO4-EF-04132018-01	Total MonoCB	pg/L		20.1	20	NBC
CO4-EF-04132018-01	Total NonaCB	pg/L		20.1	20	NBC
CO4-EF-04132018-01	Total OctaCB	pg/L	98.1	3.67	20	NBC,VIL,VJ
CO4-EF-04132018-01	Total PCBs	pg/L	2310	1.41	201	VIP,NBC,VIL,VJ
CO4-EF-04132018-01	Total PentaCB	pg/L	416	2.89	201	NBC,VIL
CO4-EF-04132018-01	Total TetraCB	pg/L	379	2.2	201	NBC,VIL
CO4-EF-04132018-01	Total TriCB	pg/L	243	3.95	50	NBC,VIL
CO5-EF-04132018-01	PCB 008	pg/L	32.3	0.6	49	J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 018/30	pg/L	53.6	2.72	49	NBC
CO5-EF-04132018-01	PCB 020/28	pg/L	75.2	2.82	49	NBC
CO5-EF-04132018-01	PCB 021/33	pg/L	38	2.88	49	J,NBC
CO5-EF-04132018-01	PCB 031	pg/L	60.8	2.63	49	NBC
CO5-EF-04132018-01	PCB 044/47/65	pg/L	71.9	1.68	98	J,NBC,VIU
CO5-EF-04132018-01	PCB 049/69	pg/L	39.3	1.59	98	J,NBC,VIU
CO5-EF-04132018-01	PCB 052	pg/L	98	1.63	49	NBC,VIL,VIU
CO5-EF-04132018-01	PCB 056	pg/L	15.5	4.5	49	J,JA,NBC
CO5-EF-04132018-01	PCB 060	pg/L	12.6	4.42	49	J,NBC
CO5-EF-04132018-01	PCB 066	pg/L	37	1.36	49	J,NBC,VIU
CO5-EF-04132018-01	PCB 070/61/74/76	pg/L	82.3	1.45	196	J,NBC,VIL,VIU,VJ
CO5-EF-04132018-01	PCB 083/99	pg/L	58.8	2.74	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	55.3	2.39	196	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 090/101/113	pg/L	82.6	2.36	196	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 093/95/100	pg/L	69.7	1.64	196	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 105	pg/L	27.8	3.43	20	NBC,VIU
CO5-EF-04132018-01	PCB 110/115	pg/L	80.2	2.17	98	J,NBC
CO5-EF-04132018-01	PCB 118	pg/L	61	3.07	20	NBC,VIL
CO5-EF-04132018-01	PCB 128/166	pg/L	22.6	1.78	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 129/138/163	pg/L	215	2.36	196	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 132	pg/L	28.4	2.06	49	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 135/151/154	pg/L	84.6	1.64	98	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 141	pg/L	21.7	1.78	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 147/149	pg/L	93.2	1.7	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 153/168	pg/L	507	1.51	98	VIP,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO5-EF-04132018-01	PCB 156/157	pg/L	13.5	5.87	39	J,NBC,VIU
CO5-EF-04132018-01	PCB 158	pg/L	12.6	1.33	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 170	pg/L	80.7	4.59	49	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 174	pg/L	31.4	3.25	49	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 177	pg/L	33.7	3.59	49	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 180/193	pg/L	252	3.47	98	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 183/185	pg/L	73.2	3.38	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 187	pg/L	221	1.71	49	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 194	pg/L	98.8	6.97	49	NBC,VIL,VJ
CO5-EF-04132018-01	PCB 195	pg/L	24.7	6	49	J,JA,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 201	pg/L	8.22	3.08	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 203	pg/L	45	5.06	49	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	Total DiCB	pg/L	32.3	0.6	20	NBC,VIL,VJ
CO5-EF-04132018-01	Total HeptaCB	pg/L	618	1.71	20	NBC,VIL,VJ
CO5-EF-04132018-01	Total HexaCB	pg/L	999	1.33	20	VIP,NBC,VIL,VJ
CO5-EF-04132018-01	Total MonoCB	pg/L		19.6	20	NBC
CO5-EF-04132018-01	Total NonaCB	pg/L		19.6	20	NBC
CO5-EF-04132018-01	Total OctaCB	pg/L	177	3.08	20	NBC,VIL,VJ
CO5-EF-04132018-01	Total PCBs	pg/L	2920	0.6	196	VIP,NBC,VIL,VJ
CO5-EF-04132018-01	Total PentaCB	pg/L	435	1.64	196	NBC,VIL
CO5-EF-04132018-01	Total TetraCB	pg/L	357	1.36	196	NBC,VIL
CO5-EF-04132018-01	Total TriCB	pg/L	228	2.63	49	NBC,VIL
CO6-EF-04132018-01	PCB 008	pg/L	52.5	1.12	48	NBC,VIL,VJ
CO6-EF-04132018-01	PCB 018/30	pg/L	82.9	3.3	48	NBC
CO6-EF-04132018-01	PCB 020/28	pg/L	105	5.3	48	NBC
CO6-EF-04132018-01	PCB 021/33	pg/L	54.1	5.41	48	NBC
CO6-EF-04132018-01	PCB 031	pg/L	80.7	4.94	48	NBC
CO6-EF-04132018-01	PCB 044/47/65	pg/L	145	3.11	97	NBC,VIU
CO6-EF-04132018-01	PCB 049/69	pg/L	96.4	2.95	97	J,NBC,VIU
CO6-EF-04132018-01	PCB 052	pg/L	264	3.03	48	NBC,VIL,VIU
CO6-EF-04132018-01	PCB 056	pg/L	22.8	4.1	48	J,NBC
CO6-EF-04132018-01	PCB 060	pg/L	14	4.03	48	J,NBC
CO6-EF-04132018-01	PCB 066	pg/L	43.1	2.52	48	J,NBC,VIU
CO6-EF-04132018-01	PCB 070/61/74/76	pg/L	94	2.7	193	J,NBC,VIL,VIU,VJ
CO6-EF-04132018-01	PCB 083/99	pg/L	146	2.94	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	74.2	2.57	193	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 090/101/113	pg/L	157	2.54	193	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 093/95/100	pg/L	175	2.24	193	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 105	pg/L	30.1	5.13	19	NBC,VIU
CO6-EF-04132018-01	PCB 110/115	pg/L	87.3	2.33	97	J,NBC
CO6-EF-04132018-01	PCB 118	pg/L	72.4	4.41	19	NBC,VIL
CO6-EF-04132018-01	PCB 128/166	pg/L	26.6	3.31	97	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 129/138/163	pg/L	284	4.39	193	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 132	pg/L	33.2	3.82	48	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 135/151/154	pg/L	221	1.5	97	VRIU,NBC,VIL,VJ
CO6-EF-04132018-01	PCB 141	pg/L	28.2	3.32	48	VRIU,J,NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO6-EF-04132018-01	PCB 147/149	pg/L	157	3.15	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 153/168	pg/L	926	2.81	97	VIP,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 156/157	pg/L	17.7	5.92	39	J,NBC,VIU
CO6-EF-04132018-01	PCB 158	pg/L	16.6	2.48	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04132018-01	PCB 170	pg/L	93	4.17	48	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 174	pg/L	36.3	2.95	48	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 177	pg/L	45.7	3.26	48	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 180/193	pg/L	328	3.15	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 183/185	pg/L	104	3.06	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 187	pg/L	357	1.75	48	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 194	pg/L	113	5.23	48	NBC,VIL,VJ
CO6-EF-04132018-01	PCB 195	pg/L	28.4	4.5	48	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 201	pg/L	13.9	2.31	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04132018-01	PCB 203	pg/L	51.9	3.79	48	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	Total DiCB	pg/L	52.5	1.12	19	NBC,VIL,VJ
CO6-EF-04132018-01	Total HeptaCB	pg/L	859	1.75	19	NBC,VIL,VJ
CO6-EF-04132018-01	Total HexaCB	pg/L	1710	1.5	19	VIP,NBC,VIL,VJ
CO6-EF-04132018-01	Total MonoCB	pg/L		19.3	19	NBC
CO6-EF-04132018-01	Total NonaCB	pg/L		19.3	19	NBC
CO6-EF-04132018-01	Total OctaCB	pg/L	207	2.31	19	NBC,VIL,VJ
CO6-EF-04132018-01	Total PCBs	pg/L	4680	1.12	193	VIP,NBC,VIL,VJ
CO6-EF-04132018-01	Total PentaCB	pg/L	742	2.24	193	NBC,VIL
CO6-EF-04132018-01	Total TetraCB	pg/L	680	2.52	193	NBC,VIL
CO6-EF-04132018-01	Total TriCB	pg/L	323	3.3	48	NBC,VIL
TW2-IN-04132018-01	PCB 008	pg/L	81.6	1.5	48	NBC,VIL,VJ
TW2-IN-04132018-01	PCB 018/30	pg/L	111	3.77	48	NBC
TW2-IN-04132018-01	PCB 020/28	pg/L	311	7.05	48	NBC
TW2-IN-04132018-01	PCB 021/33	pg/L	214	7.23	48	NBC
TW2-IN-04132018-01	PCB 031	pg/L	252	6.63	48	NBC
TW2-IN-04132018-01	PCB 044/47/65	pg/L	340	9.11	96	NBC,VIU
TW2-IN-04132018-01	PCB 049/69	pg/L	173	8.61	96	NBC,VIU
