Pollutant Monitoring in the North Richmond Pump Station: A Pilot Study for Potential Dry Flow and Seasonal First Flush Diversion for Wastewater Treatment

A Final Report for the Contra Costa County Watershed Program
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1. Executive Summary

The North Richmond Pump Station (NRPS) in Richmond California was one of five pilot projects, called for in the Municipal Regional Stormwater Permit, that aim to determine the feasibility of diverting dry season flow and seasonal first flush flow for treatment at municipal wastewater treatment plants. The NRPS was gauged and monitored for water quality from September 2010 through January 2012. Water samples were collected and analyzed for a host of chemical pollutants including mercury, polychlorinated biphenyls (PCBs), dioxins, trace metals, and a range of other constituents during both dry season and wet season flow. Continuous turbidity and stage data were also collected over the monitoring period.

Pollutant concentrations were compared to the West County Wastewater District (WCWD) local influent (set by the WCWD) and effluent limits (set by a Water Board permit). During the measurement period, all pollutant concentrations were below the local influent limits. In contrast, effluent limits for some PCB, mercury, dioxin, and selenium samples were exceeded on some occasions. Total wet and dry flow loading estimates, over the monitoring period, were 72 g for total mercury, 12.3 g for the sum of PCBs, and 47 metric t for suspended sediment (SSC). Estimated loads for Water Year 2011 were 50 g for total mercury, 9 g for the sum of PCBs, and 33 metric t for suspended sediment. Approximately 21% percent of the total suspended sediment load, 49% of the total mercury load, and 7% of the PCB load estimated during the study period appears to be associated with dry weather pumpout conditions. First flush load estimates were 5% of the wet weather suspended sediment loads, 4% of the total mercury wet weather loads, and 4% of the PCB wet weather loads when 3% of the flow passed through the station.

In relation to watersheds where other observations have been made of mercury and PCB concentrations, the Richmond pump station watershed ranks high in relative pollution levels. Therefore, we conclude that the Richmond pump station watershed may be considered a high leverage watershed in relation to mercury and PCB source areas. This suggests that, all things being equal, managing loads emanating from this watershed may be more cost-effective than more lowly ranked watersheds with lower pollution levels.

2. Introduction

San Francisco Bay is contaminated with Mercury (Hg) and polychlorinated biphenyls (PCBs). A fishing advisory issued in the early 1990s advising people to limit their consumption of fish caught from San Francisco Bay has recently been revised and reissued by the California Office of Environmental Health Hazard Assessment (OEHHA, 2011). The Bay is listed on the EPA 303(d) list of impaired water bodies for Hg and PCBs and a range of other pollutants including organochlorine pesticides (DDT, chlordane, dieldrin), chromium, copper, dioxin compounds, exotic species, furan compounds, lead, nickel, polyaromatic hydrocarbons (PAHs), selenium, silver, and zinc (SFBRWQCB, 2010). In response, the Region 2, Regional Water Quality Control Board (Water Board) has written total maximum daily loads (TMDL) cleanup plans for the Bay for PCBs and Hg that call for reductions in loads emanating from urban stormwater sources around the Bay. Other TMDLs are already written or in progress, but the PCBs and Hg TMDLs are most restrictive on urban runoff as a source.

Hg and PCBs have a long history of use for urban and industrial applications. The history of Hg in the Bay Area began with mining in the Guadalupe River tributary of the South Bay firstly to support gold and silver mining in the mid to late 19th century and then to support the burgeoning electronics industry in the early 20th-century. PCBs, first invented in the 1930s, came into vogue in the 1950s with population rise after World War II, increased energy consumption, and the recognition that PCBs could be used as a dielectric fluid in many electrical applications. About 8% of commercial use in the US was for plastics and plasticizers including the use of PCBs in caulking and sealants and industrial grade paints. Minor uses also included hydraulic and lubricating oils, carbonless copy paper, and heat transfer devices (Erickson and Kaley II, 2011). PCB use began to decline in the 1970s with increasing awareness of the potential for long-term environmental harm. PCBs were banned from production and use in the late 1970s, with the exception of closed applications which were allowed to continue until the end of life of equipment. Presently the EPA is carrying out a reassessment of use authorizations related to liquid PCBs in equipment and is focusing on small capacitors in fluorescent light ballasts, large capacitors, transformers and revised testing, characterization, and reporting requirements for PCBs in natural gas pipeline systems. Similarly, awareness of the adverse effects of Hg on wildlife and humans increased in the 1970s and 80s. Most uses of Hg were banned in the early 1990s including use in paint, thermostats, switches, and batteries. The California Department of Toxic Substances Control (DTSC) is continuing to revise and update advice in relation to mercury recycling, for example the mercury thermostat collection act of 2008 (DTSC, 2009) or the ban on the use of mercury diostats (a mercury switch that controls a gas valve in an oven or oven portion of a gas range (a “flame sensor”)). So, despite small ongoing uses, both Hg and PCBs are often described as legacy contaminants since peak use occurred about three decades ago, but both substances also present ongoing use challenges that make management complex.

The Water Board’s concern over Hg and PCBs is now reflected in the San Francisco Bay Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit (Order No R2-2009-0074), issued in October 2009. The Municipal Regional Permit (MRP) contains many references to PCBs and Hg throughout, and several specific provisions focused on Hg and PCBs. The focus in this MRP permit term (2009–2014) is to implement control measures on a pilot scale and carry out planning to support the possibility of future broader scale implementation for reducing discharge of PCBs and mercury to the Bay during subsequent permit terms in the future. Provision C.11 (Hg) and C.12 (PCBs) call for testing of a variety of cleanup options:

- C.12.a. Implement Projects throughout Region to Incorporate PCBs and PCB Containing Equipment Identification into Existing Industrial Inspections
- C.12.b. Conduct Pilot Projects to Evaluate Managing PCB-Containing Materials and Wastes during Building Demolition and Renovation (e.g., Window Replacement) Activities
- C.11/12.c. Conduct Pilot Projects To Investigate and Abate Sources in Drainages, Including Public Rights-Of-Way, and Stormwater Conveyances with Accumulated Sediment that Contains Elevated Concentrations

C.11/12.d. Conduct Pilot Projects to Evaluate and Enhance Municipal Sediment Removal and Management Practices

C.11/12.e. Conduct Pilot Projects to Evaluate On-Site Stormwater Treatment via Retrofit

C.11/12.f. Diversion of Dry Weather and First Flush Flows to Publicly Owned Treatment Works (POTWs)

At the completion of all these pilots (before September 2014) it is hoped that sufficient information will be generated to determine the implementation opportunities and costs for each management option (e.g. dollars per kilogram of Hg or PCB removed), the feasibility of implementation, and opportunity (estimates mass and locations in urban areas) for implementation. In relation to Permit provision C.11/12.f, the MRP requires a minimum of one such stormwater-POTW pilot diversion pilot project in each county covered by the MRP (Contra Costa, Solano, Alameda, Santa Clara, and San Mateo) or a minimum of five pilots in total. The North Richmond Pump Station, located at the outlet of a small watershed that drains to North San Francisco Bay, was one of the five sites selected for diversion pilot study. The objective of this project is to assist Contra Costa County to assess potential effectiveness of routing urban dry weather and first flush flows to POTWs in order to reduce loading of Hg and PCBs to the Bay.

3. Catchment physiography

The Richmond pump station is located in North Richmond on the Southwest side of the corner of Richmond Parkway and West Gertrude Avenue (Figure 1). The pump station is ~1.6 km (~1 mile) from the West County Wastewater treatment facility (the pilot potential recipient of flows). The pump station services an area of 1.96 km^2 and watershed land uses are primarily industrial, transportation, and residential with some percentage of the developed watershed being old industrial and old urban. Old industrial areas are thought to be primary sources of legacy pollutants such as PCBs and mercury (Yee and McKee, 2010). Imperviousness in the watershed is estimated at 62% based on the National Land Cover Database (NLCD, 2006). Average annual rainfall (23 inches) is approximated by the PRISM data set (http://prism.oregonstate.edu/). There has been no official measurement of run-off from the watershed by the USGS or the County; estimates of discharge can be made from stage data, generated during this study, combined with current pump rates in the station assuming some level of pump efficiency. Like other watersheds in the Bay area, most flow occurs on days when rain occurs during the wet season (October 1 to April 30). Since on average there are only about 60 rain days per year in the Bay Area, even wet season flows are typified by long periods of dry weather flow punctuated by occasional storm flow.

