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Naval Facilities use of WinSLAMM –Calibration and Source Evaluation of San Diego and Northwest Test Watersheds

Contents

Abstract

The report is a discussion of the data sources available for the San Diego and Seattle area naval facilities that are being examined using WinSLAMM. The objective of the project is to demonstrate how WinSLAMM can be used for naval facilities to identify sources of pollutants of concern, and to evaluate potential stormwater control practices that may be applicable to these unique areas.

This report starts with a summary of the available data, and the data that are currently missing. Model calibration efforts are then described, along with an analysis of the sources of the runoff volume, TSS, copper, lead, and zinc. The analyses focus on the San Diego naval facility data in this report.

Description of WinSLAMM

WinSLAMM was developed to evaluate stormwater runoff volume and pollutant loadings in developed areas using small/intermediate storm hydrology concepts (in contrast to conventional drainage design approaches that focus on very large storms). The model determines the runoff based on local rain records and calculates runoff volumes and pollutant loadings from each individual source area within each land use category for each rain. Examples of source areas include: roofs, streets, paved storage and laydown areas, loading docks, small landscaped areas, large landscaped areas, sidewalks, and parking lots. An important enhancement to WinSLAMM as part of this project was the addition of an additional ten source areas that can be used to describe unique areas for special land uses, such as the naval facilities. These are described in detail later in this report.

Besides determining the main sources of the stormwater contaminants of concern, the model can apply a series of stormwater control practices, including rain barrels and water tanks for stormwater irrigation, pavement and roof disconnections, roof rain gardens, infiltration/biofiltration in paved areas and as curb-cut biofilters, street cleaning, wet detention ponds, grass swales, porous pavement, catchbasins, media filters, hydrodynamic devices, selected proprietary devices, and combinations of these practices located throughout the watersheds and at the outfalls. The model evaluates the practices through engineering calculations of the unit processes based on the actual designs and sizes of the controls specified and determines how effectively these practices remove runoff volume and pollutants. Another important enhancement to the newest version 10 of WinSLAMM is the option to route hydrographs and particle size distributions through series of control practices; treatment trains therefore are accurately evaluated at many scales in the program, from adjacent small unit processes in a single treatment device to large-scale land use based controls.

WinSLAMM does not use a percent imperviousness or a curve number to generate runoff volume or pollutant loadings. The model applies runoff coefficients to each “source area” within a land use category. Each source area has a different volumetric runoff coefficient equation based on factors such as: slope, type and condition of surface, soil properties, etc., and calculates the runoff expected for each rain. The runoff coefficients were developed using monitoring data from typical examples of each site type under a broad range of conditions. The runoff coefficients are continuously updated as new research data become available.

Each source area also has a unique pollutant concentration (event mean concentrations - EMCs - and a probability distribution) assigned to it. The EMCs for a specific source area vary depending on the rain depth. The source area’s EMCs are based on extensive monitoring conducted in North America by the USGS, Wisconsin DNR, University of Alabama, and other groups. These monitoring efforts isolated source areas (roofs, lawns, streets, etc.) for different land uses and examined long term data on the runoff quality. The pollutant concentrations are also continuously updated as new research data become available, including information collected from source areas at naval facilities.

The model can use any length of rainfall record as determined by the user, from single rainfall events to several decades of rains. The rainfall file used in these calculations for San Diego, CA, was developed from hourly data obtained from EarthInfo CDROMs, using 1952 through 2005 recorded hourly precipitation records obtained at the San Diego airport, in addition to several rain files surrounding the northwestern naval facilities for rain periods generally from 1952 through 2010. Model calibrations were conducted using the best estimates of the closest rain data corresponding to the monitored runoff events at the different naval facilities.

For each rainfall event in a data set, WinSLAMM calculates the runoff volume and pollutant load (EMC x runoff volume) for each source area. The model then sums the loads from the source areas to generate a land use or drainage basin subtotal load. The model continues this process for the entire rain series described in the rain file. It is important to note that WinSLAMM does not apply a “unit load” to a land use. Each rainfall produces a unique load from a modeled area based on the specific source areas in that modeled area. As noted above, the model routes the resulting loads from the uppermost portion of the test areas to the outfall, passing through control practices and with additional flows joining the drainage system. As the flows, particulates, and pollutants are transported through the system, the hydrographs and particle size distributions are modified by the control practices and the different timings of the adjoining flows.

The model replicates the physical processes occurring within each stormwater control practice. For example, for a wet detention pond, the model incorporates the following information for each rain event:

1. Runoff hydrograph, pollution load, and sediment particle size distribution from the drainage basin to the pond,
2. Pond geometry (depth, area),
3. Hydraulics of the outlet structure,
4. Particle settling time and velocity within the pond based on retention time

Stokes Law and Newton’s settling equations are used in conjunction with conventional surface overflow rate calculations and modified Puls-storage indication hydraulic routing methods to determine the sediment amounts and characteristics that are trapped in the pond. Again, it is important to note that the model does not apply “default” percent efficiency values to a control practice. Each rainfall is continuously modeled in short increments (generally using about 6-minute time steps) and the pollutant control effectiveness will vary based on each rainfall and the pond’s antecedent conditions.

The model’s output is comprehensive and can be customized, and typically includes:

1. Runoff volume, pollutant loadings and EMCs for a period of record and/or for each rain event.
2. The above data pre- and post- for each stormwater management practice.
3. Removal by particle size from stormwater management practices applying particle settling.
4. Other results can be selected related to flow-duration relationships for the study area, impervious cover model expected biological receiving water conditions, and life-cycle costs of the controls.

A full explanation of the model’s capabilities, calibration, functions, and applications can be found at www.winslamm.com. For this project, the parameter files were calibrated using the local San Diego and the northwest naval facility monitoring data, supplemented by additional information from regional data from the National Stormwater Quality Database (NSQD), available at: http://www.unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

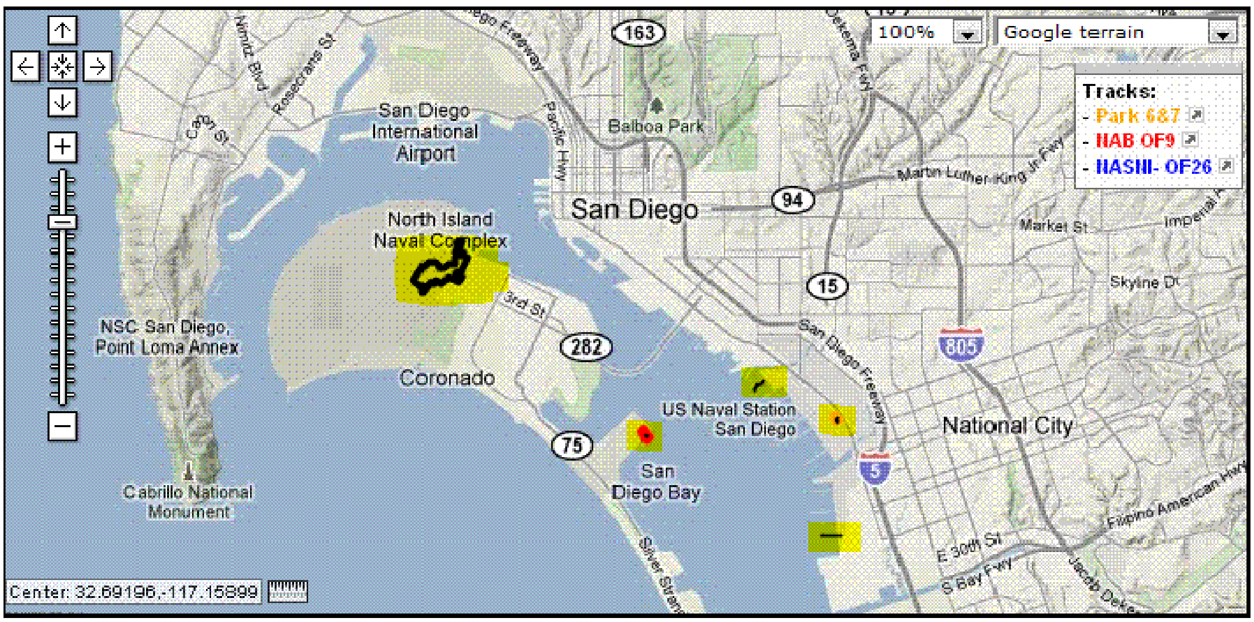
Data Availability and Site Descriptions

Overview

This section is a description of the sites surveyed in the two naval facility areas on the west coast: San Diego, California and four facilities in Puget Sound, Washington (near Seattle, WA). Both areas include multiple naval bases and include a variety of facilities including ports, piers, and air bases. The following are brief descriptions of these bases and include aerial photographs and the drainage area for the monitored outfalls. Appendix A contains the site survey information along with many site photographs of various potential pollutant source areas for each base.

Naval Base Coronado

Naval Base Coronado is comprised of seven smaller installations. Five of the outfalls examined are located on Coronado. Of the seven installations, samples were collected from four facilities in the San Diego Bay area: North Island Naval Complex, Naval Base San Diego, and the Point Loma Annex (Sub base), and the Amphibious Base (also located on North Island).

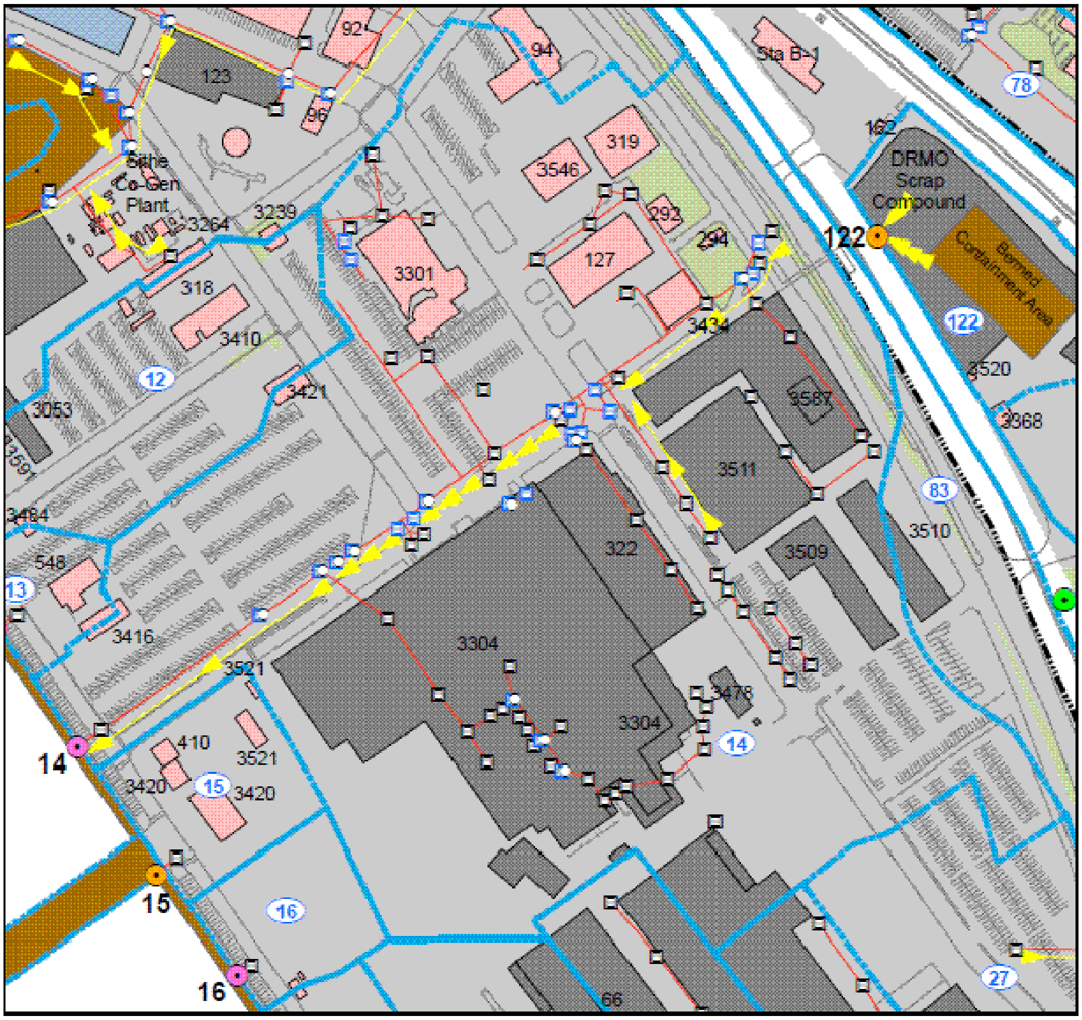


Outfalls Studied on Naval Base Coronado

Naval Base San Diego (NBSD) - Outfall 14

Naval Base San Diego (NBSD) is located on the mainland of San Diego along the eastern shore of the bay. At this base, three outfalls are examined: Outfall 14, Pier 1, and Pier 13. Outfall 14 has a complete data survey available describing the surface coverage, including the areas of each surface type. The watershed area for this outfall is approximately 50 acres. An aerial photograph, along with a CAD overlay map for the watershed, are shown in the following figures. The site is mainly comprised of industrial buildings, several smaller non-industrial buildings, and expansive impervious zones (parking lots and lay down areas). The site has 24 curb inlets and 68 catchbasins, all draining to OF14. The site has only two pervious areas inside the watershed boundary that make up approximately 2% of the total OF 14 drainage area.

Aerial Photo Outlining Land Use for Outfall 14



Drainage Overview for OF14

Total drainage area is 53.3 acres (2,321,000 ft^2)

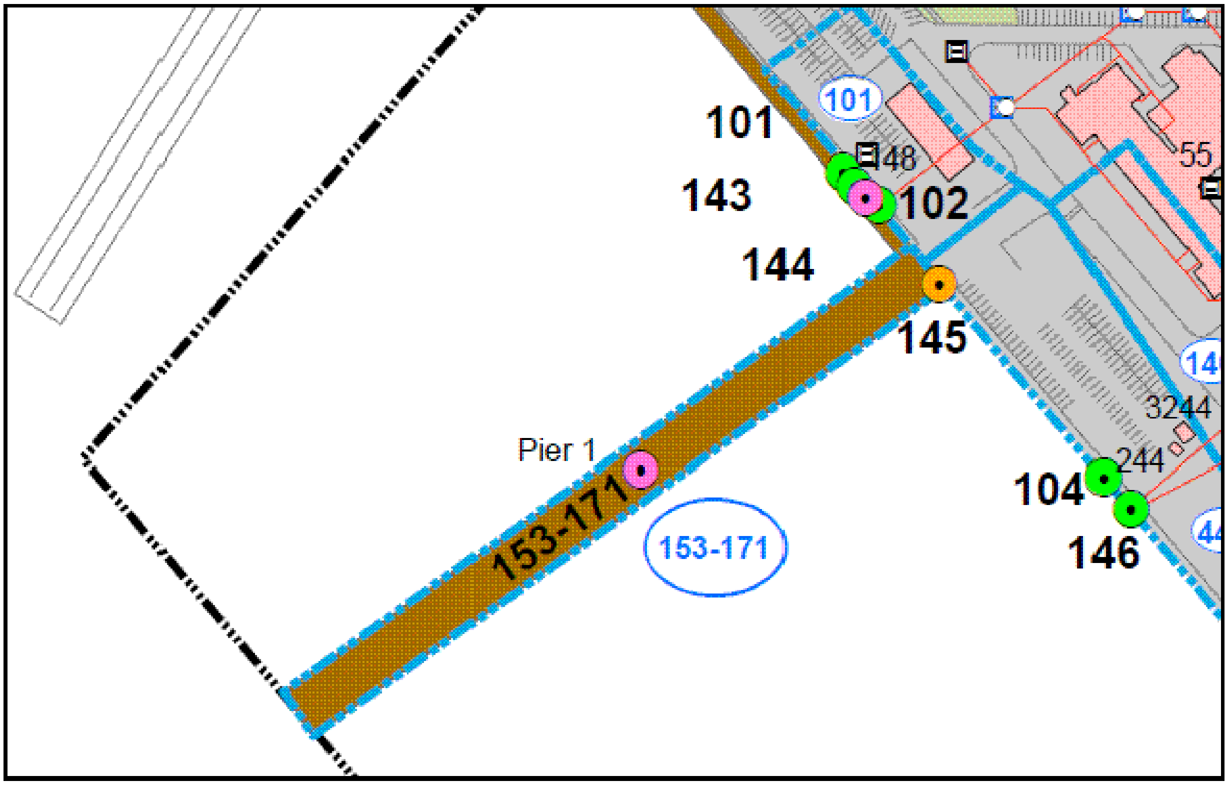
Field notes:

- All areas in the Outfall 14 drainage area are primarily at a 0-2% slope.
- Catchbasins varied from 2 to 4 ft. deep. (Distance from ground surface to top of drain pipe).
- Surveys were conducted on Mon 2/1/11 & Tues 2/2/11 at 0900-1630 & Mon 2/7/11 at 1230-1630.

Naval Base San Diego - Outfall 1 and 13

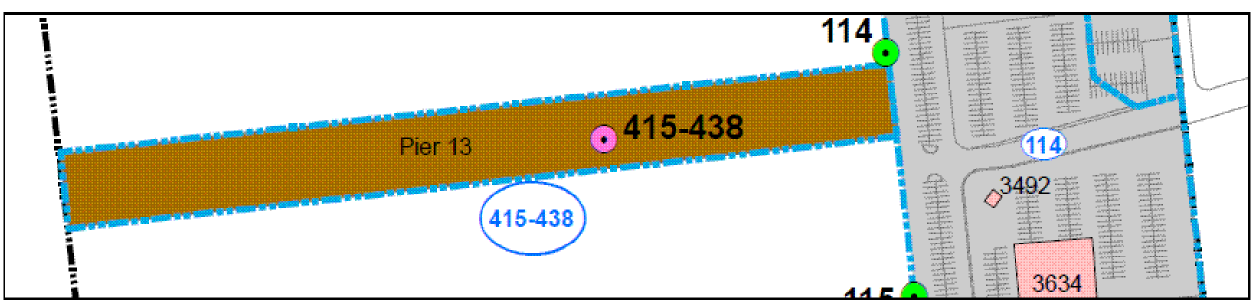
Outfalls 1 and 13, otherwise known as Piers 1 and 13, are located to the north and south of Outfall 14 respectively. Both drainage areas have complete surveys, CAD maps, sites photos, as well all other items necessary to begin modeling. These two sites are the smallest and most homogeneous of the sites being examined. The drainage areas are comprised of only the pier areas; their watershed boundary ends at the edge of the pier and does not include any shore areas. These sites drain internally towards the center of the piers. Both piers have concrete surfaces that are in good condition. Pier 1 totals 1.43 acres and Pier 13 is slightly larger totaling 3.25 acres in area. The main differences between the two sites are land use, traffic, and size. Pier 13 is the largest and most industrial pier on NBSD, receiving high daily traffic from the amount of shipping operations and other related shipping operations that take place. At the opposite end of the spectrum is Pier 1, which is a ceremonial pier, having some of the lowest traffic activity and minimal industrial activity.

Aerial Photo of Pier 1 (OF1)



Drainage Overview for Pier 1 (OF1)

Aerial Photo of Pier 13 (OF13)



Drainage Overview for Pier 13 (OF13)

Outfall 1 Ceremonial Pier area is 1.435 acres (62,509 ft^2)

Field notes:

- Survey was taken on Wednesday March 9th at approximately 1300-1400.
- Pier 1 is considered a ceremonial pier and exhibited much less activity than Pier 13 during the time of the survey.
- There was some limited truck traffic.

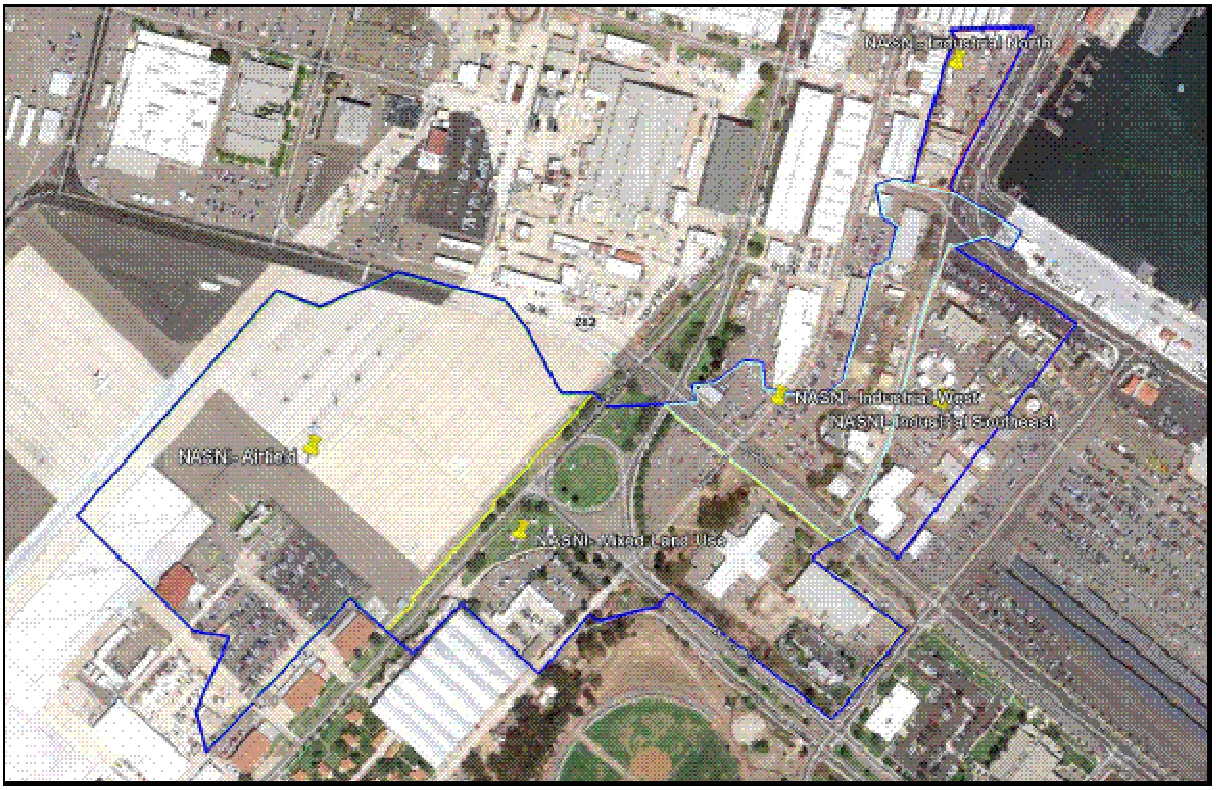
Outfall 13 Industrial Pier area is 4.253 acres (185,261 ft^2)

Field notes:

- Pier 13 is considered the most industrial pier on NBSD.
- Many of the storm drains in the middle of the pier are covered with plastic.
- There was moderately high activity with cranes, forklifts, trucks and people moving about.
- Survey was taken on Wednesday March 9th at approximately 1000-1200.

North Island Complex - Outfall 26

The North Island Complex includes the naval airfield, and is located on the north end of North Island. Outfall 26 has a complete survey describing surface coverage and materials. The watershed area for the outfall is approximately 73 acres. A CAD overlay map for the watershed is available. Photos showing items normally on the site and surface conditions are available for this outfall, along with KMZ files providing initial site overlays. This is the largest southwest region watershed study area being examined and also has the most complex and diverse drainage system. The site contains over 70 catchbasins and approximately 13% of the area is pervious. Most of the buildings are described as non-industrial, but there are some industrial buildings within this watershed also.