TW2-IN-04132018-01	PCB 052	pg/L	330	8.88	48	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 056	pg/L	167	3.54	48	NBC
TW2-IN-04132018-01	PCB 060	pg/L	92.1	3.37	48	NBC
TW2-IN-04132018-01	PCB 066	pg/L	302	7.66	48	NBC,VIU
TW2-IN-04132018-01	PCB 070/61/74/76	pg/L	664	8.02	192	NBC,VIL,VIU,VJ
TW2-IN-04132018-01	PCB 083/99	pg/L	351	4.32	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 086/87/97/109/119/125	pg/L	529	3.77	192	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 090/101/113	pg/L	641	3.75	192	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 093/95/100	pg/L	401	4.01	192	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 105	pg/L	356	3.83	19	NBC,VIU
TW2-IN-04132018-01	PCB 110/115	pg/L	906	3.42	96	NBC
TW2-IN-04132018-01	PCB 118	pg/L	728	3.52	19	NBC,VIL
TW2-IN-04132018-01	PCB 128/166	pg/L	219	2.04	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 129/138/163	pg/L	2070	2.81	192	VIP,NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 132	pg/L	388	2.49	48	NBC,VIL,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04132018-01	PCB 135/151/154	pg/L	445	1.95	96	VRIU,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 141	pg/L	256	2.15	48	VRIU,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 147/149	pg/L	860	2.12	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 153/168	pg/L	2170	1.82	96	VIP,NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 156/157	pg/L	175	6.64	38	NBC,VIU
TW2-IN-04132018-01	PCB 158	pg/L	142	1.57	48	VRIU,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 170	pg/L	548	3.84	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 174	pg/L	380	3.19	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 177	pg/L	271	3.44	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 180/193	pg/L	1490	3.02	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 183/185	pg/L	434	3.3	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 187	pg/L	1030	1.76	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 194	pg/L	367	3.01	48	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 195	pg/L	107	3.16	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 201	pg/L	46.2	2.03	48	VRIU,J,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 203	pg/L	227	2.87	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	Total DiCB	pg/L	81.6	1.5	19	NBC,VIL,VJ
TW2-IN-04132018-01	Total HeptaCB	pg/L	3720	1.76	19	NBC,VIL,VJ
TW2-IN-04132018-01	Total HexaCB	pg/L	6720	1.57	19	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	Total MonoCB	pg/L		19.2	19	NBC
TW2-IN-04132018-01	Total NonaCB	pg/L		19.2	19	NBC
TW2-IN-04132018-01	Total OctaCB	pg/L	747	2.03	19	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	Total PCBs	pg/L	18600	1.5	192	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	Total PentaCB	pg/L	3910	3.42	192	NBC,VIL
TW2-IN-04132018-01	Total TetraCB	pg/L	2070	3.37	192	NBC,VIL
TW2-IN-04132018-01	Total TriCB	pg/L	889	3.77	48	NBC,VIL
BLNK-EF-04172018-01	PCB 008	pg/L	13.7	1.82	48	J,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 018/30	pg/L	10.7	5.11	48	J,JA,NBC
BLNK-EF-04172018-01	PCB 020/28	pg/L	17.4	6.17	48	J,NBC
BLNK-EF-04172018-01	PCB 021/33	pg/L	12.8	6.3	48	J,NBC
BLNK-EF-04172018-01	PCB 031	pg/L	14.9	5.76	48	J,NBC
BLNK-EF-04172018-01	PCB 044/47/65	pg/L	37.3	4.52	95	J,NBC,VIU
BLNK-EF-04172018-01	PCB 049/69	pg/L	14.7	4.28	95	J,NBC,VIU
BLNK-EF-04172018-01	PCB 052	pg/L	52.6	4.39	48	NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 056	pg/L		4.76	48	NBC
BLNK-EF-04172018-01	PCB 060	pg/L		4.68	48	NBC
BLNK-EF-04172018-01	PCB 066	pg/L	5.97	3.65	48	J,JA,NBC,VIU
BLNK-EF-04172018-01	PCB 070/61/74/76	pg/L	14.9	3.92	190	J,NBC,VIL,VIU,VJ
BLNK-EF-04172018-01	PCB 083/99	pg/L	10.9	6.88	95	J,JA,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L		6.01	190	NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 090/101/113	pg/L	22.7	5.93	190	J,NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 093/95/100	pg/L	26.9	5.98	190	J,NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 105	pg/L		5.78	19	NBC,VIU
BLNK-EF-04172018-01	PCB 110/115	pg/L	13.8	5.45	95	J,JA,NBC
BLNK-EF-04172018-01	PCB 118	pg/L		5.31	19	NBC,VIL
BLNK-EF-04172018-01	PCB 128/166	pg/L		5.28	95	NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
BLNK-EF-04172018-01	PCB 129/138/163	pg/L	17.1	6.99	190	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 132	pg/L		6.08	48	NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 135/151/154	pg/L	10.1	3.04	95	VRIU,J,JA,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 141	pg/L		5.28	48	VRIU,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 147/149	pg/L	13.6	5.02	95	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 153/168	pg/L	20.6	4.47	95	IP,J,JA,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 156/157	pg/L		6.97	38	NBC,VIU
BLNK-EF-04172018-01	PCB 158	pg/L		3.94	48	VRIU,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 170	pg/L		8.48	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 174	pg/L		5.99	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 177	pg/L		6.63	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 180/193	pg/L	13.7	6.41	95	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 183/185	pg/L		6.23	95	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 187	pg/L	8.14	4.81	48	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 194	pg/L		8.64	48	NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 195	pg/L		7.44	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 201	pg/L		3.81	48	VRIU,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 203	pg/L		6.26	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	Total DiCB	pg/L	13.7	1.82	19	J,NBC,VIL,VJ
BLNK-EF-04172018-01	Total HeptaCB	pg/L	21.9	4.81	19	NBC,VIL,VJ
BLNK-EF-04172018-01	Total HexaCB	pg/L	61.4	3.04	19	VIP,NBC,VIL,VJ
BLNK-EF-04172018-01	Total MonoCB	pg/L		19	19	NBC
BLNK-EF-04172018-01	Total NonaCB	pg/L		19	19	NBC
BLNK-EF-04172018-01	Total OctaCB	pg/L		3.81	19	NBC,VIL,VJ
BLNK-EF-04172018-01	Total PCBs	pg/L	353	1.82	190	VIP,NBC,VIL,VJ
BLNK-EF-04172018-01	Total PentaCB	pg/L	74.4	5.31	190	J,NBC,VIL
BLNK-EF-04172018-01	Total TetraCB	pg/L	126	3.65	190	J,NBC,VIL
BLNK-EF-04172018-01	Total TriCB	pg/L	55.7	5.11	48	NBC,VIL
CO1-EF-04172018-01	PCB 008	pg/L		61.9	62	NBC,VIL,VJ
CO1-EF-04172018-01	PCB 018/30	pg/L		84.4	84	NBC
CO1-EF-04172018-01	PCB 020/28	pg/L		103	103	NBC
CO1-EF-04172018-01	PCB 021/33	pg/L		106	106	NBC
CO1-EF-04172018-01	PCB 031	pg/L		96.5	97	NBC
CO1-EF-04172018-01	PCB 044/47/65	pg/L		96.1	99	NBC,VIU
CO1-EF-04172018-01	PCB 049/69	pg/L		90.9	99	NBC,VIU
CO1-EF-04172018-01	PCB 052	pg/L		93.7	94	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 056	pg/L		44.9	50	NBC
CO1-EF-04172018-01	PCB 060	pg/L		42.7	50	NBC
CO1-EF-04172018-01	PCB 066	pg/L		80.8	81	NBC,VIU
CO1-EF-04172018-01	PCB 070/61/74/76	pg/L		84.6	199	NBC,VIL,VIU,VJ
CO1-EF-04172018-01	PCB 083/99	pg/L		32.4	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L		28.3	199	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 090/101/113	pg/L	47.8	28.1	199	J,NBC,VIL,VIU
CO1-EF-04172018-01	PCB 093/95/100	pg/L		40.1	199	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 105	pg/L		23	23	NBC,VIU
CO1-EF-04172018-01	PCB 110/115	pg/L	49.6	25.7	99	J,NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04172018-01	PCB 118	pg/L		24.1	24	NBC,VIL