4. Field Methods

Water quality constituents selected

Given the interests of the Water Board, BASMAA, and West County Wastewater District (WCWD), the chosen list of monitoring constituents was long. The majority of the list was set at

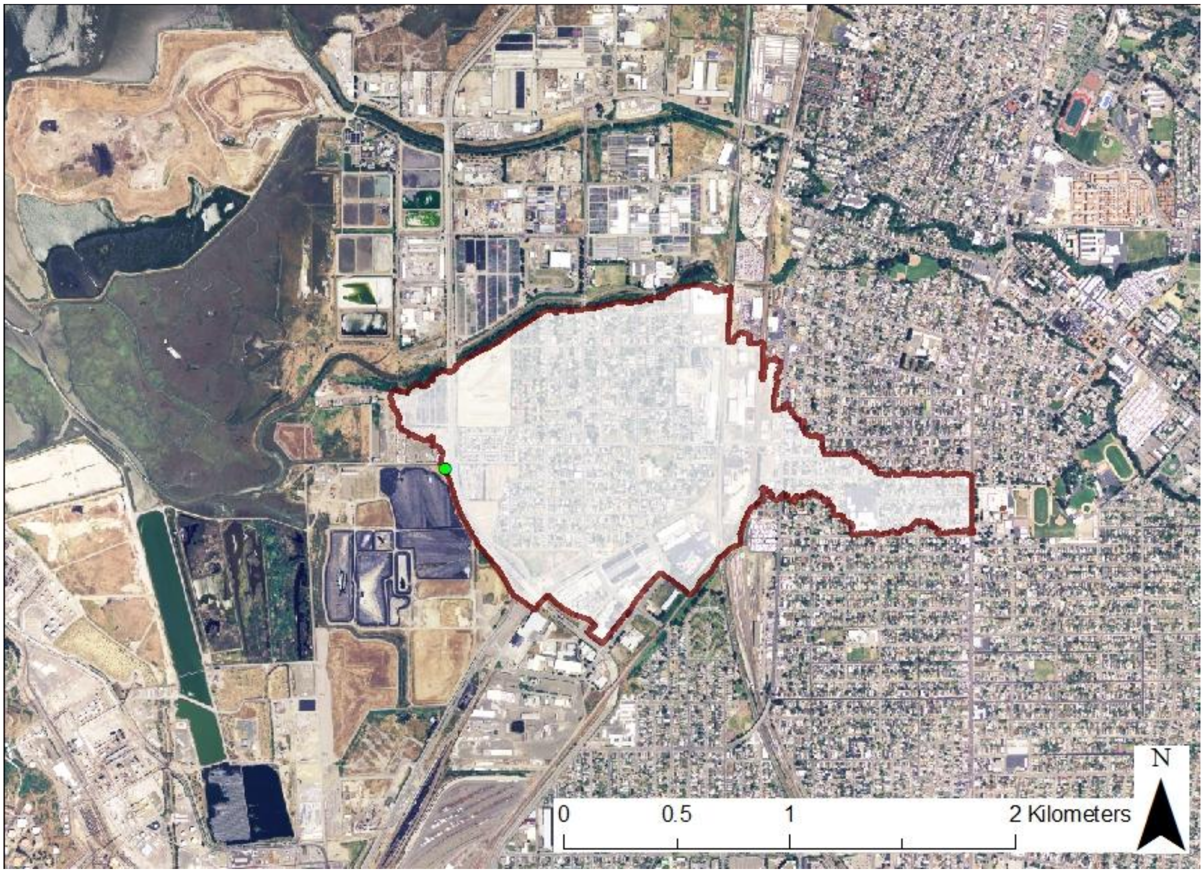

Figure 1. Location map showing the watershed boundary and the location of the pump station (green circle). Watershed delineation courtesy of the City of Richmond and Contra Costa County Public Works Department.

the request of WCWD that had an interest in knowing concentrations and/or loads of a variety of constituents in their influent in order to optimize their treatment process and manage source control in their catchment area. Many of these constituents in water also address Water Board and BASMAA questions in relation to TMDLs or building information in relation to RMP pollutant strategies (SSC, PCBs, Hg speciation, nitrogen and phosphorus compounds, dioxins, organochlorine pesticides, polyaromatic hydrocarbons, and selenium). The pollutant list was organized in relation to these questions (Table 1).

Station instrumentation - Flow and continuous turbidity measurement

The North Richmond Pump Station monitoring station was set up in September 2010 and monitoring continued through the end of January 2012. Monitoring equipment included a Forest Technologies DTS-12 turbidity sensor which measured turbidity in the sump water on 5 minute increments (September 1, 2010 – October 6, 2010). The time increment for turbidity measurement was changed to 2 minutes (October 13, 2010 forward) since dry weather pumpout

Table 1. List of pollutants analyzed, analytical laboratory, and analytical method for each constituent measured.

Analyte	Laboratory	Method Reference
Cyanide (CN-)	EBMUD	SM 4500 CN- C, E
Volatile organics	EBMUD	EPA 624
Semi-volatile organics	EBMUD	EPA 625
Ammonia	EBMUD	SM 4500-NH3 B,C
Total nitrogen	EBMUD	SM 4500-N ORG C Nitrogen
Total Phosphorus	EBMUD	SM 4500-P E Phosphorus
Alkalinity	EBMUD	SM 2320 B Alkalinity
SSC	EBMUD	ASTM D3977
Nitrate	EBMUD	EPA 300.1
Ortho-Phosphate	EBMUD	EPA 300.1
Dioxins	AXYS	EPA 1613
OC Pesticides	AXYS	AXYS method MLA 028
PAHs	AXYS	AXYS method MLA 201
PCBs	AXYS	EPA 1668 (40 congeners)
Total & Dissolved Hg	BRL	EPA 1631
Methyl Hg	BRL	EPA 1630
Trace elements (As, Cd, Cr, Cu, Pb, Ni, Se, Ag, Zn, Sb, Ba, Be, Co, Mo, Tl, V)	BRL	EPA 1638

durations could be as brief as 4 minutes. An INW PS-9805 pressure transducer was also installed to measure stage in the sump on a 5 minute then 2 minute time frame as described above. Data were recorded with a Campbell Scientific CR10X data logger.

Water sampling for water quality analysis

Water samples (except samples for analysis of volatile organic compounds (VOCs)) were collected with ISCO 6712 auto samplers from the wet well at the North Richmond Station during dry weather events (six events) and wet weather events (four storm events including one seasonal first flush event). ISCOs were cleaned prior to each sampling event with Alconox. Cleaned tubing (19 foot Teflon intake tubing, silicone pump roller tubing, and silicone distributor arm tubing cleaned by metals laboratory (Brooks Rand Laboratory) and organics laboratory (AXYS Laboratory)) was installed utilizing clean hands/dirty hands technique prior to sample collection. Laboratory cleaned borosilicate glass bottles were placed in auto samplers using clean hands/dirty hands technique prior to sample collection. Ice was placed around the bottles within the ISCO tub. There were two ISCOs for sample collection: 350 mL glass bottle set up for collection of metals (including mercury species), SSC (an estimate of suspended sediments in stormwater), nutrients, semi-volatiles, and cyanide and 3.7 L glass bottle set up for collection of organic pollutants (PCB, PAH, pesticides, dioxins). A field blank and field duplicate was collected for each analyte for dry season only. Water samples for analysis of volatile organic compounds were collected by hand with a metal sampling pole and 1 L cleaned glass container. Water was collected as a discrete grab sample midway through the pump out. A field blank sample was collected in parallel with each VOC sample collection. Upon completion of sample collection, bottles were removed from ISCO samplers using clean hands/dirty hands technique and placed in coolers with ice for transport. Samples were immediately placed in a 4°C refrigerator until shipment to analytical laboratories. For shipping, samples were packed with blue ice in order to maintain a temperature of 4°C.

There were three types of sampling events (Table 2). Dry flow composite samples were collected during six sampling events (October 2010 and July-August 2011) for each analyte (Table 1). For dry flow composites, equipment was set up and then pumps were manually switched on and run at lower speeds than normal until the pump out process was complete. A lower speed was chosen since more time was needed to fill all sample bottles than the average pumpout duration under normal operating conditions. Equal volume aliquots (total of three aliquots per sample) were taken for the duration of one pump out. During the seasonal first flush in 2010, a full storm composite was collected for each analyte. Equal volume aliquots were taken over five pumpouts during this storm event. For all other storm events, discrete grab samples were taken during pumpouts for mercury (and species), PCBs, dioxins, and SSC.

Table 2. Sample type for dry and wet season sample collection.

Season	Sample Type	Flow Type	Description
Dry	Composite	Dry Flow	3 aliquots of equal volume over 1 pumpout of dry flow (all pollutants)
Wet	Composite	Seasonal 1st flush storm flow	8 aliquots of equal volume over 5 pumpouts of storm flow (all pollutants)
Wet	Discrete	1st flush and other storm flow	Grab samples during pumpout of storm flow (PCB, SSC, Mercury only)

5. Laboratory Methods and QA

Multiple constituents were analyzed on collected water using appropriate laboratory protocols (Table 1). Filtration of samples for dissolved species occurred at the laboratory. Each laboratory provided a suite of internal QAQC samples which included laboratory duplicates, blank spikes, laboratory blanks, certified reference materials (where available), and matrix spikes. In addition, field duplicates and field blanks were collected for each analyte once during the dry season only. Overall, data were acceptable with most analytes exceeding the data quality objectives laid out in the QAPP (Table 3) (North Richmond Pump Station QAPP, EPA Document: NRPSWM 0810QV5). Generally, more non-detects (pollutant concentration below the Method Detection Limit (MDL)) were seen in samples collected during the dry season. Below is a brief summary of QA/QC review for select analytes.

Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) were mostly non-detects with 92% of analytes not detected, in wet or dry season samples. Exceptions included chloroform, tetrachloroethylene, and Bis (2-ethylhexyl) phthalate. Censoring of data due to blank contamination was limited to a few analyte groups and only for dry season composites. Precision and accuracy of the data were within acceptable limits except for VOCs.