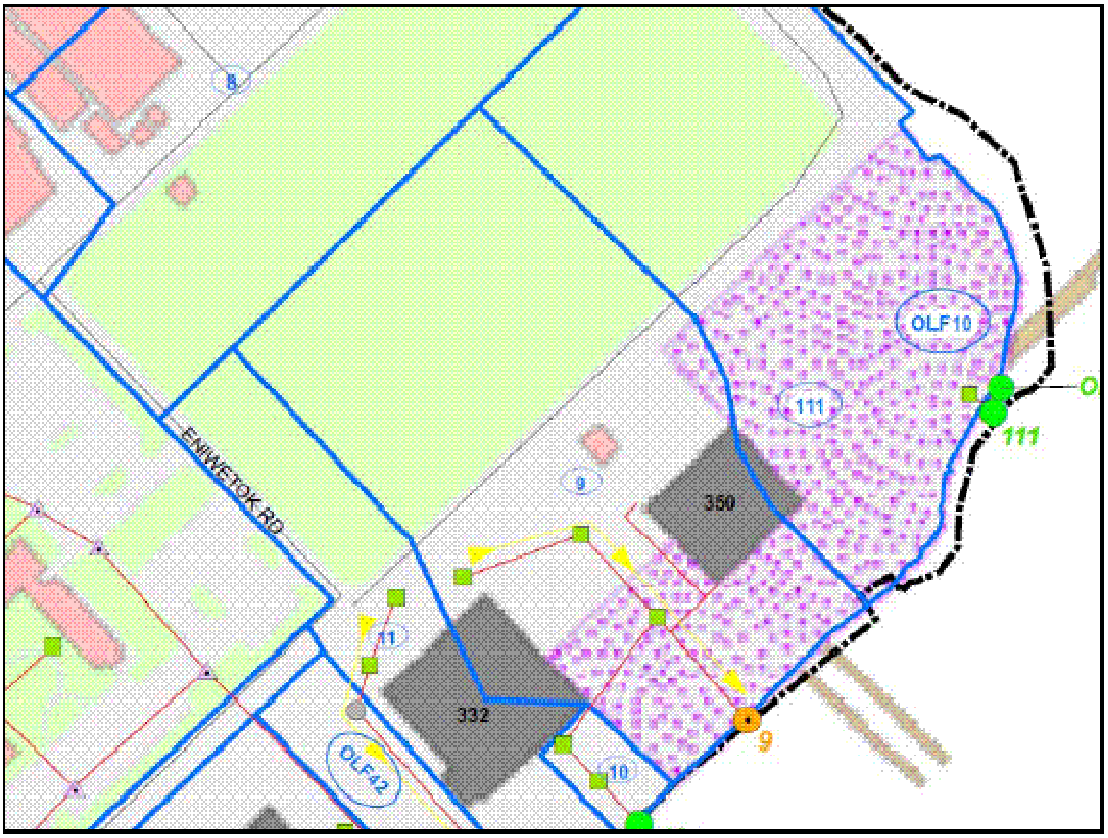
Drainage Overview and Aerial Image for Outfall 26

Total area: 72.1 acres

North Island Complex (Naval Amphibious Base) - Outfall 9

The North Island Complex also contains the Naval Amphibious Base. The base is located on the southern half of the island where it begins to narrow. Outfall 9 has a complete survey outlining the surface coverage characteristics and materials. The watershed area for the site is approximately 5 acres. The watershed has a large pervious area fraction (about 40%). A CAD overlay map for the watershed is available, along with photographs showing items normally on the site and the surface conditions. A Google aerial image and KMZ files showing site overlays indicate the areas of each surface activity in the drainage area.

Aerial Image for Outfall 9



Drainage Overview for Outfall 9

Area: 5.043 acres (219,673 ft^2)

Field notes:

- Survey was conducted on March 16, 2011 at approximately 1000-1200
- Very low activity was observed during the time of the survey, however, based on the amount of staging equipment it appears that it can get busy at times.
- Roof runoff from building 332 drains to a pervious area adjacent to the building.
- Roof runoff from building 350 is directly connected to Outfall 9.

San Diego Naval Facility Characteristic Summaries and WinSLAMM Files

The following tables summarize the site characteristics for the San Diego monitoring and modeling sites. These sites were selected to represent a typical cross-section of typical drainage areas on the regional naval bases. The sites include two piers (one with heavy industrial use and the other with light ceremonial use), an airfield, and two that include mixed industrial site activities. The range in drainage areas is large, from about 1.5 to more than 70 acres. The fraction of the sites being directly connected impervious areas ranges from 44 to 100%.

Modifications were made to WinSLAMM version 10 during this project period to enable more detailed and specific site characteristics. The following are the ten additional “other impervious areas” that were added to the standard land use categories, showing how they were designated for this project:

Area 1: Airfield apron/runway paved areas
Area 2: Other airfield paved areas
Area 3: Light industrial storage/laydown area, concrete (light industrial/laydown activity, concrete)
Area 4: Moderate industrial storage/laydown area, concrete (moderate industrial/laydown activities, concrete)
Area 5: Heavy industrial storage/laydown area, concrete (heavy industrial/laydown activities, concrete)
Area 6: Light industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)
Area 7: Moderate industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)
Area 8: Heavy industrial storage/laydown area, asphalt (heavy industrial/laydown activities, asphalt)
Area 9: Galvanized metal roofs, flat, directly connected to drainage system
Area 10: Other areas having substantial galvanized metal materials (fences, etc.)

Each of these “other areas” has unique TSS and pollutant characteristics to distinguish them from the standard paved and roof areas to better reflect the range of industrial activities occurring on the naval bases.

The detailed site surveys were examined and each building and surface area was designated as one of the WinSLAMM source area categories. These were added together for each site to develop the source description file and are summarized in the following tables.

Source Area Characteristics at San Diego Naval Station Monitoring Locations

Industrial Source Areas	**Naval Amphibious Base (NAB), Outfall 9**	**Naval Base San Diego (NAV), Outfall 14**	**Naval Air Station North Island (NASNI), Outfall 26**
AT 1: roofs	0.17 flat to silty 0.35 flat dir conn	13.43 flat dir conn 0.10 pitch to silty 3.22 pitch dir conn	26C: 0.53 ac pitched to silty 26C: 0.26 ac pitched dir conn 26D: 0.58 ac pitched dir conn 26A: 0.11 ac flat to silty 26C: 0.29 ac flat to silty 26D: 0.08 ac flat to silty 26A: 0.38 ac flat dir conn 26B: 0.63 ac flat dir conn 26C: 0.81 ac flat dir conn 26D: 0.22 ac flat dir conn 26E: 0.68 ac flat dir conn
AT 2: paved parking	0.394 dir conn	20.28 dir conn	26B: 5.20 ac dir conn 26C: 1.08 ac dir conn 26D: 2.19 ac dir conn 26E: 0.74 ac dir conn
AT 3: unpaved parking, driveways, and walkways			
AT 5: paved driveways			
AT 6: paved sidewalks and walks		0.34 dir conn	26A: 0.02 ac dir conn 26B: 0.19 ac dir conn 26C: 0.08 ac dir conn 26D: 0.005 ac dir conn
Street areas	0.34 rough and 40.1 ft wide asphalt	4.77 smooth and 40 ft wide asphalt	26B: 3.35 ac inter and 30 ft wide 26D: 2.86 ac inter and 30 ft wide
AT 7: large landscaped areas	2.07 silty baseball field		
AT 8: small landscaped areas	0.01 silty landscaping around building	1.08 ac	26A: 0.12 ac silty 26B: 6.66 ac silty 26C: 0.64 ac silty 26D: 1.55 ac silty 26E: 0.14 ac silty
AT 9: undeveloped areas		0.462 silty	
AT 10: other pervious areas			
Isolated areas		0.06 ac	26C: 0.11 ac 26E: 0.004 ac

AT 14, Area 1: airfield apron/runway paved areas			26A: 20.67 ac
AT 15, Area 2: other airfield paved areas			26A: 11.03 ac
AT 16, Area 3: light pier/laydown/storage/loading dock concrete areas			26A: 0.08 ac 26B: 1.87 ac 26C: 0.58 ac 26D: 0.32 ac 26E: 0.45 ac
AT 17, Area 4: moderate pier/laydown/storage/loading dock concrete areas	1.49 ac	0.10 ac	26C: 0.003 ac 26E: 0.001 ac
AT 18, Area 5: heavy pier/laydown/storage/loading dock and scrapyard concrete areas	0.27 ac		
AT 19, Area 6: light pier/laydown/storage/loading dock asphalt areas		0.36 ac	26B: 1.49 ac 26C: 1.66 ac 26D: 0.23 ac
AT 20, Area 7: moderate pier/laydown/storage/loading dock asphalt areas	0.15 ac	6.93 ac	26C: 0.07 ac 26D: 0.19 ac
AT 21, Area 8: heavy pier/laydown/storage/loading dock and scrapyard asphalt areas			26B: 0.01 ac 26C: 1.09 ac 26D: 0.05 ac
AT 22, Area 9: galvanized metal roofs, directly connected		6.61 ac flat dir conn (galv roofs)	26A: 0.01ac 26B: 1.57 ac 26C: 0.03 ac 26D: 0.42 ac 26E: 0.45 ac
AT 23, Area 10: other impervious areas with galvanized materials	0.09 ac	0.30 ac	26A: 0.13 ac 26B: 0.29 ac 26C: 0.68 ac 26D: 0.17 ac 26E: 0.09 ac
TOTAL AREA (ACRES)	5.33	57.58	26A: 32.55 ac 26B: 21.30 ac 26C: 8.00 ac 26D: 8.86 ac 26E: 2.55 ac Total OF26: 73.27 ac

Source Area Characteristics at San Diego Naval Station Monitoring Locations (continued)

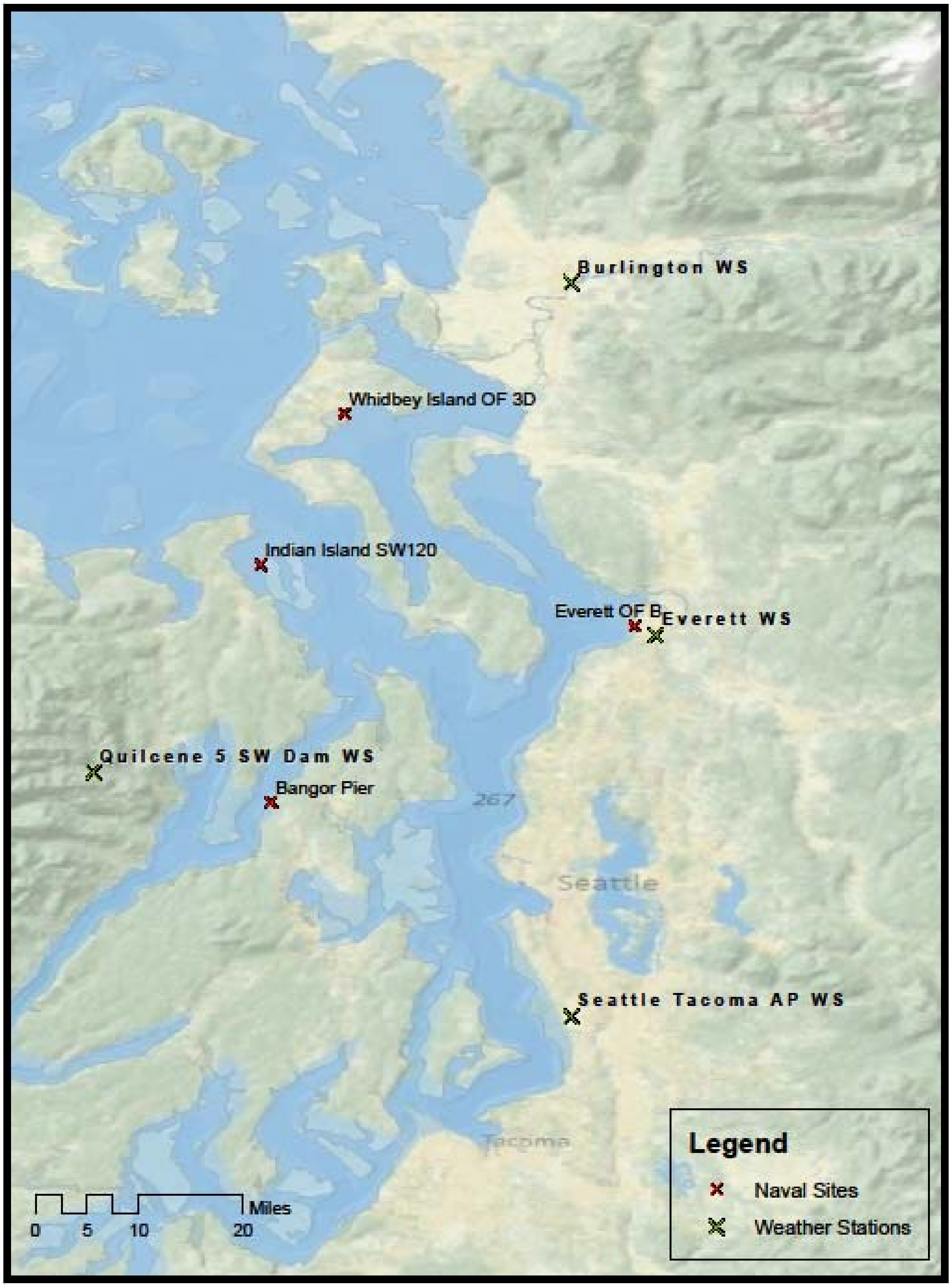
Industrial Source Areas	**Ceremonial Pier, NAV, Outfall 1**	**Industrial Pier, NAV, Outfall 13**
AT 1: roofs		
AT 2: paved parking		
AT 3: unpaved parking, driveways, and walkways		
AT 5: paved driveways		
AT 6: paved sidewalks and walks		
Street areas		
AT 7: large landscaped areas		
AT 8: small landscaped areas		
AT 9: undeveloped areas		
AT 10: other pervious areas		
Isolated areas	0.001 ac	0.048 ac
AT 14, Area 1: airfield apron/runway paved areas		
AT 15, Area 2: other airfield paved areas		
AT 16, Area 3: light pier/laydown/storage/loading dock concrete areas	1.24 ac	
AT 17, Area 4: moderate pier/laydown/storage/loading dock concrete areas		3.61 ac
AT 18, Area 5: heavy pier/laydown/storage/loading dock and scrapyard concrete areas	0.13 ac	0.49 ac
AT 19, Area 6: light pier/laydown/storage/loading dock asphalt areas		
AT 20, Area 7: moderate pier/laydown/storage/loading dock asphalt areas		
AT 21, Area 8: heavy pier/laydown/storage/loading dock and scrapyard asphalt areas		
AT 22, Area 9: galvanized metal roofs, directly connected		
AT 23, Area 10: other impervious areas with galvanized materials	0.07 ac	0.11 ac
TOTAL AREA (ACRES)	1.44 acres	4.25 acres

Summary of Surface Characteristics at San Diego Monitored Outfalls

Source Area Category	Naval Air Station North Island (NASNI), Outfall 26	Naval Base San Diego (NAV), Outfall 14	Naval Base San Diego (NAV), Piers, Point Loma, Outfall 1	Naval Base San Diego (NAV), Piers, Point Loma, Outfall 13	Naval Amphibious Base (NAB), Outfall 9
Total Area (acres)	71.96	50.26	1.44	4.25	4.97
Directly Connected Impervious Areas (DCIA) (acres)	50.12	41.8	1.44	4.25	2.18
Partially Connected Impervious Areas (acres)	12.76	7.31	0	0	0.71
Pervious Areas (acres)	9.09	1.15	0	0	2.08
DCIA % of total area	69.6	83.2	100.0	100.0	43.9

Northwestern Naval Bases

The naval bases examined in the Pacific Northwest are all located in Puget Sound area near Seattle, Washington. There are four areas where modeling is being conducted, as described in the following section. The following are just brief summaries of the characteristics of these areas. Regional rainfall data was also collected and the site characteristic descriptions were expanded considering the additional “other impervious area” categories now available in WinSLAMM.



Locations of Northwest Naval Bases Examined and Regional Weather Stations

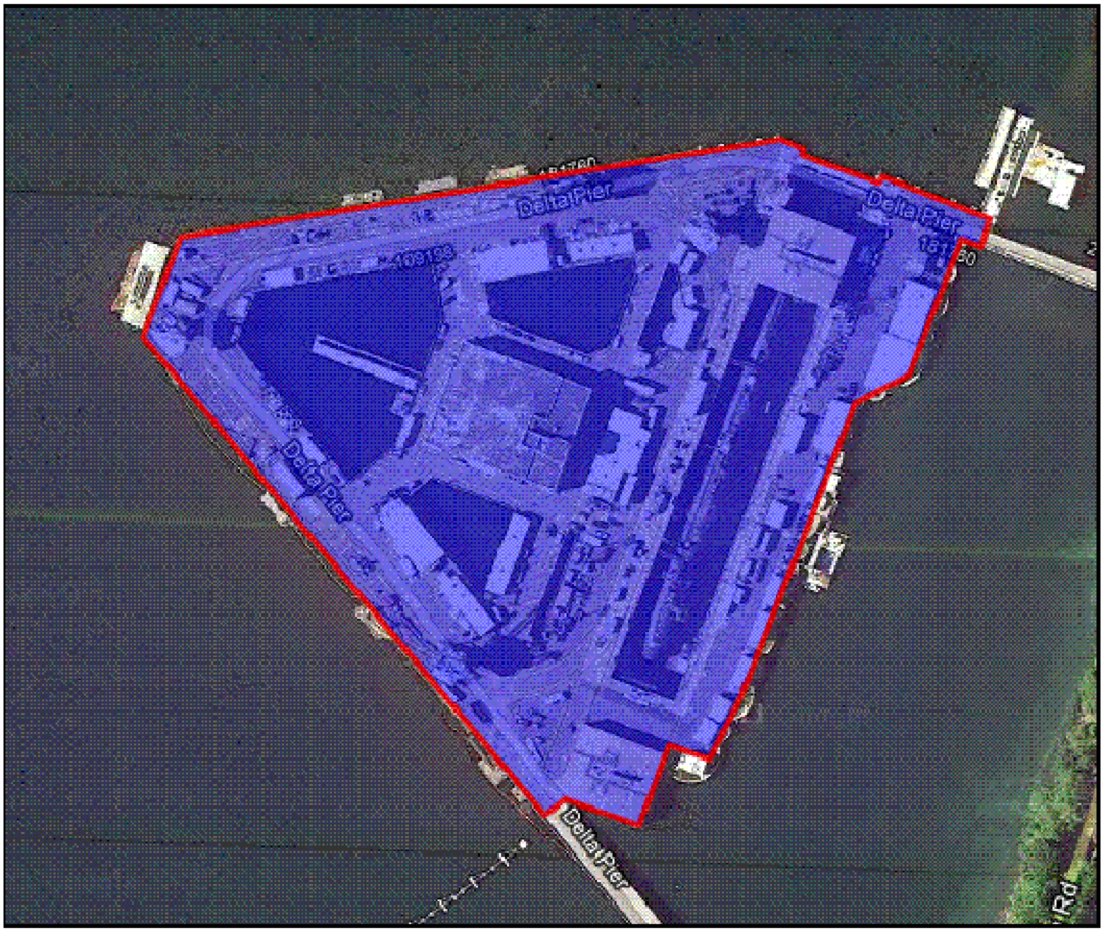
Naval Station Everett - Outfall B

Naval Station Everett is located on the eastern shore of Puget Sound, north of Seattle, Washington. A survey of the buildings and materials is available for this area. The approximate drainage area for this outfall is 12 acres.

Watershed Boundary and Aerial Image for Naval Station Everett Outfall B

Naval Submarine Base Bangor - Outfall 3A (pier 3A)

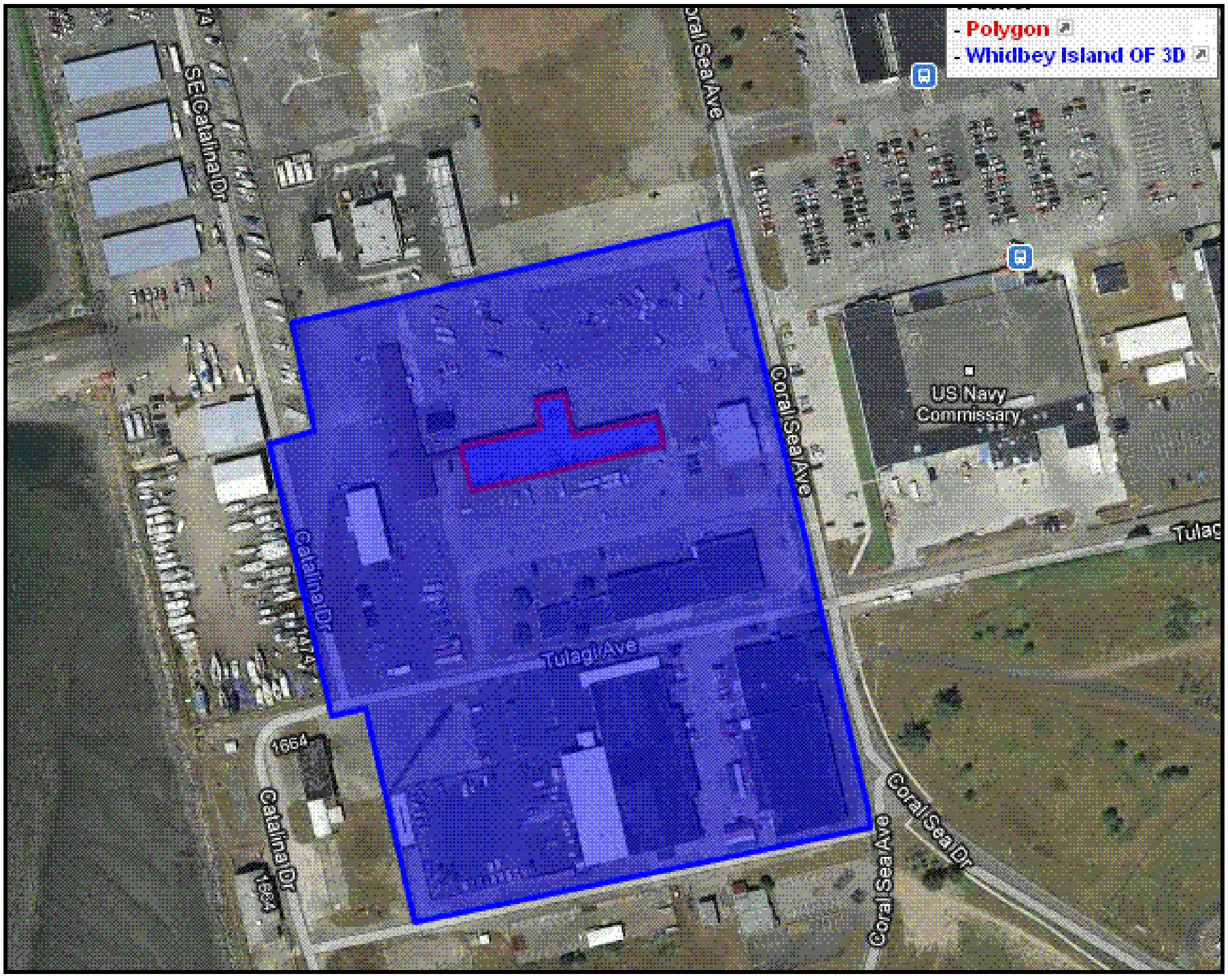
Naval Submarine Base Bangor is located on the Kitsap Peninsula, Washington. The facility is home to the Ohio-class submarine fleet. For the site, a survey of the buildings and exposed materials has been completed. The approximate size of the site is 9 acres. KMZ files are available providing site overlays.



Watershed Boundary and Aerial Image for Naval Submarine Base Bangor Outfall 3A

Whidbey Island Seaplane Base - Outfall 3D

Whidbey Island Seaplane Base is located on the northern tip of the island’s west half and north of Naval Station Everett. A survey of the buildings and exposed materials is available. The approximate size of the site is 12.8 acres. KMZ files are available providing site overlays.



Watershed Boundary and Aerial Image for Whidbey Island Seaplane Base Outfall 3D

Naval Magazine Indian Island - Outfall SW120

Naval Magazine Indian Island is located on the western shore of Puget Sound just south of Port Townsend. A survey of the buildings and exposed materials is available. This facility is the smallest being examined in this area, with an approximate size of 3 acres. KMZ files are available providing site overlays.

Watershed Boundary and Aerial Image for Naval Magazine Indian Island Outfall SW120

Summary of Puget Sound Naval Facility Site Characteristics and WinSLAMM Site Files

The following tables summarize the site survey information conducted at the four northwest naval facilities being examined in the Puget Sound area. As noted in the preceding comments, the site characteristics vary substantially in order to represent a range of conditions in the area. These sites are all relatively small (about 3 to 13 acres) and are almost completely directly connected impervious areas (77 to 100%). One site is a pier, one is a sub base, another is a sea plane base, and the other area is more traditionally industrialized.