CO1-EF-04172018-01	PCB 128/166	pg/L		14.8	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 129/138/163	pg/L	95.2	20.3	199	IP,J,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 132	pg/L		18	50	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 135/151/154	pg/L		15.2	99	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 141	pg/L		15.5	50	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 147/149	pg/L		15.3	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 153/168	pg/L	92	13.2	99	IP,J,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 156/157	pg/L		26.3	40	NBC,VIU
CO1-EF-04172018-01	PCB 158	pg/L		11.4	50	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 170	pg/L		38.5	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 174	pg/L		31.9	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 177	pg/L		34.5	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 180/193	pg/L	61.2	30.3	99	J,JA,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 183/185	pg/L		33	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 187	pg/L	36.9	16.1	50	J,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 194	pg/L		22.2	50	VRIP,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 195	pg/L		23.4	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 201	pg/L		15	50	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 203	pg/L		21.2	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	Total DiCB	pg/L		61.9	62	NBC,VIL,VJ
CO1-EF-04172018-01	Total HeptaCB	pg/L	98.1	16.1	20	NBC,VIL,VJ
CO1-EF-04172018-01	Total HexaCB	pg/L	187	11.4	20	VIP,NBC,VIL,VJ
CO1-EF-04172018-01	Total MonoCB	pg/L		19.9	20	NBC
CO1-EF-04172018-01	Total NonaCB	pg/L		19.9	20	NBC
CO1-EF-04172018-01	Total OctaCB	pg/L		15	20	VRIP,NBC,VIL,VJ
CO1-EF-04172018-01	Total PCBs	pg/L	383	11.4	199	VIP,NBC,VIL,VJ
CO1-EF-04172018-01	Total PentaCB	pg/L	97.4	23	199	J,NBC,VIL
CO1-EF-04172018-01	Total TetraCB	pg/L		42.7	199	NBC,VIL
CO1-EF-04172018-01	Total TriCB	pg/L		84.4	84	NBC,VIL
CO2-EF-04172018-01	PCB 008	pg/L	35.5	3.22	48	J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 008	pg/L	10.9	1.78	49	J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 018/30	pg/L	14.9	5.25	48	J,NBC
CO2-EF-04172018-D	PCB 018/30	pg/L	9.84	5.62	49	J,NBC
CO2-EF-04172018-01	PCB 020/28	pg/L	20	13.2	48	J,JA,NBC
CO2-EF-04172018-D	PCB 020/28	pg/L	15.6	8.61	49	J,NBC
CO2-EF-04172018-01	PCB 021/33	pg/L		13.5	48	NBC
CO2-EF-04172018-D	PCB 021/33	pg/L		8.54	49	NBC
CO2-EF-04172018-01	PCB 031	pg/L	14.4	12.4	48	J,NBC
CO2-EF-04172018-D	PCB 031	pg/L		8.22	49	NBC
CO2-EF-04172018-01	PCB 044/47/65	pg/L	34.6	8.19	96	J,NBC,VIU
CO2-EF-04172018-D	PCB 044/47/65	pg/L	27.7	6.27	98	J,NBC,VIU
CO2-EF-04172018-01	PCB 049/69	pg/L	20.2	7.75	96	J,JA,NBC,VIU
CO2-EF-04172018-D	PCB 049/69	pg/L	9.7	6.09	98	J,NBC,VIU
CO2-EF-04172018-01	PCB 052	pg/L	38.7	7.98	48	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 052	pg/L	20	6.72	49	J,NBC,VIL,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04172018-01	PCB 056	pg/L		17.3	48	NBC
CO2-EF-04172018-D	PCB 056	pg/L		4.36	49	NBC
CO2-EF-04172018-01	PCB 060	pg/L		16.5	48	NBC
CO2-EF-04172018-D	PCB 060	pg/L		4.03	49	NBC
CO2-EF-04172018-01	PCB 066	pg/L	15.4	6.89	48	J,NBC,VIU
CO2-EF-04172018-D	PCB 066	pg/L	7.41	4.39	49	J,NBC,VIU
CO2-EF-04172018-01	PCB 070/61/74/76	pg/L	32.3	7.21	192	J,NBC,VIL,VIU,VJ
CO2-EF-04172018-D	PCB 070/61/74/76	pg/L	18.2	4.76	195	J,JA,NBC,VIL,VIU,VJ
CO2-EF-04172018-01	PCB 083/99	pg/L	73.6	4.1	96	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 083/99	pg/L	11.3	3.35	98	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	38.1	3.58	192	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 086/87/97/109/119/125	pg/L	22.2	2.87	195	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 090/101/113	pg/L	60.7	3.56	192	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 090/101/113	pg/L	22.1	2.95	195	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 093/95/100	pg/L	44.5	3.08	192	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 093/95/100	pg/L	15.9	3.61	195	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 105	pg/L		12.7	19	NBC,VIU
CO2-EF-04172018-D	PCB 105	pg/L	7.29	4.52	20	J,JA,NBC,VIU
CO2-EF-04172018-01	PCB 110/115	pg/L	34	3.25	96	J,NBC
CO2-EF-04172018-D	PCB 110/115	pg/L	25.8	2.55	98	J,NBC
CO2-EF-04172018-01	PCB 118	pg/L	42.7	12	19	NBC,VIL
CO2-EF-04172018-D	PCB 118	pg/L	14.8	4.15	20	J,NBC,VIL
CO2-EF-04172018-01	PCB 128/166	pg/L	33	2.49	96	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 128/166	pg/L	5.12	1.81	98	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 129/138/163	pg/L	367	3.43	192	VIP,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 129/138/163	pg/L	36.1	2.6	195	IP,J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 132	pg/L	22.5	3.04	48	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 132	pg/L	10.2	2.43	49	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 135/151/154	pg/L	149	2.25	96	VRIU,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 135/151/154	pg/L	11.8	2.28	98	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 141	pg/L	30.6	2.62	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 141	pg/L	5.88	1.98	49	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 147/149	pg/L	120	2.59	96	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 147/149	pg/L	20.5	2.13	98	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 153/168	pg/L	1190	2.22	96	VIP,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 153/168	pg/L	24	1.71	98	VRIP,IP,J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 156/157	pg/L	19.1	8.29	38	J,NBC,VIU
CO2-EF-04172018-D	PCB 156/157	pg/L	5.08	3.9	39	J,JA,NBC,VIU
CO2-EF-04172018-01	PCB 158	pg/L	19.8	1.92	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 158	pg/L	3.24	1.4	49	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 170	pg/L	185	3.98	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 170	pg/L	6.79	3.44	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 174	pg/L	48.3	3.3	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 174	pg/L	7.59	3.29	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 177	pg/L	78	3.57	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 177	pg/L	4.44	3.32	49	J,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04172018-01	PCB 180/193	pg/L	608	3.13	96	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 180/193	pg/L	17.2	2.84	98	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 183/185	pg/L	174	3.42	96	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 183/185	pg/L	7.22	3.3	98	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 187	pg/L	585	2.28	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 187	pg/L	9.87	2.25	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 194	pg/L	203	2.9	48	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 194	pg/L	5.75	2.75	49	VRIP,IP,J,JA,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 195	pg/L	51.3	3.04	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 195	pg/L	3.92	2.79	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 201	pg/L	20.8	1.95	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 201	pg/L		1.99	49	VRIU,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 203	pg/L	87.7	2.76	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 203	pg/L	5.23	2.57	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	Total DiCB	pg/L	35.5	3.22	19	NBC,VIL,VJ