Polychlorinated Biphenyls (PCBs)

MDLs were sufficient for discrete samples with only one congener with any non-detects. However composite samples had 18 congeners with non-detects. Twelve PCB congeners were found in the lab blanks, with up to 75% composite samples censored for certain congeners. Concentrations of the most abundant congeners (138, 153, 180) averaged around 2000 pg/L (with a maximum of 10,000 pg/L). Despite these quality challenges, the sum of PCBs (40 congeners (Appendix B) was reported for each sample.

Mercury Species

Discrete mercury and methyl mercury samples had non-detects in the total phase, 4.5% and 5%, respectively. No non-detects were measured for dissolved mercury. No blank contamination was found in discrete or composite samples. Total concentrations for mercury were on average ~20 times greater than dissolved in discrete samples. Total concentrations for mercury were on average ~3 times greater than dissolved in composite samples. Average total methyl mercury concentrations were 4 to 7 times greater in the discrete samples compared to composite samples. Average dissolved mercury concentrations in the discrete samples were ~ 3 times lower than those measured in the composite samples. Thus, we were able to obtain concentration data for the majority of samples.

Dioxins and Furans

Sensitivity was good for discrete samples (only 3 furans had non-detects in 33% of samples). For composite samples, 11 of 17 congeners had over 50% non-detects. Some congeners were found in lab blanks, mostly octachlorodibenzodioxin (OCDD) and octochlorodibenzofuran (OCDF) (Appendix C), but field sample concentrations usually were much higher so only one result for HpCDD, 1,2,3,4,6,7,8- was censored.

Table 3. Quality Assurance/Quality Control results from data validation.

Grab Sample	**Range of % NDs/Sample**	**Percent of Samples Censored due to Blank Contamination**	**Precision RSD OR % Error**	**Accuracy Recoveries OR % Error**
Dioxin/Furan	0-33	0	<22	<25
PCB	0-6	0	<10	<10
Mercury, Dissolved	0	0	<11	<8
Mercury, Total	5	0	<11	<8
Methyl Mercury, Total	5	0	<11	<8
Composite Sample				
Dioxin/Furan	13-87	<1		
PAH	0-87	27	<22	<25
PCB	12-62	5	<10	<10
OC Pesticide	12-100	2	<35	<21
Mercury, Dissolved	0	0	<17	<18
Mercury, Total	0	0	<17	<18
Methyl Mercury, Total	0	0	<17	<18
Silver,Total	36	0	<17	<18
Cadmium,Total	13	0	<17	<18
Arsenic,Total	0	0	<17	<18
Chromium,Total	0	0	<17	<18
Copper,Total	0	0	<17	<18
Lead,Total	0	0	<17	<18
Mercury,Dissolved	0	0	<17	<18
Mercury,Total	0	0	<17	<18
Mercury, Methyl,Total	0	0	<17	<18
Molybdenum,Total	0	0	<17	<18
Nickel,Total	0	0	<17	<18
Selenium,Total	0	0	<17	<18
Zinc,Total	0	0	<17	<18
Cyanide	89	0	6	11
Nitrogen, Organic	71	0		
Ammonia as N	23	0	0	
Suspended Sediment Concentration	3	0		6
Nitrogen, Total Kjeldahl	0	0	7	6
Alkalinity as CaCO3	0	0	2	4
Nitrate as N	0	0	<1	8
OrthoPhosphate as P	0	0	4	6
Phosphate as P	0	0	0	15
Volatile Organic Compounds	14-100	0	0-110	4-92

6. Results

Characterization of Turbidity, SSC, and Pollutants

Turbidity collected on a five or two minute basis was despiked and the missing data were interpolated between data points. The resulting corrected turbidity ranged between 0 NTU and 494 NTU with an arithmetic average of 16.1 NTU (n=5201). This range is on the lower side but generally similar to observations in other highly urbanized small watersheds in the Bay Area (e.g. Gilbreath et al., 2012. Suspended sediment concentration, measured by our laboratory, ranged between 0 and 230 mg/L with an arithmetic average of 51.3 mg/L (n=23). The flow weighted mean concentration for SSC for water year 2011 (derived by dividing total load by total run-off volume) was 24.2 mg/L. For comparison, SSC measured in Z4LA over a four-year period, an urbanized Hayward watershed, ranged between 8-2700 mg/L (n=329) with a flow weighted mean concentration of 160 mg/L (Gilbreath et al., 2012).

Pollutant concentrations varied by season and within season (Table 4). For most pollutants, concentrations were highest in storm flow. Exceptions to this pattern were seen for arsenic, cadmium, chloroform, cyanide, selenium, tetrachloroethylene, and ammonia. Cyanide and ammonia were only detected during dry flow while heptachlor and methylene chloride were not detected in dry flow or storm flow.

Total mercury in the dry season ranged from 19-47 ng/L with an arithmetic average of 33 ng/L; wet season total mercury ranged from 22-200 ng/L with an arithmetic average of 72 ng/L. The highest measured mercury concentration was found in a discrete sample from February 15, 2011. This discrete sample also had the highest total methyl-mercury (0.6 ng/L) and suspended sediment concentration (SSC) (230 mg/L) measured in the study.

Dissolved mercury concentrations in the dry season ranged from 17-54% of total Hg with an arithmetic average of 32%. In the wet season, dissolved Hg ranged from 1-25% of total Hg with an average of 10%. Methyl-mercury, as a percentage of total mercury, was equal to or less than 1% for both dry and wet season samples (range 0.1-1%). The average ratio of Hg:SSC was higher during the dry season than during storm flow. This is likely because a greater portion of Hg was transported in dissolved phase during dry weather. Two samples (RICH-505, RICH-506) during the February 15, 2011 storm exhibited much higher Hg:SSC ratios than all others (2.1 and 3.5 mg/kg respectfully); however, due to the small sample size, the cause cannot be speculated at this time.

PCB (sum of 40 congeners) concentrations ranged from 0.3-1 ng/L with an arithmetic average of 0.7 ng/L in the dry season and ranged from 3-82 ng/L with an arithmetic average of 21 ng/L in the wet season. The highest measured PCB concentration was found in a discrete sample collected on January 20, 2012. This discrete sample also had the highest Dioxin-TEQ (58 pg/L) and moderate SSC (110 mg/L). In a similar manner to Hg, the January 2012 storm produced a sample (RICH-900) with an anomalously high particle ratio (0.75 mg/kg). In this case, the hypothesis that rainfall intensity plays a role appears to be reasonable. Rainfall, in the 2 hours preceding the sample, at the Richmond City Hall gauge (RCL) was 0.45 inches; the highest recorded rainfall in the 2 hours prior to any other samples was 0.31 inches on February 16th at

Table 4. Minimum, maximum, and average contaminant concentrations for storm and dry weather flow. Analysis included discrete and composite samples. ND denotes not detected.

Constituent	Unit	Minimum Storm Flow	Maximum Storm Flow	Average Storm Flow	Minimum Dry Flow	Maximum Dry Flow	Average Dry Flow
4,4-DDD	ng/L	0.35	0.35	0.35	ND	0.17	0.11
Arsenic	µg/L	2.9	2.9	2.9	12	10	12
Bis(2-ethylhexyl)phthalate	µg/L	1.5	1.5	1.5	0.00	0.70	0.30
Cadmium	µg/L	0.19	0.19	0.19	0.22	0.53	0.34
Chloroform	µg/L	0.25	0.25	0.25	1.8	2.4	2.0
Chromium	µg/L	4.0	4.0	4.0	0.40	1.4	0.83
Copper	µg/L	20	20	20	4.9	8.3	6.4
Cyanide	µg/L	ND	ND	ND	ND	4.60	0.80
Dioxin-TEQ*	pg/L	25	58	47	0.02	5.6	1.0
Heptachlor	ng/L	ND	ND	ND	ND	ND	ND
Lead	µg/L	8.2	8.2	8.2	0.16	1.83	0.76
Mercury, Total	ng/L	22	200	72	19	47	32
Mercury, Dissolved	ng/L	3.0	11.0	4.0	7.0	10.0	8.0
Methyl-Mercury, Total	ng/L	0.15	0.60	0.24	0.05	0.09	0.07
Methylene Chloride	mg/L	ND	ND	ND	ND	ND	ND
Nickel	µg/L	5.3	5.3	5.3	4.2	6.7	5.5
Phenolic compounds**	mg/L	ND	ND	ND	ND	ND	ND
Selenium	µg/L	0.34	0.34	0.34	4.7	9.0	6.2
Silver	µg/L	0.05	0.05	0.05	ND	0.01	0.01
SSC	mg/L	21.0	230.0	74.0	ND	14.0	6.0
Sum of PCB pg/L	ng/L	3.0	82.0	21.0	0.30	1.1	0.7
Tetrachloroethylene	µg/L	0.17	0.17	0.17	5.0	9.3	13.0
Total Ammonia	mg/L	ND	ND	ND	ND	1.7	0.90
Zinc	µg/L	118	118	118	7.0	23	13
*WHO 2005							
** Represented by phenol							

12:20 am. It is also possible that the high rainfall intensity caused suspension of material from the floor of the pump station sump. However, based on the results from our continuous turbidity monitoring, resuspension is unlikely.