Source Area Characteristics at Northwest Naval Station Monitoring Locations

Industrial Source Areas	Sub Base Bangor/3A	Everett/B	Whidbey Island/3D	Indian Island/SW120
AT 1: roofs	Flat, directly connected: 0.62 ac	Flat, directly connected: 0.29 ac	Flat, draining to pervious areas: 0.55 ac Flat, directly connected: 1.39 ac	Flat, directly connected: 0.04 ac
AT 2: paved parking		Directly connected: 5.55 ac	Directly connected: 6.00 ac	Directly connected: 2.66 ac
AT 3: unpaved parking, driveways, and walkways			Directly connected: 0.08 ac	
AT 5: paved driveways				
AT 6: paved sidewalks and walks		Directly connected: 0.54 ac	Directly connected: 0.03 ac	
Street areas		40 ft wide, intermediate texture: 1.29 ac	42 ft wide, intermediate texture: 0.35 ac	
AT 7: large landscaped areas				
AT 8: small landscaped areas		Silty soil: 0.64 ac	Silty soil: 2.36 ac	
AT 9: undeveloped areas				
AT 10: other pervious areas				
Isolated areas				
AT 14, Area 1: airfield apron/runway paved areas				
AT 15, Area 2: other airfield paved areas				
AT 16, Area 3: light pier/laydown/storage/loading dock concrete areas			0.15 ac	
AT 17, Area 4: moderate pier/laydown/storage/loading dock concrete areas				
AT 18, Area 5: heavy pier/laydown/storage/loading dock and scrapyard concrete areas				
AT 19, Area 6: light pier/laydown/storage/loading dock asphalt areas			1.75 ac	
AT 20, Area 7: moderate pier/laydown/storage/loading dock asphalt areas	7.28 ac			

AT 21, Area 8: heavy pier/laydown/storage/loading dock and scrapyard asphalt areas	0.98 ac	0.82 ac	0.06 ac	0.26 ac
AT 22, Area 9: galvanized metal roofs, directly connected	1.52 ac	3.48 ac	0.14 ac	0.09 ac
AT 23, Area 10: other impervious areas with galvanized materials	0.18 ac	0.08 ac	0.27 ac	0.08 ac
TOTAL AREA (ACRES)	10.57 acres	12.68 acres	13.13 acres	3.11 acres

Summary of Surface Characteristics at Northwest Naval Monitored Outfalls (acres and % of total area)

Source Area Category	Sub Base Bangor/3A	Everett/B	Whidbey Island/3D	Indian Island/SW120
Total Area (acres)	10.57	12.68	13.13	3.11
Directly Connected Impervious Areas (DCIA) (acres)	10.57 (100%)	12.04 (95%)	10.14 (77%)	3.11 (100%)
Partially Connected Impervious Areas (acres)	0	0	0.55 (4%)	0
Pervious Areas (acres)	0	0.64 (5%)	2.44 (19%)	0

Stormwater Characteristics

All stormwater models need to be calibrated and verified using local data for the best accuracy. As noted above, the site development characteristics for each of the naval facilities were extensively surveyed as part of the calibration process. Verification is based on the comparison of the predicted and the modeled stormwater characteristics for the different sites. The San Diego locations have historical stormwater quality data that were collected as part of earlier research projects (mostly focusing on toxicity sources and effects and as part of the stormwater permit monitoring). These data were obtained during the first 30 minutes of runoff (as "first flush" samples) and not as full event composite data. Therefore, these data were adjusted using information from local simultaneously collected first flush and total event composite samples.

First Flush vs. Composite Sample Stormwater Concentration Comparisons

"First flush" refers to an assumed elevated load of pollutants discharged in the beginning of a runoff event. First flush effects have been observed more often in small catchments than in large catchments (WEF and ASCE 1998). In some cases, the highest concentrations are observed at the times of flow peaks (Soeur, *et al.* 1994; Brown, *et al.* 1995). The presence of a first flush also has been reported to be associated with runoff duration by the City of Austin, TX (reported by Swietlik, *et al.* 1995). In other cases, peak pollutant concentrations can occur after the peak discharges, thus some pollutant discharges can be significant for events longer than the time of concentration (Ellis 1986). Adams and Papa (2000) and Deletic (1998) both concluded that the presence of a first flush depends on numerous site and rainfall characteristics.

Most of the San Diego and Northwest Navy facility stormwater quality data was collected only during the first 30 minutes of the runoff event. The WinSLAMM model is calibrated against the complete runoff period for each event (corresponding to a full storm flow-weighted composite sample, the preferred stormwater characterization monitoring method). During special toxicity evaluation studies, several storms at many sampling locations at the San Diego naval facilities had samples taken during the first 30 minutes of flow (corresponding to the first flush samples taken during most of the characterization monitoring activities) and during the full duration of the event (composite samples). These paired samples were statistically compared to detect significant differences in the data sets. For those constituents that were found to be significantly different, the relationships between the composite and first flush samples were identified for use as "correction" factors for the larger data set of first flush data for the model calibration activities.

Modifications of the First Flush San Diego Naval Facility Stormwater Data to Represent Full Event Composite Conditions

As described in Appendix A, statistical analyses were conducted to identify suitable factors to adjust the available first flush data to approximate full event composite conditions. The following tables summarize the TSS, copper, and zinc first flush concentrations observed at the five San Diego naval facilities, along with the adjusted approximate total storm average concentrations. As noted in Appendix A, the copper and zinc first flush and composite concentrations were not found to be significantly different (based on the number of samples available and the magnitude of the differences). The suspended solids concentrations were found to be significantly larger for the composite storm samples compared to the first flush samples and were therefore adjusted. These data represent information from 17 to 30 samples for each location and analyte, and the coefficients of variation ranged from about 0.7 to 1.3. As shown on the following figure (Burton and Pitt 2002), the sample numbers and the sample variabilities would enable the average concentrations to be determined with an error of about 50 to 70%. A more desirable error of 25% would require about 50 samples per site and analyte. It would be very difficult (and expensive) to obtain these smaller error levels, especially in Southern California where only about ten rain events per year produce sufficient runoff for sampling.

First Flush Samples and Composite Equivalents from Naval Air Base Outfall #26

	Number of events	Average	Minimum	Maximum	Standard deviation	Coefficient of Variation (COV)*	Approximate multiplier for total storm concentration	Approximate total storm average concentration
TSS (mg/L)	26	103	0	590	132	1.27	2.26	233
Cu (µg/L)	23	63	0	230	54	0.85	1	63
Zn (µg/L)	22	370	23	1,500	356	0.96	1	370

*ratio of standard deviation to the average concentrations

First Flush Samples and Composite Equivalents from Naval Base San Diego Outfall #14 (mixed industrial activities)

	Number of events	Average	Minimum	Maximum	Standard deviation	Coefficient of Variation (COV)	Approximate multiplier for total storm concentration	Approximate total storm average concentration
TSS (mg/L)	30	77	2	290	73	0.95	2.26	174
Cu (µg/L)	30	69	8	350	72	1.05	1	69
Zn (µg/L)	24	791	45	3,700	1,072	1.30	1	791

First Flush Samples and Composite Equivalents from Naval Base San Diego Outfall #1 (ceremonial pier)

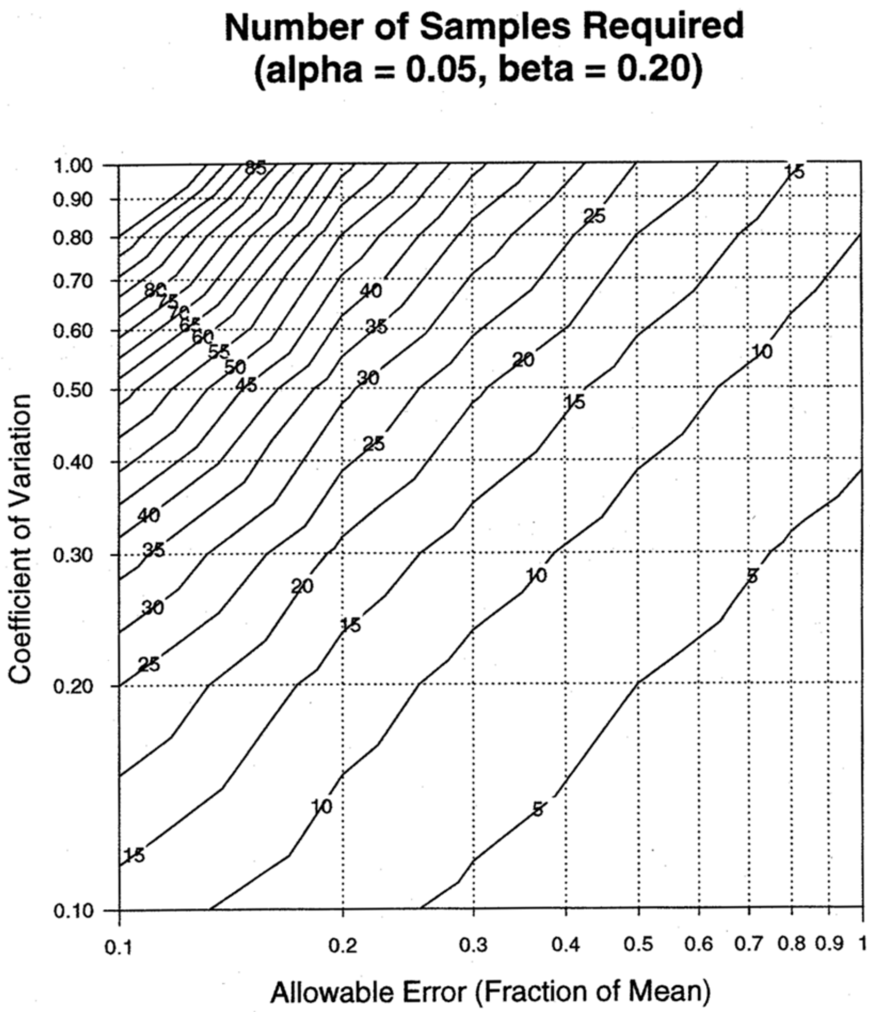
	Number of events	Average	Minimum	Maximum	Standard deviation	Coefficient of Variation (COV)	Approximate multiplier for total storm concentration	Approximate total storm average concentration
TSS (mg/L)	18	182	27	910	228	1.25	2.26	411
Cu (µg/L)	17	137	39	330	92	0.67	1	137
Zn (µg/L)	17	1,003	81	2,300	713	0.71	1	1,003

First Flush Samples and Composite Equivalents from Naval Base San Diego Outfall #13 (heavy industrial pier)

	Number of events	Average	Minimum	Maximum	Standard deviation	Coefficient of Variation (COV)	Approximate multiplier for total storm concentration	Approximate total storm average concentration
TSS (mg/L)	18	239	17	820	222	0.93	2.26	540
Cu (µg/L)	17	342	60	1,300	329	0.96	1	342
Zn (µg/L)	17	1,438	310	5,800	1,629	1.13	1	1,438

First Flush Samples and Composite Equivalents from Naval Amphibious (NAB) Outfall #9

	Number of events	Average	Minimum	Maximum	Standard deviation	Coefficient of Variation (COV)	Approximate multiplier for total storm concentration	Approximate total storm average concentration
TSS (mg/L)	21	137	0	934	250	1.82	2.26	310
Cu (µg/L)	21	163	20	505	154	0.94	1	163
Zn (µg/L)	21	1,927	180	5,600	1,946	1.01	1	1,927

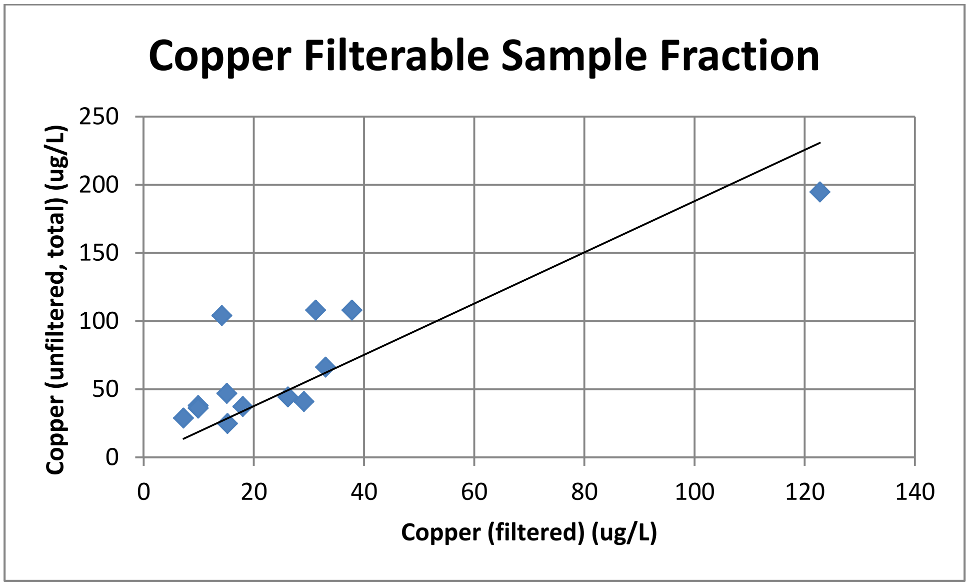


Sample Requirements for Confidence of 95% (α= 0.05) and Power of 80% (β= 0.20) (Burton and Pitt 2002).

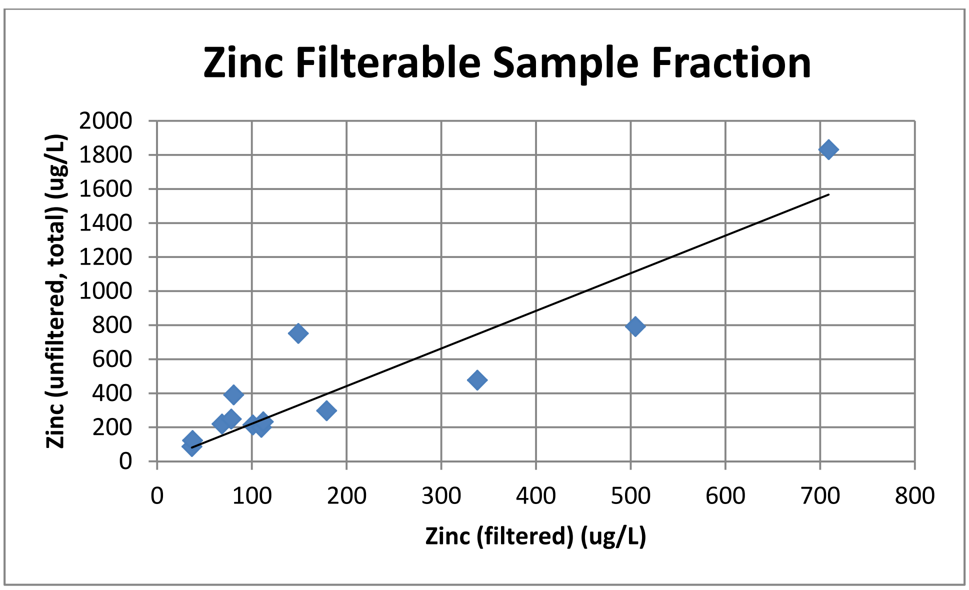
Filtered Fraction of Stormwater Pollutants

Appendix B compares parallel filtered with nonfiltered stormwater data for a number of constituents measured in the stormwater for several events. The filtered fractions were then used to estimate the filtered concentrations of copper and zinc for the observed events, data that is needed to complete the WinSLAMM calibration.

The following plots show the available total sample and filtered sample copper and zinc concentrations for the 13 events for which these concurrent data are available. The average filterable fraction of the total copper samples is about 42% (COV of 0.43), and the average filterable fraction of the total zinc samples is about 43% (COV of 0.38). The scatterplots also indicate the variability of the filterable fraction for these data. The following table therefore shows the estimated average total and filterable concentrations for total storm composite conditions at each of the five monitored outfalls. These final adjusted values were used during the WinSLAMM model calibration process.



Filterable fraction of copper samples for total storm composite samples.



Filterable fraction of zinc samples for total storm composite samples.

Total and Filterable Concentrations for Total Storm Composite Conditions

	Naval Air Base Outfall #26	Naval Base San Diego Outfall #14 (mixed industrial activities)	Naval Base San Diego Outfall #1 (ceremonial pier)	Naval Base San Diego Outfall #13 (heavy industrial pier)	Naval Amphibious Base (NAB) Outfall #9
TSS (mg/L)	233	174	411	540	310
Total Cu (µg/L)	63	69	137	342	163
Filterable Cu (µg/L)	26	29	58	144	68
Total Zn (µg/L)	370	791	1,003	1,438	1,927
Filterable Zn (µg/L)	159	340	431	618	829

Calibration of WinSLAMM using San Diego Navy Stormwater Quality Data

All models need to be calibrated to result in the most effective information. WinSLAMM calibrations for the San Diego naval facilities were based on a multi-step process. Much source area monitoring data are available from different locations (mainly from California, Alabama, Ontario, and Wisconsin). These data are summarized in a series of peer-reviewed chapters in the following modeling monographs:

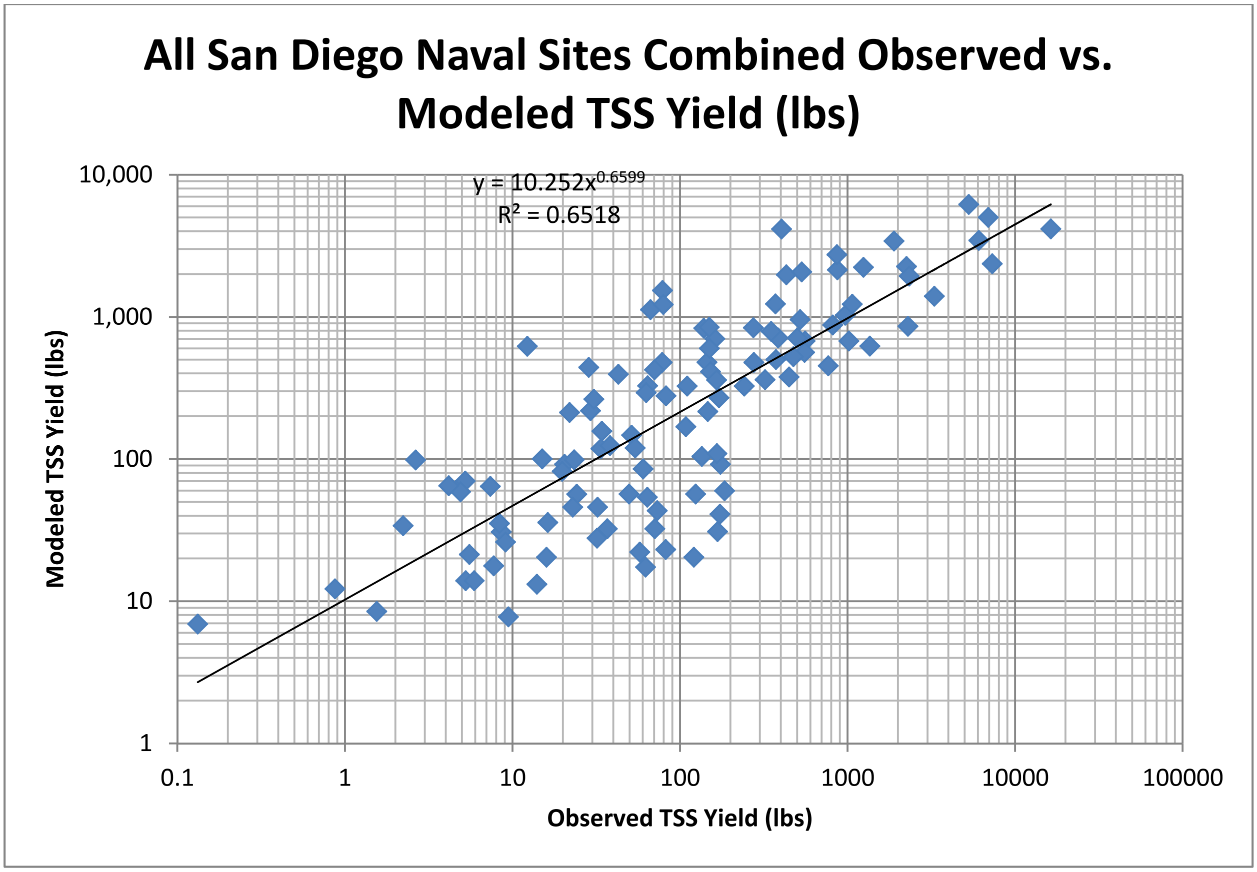
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 1) – Older monitoring projects." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 465 – 484 and 507 – 530. 2005.
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 2) – Recent sheetflow monitoring results." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 485 – 530. 2005.
- Pitt, R., D. Williamson, and J. Voorhees. "Review of historical street dust and dirt accumulation and washoff data." Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp 203 – 246. 2005.

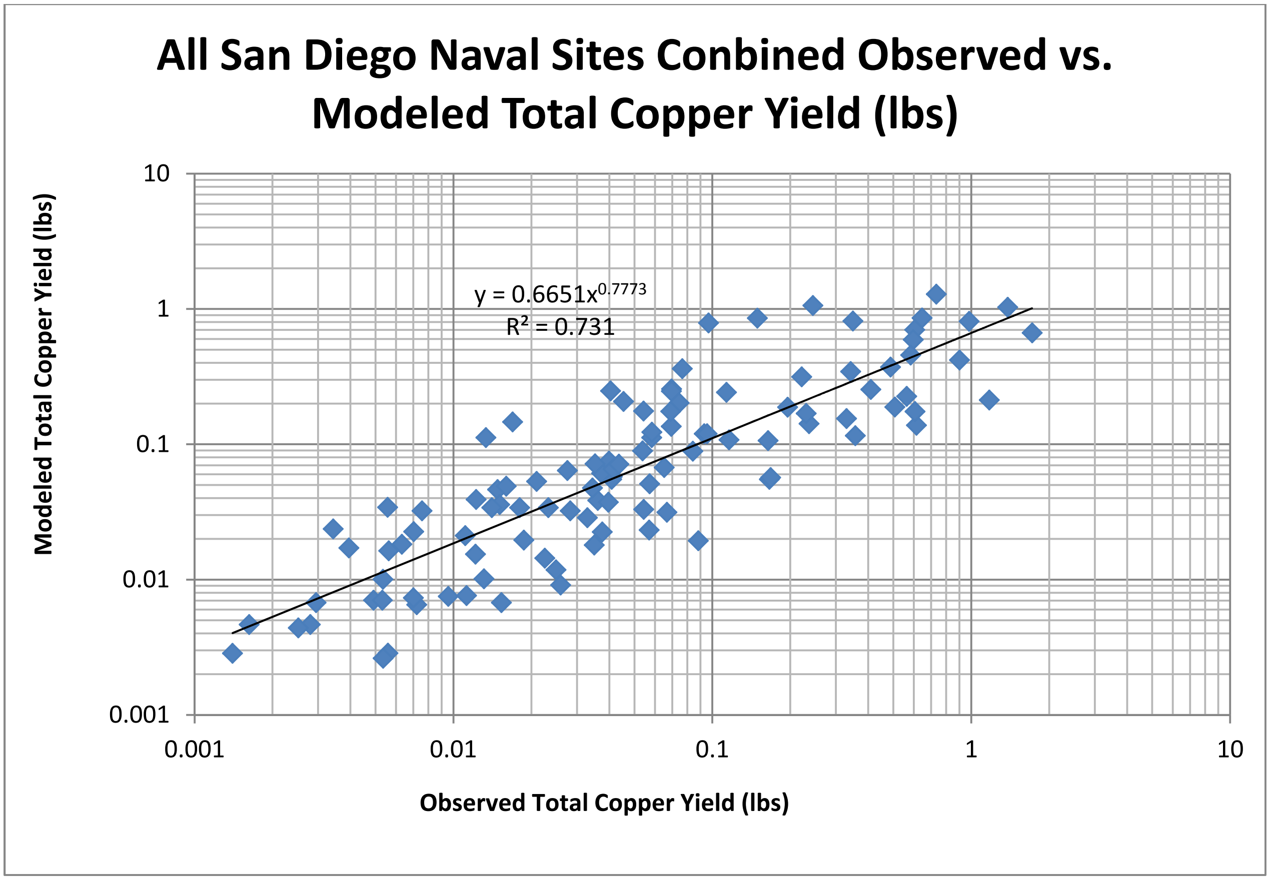
These data have been used to create calibrated WinSLAMM models in several locations that have since been verified using outfall data. The most extensive data are from the Birmingham, AL area and from the states of Wisconsin and California. Land use (and stormwater) data from throughout the nation are also available from many research reports. These data were separated into several regional groups. The San Diego area is included in the Southwest US area and was originally based on the Los Angeles area calibration and verification model sets. The Southwest regional model files were then modified based on outfall data from the events monitored in San Diego as part of the Navy's stormwater monitoring program, as described in various facility reports.