CO2-EF-04172018-D	Total DiCB	pg/L	10.9	1.78	20	J,NBC,VIL,VJ
CO2-EF-04172018-01	Total HeptaCB	pg/L	1500	2.28	19	NBC,VIL,VJ
CO2-EF-04172018-D	Total HeptaCB	pg/L	45.9	2.25	20	NBC,VIL,VJ
CO2-EF-04172018-01	Total HexaCB	pg/L	1950	1.92	19	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	Total HexaCB	pg/L	122	1.4	20	VIP,NBC,VIL,VJ
CO2-EF-04172018-01	Total MonoCB	pg/L		19.2	19	NBC
CO2-EF-04172018-D	Total MonoCB	pg/L		19.5	20	NBC
CO2-EF-04172018-01	Total NonaCB	pg/L		19.2	19	NBC
CO2-EF-04172018-D	Total NonaCB	pg/L		19.5	20	NBC
CO2-EF-04172018-01	Total OctaCB	pg/L	362	1.95	19	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	Total OctaCB	pg/L	14.9	1.99	20	VRIP,J,NBC,VIL,VJ
CO2-EF-04172018-01	Total PCBs	pg/L	4510	1.92	192	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	Total PCBs	pg/L	429	1.4	195	VIP,NBC,VIL,VJ
CO2-EF-04172018-01	Total PentaCB	pg/L	294	3.08	192	NBC,VIL
CO2-EF-04172018-D	Total PentaCB	pg/L	119	2.55	195	J,NBC,VIL
CO2-EF-04172018-01	Total TetraCB	pg/L	141	6.89	192	J,NBC,VIL
CO2-EF-04172018-D	Total TetraCB	pg/L	83	4.03	195	J,NBC,VIL
CO2-EF-04172018-01	Total TriCB	pg/L	49.3	5.25	48	NBC,VIL
CO2-EF-04172018-D	Total TriCB	pg/L	25.4	5.62	49	J,NBC,VIL
CO3-EF-04172018-01	PCB 008	pg/L		25.7	48	NBC,VIL,VJ
CO3-EF-04172018-01	PCB 018/30	pg/L		42.9	48	NBC
CO3-EF-04172018-01	PCB 020/28	pg/L		54.9	55	NBC
CO3-EF-04172018-01	PCB 021/33	pg/L		56.4	56	NBC
CO3-EF-04172018-01	PCB 031	pg/L		51.6	52	NBC
CO3-EF-04172018-01	PCB 044/47/65	pg/L		53.2	97	NBC,VIU
CO3-EF-04172018-01	PCB 049/69	pg/L		50.4	97	NBC,VIU
CO3-EF-04172018-01	PCB 052	pg/L		51.9	52	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 056	pg/L		26.5	48	NBC
CO3-EF-04172018-01	PCB 060	pg/L		25.2	48	NBC
CO3-EF-04172018-01	PCB 066	pg/L		44.8	48	NBC,VIU
CO3-EF-04172018-01	PCB 070/61/74/76	pg/L		46.9	194	NBC,VIL,VIU,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO3-EF-04172018-01	PCB 083/99	pg/L		15.9	97	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L		13.9	194	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 090/101/113	pg/L	37.1	13.8	194	J,JA,NBC,VIL,VIU
CO3-EF-04172018-01	PCB 093/95/100	pg/L		23.4	194	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 105	pg/L		16.9	19	NBC,VIU
CO3-EF-04172018-01	PCB 110/115	pg/L	54.1	12.6	97	J,NBC
CO3-EF-04172018-01	PCB 118	pg/L	38.7	17	19	NBC,VIL
CO3-EF-04172018-01	PCB 128/166	pg/L		8.58	97	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 129/138/163	pg/L	69.9	11.9	194	IP,J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 132	pg/L		10.5	48	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 135/151/154	pg/L	15.1	8.16	97	VRIU,J,JA,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 141	pg/L		9.02	48	VRIU,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 147/149	pg/L	17.9	8.91	97	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 153/168	pg/L	41.4	7.65	97	IP,J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 156/157	pg/L		11.9	39	NBC,VIU
CO3-EF-04172018-01	PCB 158	pg/L		6.6	48	VRIU,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 170	pg/L	26	16	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 174	pg/L	17.5	13.2	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 177	pg/L		14.3	48	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 180/193	pg/L	48.9	12.6	97	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 183/185	pg/L		13.7	97	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 187	pg/L	19.4	8.47	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 194	pg/L	15.4	7.39	48	VRIP,IP,J,JA,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 195	pg/L		7.77	48	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 201	pg/L		4.98	48	VRIU,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 203	pg/L	10	7.05	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	Total DiCB	pg/L		25.7	26	NBC,VIL,VJ
CO3-EF-04172018-01	Total HeptaCB	pg/L	112	8.47	19	NBC,VIL,VJ
CO3-EF-04172018-01	Total HexaCB	pg/L	144	6.6	19	VIP,NBC,VIL,VJ
CO3-EF-04172018-01	Total MonoCB	pg/L		19.4	19	NBC
CO3-EF-04172018-01	Total NonaCB	pg/L		19.4	19	NBC
CO3-EF-04172018-01	Total OctaCB	pg/L	25.4	4.98	19	VRIP,NBC,VIL,VJ
CO3-EF-04172018-01	Total PCBs	pg/L	411	4.98	194	VIP,NBC,VIL,VJ
CO3-EF-04172018-01	Total PentaCB	pg/L	130	12.6	194	J,NBC,VIL
CO3-EF-04172018-01	Total TetraCB	pg/L		25.2	194	NBC,VIL
CO3-EF-04172018-01	Total TriCB	pg/L		42.9	48	NBC,VIL
CO4-EF-04172018-01	PCB 008	pg/L	27.9	2.36	48	J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 018/30	pg/L	35.8	5.41	48	J,NBC
CO4-EF-04172018-01	PCB 020/28	pg/L	34.3	7.76	48	J,NBC
CO4-EF-04172018-01	PCB 021/33	pg/L	19.5	7.96	48	J,NBC
CO4-EF-04172018-01	PCB 031	pg/L	27.9	7.29	48	J,NBC
CO4-EF-04172018-01	PCB 044/47/65	pg/L	37.8	8.16	97	J,NBC,VIU
CO4-EF-04172018-01	PCB 049/69	pg/L	16.9	7.72	97	J,NBC,VIU
CO4-EF-04172018-01	PCB 052	pg/L	33.8	7.96	48	J,JA,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 056	pg/L	12.1	6.33	48	J,NBC
CO4-EF-04172018-01	PCB 060	pg/L		6.02	48	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04172018-01	PCB 066	pg/L	19.7	6.86	48	J,NBC,VIU
CO4-EF-04172018-01	PCB 070/61/74/76	pg/L	43.3	7.19	193	J,NBC,VIL,VIU,VJ
CO4-EF-04172018-01	PCB 083/99	pg/L	17.8	2.99	97	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	31.6	2.61	193	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 090/101/113	pg/L	38.5	2.59	193	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 093/95/100	pg/L	29.1	4.92	193	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 105	pg/L	16	4.73	19	J,NBC,VIU
CO4-EF-04172018-01	PCB 110/115	pg/L	49.7	2.37	97	J,NBC
CO4-EF-04172018-01	PCB 118	pg/L	29.7	4.35	19	NBC,VIL
CO4-EF-04172018-01	PCB 128/166	pg/L	6.79	3.24	97	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 129/138/163	pg/L	63.2	4.46	193	IP,J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 132	pg/L	14	3.95	48	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 135/151/154	pg/L	15.2	2.51	97	VRIU,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 141	pg/L	8.6	3.4	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 147/149	pg/L	31.1	3.36	97	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 153/168	pg/L	51.6	2.89	97	IP,J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 156/157	pg/L	7.15	6.26	39	J,NBC,VIU
CO4-EF-04172018-01	PCB 158	pg/L	4.99	2.49	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 170	pg/L	11.9	4.86	48	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 174	pg/L	10.8	4.03	48	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 177	pg/L	6.01	4.35	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 180/193	pg/L	33.1	3.82	97	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 183/185	pg/L	12.6	4.17	97	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 187	pg/L	23.7	3.17	48	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 194	pg/L	10.6	3.59	48	VRIP,IP,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 195	pg/L		3.77	48	NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 201	pg/L		2.42	48	VRIU,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 203	pg/L	6.36	3.42	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	Total DiCB	pg/L	27.9	2.36	19	NBC,VIL,VJ