Dioxin-TEQs (Van De Berg et al., 2006) ranged from 0.01-6 pg/L in the dry season and ranged from 25-58 pg/L in the wet season. OCDD (Octachlorodibenzodioxin) and OCDF (Octachlorodibenzofuran) were the most dominant dioxin/furan congeners found; OCDD, as a percent of sum dioxins, ranged from 86-100% while OCDF, as a percent of sum of furans, ranged from 57-100%. These results are consistent with other Bay Area urban stormwater studies (e.g. Gilbreath et al., 2012). OCDD and OCDF have the lowest toxic equivalent factors

(TEF) among the family of dioxin and furan compounds (Van den Berg et al., 2005; WHO, 2005).

DDT (sum of DDTs and degradation products) ranged from ND-740 pg/L during the dry season and one wet season sample measured 3600 pg/L. 4,4-DDT was the dominant congener ranging from ND-54% of the sum of DDT. In the one sample where 4,4-DDT was not detected, 4,4,-DDD was dominant (54%). The dominance of DDT suggests fresh sources of DDT in the watershed (Jay Davis, pers. comm.) and has also been observed in other urban watersheds in the Bay Area (e.g. Guadalupe River: McKee et al 2004; Z4LA in Hayward: Gilbreath et al 2012). Chlordanes (sum of 7 chlordanes) ranged from ND-400 pg/L in the dry season and one wet season sample measured 5600 pg/L. Dieldrin ranged from 450-3200 pg/L in the dry season and one wet season sample measured 1140 pg/L.

7. Regulatory Thresholds

Provisions C.11.f and C.12.f of the Municipal Regional Permit require pilot studies to evaluate diversion of dry weather and first storm flush urban runoff to publically owned treatment works (POTWs) in order to reduce concentrations and loads of mercury and PCBs to San Francisco Bay from urban areas. This study characterized the water quality of both dry weather and storm flows pumped from the North Richmond Pump Station. The next stage of this evaluation is to look at the feasibility of diverting dry weather flow and first flush flows to the West County Wastewater District (WCWD). One of the primary determinants of feasibility is to assess if pump station effluent pollutant concentrations exceed current WCWD local limits (influent limits) or WCWD National Pollution Discharge Elimination System (NPDES) effluent limits. The limits are assessed on the basis of maximum concentrations empirically measured during this study. For the evaluation, maximum first flush and maximum dry flow sample data were compared to the limits (Table 5).

Pollutant concentrations in dry and storm flow samples were below all local influent limits. However, some exceedance of the effluent limits occurred in both dry and storm flow samples. All storm flow dioxin-TEQ concentrations (TEQ = Concentration in matrix multiplied by the TEF) exceeded the effluent limit while approximately 20% (1 of 6) dry flow samples exceeded this limit. For mercury, 65% (11 of 17) of storm flow samples exceeded the effluent limit while 33% (2 of 6) of dry flow samples were in exceedance. For PCB wet flow samples (5 of 17) were in exceedance of the effluent limit while none of the dry flow samples were in exceedance. For selenium, one dry flow sample was at the effluent limit (1 of 6). All other pollutants of regulatory concern were below the effluent limit.

8. Estimated Flows and Loads for PCBs and Mercury

Pumpout volume estimates were derived from wet well stage data collected over the period 9/1/2010 to 1/20/2012 (507 days). Stage data (water depth in the wet well monitored) were collected on two-minute intervals. Pumpout start and end times were noted by a change in stage in the wet well. Pumpout volume estimates were calculated as follows:

Table 5. Comparison of pollutant concentrations to WCWD Local Limits and Effluent Limits including the frequency of effluent exceedance. > denotes concentration above limit; < denotes concentration below limit; = denotes concentration at the limit; -- denotes no limits available. *WHO 2005. ** Represented by phenol.

Constituent	Unit	WCWD Influent Local Limits Daily Maximum	WCWD Effluent Limits Daily Maximum	Maximum Concentration (1st flush)	Maximum Concentration (Other storm)	Maximum Concentration (Dry Flow)	Above/Below Effluent Limit (Wet Season Max)	Above/Below Effluent Limit (Dry Season Max)	Frequency of Exceedence of Effluent Limit (Wet Season)	Frequency of Exceedence of Effluent Limit (Dry Season)
Dioxin-TEQ*	pg/L	**NA**	**0.028**	**58**	**52**	**5.6**	**>**	**>**	**4/4**	**1/6**
Mercury	ng/L	**20000**	**38**	**200**	**30**	**50**	**>**	**>**	**11/17**	**2/6**
Selenium	µg/L	**1000**	**8.9**	**0.340**	--	**8.9**	<	**=**	**0/1**	**1/6**
Sum of PCB	ng/L	--	**17**	**82**	**16**	**1.1**	**>**	<	**5/17**	**0/6**
Total Ammonia	mg/L	--	**59**	**ND**	--	**1.7**	--	--	**0/1**	**0/6**
Phenolic compounds**	mg/L	**8**	--	**ND**	--	**ND**	--	--	--	--
Methylene Chloride	mg/L	**0.18**	--	**ND**	--	**ND**	--	--	--	--
4,4-DDD	ng/L	--	**1.7**	**0.35**	--	**0.17**	<	<	**0/1**	**0/6**
Heptachlor	ng/L	--	**4.1**	**ND**	--	**ND**	<	<	**0/1**	**0/6**
Cyanide	µg/L	**400**	**15**	**ND**	--	**4.6**	<	<	**0/1**	**0/6**
Copper	µg/L	**3000**	**100**	**20**	--	**8.4**	<	<	**0/1**	**0/6**
Nickel	µg/L	**800**	**59**	**5**	--	**6.7**	<	<	**0/1**	**0/6**
Bis(2-ethylhexyl)phthalate	µg/L	--	**150**	**1.5**	--	**0.70**	<	<	**0/1**	**0/6**
Arsenic	µg/L	**370**	--	**0.25**	--	**2.4**	--	--	--	--
Cadmium	µg/L	**500**	--	**0.19**	--	**0.53**	--	--	--	--
Chromium	µg/L	**2000**	--	**4.0**	--	**1.4**	--	--	--	--
Lead	µg/L	**2000**	--	**8.2**	--	**1.8**	--	--	--	--
Silver	µg/L	**300**	--	**0.045**	--	**0.014**	--	--	--	--
Zinc	µg/L	**5000**	--	**118**	--	**20**	--	--	--	--
Chloroform	µg/L	**3340**	--	**0**	--	**0**	--	--	--	--
Tetrachloroethylene	µg/L	**14260**	--	**0.17**	--	**9.3**	--	--	--	--
*WHO 2005							Number of Exceedances		20	4

** Represented by phenol

> Concentration above limit

< Concentration below limit

= Concentration at the limit

-- No limits available

- Calculate the time (T) elapsed for each pumpout during wet and dry seasons, in minutes
- Using the estimated pump rate (R) of 45,000 gallons per minute (estimate based on the original pump curves) calculate the volume (V) of water passing through the pump station for each pumpout.
- $V_{pumpout} = T \times R$

    - Note that using a pump rate of 45,00 gpm is likely an overestimate since pump efficiency has most like to get the claimant's safe ly declined over the pump lifetime (> 30 years). Without rerating the pumps, the magnitude of reduced efficiency is unknown. We assumed (speculated) 70% pump efficiency.
    - Note that the volume calculations, during storm flow, are likely underestimated since we do not have enough information to determine the periods when more than 1 pump is operating. Estimated volume is based on a single pump in operation.

The pumpout stage data set was not complete. There were data gaps associated with scheduled maintenance in September and October 2011 causing a total of 57 missing days, there were sporadic electrical outages throughout the study, and there was an electrical outage during January 2012 for a total of 10 days. Overall 126 days or 25% of the study period retained no pumpout stage data. These issues are discussed more below in the lessons learned/ recommendations section.

During days where stage data were available, two-minute loads were calculated by combining the estimated pumpout volume with pollutant concentrations estimated from regression relationships (Figure 2) or linear interpolation (one storm on February 15 for which there was sufficient laboratory data coverage but no turbidity data due to probe malfunction) (Appendix A). To account for missing days of the volume data, loads were adjusted up by a factor calculated by the total number of days in a given month divided by the total number of days with the observed data. For example, in January 2011 there were five days of missing data thus a factor of 31/26 or 1.19 was applied (Table 6). Estimated wet weather loads could not be adjusted for additional pump operation during storm flow (more than 1 pump can be in operation during storm events) due to insufficient information on the conditions under which multiple pumps were in operation.

Monthly adjusted pumpout volume correlated strongly to monthly rainfall and that correlation was better than the raw pumpout volume data. Assuming a pump efficiency of 70%, during the months when more than 1.5 inches rainfall occurred, run-off coefficients (the percentage of rainfall that manifests as run-off) ranged between 38-131 percent. Although there is a considerable amount of dry flow that is unrelated to rainfall, these run-off coefficients indicate that the quality of discharge information is not very good. Overall the annual run-off coefficient (76%) for water year 2011 seems reasonable. These simple quality assurance checks provided a moderate level of confidence that our flow data could support loads computations but improved flow data should be an objective of any further future study.