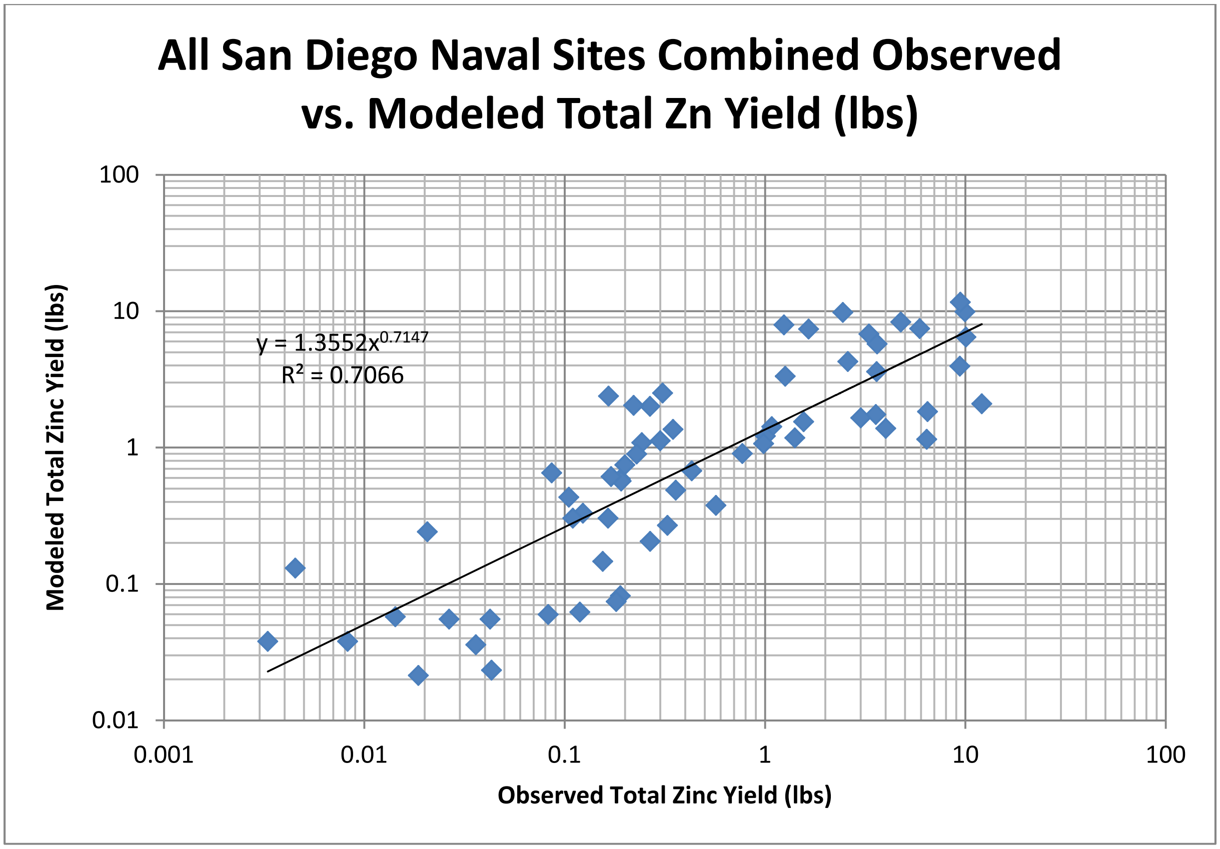
Appendix C describes the available storm-by-storm TSS, Cu, and Zn observations from the five San Diego Naval facility bases that were used to calibrate WinSLAMM, along with the best fit calibration values for TSS, Cu, and Zn, plus some comparable values from other studies. The first step was to obtain rainfall data associated with these monitored events. Since these naval facilities are located close to the San Diego International Airport, the airport rain observations were examined for the monitoring dates. In almost all cases, rains had occurred on the days of the monitoring and therefore, the rain characteristics (after processing in WinSLAMM to develop individual rain event summaries) were assumed to be applicable for the monitored conditions. As noted in this report, the monitoring data are only available for “first-flush” samples and not the complete rain events. Statistical analyses were therefore conducted to identify possible adjustment factors that could be applied to these first-flush data to approximate full storm composite conditions based on several concurrent first-flush and complete event monitoring data, as described in Appendix A. For the calibration process, both particulate-bound and filterable concentrations of the observed pollutants are needed. There were some of these data available, and again, statistical analyses were conducted to identify likely filterable fractions of the total metals observed, as described in Appendix B. Site flow data (along with site rainfall data) should also be available for the monitored storms and used in the first step of the calibration process. However, flow data were not available for these events, although rainfall data were available from a close location. Therefore, the flow processes in WinSLAMM were not calibrated with site data, but were compared to the runoff analyses results shown in the prior base hydrology report. Being highly impervious, the modeled results compared favorably with the runoff report information.

Appendix C lists the observed data and assumed rain conditions, examines the observed concentrations for possible relationships with the rain depths and antecedent dry period (and their interactions), and summarizes the results of the calibration efforts showing the observed and modeled concentrations and discharge loads. As indicated in Appendix C, none of the rainfall characteristics were able to explain any of the variability in the observed concentrations. WinSLAMM calculates the expected runoff concentrations (and pollutant loads) based on land use and source area characteristics, and rainfall characteristics (including antecedent dry period data). If no pattern is identified in the data for some of these factors, then only the remaining factors are available to explain as much of the data variation as possible. The remaining variability is then described using uncertainty measurements (such as the coefficient of variation, COV: the ratio of the standard deviation to the average) contained in the pollutant calibration files and elsewhere in the program.

The goal of the calibration process was therefore to predict the discharge loads for a long-term continuous simulation by trying to match the sum of loads of the observed and modeled events for sites having overlapping development characteristics. Very close matches are not always possible due to potentially conflicting observations for the same type of areas at different sites, so the best overall fit is used. Concentration comparisons for the data from these sites are not related to the rainfall characteristics, so differences between locations was the most important factor. The resulting predicted concentrations for each individual site are therefore not highly variable, unless the Monte Carlo calculation options are used which can result in overall concentration variations that better match the modeled values with the observed values. Event-by-event concentration comparisons are therefore not closely correlated, as rainfall effects (including interevent periods) were not found to be significant in explaining the patterns of the concentration values. Therefore, load comparisons were mostly used for the final data calibrations, as shown in the following three scatterplots for TSS, copper, and zinc.


All San Diego Naval Sites Combined Observed vs. Modeled TSS Yield (lbs)
y = 10.252x^0.6599
R² = 0.6518
Modeled TSS Yield (lbs)
10,000
1,000
100
10
1
0.1
1
10
100
1000
10000
100000
Observed TSS Yield (lbs)


All San Diego Naval Sites Conbined Observed vs. Modeled Total Copper Yield (lbs)
Modeled Total Copper Yield (lbs)
Observed Total Copper Yield (lbs)
y = 0.6651x^0.7773
R² = 0.731
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10



Appendix C contains similar plots for filterable and particulate forms of copper and zinc for these San Diego data. The following tables summarize the observed (adjusted) composite event and calculated concentrations and loads for TSS, total copper, and total zinc, while the previous figures plots are the event-by-event loads for the TAA, Cu, and Zn. Most of the yield values are quite close, although a few are seen to have larger differences (OF9 TSS yields, for example). The copper concentrations and yields for the observed and modeled conditions compare favorably, while there are larger differences between the observed and modeled zinc concentrations for OF9 again. These differences are within reason as the observed concentrations are only estimates of the actual conditions as they were adjusted from the first flush sample observations. In addition, the filtered concentrations were also estimated from samples collected from several locations. The adjustment factors were evenly applied to all rains, while they likely vary. More accurate calibrations (being able to explain a larger amount of the variation) would be possible with additional data targeted specifically for calibration purposes. These calibrations for stormwater quality measurements are expected to be within about 50% of the actual values for most conditions, a typical objective for most water quality model calibration efforts.

Observed and Modeled TSS Concentrations and Yields at San Diego Naval Facility Study Areas

	TSS observed average conc. (mg/L)	TSS modeled average conc. (mg/L)	TSS observed total yield (lbs)	TSS modeled total yield (lbs)
Naval Air Base Outfall #26	243	337	43,956	40,327
Naval Base San Diego Outfall #14 (mixed industrial activities)	174	252	26,733	29,919
Naval Base San Diego Outfall #1 (ceremonial pier)	412	358	735	918
Naval Base San Diego Outfall #13 (heavy industrial pier)	541	482	2,314	3,100
Naval Amphibious Base (NAB) Outfall #9 (industrial area and ball field)	326	351	958	1,828

Observed and Modeled Cu Concentrations and Yields at San Diego Naval Facility Study Areas

	Total Cu observed average conc. (µg/L)	Total Cu modeled average conc. (µg/L)	Total Cu observed total yield (lbs)	Total Cu modeled total yield (lbs)
Naval Air Base Outfall #26	66	53	8.16	6.22
Naval Base San Diego Outfall #14 (mixed industrial activities)	69	69	7.47	9.36
Naval Base San Diego Outfall #1 (ceremonial pier)	137	117	0.26	0.26
Naval Base San Diego Outfall #13 (heavy industrial pier)	342	288	1.8	1.6
Naval Amphibious Base (NAB) Outfall #9 (industrial area and ball field)	163	177	0.69	0.99

Observed and Modeled Zn Concentrations and Yields at San Diego Naval Facility Study Areas

	Total Zn observed average conc. (µg/L)	Total Zn modeled average conc. (µg/L)	Total Zn observed total yield (lbs)	Total Zn modeled total yield (lbs)
Naval Air Base Outfall #26	370	530	50	61
Naval Base San Diego Outfall #14 (mixed industrial activities)	791	672	66	72
Naval Base San Diego Outfall #1 (ceremonial pier)	1003	951	2.0	2.1
Naval Base San Diego Outfall #13 (heavy industrial pier)	1438	1646	9.4	9.7
Naval Amphibious Base (NAB) Outfall #9 (industrial area and ball field)	1926	1056	6.8	5.8

Sources of Flows and Pollutants at San Diego Naval Facilities

The calibrated WinSLAMM model was used to make calculations of flow, TSS, copper, and zinc sources in the five San Diego naval facility watersheds. The following tables and figures illustrate these likely sources for the five areas. The figures illustrate how these contributions vary with different rain categories.

Major flow sources for OF26 sub areas:

Sub area and portion of total flow	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
26A (49.5%)	oi1 (32%) oi2 (17%)	oi1 (31%) oi2 (17%)	oi1 (31%) oi2 (17%)
26B (24.5%)	pvd park/sto (8%) streets (6%)	pvd park/sto (8%) streets (6%)	pvd park/sto (8%) streets (5%)
26C (10.3%)	oi6 (3%)	oi6 (3%)	oi6 (3%)
26D (11.9%)	streets (5%)	streets (5%)	streets (5%)
26E (3.7%)	all <2%	all <2%	all <2%
total OF26	oi1 (32%) oi2 (17%) streets (11%) pvd park/sto (8%) oi6 (3%) (total 71%)	oi1 (31%) oi2 (17%) streets (11%) pvd park/sto (8%) oi6 (3%) (total 70%)	oi1 (32%) oi2 (17%) streets (10%) pvd park/sto (8%) oi6 (3%) (total 70%)

Major TSS sources for OF26 sub areas:

Sub area and portion of total TSS	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
26A (52.8%)	oi1 (27%) oi2 (15%)	oi1 (37%) oi2 (20%)	oi1 (34%) oi2 (18%)
26B (26.1%)	streets (17%)	pvd park/sto (8%) streets (5%)	small landscaped (14%) pvd park/sto (7%)
26C (10.1%)	oi8 (5%)	oi8 (6%)	oi8 (4%)
26D (9.0%)	streets (15%)	streets (4%) pvd park/sto (4%)	pvd park/sto (3%) small landscaped (3%)
26E (2%)	all <2%	all <2%	all <2%
total OF26	streets (32%) oi1 (27%) oi2 (15%) oi8 (5%) (total 79%)	oi1 (37%) oi2 (20%) pvd park/sto (12%) streets (9%) oi8 (6%) (total 84%)	oi1 (34%) oi2 (18%) small landscaped (17%) pvd park/sto (10%) oi8 (4%) (total 83%)

Major copper sources for OF26 sub areas:

Sub area and portion of total Cu	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
26A (19%)	oi1 (9%) oi2 (6%)	oi1 (10%) oi2 (7%)	oi1 (11%) oi2 (7%)
26B (39%)	pvd park/sto (16%) streets (15%) oi3 (5%)	pvd park/sto (19%) streets (11%) oi3 (5%)	pvd park/sto (21%) streets (8%) oi3 (6%)
26C (19%)	oi8 (10%) pvd park/sto (3%)	oi8 (10%) pvd park/sto (4%)	oi8 (9%) pvd park/sto (4%)
26D (19.0%)	streets (13%) pvd park/sto (7%)	streets (9%) pvd park/sto (8%)	pvd park/sto (9%) streets (6%)
26E (5%)	pvd park/sto (2%)	pvd park/sto (3%)	pvd park/sto (3%)
total OF26	streets (28%) pvd park/sto (16%) oi8 (10%) oi1 (9%) pvd park/sto (9%) oi2 (6%) oi3 (5%) pvd park/sto (3%) (total 86%)	pvd park/sto (34%) streets (20%) oi8 (10%) oi1 (10%) oi2 (7%) oi3 (5%) (total 86%)	pvd park/sto (37%) streets (14%) oi1 (11%) oi8 (9%) oi2 (7%) oi3 (6%) (total 84%)

Major zinc sources for OF26 sub areas:

Sub area and portion of total Zn	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
26A (29%)	oi2 (12%) oi1 (11%)	oi2 (15%) oi1 (12%)	oi2 (16%) oi1 (13%)
26B (31%)	streets (12%) pvd park/sto (9%) oi9 (7%) oi3 (4%)	pvd park/sto (11%) oi9 (8%) streets (5%) oi3 (4%)	pvd park/sto (16%) oi9 (7%) oi3 (5%) streets (3%)
26C (21%)	oi8 (13%)	oi8 (15%) pvd park/sto (2%)	oi8 (13%) pvd park/sto (2%)
26D (13%)	streets (10%) pvd park/sto (4%)	streets (5%) pvd park/sto (4%) oi9 (2%)	pvd park/sto (5%) streets (3%) oi9 (2%)
26E (5%)	all <2%	oi9 (2%)	oi9 (2%)
total OF26	streets (22%) pvd park/sto (13%) oi8 (13%) oi2 (12%) oi1 (11%) oi9 (7%) oi3 (4%) (total 82%)	pvd park/sto (17%) oi2 (15%) oi8 (15%) oi1 (12%) oi9 (12%) streets (10%) oi3 (4%) (total 85%)	pvd park/sto (23%) oi2 (16%) oi1 (13%) oi8 (13%) oi9 (11%) streets (6%) oi3 (5%) (total 87%)

Major flow, TSS, copper, and zinc sources for OF14:

	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Major flow sources:			
	pvd park/sto (33%) roofs 4 (26%) oi7 (11%) oi9 (11%) streets (9%)	pvd park/sto (34%) roofs 4 (25%) oi7 (11%) oi9 (11%) streets (10%)	pvd park/sto (36%) roofs 4 (24%) oi7 (12%) oi9 (12%) streets (9%)
Major TSS sources:			
	streets (33%) pvd park/sto (32%) oi7 (17%) roofs4 (11)	pvd park/sto (51%) oi7 (23%) streets (12%) roofs4 (7)	pvd park/sto (62%) oi7 (23%) streets (4%) roofs4 (3)
Major Cu sources:			
	pvd park/sto (52%) oi7 (21%) streets (18%)	pvd park/sto (59%) oi7 (21%) streets (13%)	pvd park/sto (66%) oi7 (20%) streets (9%)
Major Zn sources:			
	pvd park/sto (29%) oi9 (26%) oi7 (19%) streets (14%) roofs 4 (8%)	pvd park/sto (35%) oi9 (28%) oi7 (20%) streets (7%) roofs 4 (7%)	pvd park/sto (40%) oi9 (28%) oi7 (20%) roofs 4 (5%) streets (4%)

Major flow, TSS, copper, and zinc sources for OF1:

	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Major flow sources:			
	oi3 (86%) oi5 (9%) oi10 (5%)	oi3 (86%) oi5 (9%) oi10 (5%)	oi3 (86%) oi5 (9%) oi10 (5%)
Major TSS sources:			
	oi3 (68%) oi5 (31%)	oi3 (71%) oi5 (28%)	oi3 (78%) oi5 (23%)
Major Cu sources:			
	oi3 (72%) oi5 (25%)	oi3 (74%) oi5 (23%)	oi3 (76%) oi5 (21%)
Major Zn sources:			
	oi3 (69%) oi5 (30%)	oi3 (70%) oi5 (28%)	oi3 (73%) oi5 (25%)

Major flow, TSS, copper, and zinc sources for OF13:

	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Major flow sources:			
	oi4 (86%) oi5 (12%)	oi4 (86%) oi5 (12%)	oi4 (86%) oi5 (12%)
Major TSS sources:			
	oi4 (72%) oi5 (28%)	oi4 (72%) oi5 (27%)	oi4 (73%) oi5 (27%)
Major Cu sources:			
	oi4 (87%) oi5 (12%)	oi4 (87%) oi5 (12%)	oi4 (87%) oi5 (12%)
Major Zn sources:			
	oi4 (78%) oi5 (21%)	oi4 (78%) oi5 (21%)	oi4 (79%) oi5 (20%)

Major flow, TSS, copper, and zinc sources for OF9:

	0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Major flow sources:			
	oi4 (47%) roofs4 (13%) pvd park/sto (13%) streets (10%)	oi4 (46%) roofs4 (12%) pvd park/sto (12%) streets (10%)	oi4 (42%) large landscaped (13%) pvd park/sto (11%) roofs4 (10%) streets (9%)
Major TSS sources:			
	oi4 (39%) streets (24%) oi5 (20%) pvd park/sto (8%)	oi4 (48%) oi5 (25%) pvd park/sto (11%) oi7 (6%)	oi4 (35%) large landscaped (32%) oi5 (17%) pvd park/sto (10%)
Major Cu sources:			
	oi4 (67%) oi5 (13%) streets (7%) pvd park/sto (7%)	oi4 (69%) oi5 (13%) pvd park/sto (8%) streets (4%)	oi4 (67%) oi5 (12%) pvd park/sto (10%) streets (4%)
Major Zn sources:			
	oi4 (56%) oi5 (20%) streets (9%) pvd park/sto (6%) oi7 (5%)	oi4 (60%) oi5 (21%) pvd park/sto (8%) oi7 (5%) streets (3%)	oi4 (58%) oi5 (20%) pvd park/sto (9%) oi7 (5%) large landscaped (3%) streets (2%)

The following tables are descriptions of the major source areas in the San Diego naval drainage areas:

Major source areas for North Island Complex – Outfall 26 (73.27 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Paved parking and storage area	Directly connected paved parking areas	9.21 ac (12.6%)	8%	12%	34%	17%
Streets	30 ft wide paved streets	6.21 ac (8.5%)	11%	9%	20%	10%
Small landscaped area*	Silty soil small landscaped areas	9.11 ac (12.4%)				
Other impervious area #1	Airfield apron/runway paved areas	20.67 ac (28.2%)	31%	37%	10%	12%
Other impervious area #2	Other airfield paved areas	11.03 ac (15.1%)	17%	20%	7%	15%
Other impervious area #3	Light industrial storage/laydown area, concrete (light industrial/laydown activity, concrete)	3.30 ac (4.5%)			5%	4%
Other impervious area #6	Light industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)	3.38 ac (4.6%)	3%			
Other impervious area #8	Heavy industrial storage/laydown area, asphalt (heavy industrial/laydown activities, asphalt)	1.15 ac (1.6%)		6%	10%	15%
Other impervious area #9	Galvanized metal roofs, flat, directly connected to drainage system	2.48 ac (3.4%)				12%

* Landscaped areas are significant sources for the larger rains

Major source areas for Naval Base San Diego (NBSD) - Outfall 14 (57.58 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Roof areas 4	Directly connected flat roof	13.43 ac (23.3%)	25%	7%		7%
Paved parking and storage area	Directly connected paved parking areas	20.28 ac (35.2%)	34%	51%	59%	35%
Streets	40 ft wide paved streets	4.77 ac (8.3%)	10%	12%	13%	7%
Other impervious area #7	Moderate industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)	6.93 ac (12.0%)	11%	23%	21%	20%
Other impervious area #9	Galvanized metal roofs, flat, directly connected to drainage system	6.61 ac (11.5%)	11%			28%

Major source areas for Naval Base San Diego (NBSD) - Outfall 1 (ceremonial pier) (1.44 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Other impervious area #3	Light industrial storage/laydown area, concrete (light industrial/laydown activity, concrete)	1.24 ac (86.1%)	86%	71%	74%	70%
Other impervious area #5	Heavy industrial storage/laydown area, concrete (heavy industrial/laydown activities, concrete)	0.13 ac (9.0%)	9%	28%	23%	28%
Other impervious area #10	Other areas having substantial galvanized metal materials (fences, etc.)	0.07 ac (4.9%)	5%			

Major source areas for Naval Base San Diego (NBSD) - Outfall 13 (industrial pier) (4.25 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Other impervious area #4	Moderate industrial storage/laydown area, concrete (moderate industrial/laydown activities, concrete)	3.61 ac (84.9%)	86%	72%	87%	78%
Other impervious area #5	Heavy industrial storage/laydown area, concrete (heavy industrial/laydown activities, concrete)	0.49 ac (11.5%)	12%	27%	12%	21%

Major source areas for North Island Complex (Naval Amphibious Base) – Outfall 9 (5.33 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Roof areas 4	Directly connected flat roof	0.35 ac (6.6%)	12%			
Paved parking and storage area	Directly connected paved parking areas	0.39 ac (7.3%)	12%	11%	8%	8%
Streets	40 ft wide paved streets	0.34 ac (6.4%)	10%		4%	3%
Large landscaped area*	Silty soil baseball field	2.07 ac (38.8%)				
Other impervious area #4	Moderate industrial storage/laydown area, concrete (moderate industrial/laydown activities, concrete)	1.49 ac (28.0%)	46%	48%	69%	60%
Other impervious area #5	Heavy industrial storage/laydown area, concrete (heavy industrial/laydown activities, concrete)	0.27 ac (5.1%)		25%	13%	21%
Other impervious area #7	Moderate industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)	0.15 ac (2.8%)		6%		5%

* Landscaped areas are significant sources for the larger rains

The following lists show the areas contributing the largest portions of the flows, TSS, Cu, and Zn in each of the five areas, along with the percentage of the total watershed area. The directly connected impervious areas contribute the largest portion of these contaminants; usually by percentages that are greater than their surface area coverage. As an example, in the NBSD OF14 drainage area, directly connected paved parking areas make up 35% of the total area, but contribute about 51% of the runoff volume. Examples where the source areas contribute more than twice the percentage of the contaminants as their surface areas in OF14 include galvanized metal roofs for zinc. In OF26, the directly connected paved parking areas and streets for copper, heavy industrial storage and laydown areas for TSS, copper, and zinc, and galvanized metal roofs for zinc all contribute more than twice the percentage of the contaminants as their surface areas.