CO4-EF-04172018-01	Total HeptaCB	pg/L	85.6	3.17	19	NBC,VIL,VJ
CO4-EF-04172018-01	Total HexaCB	pg/L	203	2.49	19	VIP,NBC,VIL,VJ
CO4-EF-04172018-01	Total MonoCB	pg/L		19.3	19	NBC
CO4-EF-04172018-01	Total NonaCB	pg/L		19.3	19	NBC
CO4-EF-04172018-01	Total OctaCB	pg/L	16.9	2.42	19	VRIP,J,NBC,VIL,VJ
CO4-EF-04172018-01	Total PCBs	pg/L	839	2.36	193	VIP,NBC,VIL,VJ
CO4-EF-04172018-01	Total PentaCB	pg/L	212	2.37	193	NBC,VIL
CO4-EF-04172018-01	Total TetraCB	pg/L	164	6.02	193	J,NBC,VIL
CO4-EF-04172018-01	Total TriCB	pg/L	117	5.41	48	NBC,VIL
CO5-EF-04172018-01	PCB 008	pg/L	19.6	1.35	49	J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 018/30	pg/L	27.1	2.91	49	J,NBC
CO5-EF-04172018-01	PCB 020/28	pg/L	33.9	3.59	49	J,NBC
CO5-EF-04172018-01	PCB 021/33	pg/L	16	3.69	49	J,JA,NBC
CO5-EF-04172018-01	PCB 031	pg/L	24.3	3.38	49	J,NBC
CO5-EF-04172018-01	PCB 044/47/65	pg/L	30.5	5.41	98	J,NBC,VIU
CO5-EF-04172018-01	PCB 049/69	pg/L	14.2	5.12	98	J,NBC,VIU
CO5-EF-04172018-01	PCB 052	pg/L	29.9	5.28	49	J,NBC,VIL,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO5-EF-04172018-01	PCB 056	pg/L	8.04	5	49	J,NBC
CO5-EF-04172018-01	PCB 060	pg/L		4.76	49	NBC
CO5-EF-04172018-01	PCB 066	pg/L	15.1	4.55	49	J,NBC,VIU
CO5-EF-04172018-01	PCB 070/61/74/76	pg/L	33.1	4.76	197	J,NBC,VIL,VIU,VJ
CO5-EF-04172018-01	PCB 083/99	pg/L	13.6	2.87	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	23.9	2.51	197	J,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 090/101/113	pg/L	28.1	2.49	197	J,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 093/95/100	pg/L	19.9	2.66	197	J,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 105	pg/L	11.6	4.63	20	J,NBC,VIU
CO5-EF-04172018-01	PCB 110/115	pg/L	30.8	2.28	98	J,NBC
CO5-EF-04172018-01	PCB 118	pg/L	20.6	4.24	20	JA,NBC,VIL
CO5-EF-04172018-01	PCB 128/166	pg/L	5.1	2.12	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 129/138/163	pg/L	38.2	2.92	197	IP,J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 132	pg/L	8.85	2.58	49	J,JA,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 135/151/154	pg/L	7.19	1.59	98	VRIU,J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 141	pg/L	4.64	2.23	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 147/149	pg/L	20	2.2	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 153/168	pg/L	24.8	1.89	98	VRIP,IP,J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 156/157	pg/L	4.32	3.83	39	J,NBC,VIU
CO5-EF-04172018-01	PCB 158	pg/L	2.76	1.63	49	VRIU,J,JA,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 170	pg/L	6.83	2.82	49	J,JA,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 174	pg/L	7.9	2.34	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 177	pg/L	4.04	2.52	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 180/193	pg/L	20.6	2.22	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 183/185	pg/L	7.29	2.42	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 187	pg/L	12	1.63	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 194	pg/L	6.34	2.15	49	VRIP,IP,J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 195	pg/L		2.25	49	NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 201	pg/L		1.45	49	VRIU,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 203	pg/L	5.01	2.05	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	Total DiCB	pg/L	19.6	1.35	20	J,NBC,VIL,VJ
CO5-EF-04172018-01	Total HeptaCB	pg/L	51.4	1.63	20	NBC,VIL,VJ
CO5-EF-04172018-01	Total HexaCB	pg/L	116	1.59	20	VIP,NBC,VIL,VJ
CO5-EF-04172018-01	Total MonoCB	pg/L		19.7	20	NBC
CO5-EF-04172018-01	Total NonaCB	pg/L		19.7	20	NBC
CO5-EF-04172018-01	Total OctaCB	pg/L	11.3	1.45	20	VRIP,J,NBC,VIL,VJ
CO5-EF-04172018-01	Total PCBs	pg/L	586	1.35	197	VIP,NBC,VIL,VJ
CO5-EF-04172018-01	Total PentaCB	pg/L	149	2.28	197	J,NBC,VIL
CO5-EF-04172018-01	Total TetraCB	pg/L	131	4.55	197	J,NBC,VIL
CO5-EF-04172018-01	Total TriCB	pg/L	101	2.91	49	NBC,VIL
CO6-EF-04172018-01	PCB 008	pg/L	43.7	3.44	48	J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 018/30	pg/L	49.8	7.74	48	NBC
CO6-EF-04172018-01	PCB 020/28	pg/L	48.2	11.1	48	NBC
CO6-EF-04172018-01	PCB 021/33	pg/L	27.8	11.4	48	J,NBC
CO6-EF-04172018-01	PCB 031	pg/L	37.8	10.5	48	J,NBC
CO6-EF-04172018-01	PCB 044/47/65	pg/L	47.9	13.9	96	J,NBC,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO6-EF-04172018-01	PCB 049/69	pg/L	20.2	13.2	96	J,JA,NBC,VIU
CO6-EF-04172018-01	PCB 052	pg/L	49.5	13.6	48	NBC,VIL,VIU
CO6-EF-04172018-01	PCB 056	pg/L	14.5	11.4	48	J,NBC
CO6-EF-04172018-01	PCB 060	pg/L		10.9	48	NBC
CO6-EF-04172018-01	PCB 066	pg/L	23.7	11.7	48	J,NBC,VIU
CO6-EF-04172018-01	PCB 070/61/74/76	pg/L	53.5	12.3	192	J,NBC,VIL,VIU,VJ
CO6-EF-04172018-01	PCB 083/99	pg/L	23.4	6.28	96	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	37.7	5.49	192	J,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 090/101/113	pg/L	47.3	5.45	192	J,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 093/95/100	pg/L	29.5	8.33	192	J,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 105	pg/L	15	7.25	19	J,NBC,VIU
CO6-EF-04172018-01	PCB 110/115	pg/L	53.5	4.98	96	J,NBC
CO6-EF-04172018-01	PCB 118	pg/L	35	6.82	19	NBC,VIL
CO6-EF-04172018-01	PCB 128/166	pg/L	8.2	3.23	96	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 129/138/163	pg/L	71.8	4.45	192	IP,J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 132	pg/L	14	3.94	48	J,JA,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 135/151/154	pg/L	16.5	3.43	96	VRIU,J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 141	pg/L	10.9	3.4	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 147/149	pg/L	34.4	3.36	96	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 153/168	pg/L	44.2	2.88	96	IP,J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 156/157	pg/L		7.1	39	NBC,VIU
CO6-EF-04172018-01	PCB 158	pg/L	5.53	2.49	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 170	pg/L	10.7	7.54	48	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 174	pg/L	11.6	6.25	48	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 177	pg/L	6.75	6.75	48	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 180/193	pg/L	33.5	5.93	96	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 183/185	pg/L	8.35	6.47	96	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 187	pg/L	17	3.17	48	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 194	pg/L	8.43	5.44	48	VRIP,IP,J,JA,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 195	pg/L		5.71	48	NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 201	pg/L		3.66	48	VRIU,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 203	pg/L		5.18	48	NBC,VIL,VJ,VIU
CO6-EF-04172018-01	Total DiCB	pg/L	43.7	3.44	19	NBC,VIL,VJ
CO6-EF-04172018-01	Total HeptaCB	pg/L	79.6	3.17	19	NBC,VIL,VJ
CO6-EF-04172018-01	Total HexaCB	pg/L	206	2.49	19	VIP,NBC,VIL,VJ
CO6-EF-04172018-01	Total MonoCB	pg/L		19.2	19	NBC
CO6-EF-04172018-01	Total NonaCB	pg/L		19.2	19	NBC
CO6-EF-04172018-01	Total OctaCB	pg/L	8.43	3.66	19	VRIP,J,NBC,VIL,VJ
CO6-EF-04172018-01	Total PCBs	pg/L	960	2.49	192	VIP,NBC,VIL,VJ
CO6-EF-04172018-01	Total PentaCB	pg/L	241	4.98	192	NBC,VIL
CO6-EF-04172018-01	Total TetraCB	pg/L	209	10.9	192	NBC,VIL