During the study, the best estimate of monthly suspended sediment loads assuming all the adjustment factors varied from 0.07 – 14 metric tonnes. Loads of mercury and PCBs varied

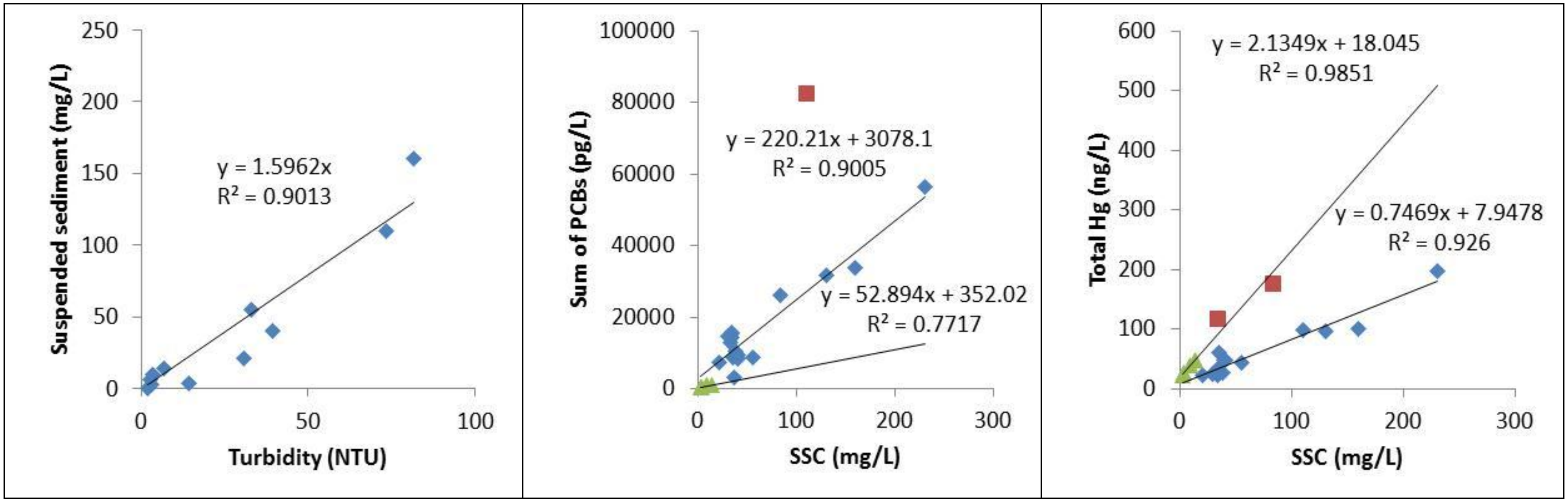

Figure 2. Scatter plots and regression relationships used for interpolating concentration data in the context of calculating suspended sediment, total mercury, and PCB loads passing through the North Richmond pump station. Dry weather pumpout conditions (Green triangles); Wet weather pumpout conditions (blue diamonds); Outliers not used for generating regression relationships (red squares).

Table 6. Monthly rainfall (WCWD data), estimated average daily discharge (million gallons/day), total monthly discharge and monthly loads. The discharges and loads were adjusted to take into account days of missing data for each month during the study period and an average pump efficiency of 70%.

Month-Year	Rainfall (in)	Average Discharge (MGD)	Discharge (m3)	SS load (metric t)	HgT (g)	PCB (40) (g)	Missing days	Adjustment Factor	Pump effiency	Adjusted Discharge (m3)	Adjusted SS load (metric t)	Adjusted HgT (g)	Adjusted PCB (40) (g)
Sep-10	0.0	0.97	84,320	0.7	3.0	0.1	0	1.0	0.7	59,024	0.49	2.11	0.047
Oct-10	2.6	2.26	77,506	3.0	4.1	0.6	7	1.29	0.7	70,079	2.70	3.75	0.56
Nov-10	2.8	1.37	145,474	7.1	11	1.4	0	1.00	0.7	101,832	4.98	7.82	0.96
Dec-10	8.4	2.95	346,479	5.5	7.8	2.1	0	1.00	0.7	242,536	3.86	5.49	1.47
Jan-11	1.8	1.49	141,045	1.0	3.3	0.3	5	1.19	0.7	117,718	0.83	2.75	0.29
Feb-11	5.7	2.97	303,893	2.2	5.2	1.3	0	1.00	0.7	212,725	1.52	3.61	0.88
Mar-11	9.2	3.38	269,143	14	14	3.7	9	1.43	0.7	269,143	13.96	13.71	3.69
Apr-11	0.5	0.79	50,762	0.6	1.6	0.1	13	1.76	0.7	62,707	0.73	1.94	0.16
May-11	1.5	0.64	48,718	0.4	1.3	0.1	8	1.35	0.7	45,965	0.35	1.21	0.10
Jun-11	2.5	1.16	122,648	4.1	5.3	1.0	0	1.00	0.7	85,853	2.86	3.68	0.73
Jul-11	0.0	0.53	34,409	0.5	1.6	0.0	13	1.72	0.7	41,483	0.55	1.92	0.044
Aug-11	0.0	0.50	43,267	0.2	1.2	0.0	0	1.00	0.7	30,287	0.13	0.82	0.017
Sep-11	0.0	0.45	6,814	0.01	0.2	0.0	26	7.50	0.7	35,772	0.07	0.80	0.016
Oct-11	2.0	-	-	-	-	-	31	-	-	-	-	-	-
Nov-11	1.7	0.66	57,576	3.4	7.2	0.4	4	1.15	0.7	46,504	2.74	5.79	0.29
Dec-11	0.1	0.48	37,816	0.1	1.0	0.0	0	1.00	0.7	26,471	0.10	0.67	0.018
Jan-12	4.0	1.19	72,226	4.4	4.3	1.1	10	1.48	0.7	74,633	4.56	4.49	1.14

similarly (Table 6) and showed a strong and logical relationship to monthly rainfall, flow volume, and suspended sediment loads. Normalized to watershed area, loads were equivalent to 17 t/km^2, 24 ug/m^2, and 4.6 ug/m^2 for suspended sediments, total mercury, and PCBs respectively. The closest well studied analogue in the Bay Area is the Z4LA urban watershed in Hayward which was studied for four water years and has a watershed area of 4.17 km^2 and land use that includes 19 percent industrial area (Gilbreath et al 2012). Estimated long-term average area normalized loads for Z4LA were 30 t/km^2, 5.7 ug/m^2, and 3.1 ug/m^2 for suspended sediments, total mercury, and PCBs respectively. Given our Richmond observations were made during a wetter than normal year (see below), the data suggests that the Richmond pump station watershed has lower loads of suspended sediments, greatly elevated loads of mercury, and similar loads PCBs relative to Z4LA.

9. Stakeholder Management Questions

What is the estimated quantitative load reduction to the Bay from dry weather diversion, 1st flush diversion, and diversion of other storm flow?

During the monitoring period, there were 418 pumpouts during dry flow and 610 pumpouts during wet flow. Loading of SSC and PCBs, from the pump station, occurred primarily during wet season pumpouts (Table 7). However, total mercury loading was similar between dry and wet season pumpouts. Based on the data available, dry flow diversion of pump station effluent to the WCWD wastewater treatment plant could reduce sediment associated pollutants loading to San Francisco Bay. Dry flow diversion of water measured during this study would move an estimated 21% of total suspended sediment loads to treatment while an estimated 49% of total mercury loads could be treated. Dry diversion would move an estimated 7% of total PCB to treatment.

Table 7. Estimated loads (non-adjusted) of SSC, total mercury, and PCBs for the Richmond Pump Station for dry and wet season pumpouts (September 2010-January 2012).

Season	SSC loads (metric t)	Total Mercury Loads (Grams)	PCB Loads (sum RMP 40) (Grams)
Dry	10	35	0.80
Wet	37	37	11

Loads were also calculated for the seasonal 1st flush during water year (WY) 2011 (Table 8). A water year is defined as measurements (precipitation, flow) observed from October 1-September 30. First flush loads accounted for 3% of wet flow, 5% of the total wet weather SSC load, 4% of the total mercury wet weather load, and 4% of the PCB wet weather load. This supports our conceptual model that the seasonal 1st flush can carry a disproportionate amount of sediment, and potentially, associated pollutants, at a lower volume of water. Data on 1st flush WY2012 are not available due to pump station construction during October 2011. Other storm events (non-1st flush) accounted for an estimated 95% of sediment wet weather loading, 96% of total mercury wet weather loading, and 96% of PCB wet weather loading. In total, diversion of seasonal 1st flush and dry weather flows during our study period would have resulted in an estimated 26% reduction in SSC, 53% reduction in total mercury loads, and 11% reduction in PCB loads if we assume that the subsequent treatment was 100% efficient. The total volume of water involved would have been 0.6 million m^3 (160 million gallons).

Table 8. Seasonal 1st flush estimated loads (non-adjusted) of SSC, total mercury, and PCBs for the Richmond Pump Station.

Season	SSC loads (metric t)	Total Mercury Loads (Grams)	PCB Loads (sum RMP 40) (Grams)	Flow (metric cubic meters/minute)	Flow (cubic feet/minute)	Volume (metric cubic meters)	Volume (gallons)
1st Flush WY2011	1.70	1.47	0.41	14990	8823	166,919	4,410,000
1st Flush WY2012	Data NA	Data NA	Data NA	Data NA	Data NA	Data NA	Data NA

Are any of the pollutant concentrations particularly high or low compared to other monitoring data for the Bay Area?