North Island Complex – Outfall 26 (73.27 ac)

- Directly connected paved parking (13% of area, 34% Cu, 17% Zn)
- Streets (9% of area, 20% Cu)
- Airfield runway and apron (28% of area, 37% TSS)
- Other airfield paved areas (15% of area, 20% TSS)
- Heavy industrial storage or laydown areas (2% of area, 6% TSS, 10% Cu, 15% Zn)
- Galvanized metal roofs (3% of area, 12% Zn)

- Runoff volume (airfield apron and runway 31%, other airfield paved areas 17%, streets 11%)
- TSS sources (airfield apron and runway 37%, other airfield paved areas 20%, paved parking 12%)
- Cu sources (paved parking 34%, streets 20%, airfield apron and runway 10%, heavy industrial storage or laydown areas 10%)
- Zn sources (paved parking 17%, other paved airfield areas 15%, heavy industrial storage or laydown areas 15%, galvanized roofs 12%, airfield apron and runway 12%, streets 10%)

Naval Base San Diego (NBSD) - Outfall 14 (57.58 ac)

- Paved parking area (35% of area, 51% flow, 59% Cu)
- Streets (8% of area, TSS 12%, Cu 14%)
- Moderate industrial storage or laydown areas (12% of area, 23% TSS, 21% Cu, 20% Zn)
- Galvanized metal roofs (12% of area, 28% Zn)

- Runoff volume (directly connected paved parking areas 34%, directly connected flat roofs 25%, moderate industrial storage/laydown areas 11%, galvanized metal roofs 11%, streets 10%)
- TSS sources (directly connected paved parking areas 51%, moderate industrial storage/laydown areas 23%, streets 12%)
- Cu sources (directly connected paved parking areas 59%, moderate industrial storage/laydown areas 21%, streets 13%)
- Zn sources (directly connected paved parking areas 35%, moderate industrial storage/laydown areas 20%, galvanized metal roofs 28%)

Naval Base San Diego (NBSD) - Outfall 1 (ceremonial pier) (1.44 ac)

- Light industrial storage or laydown areas (86% of area, 86% flow, 71% TSS, 74% Cu, 70% Zn)
- Heavy industrial storage or laydown areas (9% of area, 28% TSS, 23% Cu, 28% Zn)

• Runoff volume (light industrial storage or laydown areas 86%)
• TSS sources (light industrial storage or laydown areas 71%, heavy industrial storage or laydown areas 28%)
• Cu sources (light industrial storage or laydown areas 74%, heavy industrial storage or laydown areas 23%)
• Zn sources (light industrial storage or laydown areas 70%, heavy industrial storage or laydown areas 28%)

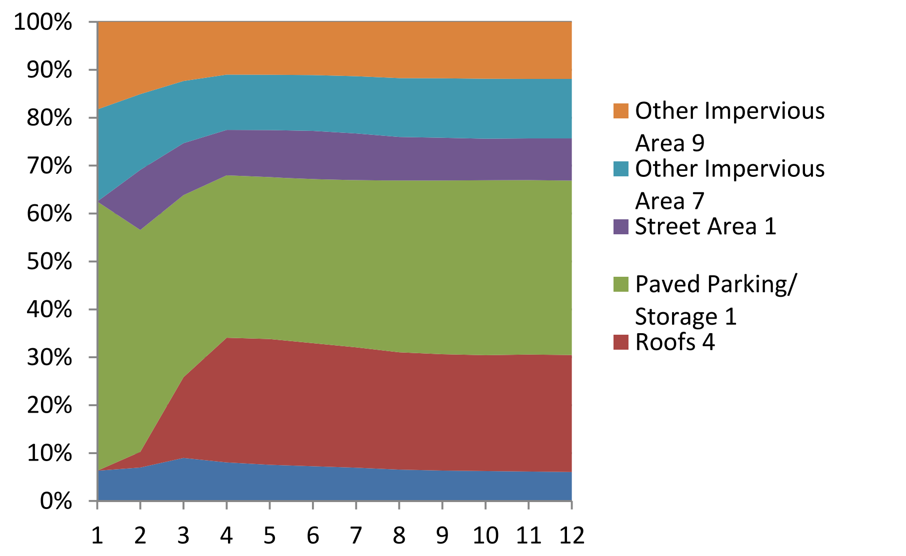
Naval Base San Diego (NBSD) - Outfall 13 (industrial pier) (4.25 ac)
• Moderate industrial storage or laydown areas (85% of area, 86% flow, 72% TSS, 87% Cu, 78% Zn)
• Heavy industrial storage or laydown areas (12% of area, 12% flow, 27% TSS, 12% Cu, 21% Zn)

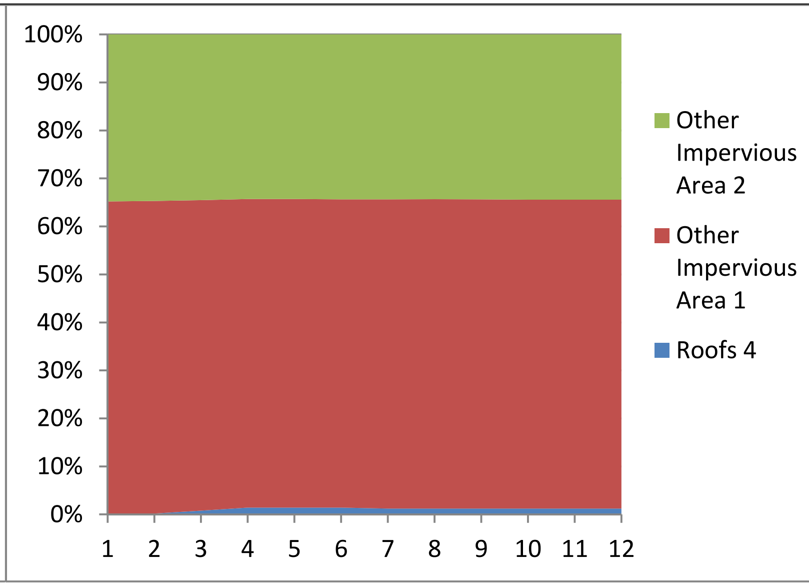
• Runoff volume (moderate industrial storage or laydown areas 86%, heavy industrial storage or laydown areas 12%)
• TSS sources (moderate industrial storage or laydown areas 72%, heavy industrial storage or laydown areas 27%)
• Cu sources (moderate industrial storage or laydown areas 87%, heavy industrial storage or laydown areas 12%)
• Zn sources (moderate industrial storage or laydown areas 78%, heavy industrial storage or laydown areas 21%)

North Island Complex (Naval Amphibious Base) – Outfall 9 (5.33 ac)
• Directly connected flat roofs (7% of area, 12% of flow)
• Paved parking areas (7% of area, 12% of flow, 11% of TSS)
• Streets (6% of area, 10% of flow)
• Moderate industrial storage or laydown areas, concrete (28% of area, 46% flow, 48% TSS, 69% Cu, 60% Zn)
• Heavy industrial storage or laydown areas, concrete (5% of area, 25% TSS, 13% Cu, 21% Zn)
• Moderate industrial storage or laydown areas, asphalt (3% of area, 6% TSS, 5% Zn)

• Runoff volume (moderate industrial storage or laydown areas, asphalt 46%, directly connected flat roofs 12%, directly connected parking areas 12%, streets 10%)
• TSS sources (moderate industrial storage or laydown areas, asphalt 48%, heavy industrial storage or laydown areas, asphalt 25%, directly connected paved parking areas 11%)
• Cu sources (moderate industrial storage or laydown areas, asphalt 69%, heavy industrial storage or laydown areas, asphalt 13%)
• Zn sources (moderate industrial storage or laydown areas, asphalt 60%, heavy industrial storage or laydown areas, asphalt 21%)

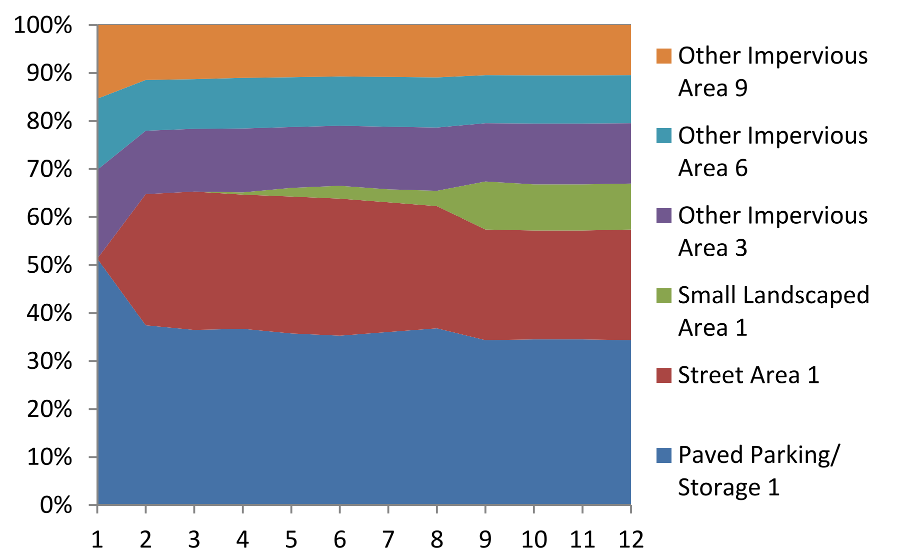
The following figures illustrate how the mass contributions for runoff volume, TSS, copper, and zinc varies for different rain depths. The runoff volume source contributions for the different areas are relatively constant, especially for rains larger than 0.25 inches, mostly because pervious area contributions are all very small for these constituents for these sites. TSS and the metal contributions vary more for these areas due to the street contribution changes (much larger for the smaller rains, then much smaller for the larger rains), and paved parking and storage areas becoming much more significant for larger rains. These plots are very useful when identifying the potential for critical source area stormwater controls.

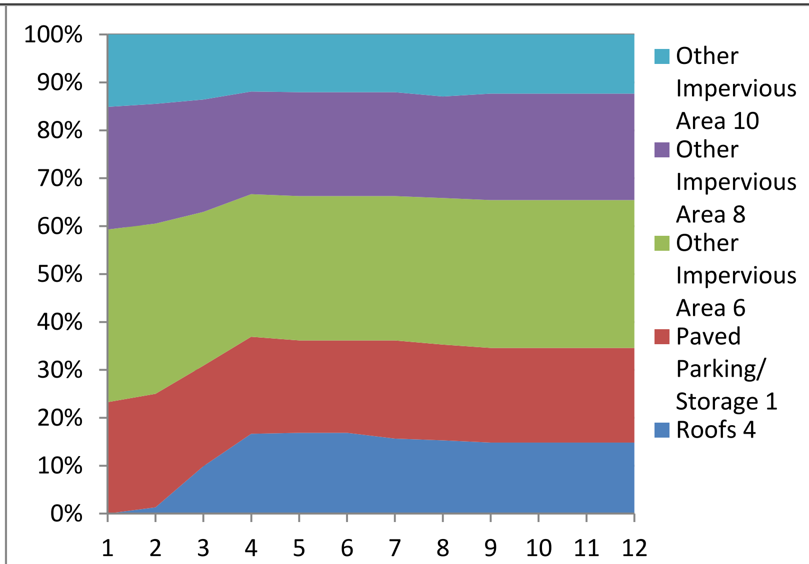




Runoff volume contributions: Naval Base San Diego OF#14

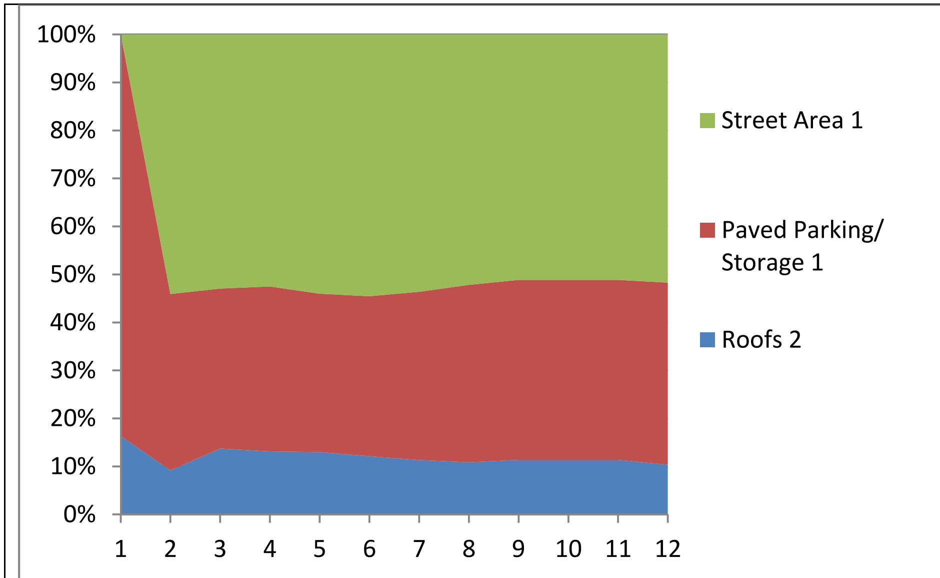
Runoff volume contributions: North Island OF #26A



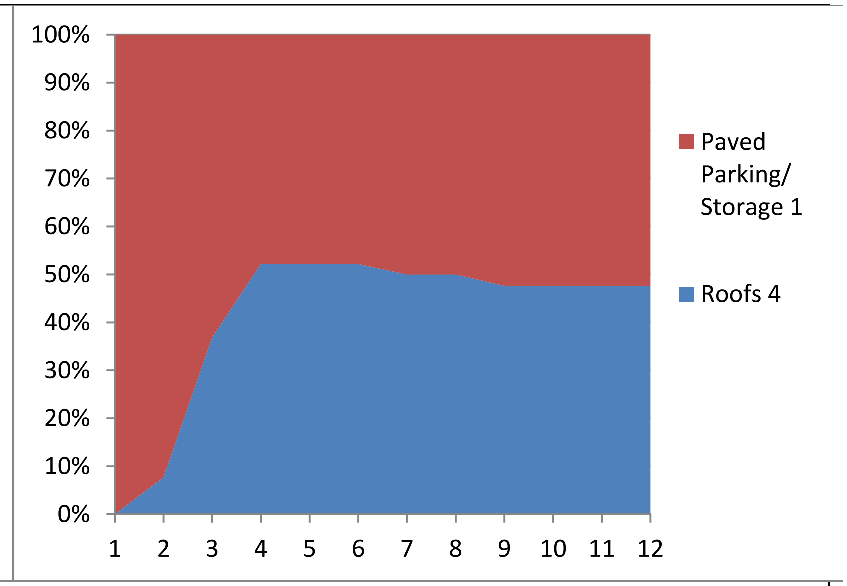


Runoff volume contributions: North Island OF #26B

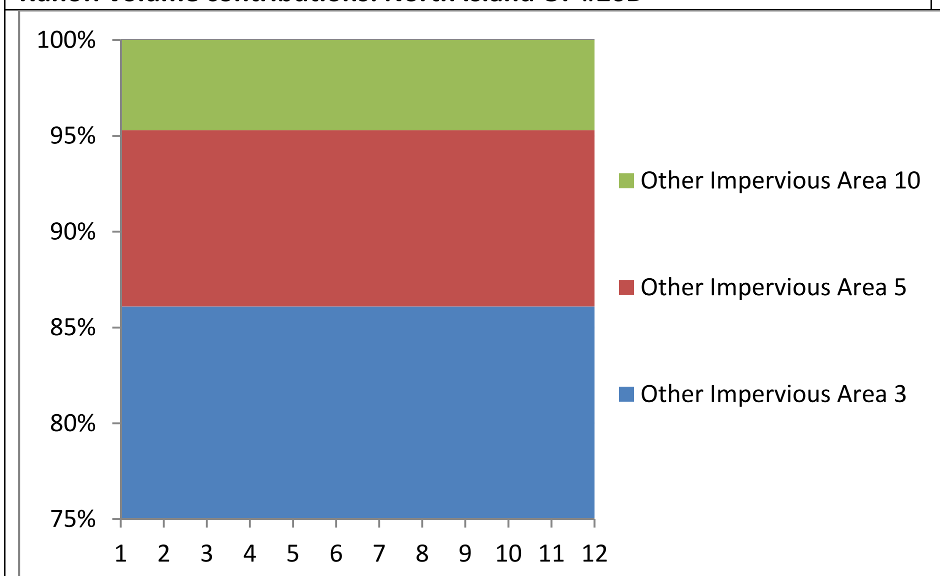
Runoff volume contributions: North Island OF #26C



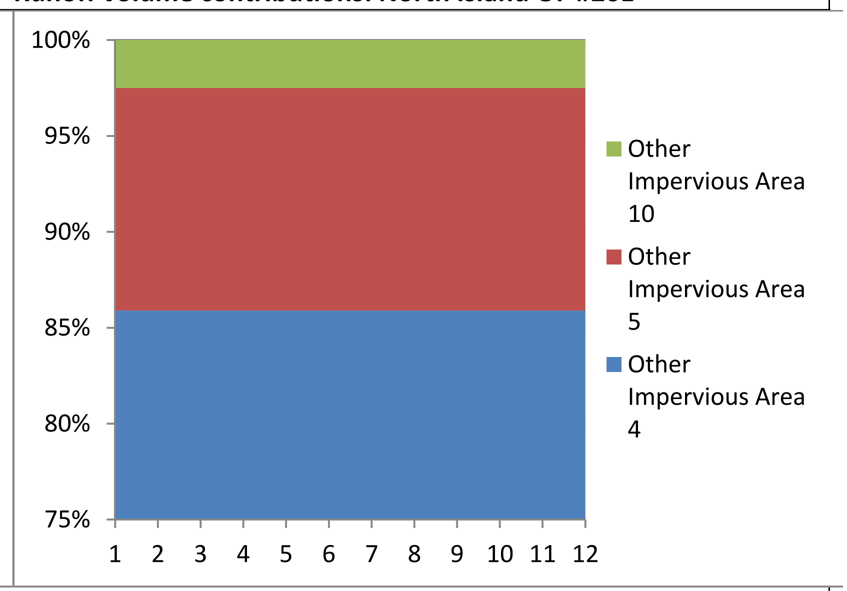
Runoff volume contributions: North Island OF #26D



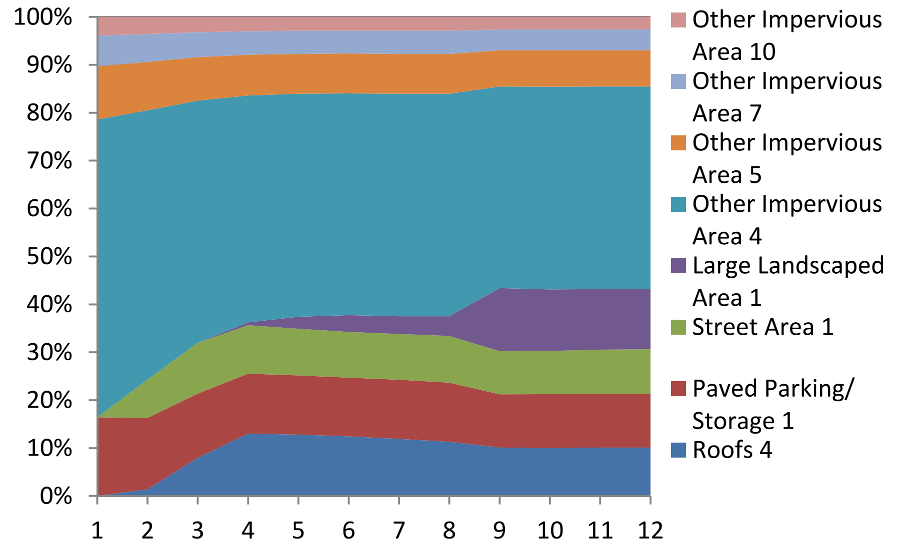
Runoff volume contributions: North Island OF #26E



Runoff volume contributions: Ceremonial Pier OF #1



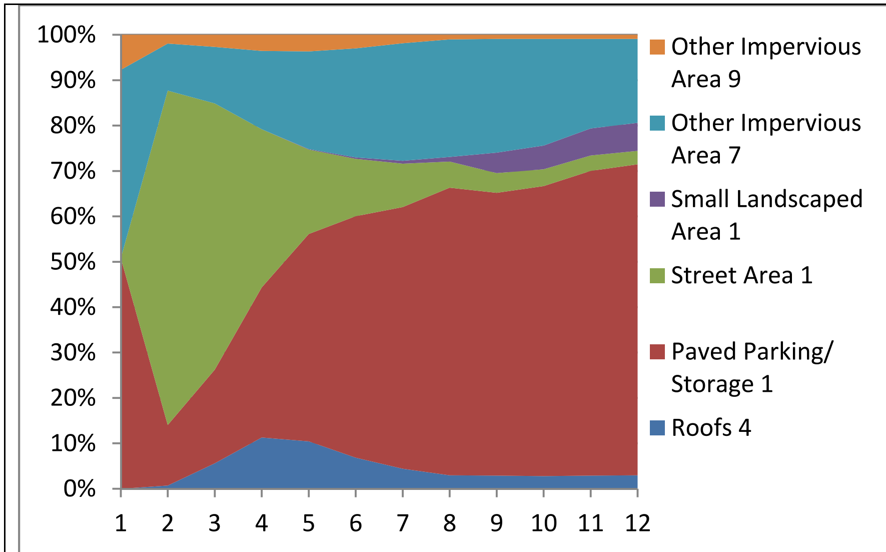
Runoff volume contributions: Industrial Pier #13



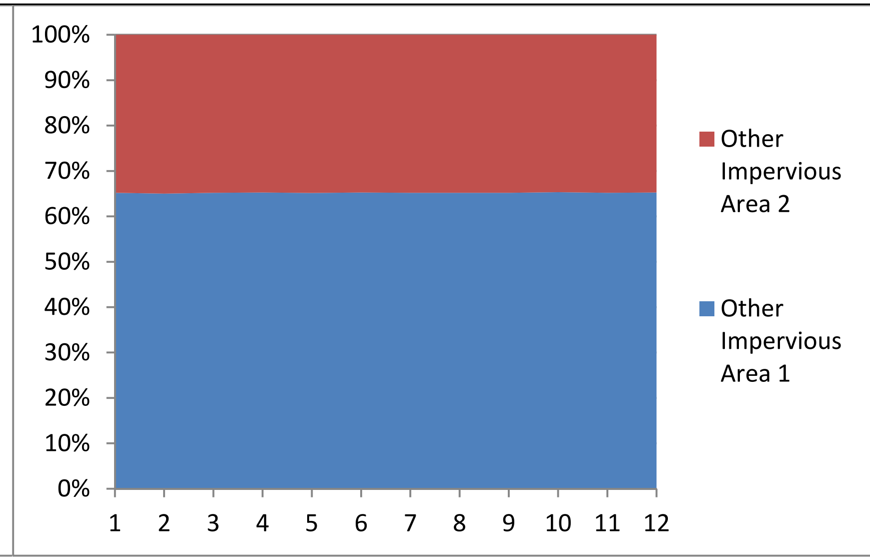
Event number	Rain Total (inches)
1	0.01
2	0.05
3	0.1
4	0.25
5	0.5
6	0.75
7	1
8	1.5
9	2
10	2.5
11	3
12	4

Runoff volume contributions: Naval Amphibious Base, OF #9

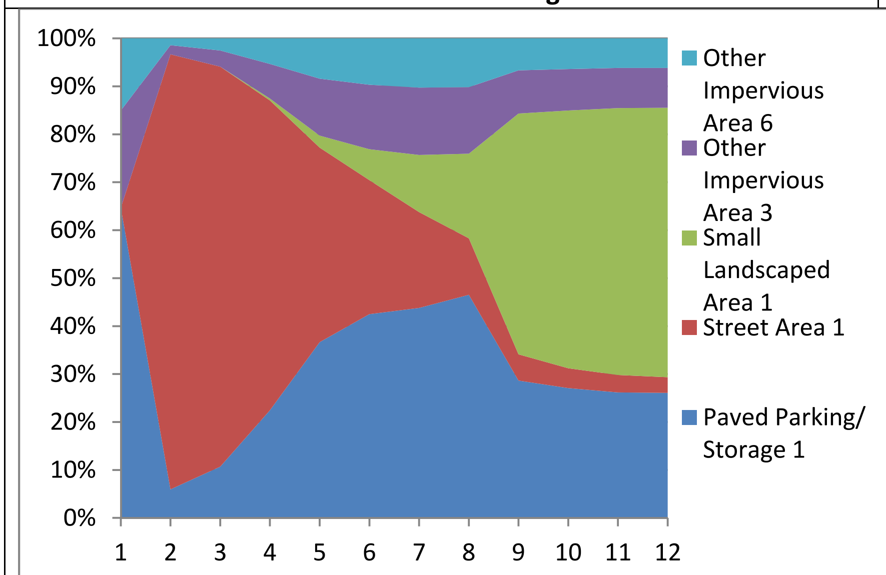
Runoff volume source area contribution plots for different rain depths.