CO6-EF-04172018-01	Total TriCB	pg/L	164	7.74	48	NBC,VIL
TW6-IN-04172018-01	PCB 008	pg/L	35.9	3.61	55	J,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 018/30	pg/L	47	6.31	55	J,NBC
TW6-IN-04172018-01	PCB 020/28	pg/L	176	8.1	55	NBC
TW6-IN-04172018-01	PCB 021/33	pg/L	71	8.31	55	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW6-IN-04172018-01	PCB 031	pg/L	107	7.61	55	NBC
TW6-IN-04172018-01	PCB 044/47/65	pg/L	222	10.5	109	NBC,VIU
TW6-IN-04172018-01	PCB 049/69	pg/L	107	9.88	109	J,NBC,VIU
TW6-IN-04172018-01	PCB 052	pg/L	282	10.2	55	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 056	pg/L	91	6.89	55	NBC
TW6-IN-04172018-01	PCB 060	pg/L	43.4	6.56	55	J,NBC
TW6-IN-04172018-01	PCB 066	pg/L	172	8.78	55	NBC,VIU
TW6-IN-04172018-01	PCB 070/61/74/76	pg/L	377	9.19	218	NBC,VIL,VIU,VJ
TW6-IN-04172018-01	PCB 083/99	pg/L	205	5.09	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 086/87/97/109/119/125	pg/L	338	4.44	218	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 090/101/113	pg/L	437	4.42	218	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 093/95/100	pg/L	302	4.61	218	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 105	pg/L	228	2.88	22	NBC,VIU
TW6-IN-04172018-01	PCB 110/115	pg/L	630	4.03	109	NBC
TW6-IN-04172018-01	PCB 118	pg/L	454	2.64	22	NBC,VIL
TW6-IN-04172018-01	PCB 128/166	pg/L	138	2.47	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 129/138/163	pg/L	1180	3.41	218	VIP,NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 132	pg/L	256	3.01	55	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 135/151/154	pg/L	193	2.25	109	VRIU,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 141	pg/L	166	2.6	55	VRIU,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 147/149	pg/L	512	2.57	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 153/168	pg/L	664	2.21	109	VIP,NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 156/157	pg/L	109	6.21	44	NBC,VIU
TW6-IN-04172018-01	PCB 158	pg/L	87.7	1.9	55	VRIU,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 170	pg/L	285	6.02	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 174	pg/L	246	4.99	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 177	pg/L	150	5.39	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 180/193	pg/L	668	4.73	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 183/185	pg/L	188	5.17	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 187	pg/L	321	2.6	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 194	pg/L	160	3.94	55	IP,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 195	pg/L	55.9	4.15	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 201	pg/L	22.9	2.66	55	VRIU,J,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 203	pg/L	134	3.76	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	Total DiCB	pg/L	35.9	3.61	22	NBC,VIL,VJ
TW6-IN-04172018-01	Total HeptaCB	pg/L	1670	2.6	22	NBC,VIL,VJ
TW6-IN-04172018-01	Total HexaCB	pg/L	3310	1.9	22	VIP,NBC,VIL,VJ
TW6-IN-04172018-01	Total MonoCB	pg/L		21.8	22	NBC
TW6-IN-04172018-01	Total NonaCB	pg/L		21.8	22	NBC
TW6-IN-04172018-01	Total OctaCB	pg/L	373	2.66	22	VIP,NBC,VIL,VJ
TW6-IN-04172018-01	Total PCBs	pg/L	9860	1.9	218	VIP,NBC,VIL,VJ
TW6-IN-04172018-01	Total PentaCB	pg/L	2590	2.64	218	NBC,VIL
TW6-IN-04172018-01	Total TetraCB	pg/L	1300	6.56	218	NBC,VIL
TW6-IN-04172018-01	Total TriCB	pg/L	401	6.31	55	NBC,VIL
CO4-EF-04192018-01	PCB 008	pg/L	37.8	1.74	48	J,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 018/30	pg/L	38	4.44	48	J,NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04192018-01	PCB 020/28	pg/L	36.1	8.56	48	J,NBC
CO4-EF-04192018-01	PCB 021/33	pg/L	24.1	8.53	48	J,JA,NBC
CO4-EF-04192018-01	PCB 031	pg/L	33.5	7.91	48	J,NBC
CO4-EF-04192018-01	PCB 044/47/65	pg/L	47.2	4.23	96	J,NBC,VIU
CO4-EF-04192018-01	PCB 049/69	pg/L	24.9	3.97	96	J,NBC,VIU
CO4-EF-04192018-01	PCB 052	pg/L	66.1	4.18	48	NBC,VIL,VIU
CO4-EF-04192018-01	PCB 056	pg/L		12.3	48	NBC
CO4-EF-04192018-01	PCB 060	pg/L		12.1	48	NBC
CO4-EF-04192018-01	PCB 066	pg/L	17.7	3.27	48	J,NBC,VIU
CO4-EF-04192018-01	PCB 070/61/74/76	pg/L	45.9	3.52	192	J,NBC,VIL,VIU,VJ
CO4-EF-04192018-01	PCB 083/99	pg/L	21.5	4.34	96	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 086/87/97/109/119/125	pg/L	30.2	3.8	192	J,JA,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 090/101/113	pg/L	43	3.75	192	J,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 093/95/100	pg/L	36.4	3.18	192	J,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 105	pg/L	10	6.39	19	J,NBC,VIU
CO4-EF-04192018-01	PCB 110/115	pg/L	41.8	3.47	96	J,NBC
CO4-EF-04192018-01	PCB 118	pg/L	22.9	5.91	19	JA,NBC,VIL
CO4-EF-04192018-01	PCB 128/166	pg/L	6.91	4.6	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 129/138/163	pg/L	47.5	5.99	192	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 132	pg/L	11	5.47	48	J,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 135/151/154	pg/L	15	2.55	96	VRIU,J,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 141	pg/L	5.69	4.62	48	VRIU,J,JA,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 147/149	pg/L	24.5	4.54	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 153/168	pg/L	36	3.94	96	IP,J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 156/157	pg/L		6.32	38	NBC,VIU
CO4-EF-04192018-01	PCB 158	pg/L		3.46	48	VRIU,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 170	pg/L		5.97	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 174	pg/L	8.3	4.49	48	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 177	pg/L		4.84	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 180/193	pg/L	20.4	4.47	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 183/185	pg/L	9.78	4.39	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 187	pg/L	11.1	2.53	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 194	pg/L	8.43	5.4	48	J,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 195	pg/L		4.61	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 201	pg/L		2.31	48	VRIU,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 203	pg/L		3.81	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	Total DiCB	pg/L	37.8	1.74	19	NBC,VIL,VJ
CO4-EF-04192018-01	Total HeptaCB	pg/L	39.8	2.53	19	NBC,VIL,VJ
CO4-EF-04192018-01	Total HexaCB	pg/L	147	2.55	19	VIP,NBC,VIL,VJ
CO4-EF-04192018-01	Total MonoCB	pg/L		19.2	19	NBC
CO4-EF-04192018-01	Total NonaCB	pg/L		19.2	19	NBC
CO4-EF-04192018-01	Total OctaCB	pg/L	8.43	2.31	19	J,NBC,VIL,VJ
CO4-EF-04192018-01	Total PCBs	pg/L	782	1.74	192	VIP,NBC,VIL,VJ
CO4-EF-04192018-01	Total PentaCB	pg/L	206	3.18	192	NBC,VIL
CO4-EF-04192018-01	Total TetraCB	pg/L	202	3.27	192	NBC,VIL
CO4-EF-04192018-01	Total TriCB	pg/L	132	4.44	48	NBC,VIL

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04192018-01	PCB 008	pg/L	19.9	2.59	48	J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 018/30	pg/L	49.1	7.77	48	NBC
TW2-IN-04192018-01	PCB 020/28	pg/L	91.5	6.35	48	NBC
TW2-IN-04192018-01	PCB 021/33	pg/L	37.1	6.33	48	J,NBC
TW2-IN-04192018-01	PCB 031	pg/L	74.5	5.87	48	NBC
TW2-IN-04192018-01	PCB 044/47/65	pg/L	115	5.83	96	NBC,VIU
TW2-IN-04192018-01	PCB 049/69	pg/L	55.8	5.47	96	J,NBC,VIU
TW2-IN-04192018-01	PCB 052	pg/L	125	5.76	48	NBC,VIL,VIU
TW2-IN-04192018-01	PCB 056	pg/L	39.2	5.48	48	J,NBC
TW2-IN-04192018-01	PCB 060	pg/L	20.6	5.37	48	J,JA,NBC