Previous work quantifying street and storm drain sediments has been done in various industrialized watersheds in the Bay Area. The data suggest high mercury and PCB levels in the North Richmond Pump Station watershed relative to samples taking in other industrial areas around the Bay Area (Yee and McKee, 2010). PCB concentrations in the North Richmond Pump Station watershed sediments ranged from below detection to 0.91 mg/kg (Figure 3). The highest North Richmond Pump Station watershed PCB sediment concentration fell into the 90th percentile of the available data (729 records) (Bay Area Urban Stormwater BMP soils and sediment database, SFEI: SFEI, 2010). For Hg, the highest sediment concentration sampled was 0.86 mg/kg (Figure 4). This concentration ranks in the 94th percentile of the 564 Hg records in the Stormwater database. These sediment samples were taken from the southern industrial portion of the North Richmond Pump Station watershed.

A recent reconnaissance level study to characterize pollutant concentrations in stormwater runoff from various Bay Area watersheds found a range of PCB and Hg concentrations as well as pollutant:SSC ratios (McKee et al., in review). PCB concentrations (sum of 40 PCB congeners) ranged from a low of 700 pg/L (Lower Marsh Creek) to a high of 468,000 pg/L (Santa Fe Channel in Richmond). The highest PCB concentration measured at the North Richmond Pump Station, during this study, was 82,400 pg/L (January 20, 2012 storm event).

Pollutant comparisons between watersheds are best made on a particle ratio basis since Bay Area watersheds have highly variable sediment erosion characteristics due to active tectonics and geologic complexity. Total mercury and PCBs, in stormwater, are primarily transported as particle associated complexes. The ratio of pollutant concentration to SSC can be used as a

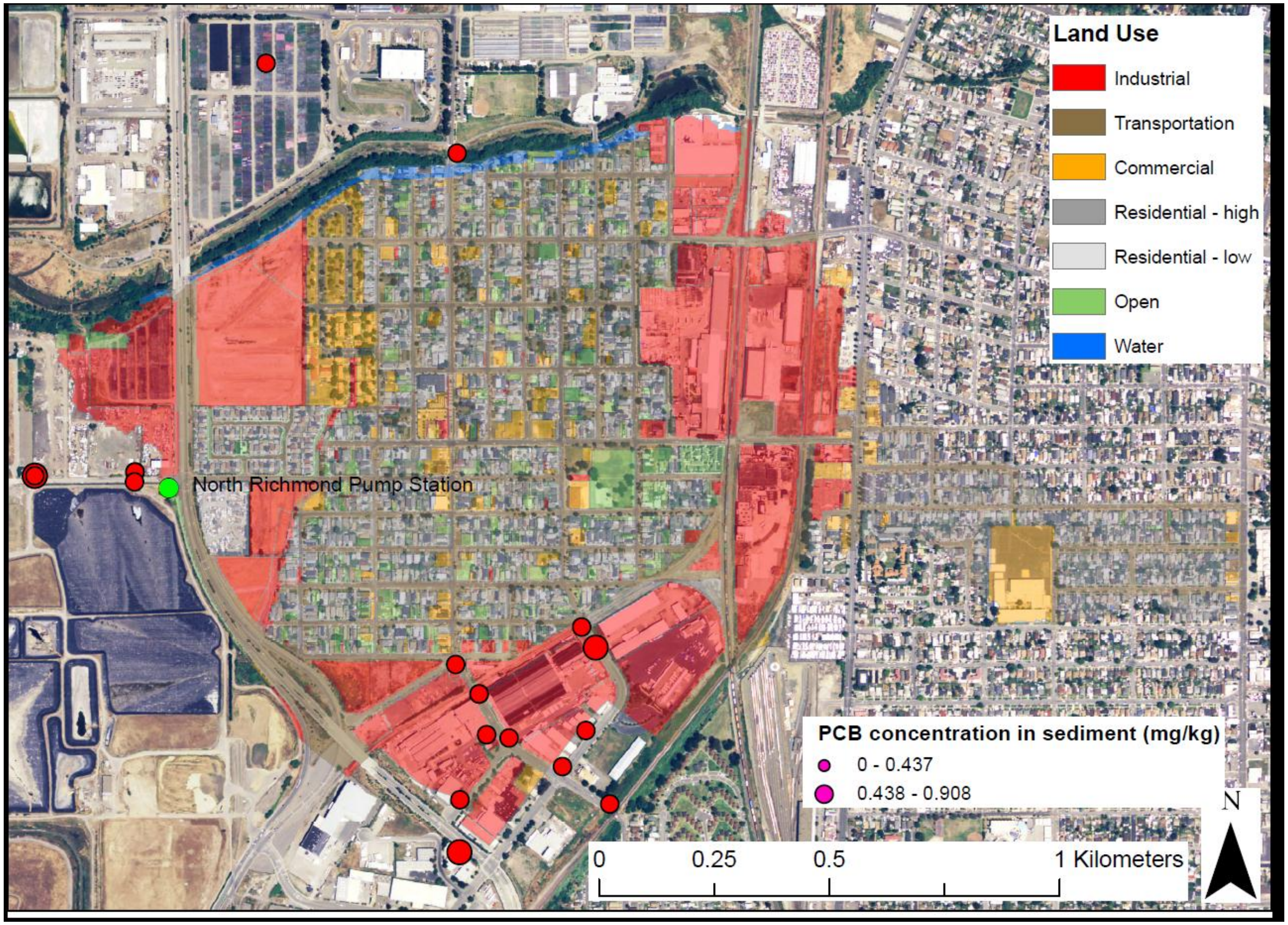

Figure 3. PCB concentrations (mg/kg) in sediments collected from streets and drop inlets (Yee and McKee 2010) within the North Richmond Pump Station watershed area outline. ABAG 2005 land use categories shown according to legend.

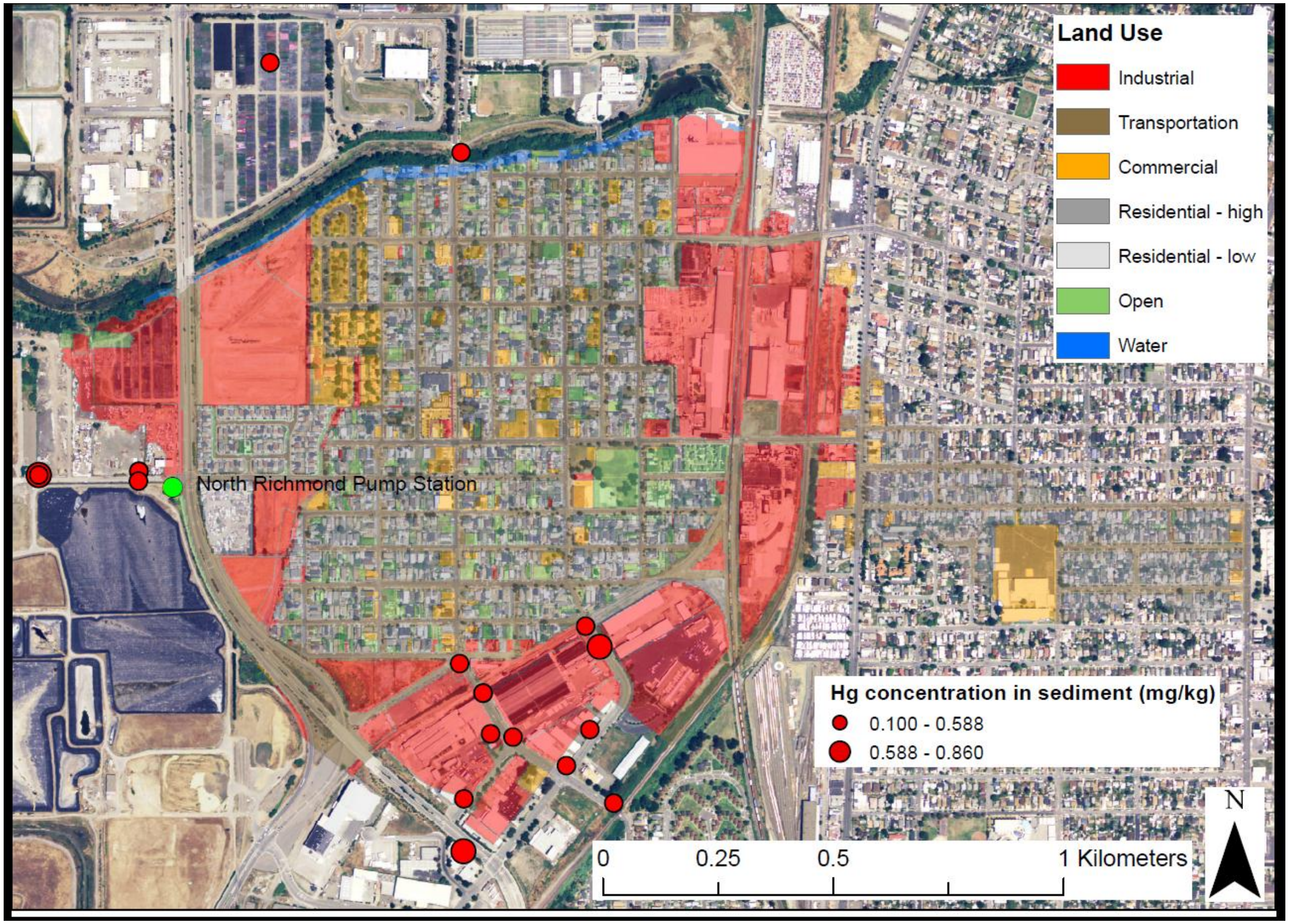

Figure 4. Total Mercury concentrations (mg/kg) in sediments collected from streets and drop inlets (Yee and McKee 2010) within the North Richmond Pump Station watershed area outline. ABAG 2005 land use categories shown according to legend.