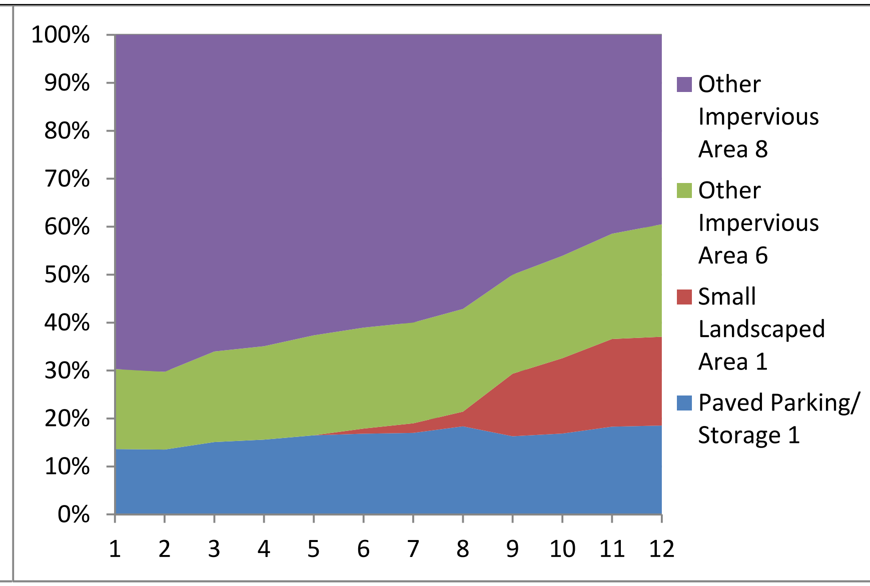
TSS mass contributions: Naval Base San Diego OF#14



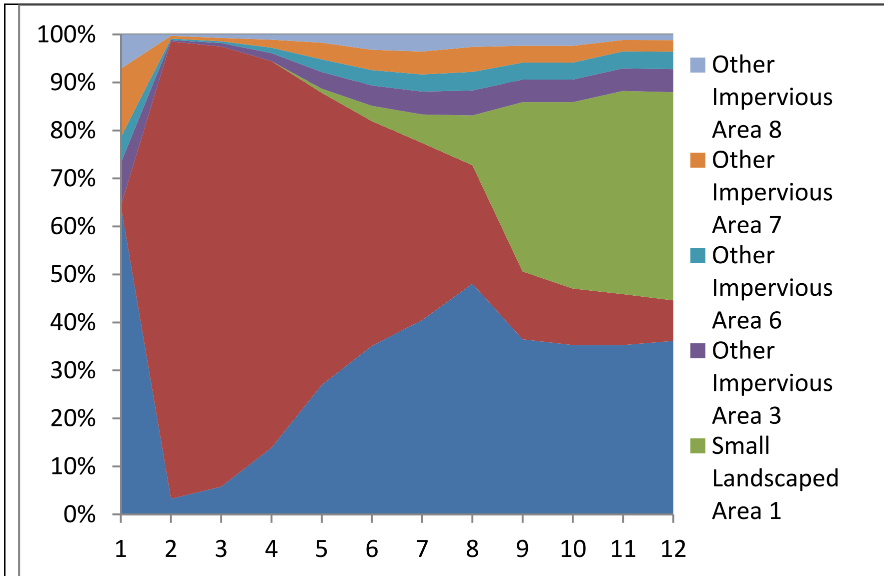
TSS mass contributions: North Island OF #26A



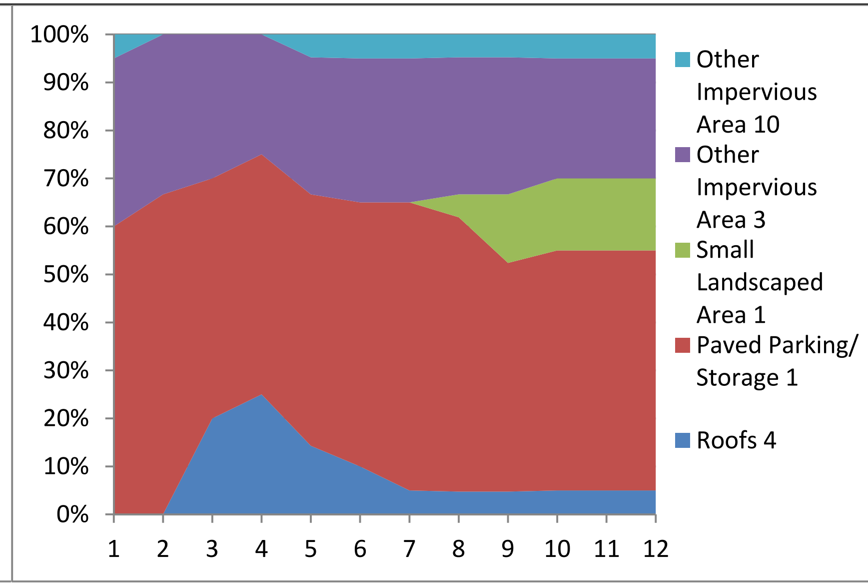
TSS mass contributions: North Island OF #26B



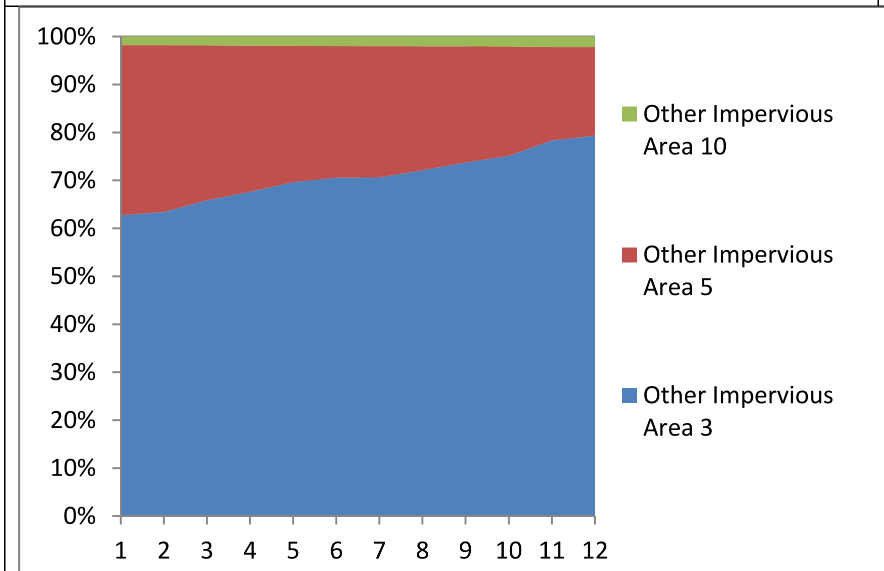
TSS mass contributions: North Island OF #26C



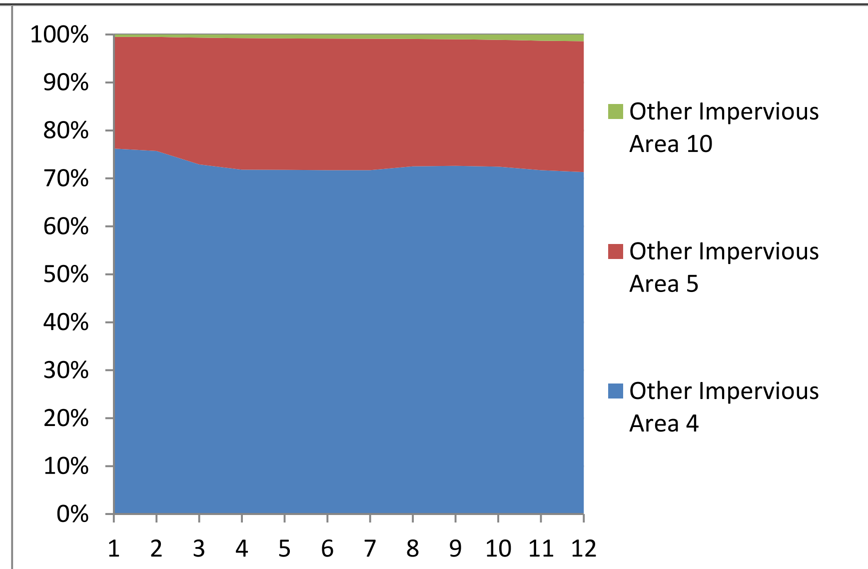
TSS mass contributions: North Island OF #26D



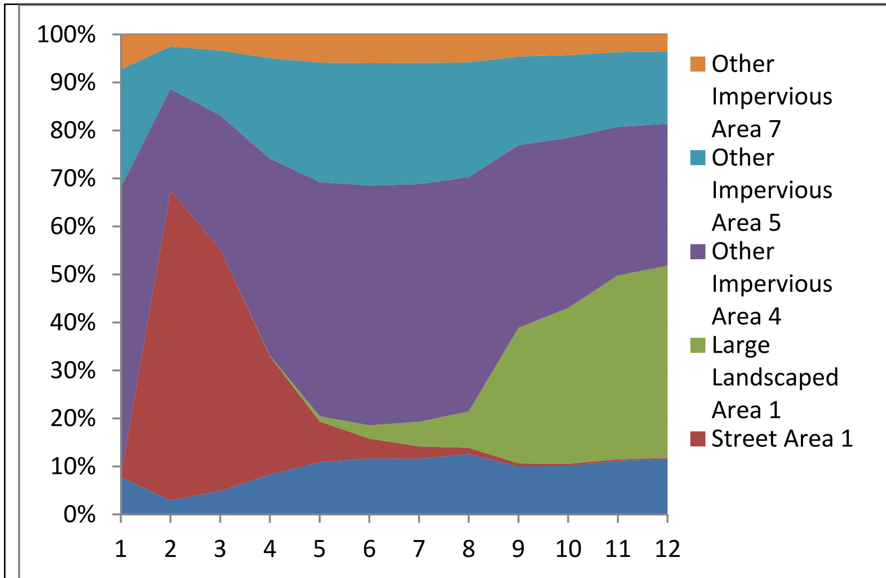
TSS mass contributions: North Island OF #26E



TSS mass contributions: Ceremonial Pier OF #1



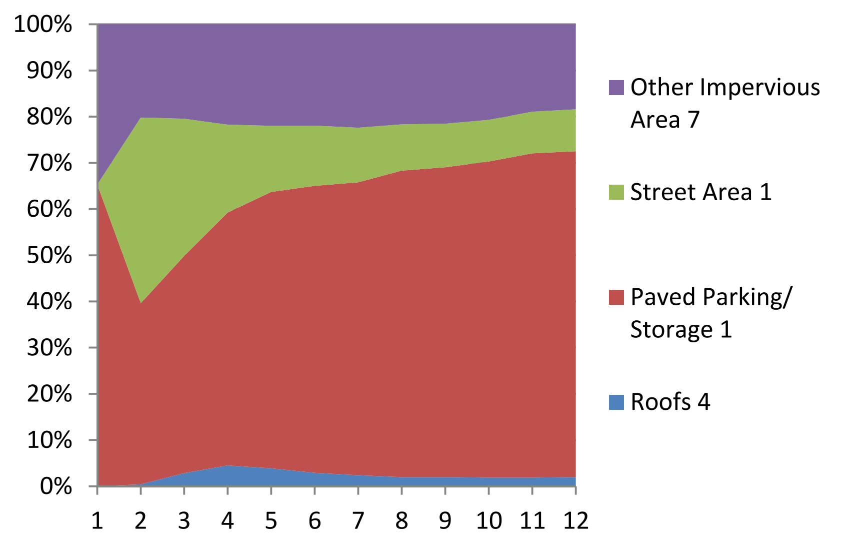
TSS mass contributions: Industrial Pier OF #13



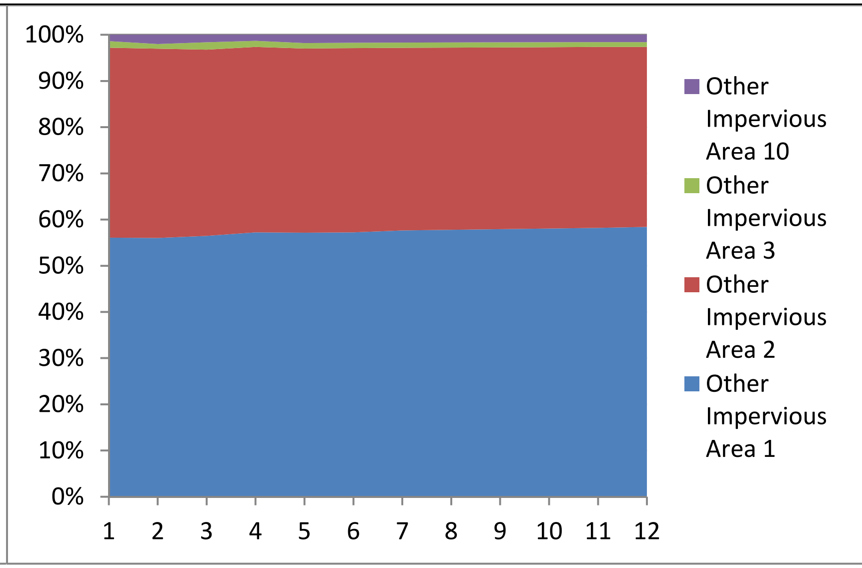
Event number	Rain Total (inches)
1	0.01
2	0.05
3	0.1
4	0.25
5	0.5
6	0.75
7	1
8	1.5
9	2
10	2.5
11	3
12	4

TSS mass contributions: Naval Amphibious Base, OF #9

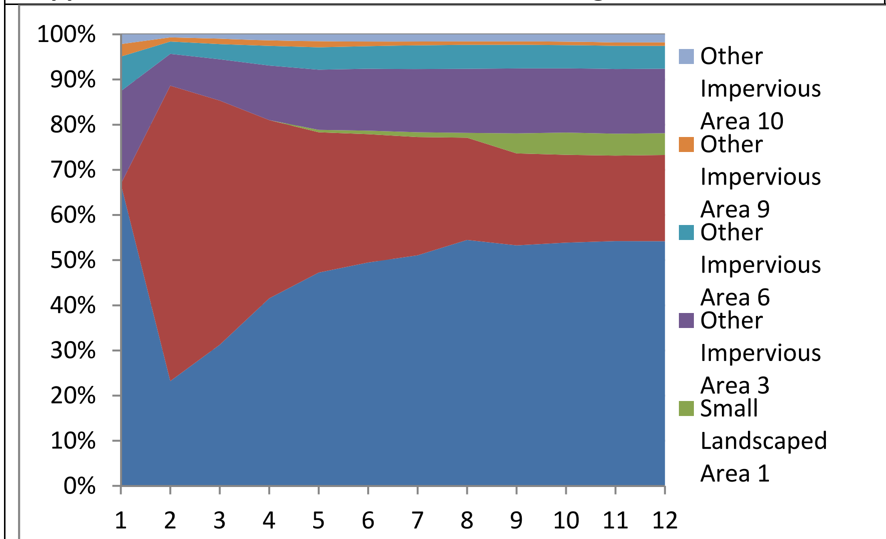
TSS mass source area contribution plots for different rain depths.



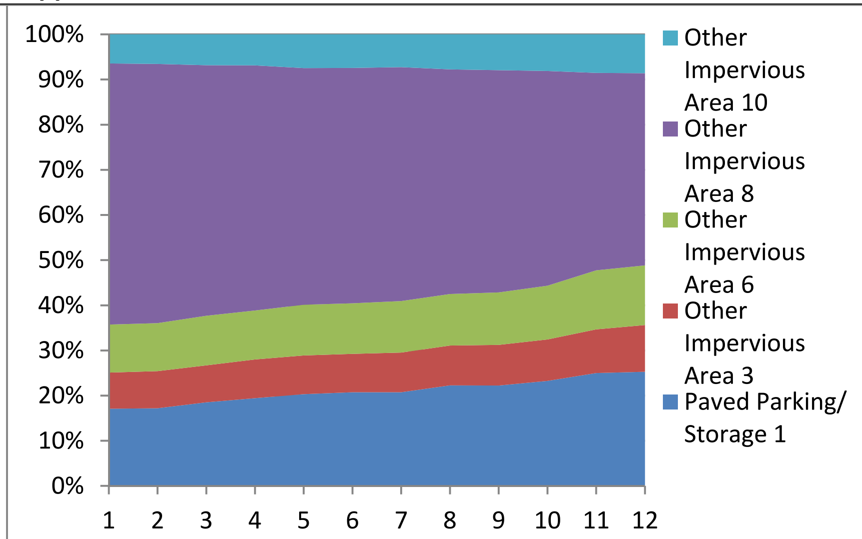
Copper mass contributions: Naval Base San Diego OF#14



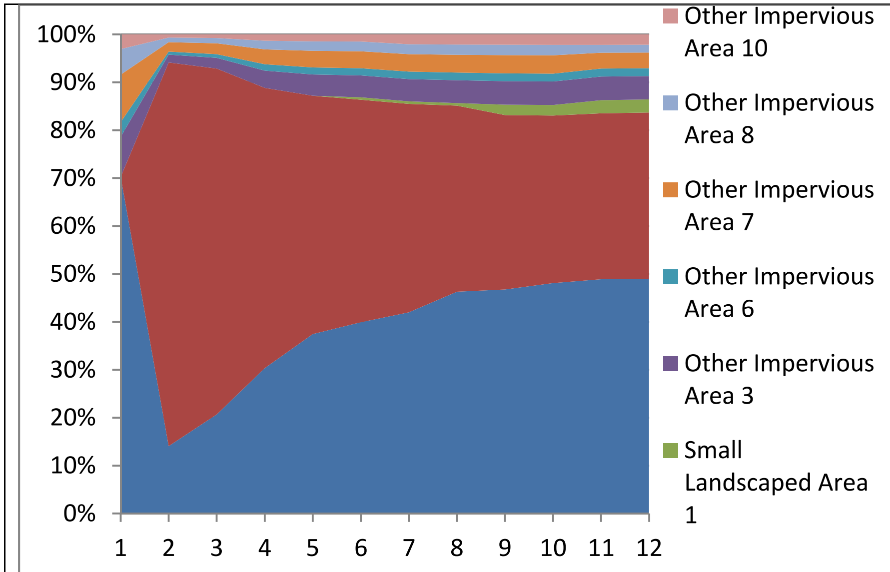
Copper mass contributions: North Island OF #26A



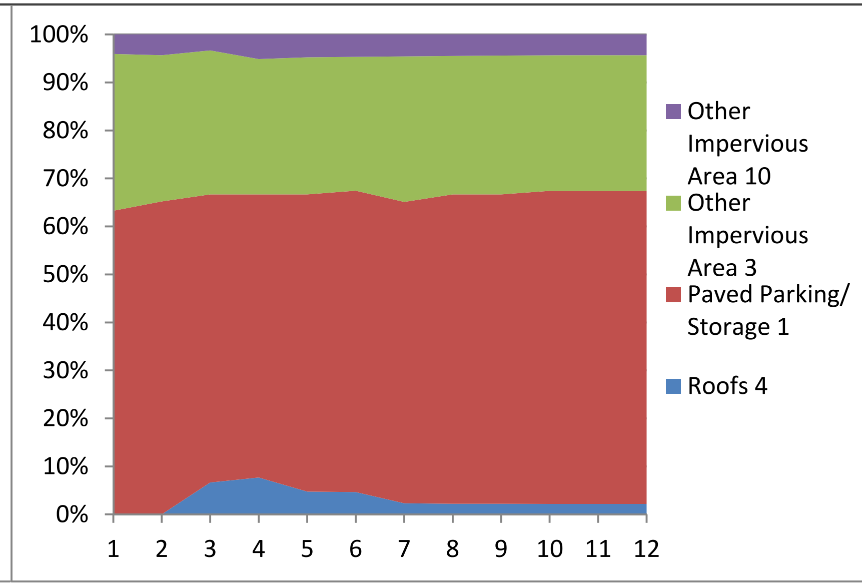
Copper mass contributions: North Island OF #26B



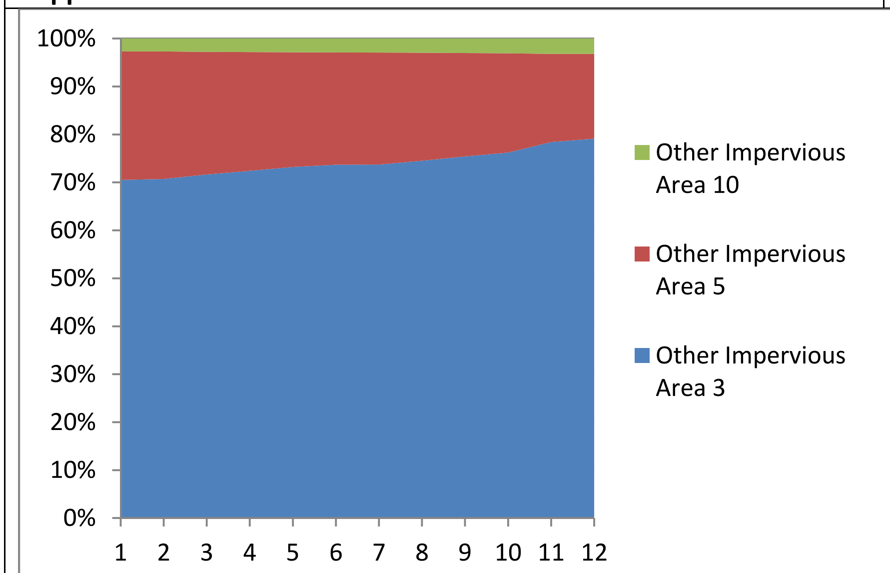
Copper mass contributions: North Island OF #26C



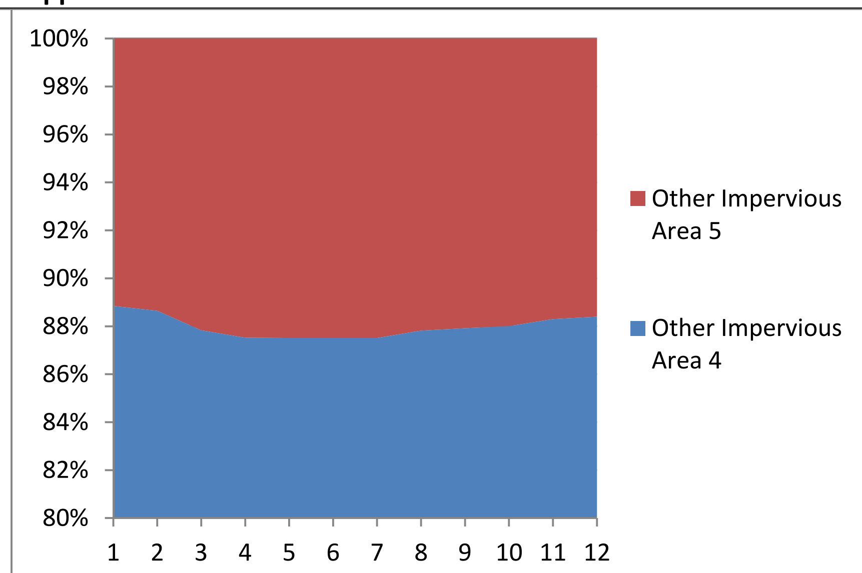
Copper mass contributions: North Island OF #26D



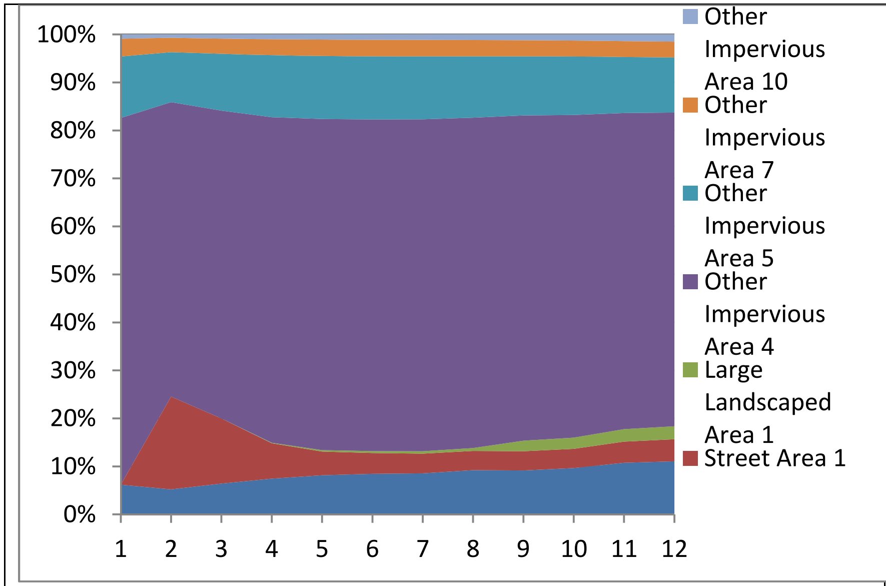
Copper mass contributions: North Island OF #26E