TW2-IN-04192018-01	PCB 066	pg/L	63.3	4.51	48	NBC,VIU
TW2-IN-04192018-01	PCB 070/61/74/76	pg/L	136	4.85	192	J,NBC,VIL,VIU,VJ
TW2-IN-04192018-01	PCB 083/99	pg/L	50.3	5.21	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 086/87/97/109/119/125	pg/L	67.6	4.56	192	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 090/101/113	pg/L	74.4	4.51	192	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 093/95/100	pg/L	58.4	5.1	192	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 105	pg/L	35.6	4.34	19	NBC,VIU
TW2-IN-04192018-01	PCB 110/115	pg/L	105	4.16	96	NBC
TW2-IN-04192018-01	PCB 118	pg/L	66.3	4.03	19	NBC,VIL
TW2-IN-04192018-01	PCB 128/166	pg/L	17.8	4.24	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 129/138/163	pg/L	150	5.53	192	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 132	pg/L	29.4	5.05	48	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 135/151/154	pg/L	34.3	3.07	96	VRIU,J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 141	pg/L	15.7	4.26	48	VRIU,J,JA,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 147/149	pg/L	52.2	4.19	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 153/168	pg/L	171	3.64	96	VIP,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 156/157	pg/L	13.9	6.31	38	J,NBC,VIU
TW2-IN-04192018-01	PCB 158	pg/L	8.3	3.2	48	VRIU,J,JA,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 170	pg/L	38	7.21	48	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 174	pg/L	18.1	5.42	48	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 177	pg/L	16.2	5.85	48	J,JA,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 180/193	pg/L	88.8	5.4	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 183/185	pg/L	24.5	5.3	96	J,JA,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 187	pg/L	73.2	3.48	48	NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 194	pg/L	32.7	6.48	48	J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 195	pg/L	8.1	5.53	48	J,JA,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 201	pg/L	3.5	2.78	48	VRIU,J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 203	pg/L	17.9	4.57	48	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	Total DiCB	pg/L	19.9	2.59	19	NBC,VIL,VJ
TW2-IN-04192018-01	Total HeptaCB	pg/L	234	3.48	19	NBC,VIL,VJ
TW2-IN-04192018-01	Total HexaCB	pg/L	493	3.07	19	VIP,NBC,VIL,VJ
TW2-IN-04192018-01	Total MonoCB	pg/L		19.2	19	NBC
TW2-IN-04192018-01	Total NonaCB	pg/L		19.2	19	NBC
TW2-IN-04192018-01	Total OctaCB	pg/L	62.2	2.78	19	NBC,VIL,VJ
TW2-IN-04192018-01	Total PCBs	pg/L	2100	2.59	192	VIP,NBC,VIL,VJ
TW2-IN-04192018-01	Total PentaCB	pg/L	458	4.03	192	NBC,VIL

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04192018-01	Total TetraCB	pg/L	556	4.51	192	NBC,VIL
TW2-IN-04192018-01	Total TriCB	pg/L	252	5.87	48	NBC,VIL
CO1-EF-05092018-01	PCB 008	pg/L	31.9	7.11	48	J,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 018/30	pg/L	18.9	9.26	48	J,NBC
CO1-EF-05092018-01	PCB 020/28	pg/L	23.1	10.9	48	J,JA,NBC
CO1-EF-05092018-01	PCB 021/33	pg/L	27.4	11.1	48	J,NBC
CO1-EF-05092018-01	PCB 031	pg/L		10.2	48	NBC
CO1-EF-05092018-01	PCB 044/47/65	pg/L	23.3	12.4	96	J,JA,NBC,VIU
CO1-EF-05092018-01	PCB 049/69	pg/L		11.7	96	NBC,VIU
CO1-EF-05092018-01	PCB 052	pg/L	21	12.1	48	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 056	pg/L		19.4	48	NBC
CO1-EF-05092018-01	PCB 060	pg/L		19.4	48	NBC
CO1-EF-05092018-01	PCB 066	pg/L		10.5	48	NBC,VIU
CO1-EF-05092018-01	PCB 070/61/74/76	pg/L	105	43.6	191	J,NBC,VIL,VIU,VJ
CO1-EF-05092018-01	PCB 083/99	pg/L	13.3	6.37	96	J,JA,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 086/87/97/109/119/125	pg/L	25.5	5.66	191	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 090/101/113	pg/L	27.1	5.52	191	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 093/95/100	pg/L	32.6	4.44	191	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 105	pg/L		11.8	19	NBC,VIU
CO1-EF-05092018-01	PCB 110/115	pg/L	48.9	5.19	96	J,NBC
CO1-EF-05092018-01	PCB 118	pg/L	12.5	10.8	19	J,NBC,VIL
CO1-EF-05092018-01	PCB 128/166	pg/L	9.24	4.56	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 129/138/163	pg/L	50	4.98	191	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 132	pg/L	14.1	5.15	48	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 135/151/154	pg/L	14.6	3.33	96	VRIU,J,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 141	pg/L	7.76	4.62	48	VRIU,J,JA,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 147/149	pg/L	26.6	4.19	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 153/168	pg/L	32.7	3.92	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 156/157	pg/L		7.24	38	NBC,VIU
CO1-EF-05092018-01	PCB 158	pg/L	7.17	3.45	48	VRIU,J,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 170	pg/L	11.9	8.21	48	J,JA,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 174	pg/L	13.3	6.26	48	J,JA,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 177	pg/L		6.69	48	NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 180/193	pg/L	34.2	6.4	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 183/185	pg/L	12.5	6.13	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 187	pg/L	17.6	3.55	48	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 194	pg/L		10.4	48	NBC,VIL,VJ
CO1-EF-05092018-01	PCB 195	pg/L		9.39	48	NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 201	pg/L		5.12	48	VRIU,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 203	pg/L		8.14	48	NBC,VIL,VJ,VIU
CO1-EF-05092018-01	Total DiCB	pg/L	31.9	7.11	19	NBC,VIL,VJ
CO1-EF-05092018-01	Total HeptaCB	pg/L	77	3.55	19	NBC,VIL,VJ
CO1-EF-05092018-01	Total HexaCB	pg/L	162	3.33	19	NBC,VIL,VJ
CO1-EF-05092018-01	Total MonoCB	pg/L		19.1	19	NBC
CO1-EF-05092018-01	Total NonaCB	pg/L		19.1	19	NBC
CO1-EF-05092018-01	Total OctaCB	pg/L		5.12	19	NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-05092018-01	Total PCBs	pg/L	662	3.33	191	NBC,VIL,VJ
CO1-EF-05092018-01	Total PentaCB	pg/L	160	4.44	191	J,NBC,VIL
CO1-EF-05092018-01	Total TetraCB	pg/L	149	10.5	191	J,NBC,VIL
CO1-EF-05092018-01	Total TriCB	pg/L	69.5	9.26	48	NBC,VIL
TW2-IN-05092018-01	PCB 008	pg/L	37.8	2.15	48	J,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 018/30	pg/L	29.2	4.43	48	J,NBC
TW2-IN-05092018-01	PCB 020/28	pg/L	93.6	4.35	48	NBC
TW2-IN-05092018-01	PCB 021/33	pg/L	44.8	4.45	48	J,NBC
TW2-IN-05092018-01	PCB 031	pg/L	62.1	4.08	48	NBC
TW2-IN-05092018-01	PCB 044/47/65	pg/L	123	5.66	96	NBC,VIU
TW2-IN-05092018-01	PCB 049/69	pg/L	52	5.33	96	J,NBC,VIU
TW2-IN-05092018-01	PCB 052	pg/L	247	5.5	48	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 056	pg/L	26.9	10.1	48	J,JA,NBC
TW2-IN-05092018-01	PCB 060	pg/L	17.3	10.2	48	J,NBC
TW2-IN-05092018-01	PCB 066	pg/L	85.3	4.8	48	NBC,VIU
TW2-IN-05092018-01	PCB 070/61/74/76	pg/L	501	20	192	NBC,VIL,VIU,VJ
TW2-IN-05092018-01	PCB 083/99	pg/L	204	3.25	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 086/87/97/109/119/125	pg/L	310	2.89	192	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 090/101/113	pg/L	414	2.82	192	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 093/95/100	pg/L	410	3.36	192	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 105	pg/L	191	5.48	19	NBC,VIU
TW2-IN-05092018-01	PCB 110/115	pg/L	795	2.65	96	NBC
TW2-IN-05092018-01	PCB 118	pg/L	401	5.03	19	NBC,VIL