proxy for the analytical particulate fraction which can then provide a relative ranking of watershed pollutants. The highest average particle ratio measured in the watershed reconnaissance study was 1400 pg/mg (Santa Fe Channel) (Table 9). The arithmetic averaged ratio for the North Richmond Pump Station was 325 pg/mg (range 87 – 749 pg/mg). In comparison to the other reconnaissance watersheds, North Richmond Pump Station ranked as the fifth highest in PCB particle ratios. For mercury, reconnaissance levels ranged from 8.2 ng/L (Lower Penitencia Creek) to 1660 ng/L (Zone 5 Line M). The highest mercury stormwater concentration measured at North Richmond Pump Station in this study was 198 ng/L. In terms of mercury particle ratios (arithmetic average), reconnaissance watersheds ranged from 0.10 ng/mg (Walnut Creek) to 0.83 (Pulgas Creek storm drain) (Table 10). The average particle ratio for the North Richmond Pump Station, in this study, was 1.2 ng/mg (range 0.63 – 3.5 ng/mg). These rankings suggest that this watershed may be considered "high leverage" in relation to PCBs and mercury source areas and provides preliminary support that treatment of this load may be reasonably cost-effective at least in comparison to treatment of loads in watersheds that rank lower.

Table 9. Average PCB: SSC ratio (pg/mg) for various Bay Area watersheds.

Sampling Location	PCB/SSC (pg/mg)	Rank
Santa Fe Channel	1403	1
Pulgas Creek North	1050	2
Pulgas Creek South	906	3
Ettie Street Pump Station	745	4
North Richmond PS	325	5
Zone 4 Line A	119	6
Guadalupe River	119	7
Glen Echo Creek	86	8
San Leandro Creek	85	9
Sunnyvale Channel	79	10
San Lorenzo Creek	75	11
Zone 5 Line M	48	12
Coyote Creek	45	13
Calabassas Creek	41	14
Gellert Park	41	15
Stevens Creek	34	16
San Tomas Creek	20	17
Walnut Creek	19	18
Lower Pentencia Creek	17	19
Belmont Creek	14	20
Borel Creek	13	21
Lower Marsh Creek	3	22

Table 10. Average total Mercury: SSC ratio (ng/mg equivalent to mg/kg) for various Bay Area watersheds.

Sampling Location	THg/SSC (ng/mg)	Rank
Guadalupe River	4.5	1
San Pedro Storm Drain	2.4	2
Gellert Park	1.2	3
North Richmond PS	1.2	3
Pulgas Creek South	0.8	4
San Leandro Creek	0.8	5
Ettie St. Pump Station	0.8	6
Santa Fe Channel	0.7	7
Pulgas Creek North	0.5	8
Glen Echo Creek	0.4	9
Zone 5 Line M	0.4	10
Sunnyvale Channel	0.3	11
Zone 4 Line A	0.3	12
San Lorenzo Creek	0.3	13
San Tomas Creek	0.3	14
Stevens Creek	0.3	15
Coyote Creek	0.3	16
Belmont Creek	0.2	17
Lower Marsh Creek	0.2	18
Borel Creek	0.2	19
Lower Pentencia Creek	0.2	20
Calabassas Creek	0.2	21
Walnut Creek	0.1	22

Qualify the climate during the data collection period relative to the range of climate conditions for the area and discuss how this could affect loading estimates

Daily precipitation data were acquired from West County Wastewater District. The rain gauge was at the WCWD wastewater treatment plant approximately 1.0 miles from the North Richmond Pump Station. Only quantifiable data were used in this analysis. Mean annual rainfall (MAR) for the Richmond area for the period 1981-2011 calculated on a climatic year (July 1st to June 30th) is estimated at 23 inches per year (modeled PRISM data). Rainfall for water year 2011 was 31 inches or 134 percent of normal. Rainfall for water year 2012 was 21 inches or 91 percent of normal. Therefore, it is possible that the annual load computed for water year 2011 was possibly slightly higher than average (note, average loads are always biased towards wet years and rainfall intensity plays a role so it’s hard to predict an average year without long term data).

Results in context to watershed land use

The North Richmond Pump Station is located in an historically industrial part of Richmond, CA. The current watershed (based on ABAG 2005 land use data) is approximately 32% industrial which includes 10% heavy industrial and 5% former industrial land (vacant) (Table 11). The industrial area rings the western, southern and eastern watershed boundary while Wildcat Creek bounds the northern part of the watershed. The watershed currently includes an auto dismantling yard (37.95477, -122.374412), a junk/wrecking yard (37.953573, -122,372371), a greenhouse facility (37.958324, -122.361155), and a brass foundry (37.954643, -122.357569). The results of this study add support to the conceptual model that PCBs and mercury are found at higher concentrations in heavily industrialized areas, particularly those with old industrial areas. The North Richmond Pump Station is approximately 33% old industrial.

Table 11. Land use classification and percent of land use for the North Richmond Pump Station watershed.

Land Use Classification	Percent Land Use Type
Transportation	24%
Residential - high density	21%
Light Industrial	17%
Heavy Industrial	10%
Industrial Vacant	5%
Residential Vacant	5%
Residential - medium density	4%
Other	14%

10. Summary and Lessons Learned

A pilot dataset was collected in the North Richmond pump station from September 2010 through to January 2012 in order to characterize concentrations of a variety of pollutants and loads of suspended sediments, total mercury, and PCBs. This project report provides information to support one of the five stormwater diversion projects called for in the Municipal Regional Permit and one located in Contra Costa County. Data collection was focused on both dry season and wet season pumpout events in order to answer two main questions:

Q1. What are the concentrations and/or loads of a variety of compounds in pump station water that, if received by West County Wastewater Treatment Plant, would potentially impact the treatment process?

Q2. What is the load of total mercury and PCBs associated with first flush storms and dry season conditions in order to help assess the potential effectiveness of routing urban dry weather and first flush flows to POTWs?

In relation to the first question, our observations support the likelihood that concentrations of the constituents measured are below the influent limits desired by the wastewater treatment managers at the West County treatment plant. There were some exceedances of the effluent limits for dioxins, mercury, PCBs, and selenium. In relation to the loads question, approximately 21% percent of the total suspended sediment load, 49% of the total mercury load, and 7% of the PCB load estimated during the study period appears to be associated with dry weather pumpout conditions. First flush load estimates were 5% of the wet weather suspended sediment loads, 4% of the total mercury wet weather loads, and 4% of the PCB wet weather loads. In relation to watersheds where other observations have been made of mercury and PCB concentrations, the Richmond pump station watershed ranks fairly high in relative pollution levels. Therefore, we conclude that the Richmond pump station watershed may be considered a high leverage watershed in relation to mercury and PCB source areas. This suggests that, all things equal, managing loads emanating from this watershed may be more cost-effective than more lowly ranked watersheds with lower pollution levels.

There were a number of lessons learned in relation to collecting this kind of data in a pump station. Lessons learned were mostly logistical and will help any future monitoring efforts. Lessons include:

- Future pump station sampling should independently automate and log data associated with pump operations including pump RPM, run-times, number of pumps running, in addition to water levels in the sump.
- Given the unreliability of pump station electrical systems, data loggers and other instrumentation should be independently powered using batteries, and solar panels installed on the roof of the station.
- In order to check the quality of the pump volume data derived from pump run-times, pump capacity, and pump efficiency curves, sump geometry should be measured following safety precautions associated with confined entry (sulfur and other gases being a particular concern).
- Given the small size of the pump station watershed and the paucity of tipping bucket data, a rain gauge should be installed on the pump station roof and rainfall data should be logged on at least a 15 minute basis.
- Given the short duration of pumpout process, turbidity data should be logged at a time interval no less than 2 minute and perhaps even at 1 minute intervals.
- In order to assess resuspension of sump bottom sediments, two turbidity probes could be deployed, one probe 4-6 inches from the sump bottom but above any sediment deposit, and the other about 2 feet off the bottom but below the lowest pumpout water level. Alternatively and probably more cheaply, turbidity profiling could be done during a selected number of pumpout events during wet and dry flow conditions.

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APPENDIX A

Interpolation techniques applied to estimate continuous concentration data in preparation for loads computations. Concentrations thus determined were multiplied by the corresponding pump volume to determine loads which were then summed to any time step desired (first flush, largest storm, dry season, wet season, annual, total study time).