Copper mass contributions: Ceremonial Pier OF #1



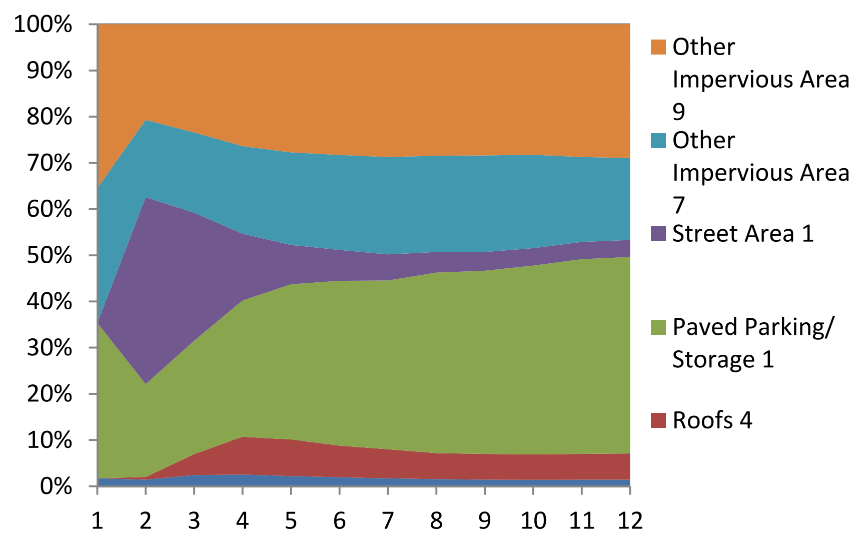
Copper mass contributions: Industrial Pier OF #13



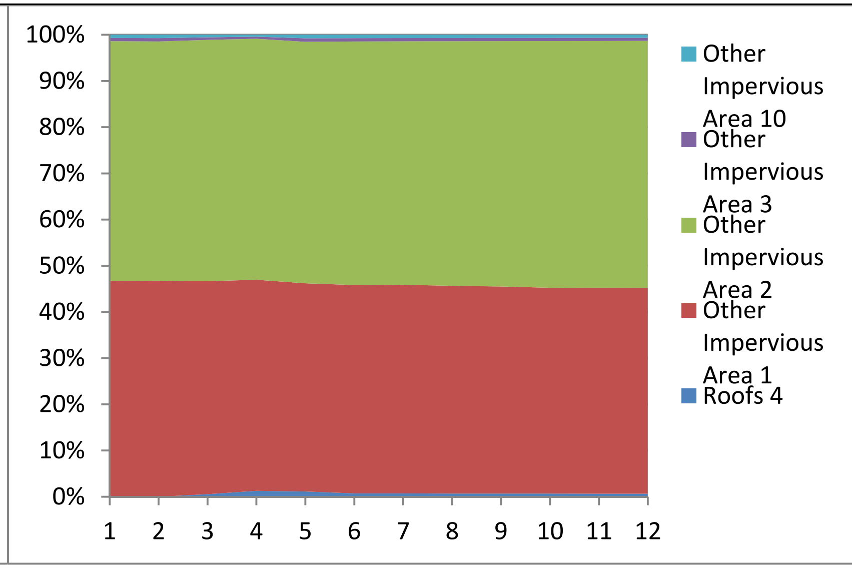
Event number	Rain Total (inches)
1	0.01
2	0.05
3	0.1
4	0.25
5	0.5
6	0.75
7	1
8	1.5
9	2
10	2.5
11	3
12	4

Copper mass contributions: Naval Amphibious Base, OF #9

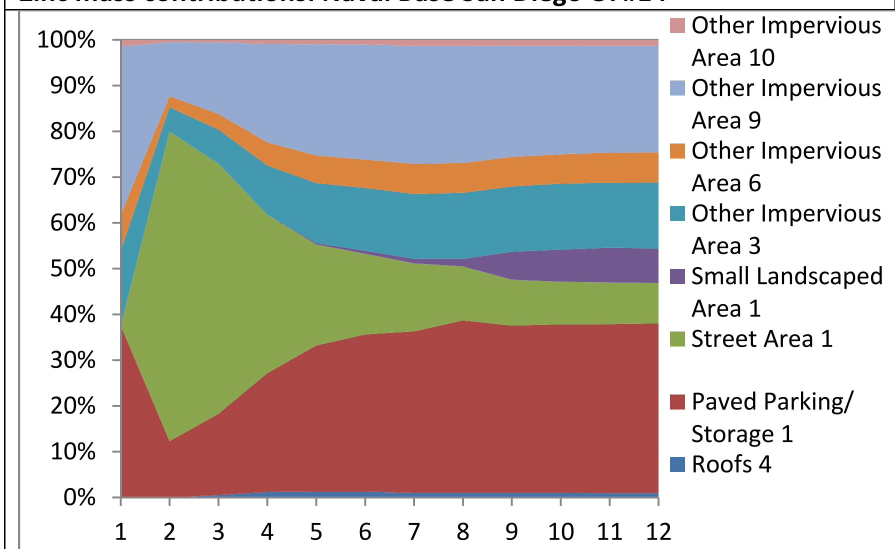
Copper mass source area contribution plots for different rain depths.



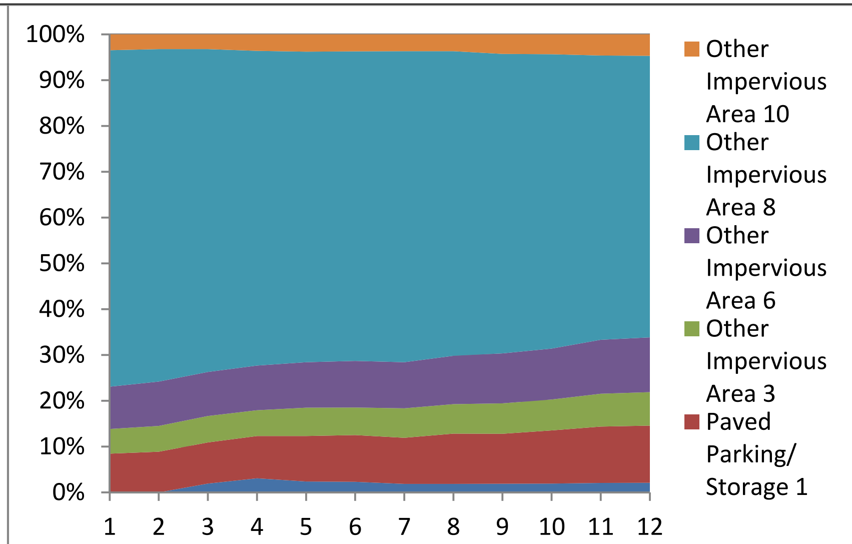
Zinc mass contributions: Naval Base San Diego OF#14



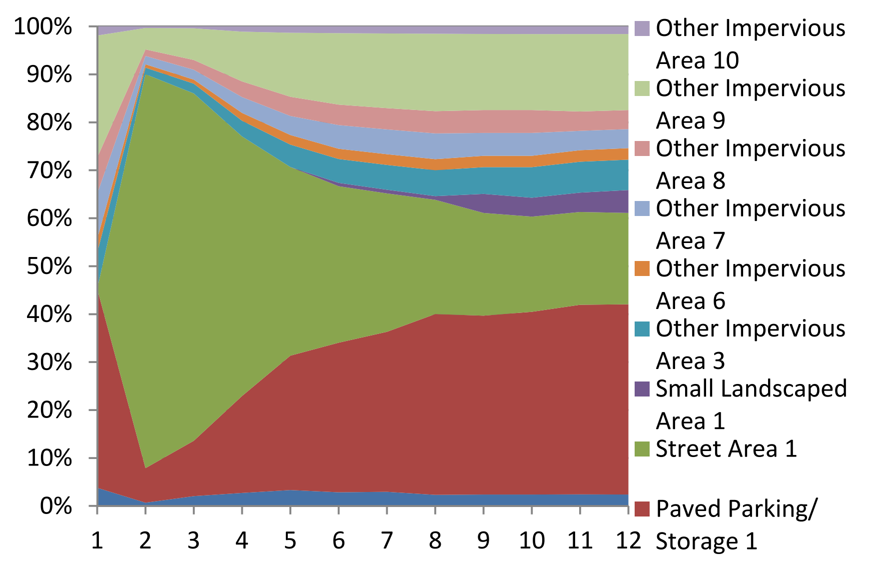
Zinc mass contributions: North Island OF #26A



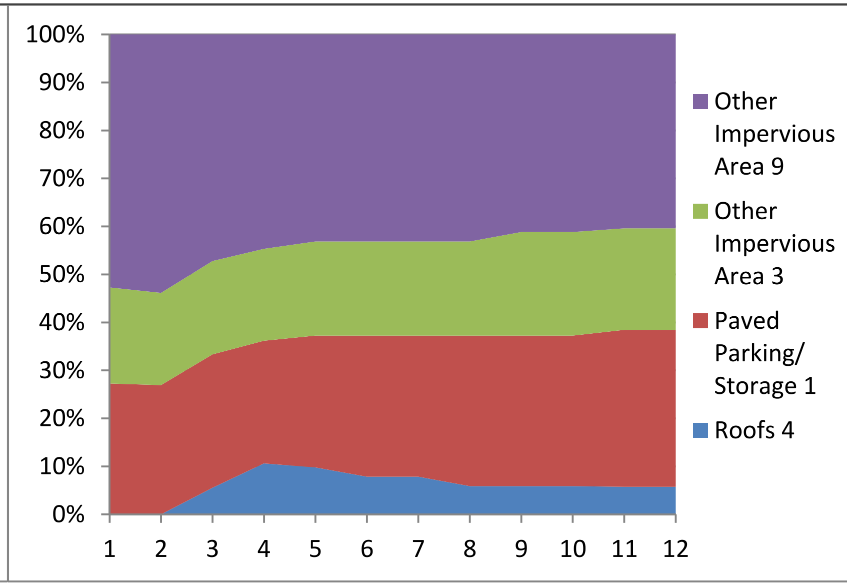
Zinc mass contributions: North Island OF #26B



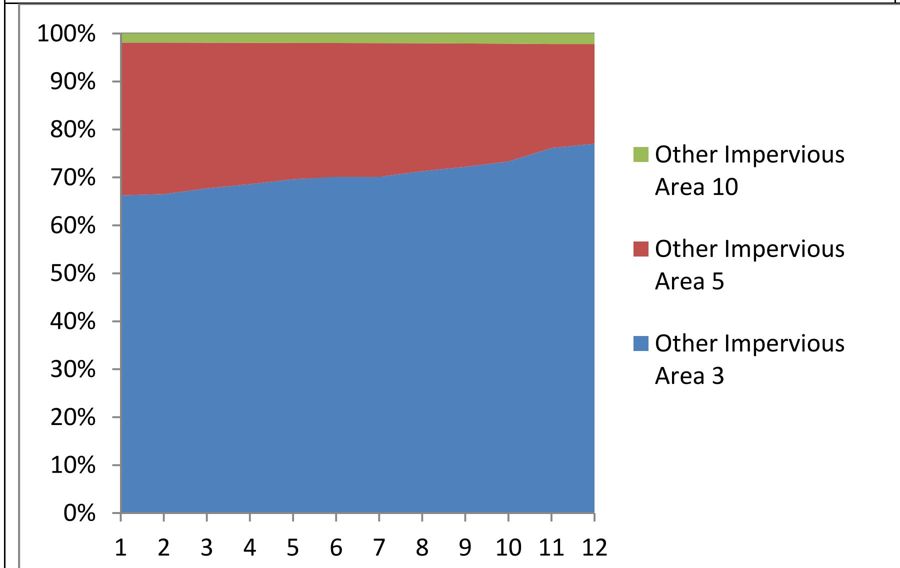
Zinc mass contributions: North Island OF #26C



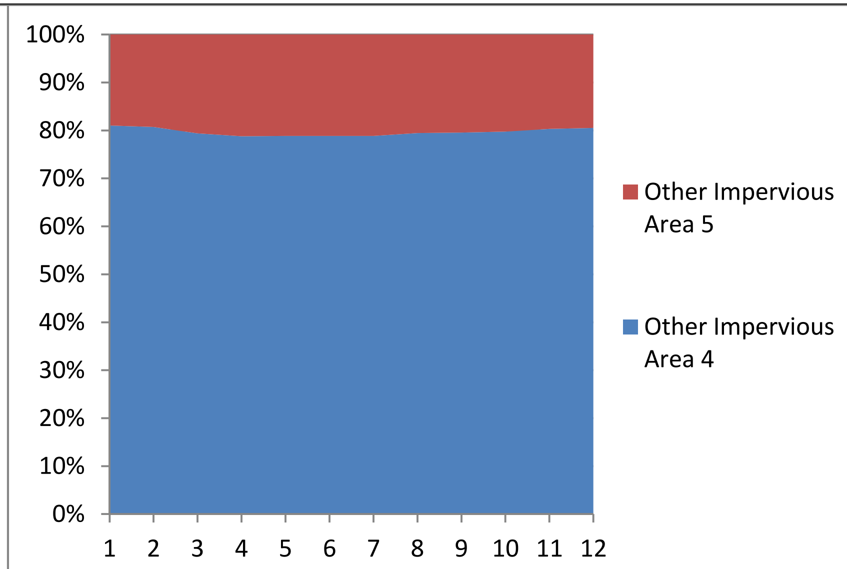
Zinc mass contributions: North Island OF #26D



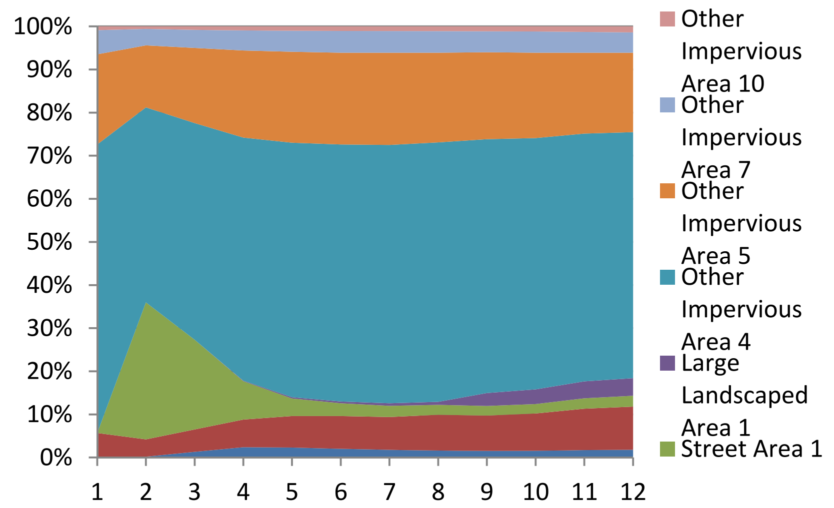
Zinc mass contributions: North Island OF #26E



Zinc mass contributions: Ceremonial Pier OF #1



Zinc mass contributions: Industrial Pier OF #13



Event number	Rain Total (inches)
1	0.01
2	0.05
3	0.1
4	0.25
5	0.5
6	0.75
7	1
8	1.5
9	2
10	2.5
11	3
12	4

Zinc mass contributions: Naval Amphibious Base, OF #9

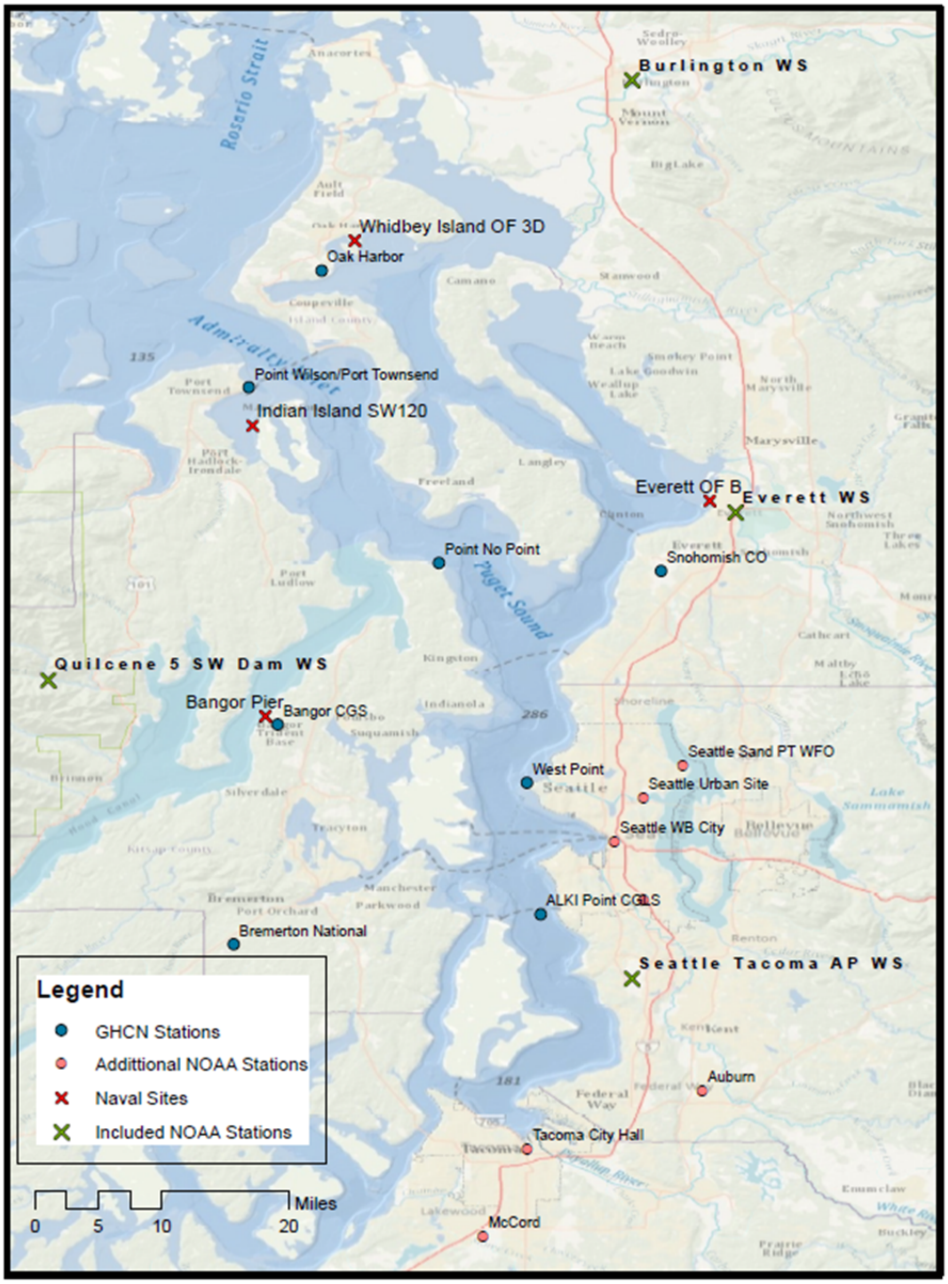
Zinc mass source area contribution plots for different rain depths.

Calibration of WinSLAMM using Northwest Navy Stormwater Quality Data

This section of the report presents similar results of WinSLAMM model calibration for the four Pacific Northwest naval facilities examined. This calibration was not as comprehensive as for the San Diego sites due to sparse data. Few events were monitored at each location and many had missing monitoring dates. Close-by rainfall data was also generally lacking for the events. In addition, the first-flush observations were not adjusted as no comparison data were available, nor were filtered and non-filtered concentrations available. However, substantial regional stormwater quality data are available from long-term monitoring, but not for industrial areas. These regional data were used as starting conditions for northwest calibrations for the basic source areas (as described in Appendix E), along with the San Diego navy facility data for the “other impervious area” source areas. These conditions were then compared to the available observed runoff data from the northwest sites, and then adjusted to obtain the best overall mass discharge fit. The first discussion below describes the rainfall conditions and available rain data for the northwest navy facility locations.

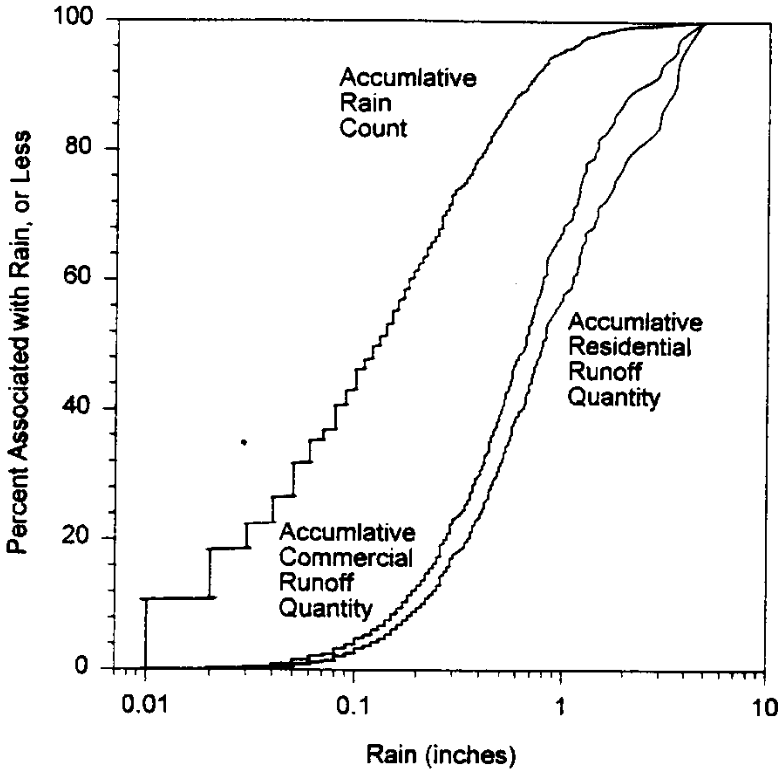
Available Weather Stations: Northwest Naval Bases

The bases in the northwest study area are located along the shores and islands of Puget Sound, Washington. An important part of the model calibration process relies on using rainfall data for each site that correlates with the samples collected at each outfall. This summarizes the available data for each naval and weather station. The following figure shows the locations for the naval bases and the nearby weather stations in this study area.



Map of Naval Bases and nearby weather stations.

The following figure is a probability plot showing the accumulative rain counts and modeled runoff quantities associated with different rainfall amounts for Seattle. This shows that the median rain (by count) is about 0.15 inches, while the median runoff quantity is associated with about 0.75 inches (half of the annual runoff occurs for smaller and half occurs for larger rains). About 80% if the annual runoff is associated with rains in the range from about 0.2 to 2.5 inches. Therefore, stormwater treatment focusing on pollutant mass discharges should stress these smaller and intermediate-sized rains. Rains associated with drainage design only contribute a small fraction of the total annual flows.



Rain and runoff probability distribution for Seattle (WinSLAMM modeled runoff using 1897 through 1993 rain events).

Hourly Precipitation Data

Hourly precipitation data is archived by the National Climate Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). The weather stations are generally operated by the U.S. National Weather Service (NWS), Federal Aviation Administration (FFA), or by cooperative stations in the U.S. and its territories. The following table is a list of the weather stations near the northwestern naval bases that have hourly rainfall data, as supplied on the most recent EarthInfo CDs (Santa Monica, CA), a commercial supplier of nationwide NOAA weather information. These weather stations are shown on the preceding map. This table shows the approximate range of historical data available for each site, along with the completeness of the data record. The most comprehensive data sets are for Quilcene, Everett, Burlington, and the Seattle Tacoma International Airport (SEATAC). The other data records are for much shorter times and usually have substantial data gaps. These four locations were therefore the main locations used in the analyses of the northwest naval base runoff data.