TW2-IN-05092018-01	PCB 128/166	pg/L	166	3.43	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 129/138/163	pg/L	914	3.75	192	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 132	pg/L	270	3.87	48	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 135/151/154	pg/L	159	2.21	96	VRIU,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 141	pg/L	132	3.47	48	VRIU,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 147/149	pg/L	437	3.15	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 153/168	pg/L	520	2.95	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 156/157	pg/L	101	6.26	38	NBC,VIU
TW2-IN-05092018-01	PCB 158	pg/L	87.8	2.6	48	VRIU,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 170	pg/L	178	5.62	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 174	pg/L	142	4.28	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 177	pg/L	84.6	4.58	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 180/193	pg/L	372	4.38	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 183/185	pg/L	107	4.19	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 187	pg/L	185	2.73	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 194	pg/L	110	8.51	48	NBC,VIL,VJ
TW2-IN-05092018-01	PCB 195	pg/L	35.9	7.71	48	J,NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 201	pg/L	18.1	4.2	48	VRIU,J,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 203	pg/L	93.2	6.68	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	Total DiCB	pg/L	37.8	2.15	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total HeptaCB	pg/L	962	2.73	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total HexaCB	pg/L	2790	2.21	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total MonoCB	pg/L		19.2	19	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-05092018-01	Total NonaCB	pg/L		19.2	19	NBC
TW2-IN-05092018-01	Total OctaCB	pg/L	257	4.2	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total PCBs	pg/L	8160	2.15	192	NBC,VIL,VJ
TW2-IN-05092018-01	Total PentaCB	pg/L	2730	2.65	192	NBC,VIL
TW2-IN-05092018-01	Total TetraCB	pg/L	1050	4.8	192	NBC,VIL
TW2-IN-05092018-01	Total TriCB	pg/L	230	4.08	48	NBC,VIL
QA Codes	http://www.ceden.org/CEDEN_Checker/Checker/DisplayCEDENLookUp.php?List=QALookUp					

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04102018-01	Mercury	ng/L	24.4	0.06	0.5	VIP,NBC
CO1-EF-04102018-01	Suspended Sediment Concentration	mg/L	116	0.91	0.9	NBC
CO1-EF-04102018-01	Total Organic Carbon	mg/L	26.7	0.3	2	D,NBC
CO2-EF-04102018-01	Mercury	ng/L	16.3	0.06	0.5	VIP,NBC
CO2-EF-04102018-01	Suspended Sediment Concentration	mg/L	104	0.9	0.9	NBC
CO2-EF-04102018-01	Total Organic Carbon	mg/L	11	0.07	0.5	NBC
CO3-EF-04102018-01	Mercury	ng/L	6.77	0.06	0.5	VIP,NBC
CO3-EF-04102018-01	Suspended Sediment Concentration	mg/L	50.3	0.92	0.9	NBC
CO3-EF-04102018-01	Total Organic Carbon	mg/L	42	0.3	2	D,NBC
CO4-EF-04102018-01	Mercury	ng/L	15.2	0.06	0.5	VIP,NBC
CO4-EF-04102018-01	Suspended Sediment Concentration	mg/L	89.1	0.96	1	NBC
CO4-EF-04102018-01	Total Organic Carbon	mg/L	28.9	0.3	2	D,NBC
CO5-EF-04102018-01	Mercury	ng/L	7.57	0.06	0.5	VIP,NBC
CO5-EF-04102018-01	Suspended Sediment Concentration	mg/L	78	0.92	0.9	NBC
CO5-EF-04102018-01	Total Organic Carbon	mg/L	27.7	0.3	2	D,NBC
CO6-EF-04102018-01	Mercury	ng/L	14	0.06	0.5	VIP,NBC
CO6-EF-04102018-01	Suspended Sediment Concentration	mg/L	118	0.91	0.9	NBC
CO6-EF-04102018-01	Total Organic Carbon	mg/L	32.9	0.3	2	D,NBC
TW2-IN-04102018-01	Mercury	ng/L	9.99	0.06	0.5	VIP,NBC
TW2-IN-04102018-01	Suspended Sediment Concentration	mg/L	19.4	0.9	0.9	NBC
TW2-IN-04102018-01	Total Organic Carbon	mg/L	5.39	0.07	0.5	NBC
CO1-EF-04132018-01	Mercury	ng/L	9.68	0.06	0.5	VIP,NBC
CO1-EF-04132018-01	Suspended Sediment Concentration	mg/L	21.9	0.89	0.9	NBC
CO1-EF-04132018-01	Total Organic Carbon	mg/L	12.3	0.3	2	D,NBC
CO2-EF-04132018-01	Mercury	ng/L	8.58	0.06	0.5	VIP,NBC
CO2-EF-04132018-01	Suspended Sediment Concentration	mg/L	13.3	0.9	0.9	NBC
CO2-EF-04132018-01	Total Organic Carbon	mg/L	5.72	0.07	0.5	NBC
CO3-EF-04132018-01	Mercury	ng/L	5.69	0.06	0.5	VIP,NBC
CO3-EF-04132018-01	Suspended Sediment Concentration	mg/L	14.5	0.89	0.9	NBC
CO3-EF-04132018-01	Total Organic Carbon	mg/L	19.1	0.3	2	D,NBC
CO4-EF-04132018-01	Mercury	ng/L	11.2	0.06	0.5	VIP,NBC
CO4-EF-04132018-01	Suspended Sediment Concentration	mg/L	17	0.93	0.9	NBC
CO4-EF-04132018-01	Total Organic Carbon	mg/L	13.8	0.3	2	D,NBC
CO5-EF-04132018-01	Mercury	ng/L	4.53	0.06	0.5	VIP,NBC
CO5-EF-04132018-01	Suspended Sediment Concentration	mg/L	17.3	0.92	0.9	NBC
CO5-EF-04132018-01	Total Organic Carbon	mg/L	12.5	0.3	2	D,NBC
CO6-EF-04132018-01	Mercury	ng/L	13.1	0.06	0.5	VIP,NBC
CO6-EF-04132018-01	Suspended Sediment Concentration	mg/L	35	0.93	0.9	NBC
CO6-EF-04132018-01	Total Organic Carbon	mg/L	15.9	0.3	2	D,NBC
TW2-IN-04132018-01	Mercury	ng/L	10.2	0.06	0.5	VIP,NBC
TW2-IN-04132018-01	Suspended Sediment Concentration	mg/L	40.2	0.89	0.9	NBC
TW2-IN-04132018-01	Total Organic Carbon	mg/L	1.71	0.07	0.5	NBC
BLNK-EF-04172018-01	Mercury	ng/L	1.96	0.06	0.5	VIP,NBC
BLNK-EF-04172018-01	Suspended Sediment Concentration	mg/L	1.4	0.9	0.9	NBC
BLNK-EF-04172018-01	Total Organic Carbon	mg/L	0.19	0.07	0.5	J,NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04172018-01	Mercury	ng/L	9.74	0.06	0.5	VIP,NBC
CO1-EF-04172018-01	Suspended Sediment Concentration	mg/L	12.5	0.93	0.9	NBC
CO1-EF-04172018-01	Total Organic Carbon	mg/L	12.1	0.07	0.5	NBC
CO2-EF-04172018-01	Mercury	ng/L	2.17	0.06	0.5	VIP,NBC
CO2-EF-04172018-01	Suspended Sediment Concentration	mg/L	8.4	0.91	0.9	NBC
CO2-EF-04172018-01	Total Organic Carbon	mg/L	5.12	0.07	0.5	NBC
CO2-EF-04172018-D	Suspended Sediment Concentration	mg/L	9.1	0.92	0.9	NBC
CO2-EF-04172018-D	Total Organic Carbon	mg/L	5.15	0.07	0.5	NBC
CO3-EF-04172018-01	Mercury	ng/L	6.02	0.06	0.5	VIP,NBC
CO3-EF-04172018-01	Suspended Sediment Concentration	mg/L	19.3	0.96	1	NBC
CO3-EF-04172018-01	Total Organic Carbon	mg/L	21.6	0.3	2	D,NBC
CO4-EF-04172018-01	Mercury	ng/L	7.58	0.06	0.5	VIP,NBC
CO4-EF-04172018-01	Suspended Sediment Concentration	mg/L	16.5	0.94	0.9	NBC
CO4-EF-04172018-01	Total Organic Carbon	mg/L	14.4	0.3	2	D,NBC
CO5-EF-04172018-01	Mercury	ng/L	7.36	0.06	0.5	VIP,NBC
CO5-EF-04172018-01	Suspended Sediment Concentration	mg/L	11.7	0.92	0.9	NBC
CO5-EF-04172018-01	Total Organic Carbon	mg/L	12	0.3	2	D,NBC
CO6-EF-04172018-01	Mercury	ng/L	11.3	0.06	0.5	VIP,NBC
CO6-EF-04172018-01	Suspended Sediment Concentration	mg/L	26.7	0.95	1	NBC
CO6-EF-04172018-01	Total Organic Carbon	mg/L	17.2	0.3	2	D,NBC
TW6-IN-04172018-01	Mercury	ng/L	9.86	0.06	0.5	VIP,NBC
TW6-IN-04172018-01	Suspended Sediment Concentration	mg/L	16.3	0.89	0.9	NBC
TW6-IN-04172018-01	Total Organic Carbon	mg/L	1.64	0.07	0.5	NBC
CO4-EF-04192018-01	Mercury	ng/L	5.26	0.06	0.5	VIP,NBC
CO4-EF-04192018-01	Suspended Sediment Concentration	mg/L	9.7	0.9	0.9	NBC
CO6-EF-04192018-01	Mercury	ng/L	7.41	0.06	0.5	VIP,NBC
CO6-EF-04192018-01	Suspended Sediment Concentration	mg/L	11.1	0.94	0.9	NBC
CO6-EF-04192018-01	Total Organic Carbon	mg/L	10.9	0.3	2	D,NBC
TW2-IN-04192018-01	Mercury	ng/L	3	0.06	0.5	VIP,NBC
TW2-IN-04192018-01	Suspended Sediment Concentration	mg/L	1.9	0.89	0.9	NBC
QA Codes	http://www.ceden.org/CEDEN_Checker/Checker/DisplayCEDENLookUp.php?List=QALookUp					