SampleID	DateTime	End	Wet or Dry Flow	Loads methods
RICH-100	10/6/10 9:15 AM	10/6/10 9:45 AM	Dry	
RICH-200	10/13/10 2:36 PM	10/15/10 10:06 AM	Dry	Laboratory measured concentration
RICH-400	10/24/10 11:36 AM	10/24/10 2:40 PM	Wet	
RICH-500-507	2/15/11 10:52 PM	2/16/11 1:02 AM	Wet	Concentrations determined by linear interpolation
RICH-600	6/21/11 12:24 PM	6/21/11 12:38 PM	Dry	SSC by SSC:Turbidity regression; Laboratory measured Hg and PCB concentrations
RICH-700	7/13/11 12:10 PM	7/13/11 12:28 PM	Dry	
RICH-800	8/16/11 1:00 PM	8/16/11 1:18 PM	Dry	
RICH-900	1/20/12 6:40 PM	1/20/12 6:40 PM	Wet	Laboratory measured concentration
RICH-901	1/20/12 7:36 PM	1/20/12 7:36 PM	Wet	
RICH-902	1/20/12 9:46 PM	1/20/12 9:46 PM	Wet	
	9/1/10 10:15 AM	10/3/10 3:30 AM	Dry	
	10/13/10 12:00 PM	10/13/10 12:24 PM	Dry	
	10/17/10 1:58 AM	10/17/10 2:06 AM	Dry	
	10/19/10 2:14 AM	10/21/10 1:42 PM	Dry	
	10/25/10 7:24 AM	10/28/10 10:18 AM	Dry	
	10/31/10 3:24 AM	11/6/10 5:48 AM	Dry	
	11/8/10 7:30 AM	11/9/10 9:56 PM	Dry	
	11/11/10 3:12 AM	11/18/10 9:20 AM	Dry	
	11/22/10 3:20 AM	11/22/10 6:22 PM	Dry	
	11/24/10 9:54 AM	11/26/10 12:46 PM	Dry	
	11/29/10 4:50 AM	12/2/10 10:34 PM	Dry	Concentrations determined by linear regression (SSC:Turbidity all data; HgT:SSC, dry data; PCBs:SSC dry data)
	12/4/10 3:12 AM	12/4/10 3:20 AM	Dry	
	12/7/10 9:28 AM	12/7/10 8:56 PM	Dry	
	12/11/10 3:00 AM	12/13/10 12:04 PM	Dry	
	12/16/10 3:18 AM	12/16/10 12:56 PM	Dry	
	12/24/10 4:18 AM	12/24/10 8:44 PM	Dry	
	12/27/10 2:02 AM	12/27/10 11:42 PM	Dry	
	12/30/10 2:24 AM	12/31/10 6:12 PM	Dry	
	1/3/11 2:30 AM	1/12/11 10:12 AM	Dry	
	1/14/11 4:22 AM	2/13/11 6:18 PM	Dry	
	2/21/11 1:34 AM	2/21/11 6:30 PM	Dry	
	2/23/11 12:58 AM	2/23/11 4:34 PM	Dry	

SampleID	DateTime	End	Wet or Dry Flow	Loads methods
	2/26/11 2:52 AM	3/1/11 11:58 PM	Dry	
	3/3/11 6:26 AM	3/5/11 11:58 PM	Dry	
	3/10/11 3:56 AM	3/12/11 6:58 PM	Dry	
	3/17/11 3:54 AM	3/17/11 9:50 PM	Dry	
	3/21/11 2:24 AM	3/22/11 10:46 PM	Dry	
	4/1/11 5:34 AM	4/12/11 9:46 PM	Dry	
	4/14/11 11:58 AM	5/25/11 8:26 AM	Dry	
	5/26/11 1:00 AM	5/28/11 4:56 PM	Dry	
	6/2/11 1:06 PM	6/3/11 7:40 AM	Dry	
	6/5/11 10:08 AM	6/21/11 11:32 AM	Dry	
	6/22/11 1:28 PM	6/26/11 11:50 AM	Dry	
	6/30/11 2:36 AM	7/11/11 8:28 AM	Dry	
	7/13/11 12:36 PM	8/15/11 7:56 PM	Dry	
	8/17/11 7:14 AM	11/5/11 8:10 PM	Dry	
	11/8/11 7:20 AM	11/10/11 7:40 AM	Dry	
	11/13/11 9:36 AM	11/19/11 10:38 PM	Dry	
	11/22/11 6:38 AM	11/23/11 12:30 AM	Dry	
	11/25/11 12:56 PM	12/11/11 7:24 AM	Dry	
	12/14/11 3:50 PM	1/19/2012 23:14	Dry	
	10/17/10 10:52 PM	10/17/10 10:58 PM	Wet	Concs determined by linear regression (SSC:Turb all data; HgT:SSC, wet data excluding 2 outliers; PCBs:SSC wet data excluding 1 outlier)
	10/22/10 2:16 AM	10/24/10 10:38 AM	Wet	
	10/24/10 3:04 PM	10/24/10 4:30 PM	Wet	
	10/29/10 5:20 AM	10/30/10 4:24 AM	Wet	
	11/7/10 4:18 AM	11/7/10 7:02 PM	Wet	
	11/10/10 4:38 AM	11/10/10 4:46 AM	Wet	
	11/19/10 6:34 AM	11/21/10 2:52 PM	Wet	
	11/23/10 12:54 AM	11/23/10 10:52 PM	Wet	
	11/27/10 2:32 AM	11/28/10 3:34 PM	Wet	
	12/3/10 1:46 AM	12/3/10 11:18 AM	Wet	
	12/5/10 3:12 AM	12/6/10 6:08 PM	Wet	
	12/8/10 6:44 AM	12/10/10 4:58 PM	Wet	
	12/14/10 1:00 AM	12/15/10 9:06 PM	Wet	
	12/17/10 5:28 AM	12/23/10 8:50 PM	Wet	
	12/25/10 5:26 AM	12/26/10 8:16 PM	Wet	
	12/28/10 7:24 AM	12/29/10 10:28 PM	Wet	
	1/1/11 1:24 AM	1/2/11 10:10 PM	Wet	
	1/13/11 3:10 AM	1/13/11 4:24 PM	Wet	
	2/14/11 5:38 AM	2/15/11 10:50 PM	Wet	
	2/16/11 1:04 AM	2/20/11 9:14 PM	Wet	

SampleID	DateTime	End	Wet or Dry Flow	Loads methods
	2/22/11 2:18 AM	2/22/11 3:28 PM	Wet	
	2/24/11 3:42 AM	2/25/11 10:44 PM	Wet	
	3/2/11 12:00 AM	3/2/11 9:26 PM	Wet	
	3/6/11 12:00 AM	3/6/11 4:52 AM	Wet	
	3/13/11 6:28 AM	3/16/11 8:56 PM	Wet	
	3/18/11 2:18 AM	3/20/11 10:46 PM	Wet	
	3/23/11 2:02 AM	3/24/11 3:52 AM	Wet	
	4/13/11 9:20 AM	4/13/11 8:00 PM	Wet	
	5/25/11 8:28 AM	5/25/11 11:16 AM	Wet	
	5/29/11 4:14 AM	6/1/11 7:42 PM	Wet	
	6/4/11 1:26 AM	6/4/11 11:28 PM	Wet	
	6/28/11 12:08 AM	6/29/11 7:28 AM	Wet	
	11/6/11 5:40 PM	11/6/11 5:48 PM	Wet	
	11/11/11 12:24 PM	11/12/11 7:52 AM	Wet	
	11/20/11 5:30 AM	11/21/11 11:16 AM	Wet	
	11/24/11 4:42 AM	11/24/11 2:38 PM	Wet	
	12/12/11 10:10 PM	12/12/11 10:18 PM	Wet	
	1/20/12 7:32 AM	1/20/12 6:20 PM	Wet	
	1/20/12 6:42 PM	1/20/12 7:34 PM	Wet	
	1/20/12 7:38 PM	1/20/12 9:44 PM	Wet	
	1/20/12 9:48 PM	1/20/12 9:48 PM	Wet	

APPENDIX B
PCB Congeners Analyzed in this Study

PCB Congener
PCB 008
PCB 018
PCB 028
PCB 033
PCB 044
PCB 049
PCB 052
PCB 056
PCB 060
PCB 066
PCB 070
PCB 074
PCB 031
PCB 087
PCB 095
PCB 097
PCB 099
PCB 101
PCB 105
PCB 110
PCB 118
PCB 128
PCB 132
PCB 138
PCB 141
PCB 149
PCB 153
PCB 156
PCB 158
PCB 170
PCB 174
PCB 177
PCB 180
PCB 183
PCB 187
PCB 194
PCB 195
PCB 201
PCB 203

APPENDIX C
Dioxins and Furans Analyzed in this Study

Dioxins and Furans
TCDF, 2,3,7,8-
PeCDF, 1,2,3,7,8-
PeCDF, 2,3,4,7,8-
HpCDF, 1,2,3,4,6,7,8-
HpCDF, 1,2,3,4,7,8,9-
HxCDF, 1,2,3,4,7,8-
HxCDF, 1,2,3,6,7,8-
HxCDF, 1,2,3,7,8,9-
HxCDF, 2,3,4,6,7,8-
OCDF, 1,2,3,4,6,7,8,9-
TCDD, 2,3,7,8-
PeCDD, 1,2,3,7,8-
HpCDD, 1,2,3,4,6,7,8-
HxCDD, 1,2,3,4,7,8-
HxCDD, 1,2,3,6,7,8-
HxCDD, 1,2,3,7,8,9-
OCDD, 1,2,3,4,6,7,8,9-