Stations with Hourly Precipitation Data Included for Northwest Naval Stations

Station	COOPID	Latitude	Longitude	Data Range	% Completeness
Quilcene 5 SW Dam WS	456851	47.784	-122.979	1948-2011	89
Everett WS	452675	47.975	-122.195	1948-2011	91
Burlington WS	450986	48.467	-122.313	1948-2011	91
Seattle Tacoma AP WS (SEATAC)	457473	47.444	-122.313	1948-2011	99
Tacoma City Hall	458286	47.25	-122.433	1948-1953	99
Auburn	450324	47.316	-122.233	1954-1977	97
Seattle Boeing Field	457456	47.533	-122.3	1965-1967	90
Seattle WB City	457488	47.6	-122.333	1948-1964	99
Seattle Urban Site	457458	47.65	-122.3	1973-1998	98
McCord	455149	47.15	-122.483	1948-1978	89
Seattle Sand PT WFO	457470	47.687	-122.255	1998-2011	41

Global Historical Climatological Network

Besides the basic NOAA data shown above, additional rainfall data for the region were also investigated that were located closer to the naval bases being studied. Data from the Global Historical Climatological Network (GHCN) is also archived by the National Climate Data Center (NCDC). These weather stations are comprised of a worldwide network of weather stations (approximately 20,000 stations). Numerous organizations such as the Automated Weather Network (AWN), Global Telecommunications System (GTS), the Automated Surface Observing System (ASOS), participate in this effort. The data is routed through the Federal Climate Complex (FCC) in Asheville, NC, or decoded at the Federal Climate Complex (FCC). The US Air Force 14th Weather Squadron, the National Climatic Data Center (NCDC), and the US Navy's Fleet Numerical Meteorological and Oceanographic Command Detachment (FNMOD), make up the FCC in Asheville. Stations geographically similar to each naval station are included in the following table along with the historical data range for the site.

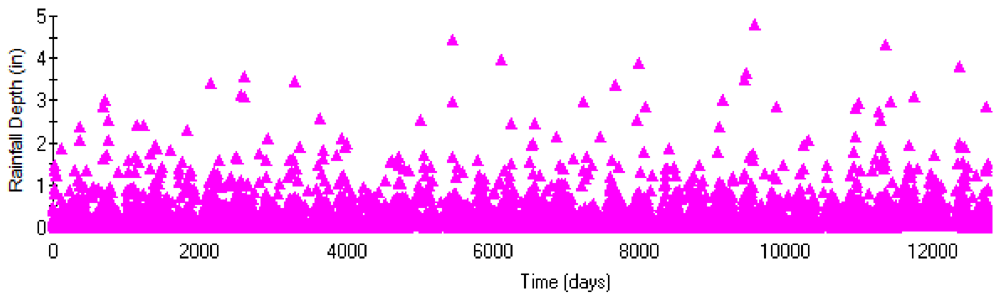
Stations with GHCN Precipitation Data Included for Northwest Naval Stations

Station	Station Owner	Latitude	Longitude	Data Range
Bangor CGS	U.S. Coast Guard	47.733	-122.717	1985-1988
West Point	National Data Buoy Center	47.667	-122.433	1975-2012
Point No Point	National Data Buoy Center	47.917	-122.533	1975-1995
Bremerton National	Bremerton National Airport	47.483	-122.767	1973-2012
Point Wilson/Port Townsend	U.S. Coast Guard	48.117	-122.75	1975-2012
ALKI Point CGLS	U.S. Coast Guard	47.517	-122.417	1975-1990
Oak Harbor	A.J. Eisenberg Airport	48.25	-122.667	1981-2008
Snohomish CO	Snohomish County Airport	47.908	-122.28	2006-2012

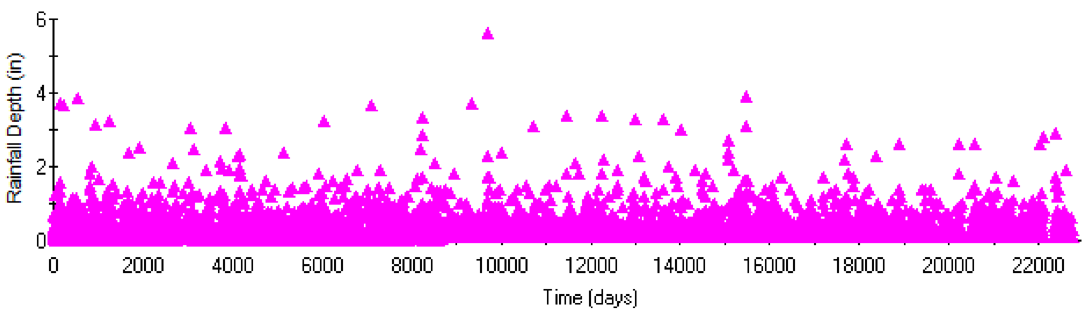
Data for these locations were obtained through the libraries at the University of Alabama. Unfortunately, the raw hourly rainfall data are not available through this network, but only processed statistical summaries of the information that could not be directly related to the monitored events. Therefore, rainfall analyses were restricted to the four main NOAA stations of Quilcene, Everett, Burlington, and SEATAC.

Rainfall Patterns near the Northwest Naval Bases

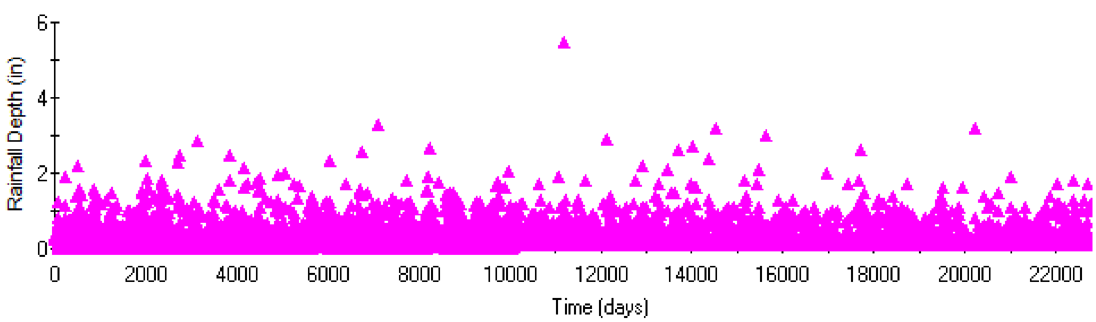
The following four figures are scatterplots showing the rain depths for each rain that occurred during the period noted for each station. Everett, Burlington, and SeaTac are quite similar, with most rains less than one inch, with occasional rains as large as 5 or 6 inches (one or two events this size in the 60 years of record). However, Quilcene rains are much larger, with common rains less than about 2 inches and rare rains in the 10 to 15 inch category.



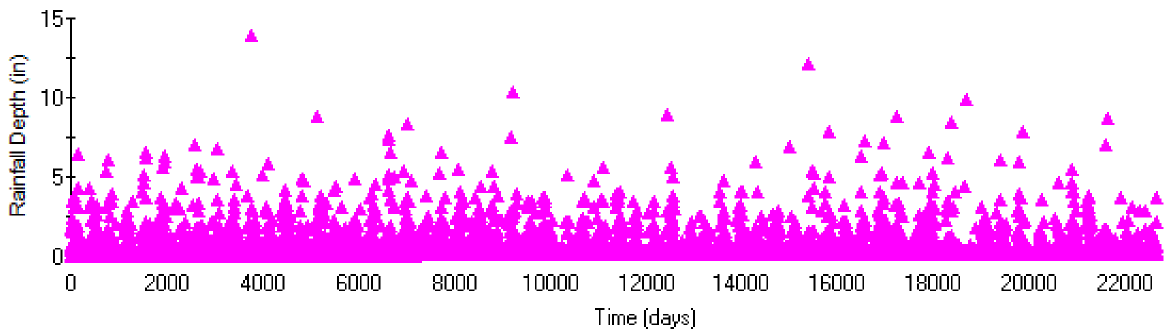
SEATAC, WA, rainfall from January 1, 1965 through December 31, 1999.



Burlington, WA, rainfall from July 4, 1948 through November 1, 2010.



Everett, WA, rainfall from July 6, 1948 through November 1, 2010.



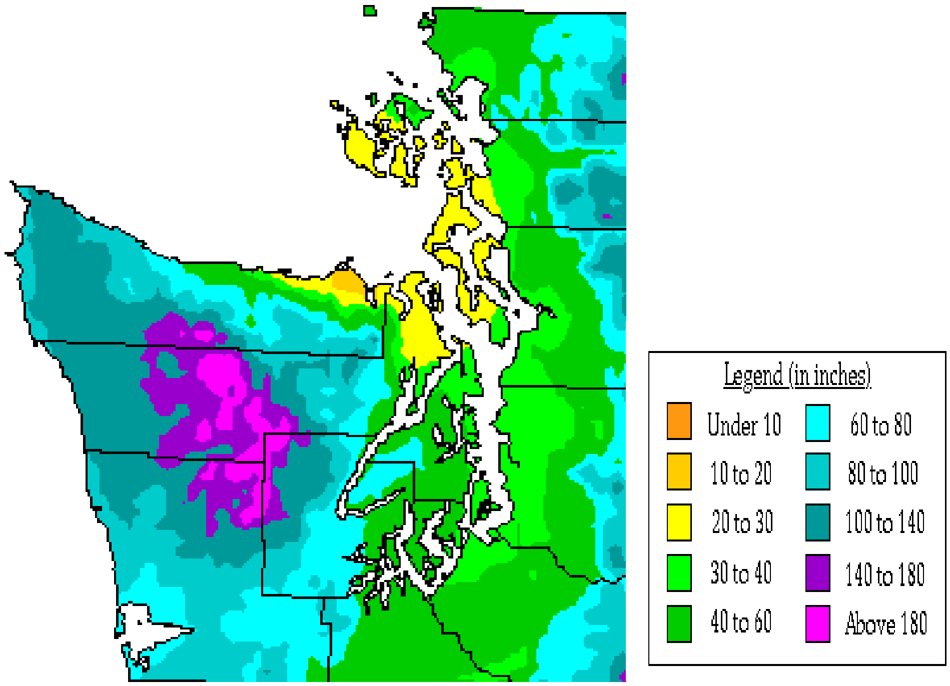
Quilcene, WA, rainfall from September 26, 1948 through October 29, 2010.

The following table summarizes these rain depths for each month, and for the total years. Again, Quilcene is seen to have much larger rain depths per month and about twice the annual rain depth as the other locations.

Monthly Rain Depths (inches) and Standard Deviations (inches) for Puget Sound NOAA Stations

	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Annual
Quilcene, WA (1948 – 2010)	9.17 (7.31)	7.51 (4.73)	7.29 (4.63)	3.98 (2.35)	2.92 (1.57)	1.95 (1.39)	1.19 (0.94)	1.28 (1.27)	1.96 (1.98)	4.73 (4.31)	8.67 (5.99)	8.99 (6.49)	59.64 (15.95)
Burlington, WA (1948 – 2010)	4.19 (2.27)	3.05 (2.34)	2.65 (1.43)	2.31 (1.20)	2.07 (1.26)	1.71 (1.11)	1.14 (0.83)	1.38 (1.20)	1.91 (1.21)	3.27 (2.11)	4.48 (2.68)	3.98 (2.00)	32.14 (6.87)
Everett, WA (1948 – 2010)	3.76 (2.35)	3.05 (1.52)	3.05 (1.43)	2.40 (1.15)	2.28 (0.99)	1.75 (1.27)	0.96 (0.79)	1.16 (1.09)	1.70 (1.12)	2.82 (1.80)	4.22 (2.19)	4.26 (2.41)	31.39 (6.25)
SeaTac, WA (1965 – 1999)	5.46 (2.17)	3.95 (1.95)	3.64 (1.62)	2.61 (1.33)	1.65 (0.91)	1.39 (0.77)	0.74 (0.52)	1.11 (1.22)	1.69 (1.38)	3.22 (1.79)	5.76 (2.55)	5.86 (2.47)	37.08 (5.87)

The following figure (from: http://www.ocs.orst.edu/pub/maps/Precipitation/Total/States/WA/wa.gif) show how the total rain depths vary significantly in this region. Most of the area receives annual rain depths in the 30 to 40 inch range, while areas near the Olympics receive much greater amounts of rains (>180 inches per year).



Rainfall map of NW Washington (from: http://www.ocs.orst.edu/pub/maps/Precipitation/Total/States/WA/wa.gif)

The ranges for each of the four NOAA locations are shown below, along with the calculated total rain depths as reflected in the previous scatterplots. The trends are similar, with Everett and Burlington having the least amount of annual rains (31 and 32 inches per year), SeaTac slightly more (at 37 inches per year), and Quilcene having the largest annual depths (about 60 inches per year):

SeaTac: 30 to 40 in/yr [37 in/yr between 1965 and 1999]
Everett: 30 to 40 in/yr [31 in/yr between 1948 and 2010]
Burlington: 30 to 40 in/yr [32 in/yr between 1948 and 2010]
Quilcene: 60 to 80 in/yr [60 in/yr between 1948 and 2010]

The regional naval facilities and the closest available NOAA rainfall data are summarized below:

Whidbey Island: 20 to 30 in/yr (20 to 30 mi from Everett, 31 in/yr, and Burlington, 32 in/yr, NOAA)
Indian Island: 20 to 30 in/yr (30 mi from Everett, 31 in/yr, and Burlington, 32 in/yr, NOAA)
Everett: 30 to 40 in/yr (<5 mi from Everett, 31 in/yr, NOAA)
Bangor: 40 to 60 in/yr (15 mi from Quilcene, 60 in/yr, NOAA)

Therefore, the WinSLAMM calibration efforts will focus on the Quilcene NOAA data for the Bangor naval facilities, and the Everett NOAA data for the Whidbey Island, Indian, Island, and Everett naval facilities. Because the rainfall pattern varies significantly over relatively short distances in this area, it is unlikely that direct comparisons can be made between specific monitored runoff events at these naval facilities and these "closest" rain data locations.

As noted above, the GHCN rainfall data are difficult to access and will require substantial reformatting to be useful. Future data extraction will be used for the Oak Harbor (for the Whidbey Island runoff data), Port Wilson/Port Townsend (for the Indian Island runoff data), and Bangor CGS (for the Bangor Pier runoff data). In the interest of time, the WinSLAMM model calibration efforts for this report will continue using the available NOAA data. Hopefully, future calibration refinements can be conducted using the closer GHCN data.

Runoff Water Quality at NW Naval Bases

Quarterly runoff samples were obtained at the naval bases as part of their National Pollutant Discharge Elimination System (NPDES) permits. The following tables list the available data from these four locations:

Indian Island Naval Base Runoff Water Quality

Date Sampled	Quarter	Year	Aluminum (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Zinc (µg/L)	COD (mg/L)	TSS (mg/L)
11/16/2009	Q4	2009.75	1,790		2,450	51	240		
3/29/2010	Q1	2010.00	76		112	<4	35.4		
5/10/2010	Q2	2010.25	457		625	10	95.5		
9/20/2010	Q3	2010.50	1,560		2,110	46	175		
12/18/2010	Q4	2010.75	1,420		2,030		101		
2/14/2011	Q1	2011.00	11,900		19,400		1,110		

Whidbey Island Naval Base Runoff Water Quality

Date Sampled	Quarter	Year	Aluminum (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Zinc (µg/L)	COD (mg/L)	TSS (mg/L)
2/11/1997	Q1	1997.00	2,400		4,300	26	100	62	143
5/27/1997	Q2	1997.25	1,200	28	1,600	8	130	54	51
9/30/1997	Q3	1997.50	250	47	410	5	120	25	16
n/a	Q4	1997.75	550		670	9	70	13	91
3/8/1999	Q1	1999.00	10,000	33	17,200		137	41	53
8/29/1999	Q3	1999.50	2,000	161	2,950		230	181	110
n/a	Q1	2001.00	2,410	29	2,780	75	88	33	19
n/a	Q2	2001.25	5,250	66	6,910	167	207	59	165
n/a	Q3	2001.50	805	26	883	24	136	33	18
n/a	Q4	2001.75	550	33	778	27	164	56	60
1/21/2003	Q1	2003.00	268	13	459	10	224	19	9
n/a	Q2	2003.25	714	15	985		46	44	7
9/7/2003	Q3	2003.50	2,260	73	3,100	46	356	100	84
11/10/2003	Q4	2003.75	1,500	39	2,500	27	484	69	34
1/3/2008	Q1	2008.00	410	23	1,740	7	120	31	18
6/3/2008	Q2	2008.25	1,700	22	2,130	11	77	ND	74

Bangor Pier Naval Base Runoff Water Quality (after site wet detention pond)

Date Sampled	Quarter	Year	Aluminum (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Zinc (µg/L)	COD (mg/L)	TSS (mg/L)
12/28/2001	Q4	2001.75	30		40	2.9	8.2		
4/17/2002	Q2	2001.25	40		390	50	103		
1/14/2004	Q1	2004.00	110		230	4	24		
5/26/2004	Q2	2004.25	10		150	4	6		

Everett Naval Base Runoff Water Quality

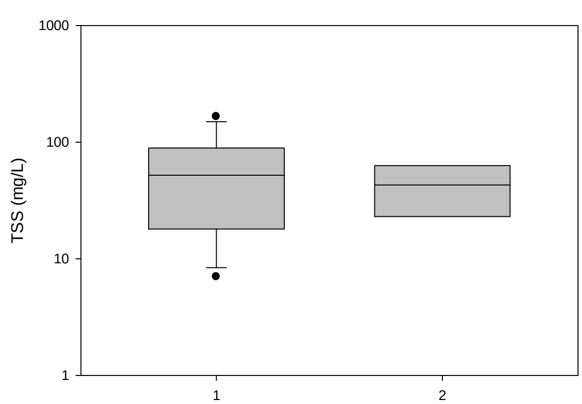
Date Sampled	Quarter	Year	Aluminum (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Zinc (µg/L)	COD (mg/L)	TSS (mg/L)
98'-99	n/a	n/a					10		
98'-99	n/a	n/a					10		
01'-02'	n/a	n/a					1500		
01'-02'	n/a	n/a					54		
03'-04'	n/a	n/a					70		
03'-04'	n/a	n/a					760		
11/5/2009	Q4	2009.75	1,500	5	1,200		10		23
8/26/2010	Q3	2010.50		33			170		63
9/23/2010	Q3	2010.50		10			60		
12/20/2010	Q4	2010.75		6			53		
1/20/2011	Q1	2011.00		8			60		

Stormwater quality is known to be highly variable, as shown on the following summary table for all of the above data combined. The coefficients of variation (the COV, or the ratio of the standard deviation to the average) ranged from 0.8 to 1.6 for these data, typical for stormwater observations. As the COV value increases, the uncertainty also increases, requiring more samples to characterize runoff quality conditions. Some of the constituents have few observations. Unfortunately, rainfall and runoff was not recorded along with these runoff observations, and only total heavy metal forms were evaluated, making model calibration challenging. As noted previously, only Everett has a NOAA weather station with complete data nearby.

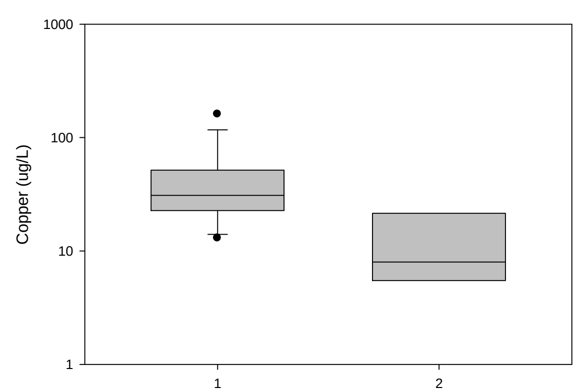
Summary of All Observed Northwest Naval Facility Stormwater Quality Data

	Aluminum (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Zinc (µg/L)	COD (mg/L)	TSS (mg/L)
count	27	19	27	20	37	15	18
median	1,200	28	1,600	18	101	44	52
average	1,895	35	2,894	30	198	55	58
st dev	2,853	36	4,701	38	308	41	47
COV	1.5	1.0	1.6	1.2	1.6	0.8	0.8
min	10	5	40	3	6	13	7
max	11,900	161	19,400	167	1,500	181	165

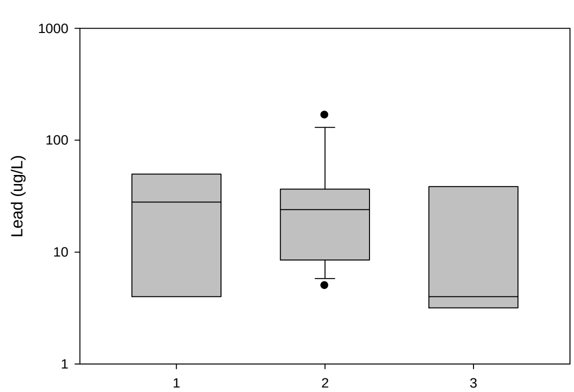
The following are grouped box and whisker plots comparing the observed stormwater concentrations for total suspended solids, copper, lead, and zinc for the four northwest naval bases. Some constituents only have a few observations for a location (TSS at Everett and lead at the Bangor Pier) and the resulting plots have more uncertainty than desired. In addition, some constituents were not monitored at some locations (TSS and copper at Indian Island and at the Bangor Pier, and lead at Everett) so these are not plotted. Even with these missing data, it seems that Indian Island and Whidbey Island have similar concentrations for zinc (and for iron and aluminum that were not plotted). The Everett zinc concentrations are much more variable (and have some very high values) compared to the other locations (and the few copper values are lower than observed at Whidbey Island, the only other location having copper observations).



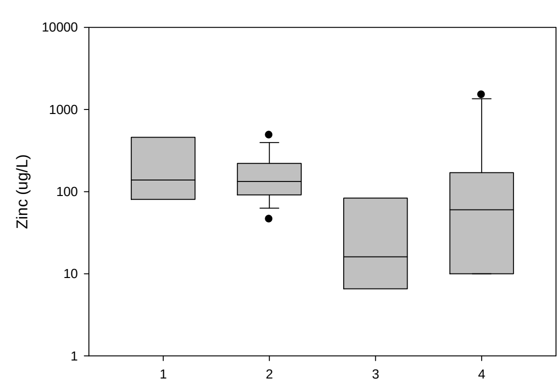
Total suspended solids stormwater concentrations observed for Whidbey Island (#1) and Everett (#2) naval facilities.



Copper stormwater concentrations observed for Whidbey Island (#1) and Everett (#2) naval facilities.



Lead stormwater concentrations observed for Indian Island (#1), Whidbey Island (#2) and Bangor Pier (#3) naval facilities.



Zinc stormwater concentrations observed for Indian Island (#1), Whidbey Island (#2), Bangor Pier (#3), and Everett (#4) naval facilities.

The Bangor Pier site has a wet detention pond which is expected to significantly reduce the concentrations of the particulate forms of the pollutants. Iron, lead, and zinc were monitored at this location during four events from December 2001 and May 2004. The concentrations of these three metals were all substantially lower than data obtained at the other sites. Iron, typically highly associated with particulate pollutants, was monitored at all four locations and the Bangor iron concentrations are only about 10% of the concentrations observed at the other locations. The lead concentrations at Bangor were about half of the values observed at Indian Island and Whidbey Island, while the zinc concentrations at Bangor were about 25%, or less, compared the other three locations.

Calibration of WinSLAMM using Northwest Naval Facility Data

The above site data were therefore used to modify the pollutant concentration parameter files developed for the San Diego naval facilities and for the Pacific Northwest regional data. The following data compare the observed pollutant concentrations and yields for the events used in the calibration effort (for which dates were available and regional rainfall conditions were identified), with the post-calibrated modeled values. The calibration adjustments were bases on matching the yield sums from these events. As seen, these compare favorably. However, the average concentrations do vary, but are within the expected 25 to 50% error range usually obtained for stormwater quality models. Also shown below are the five year calculated concentrations for each of the four locations, showing the averages and the ranges of the modeled concentrations.

Observed and Modeled TSS Concentrations and Yields at Northwest Naval Facility Study Areas

	TSS observed average (mg/L)	TSS modeled average (mg/L)	TSS observed total yield (lbs)	TSS modeled total yield (lbs)
Whidbey Island	69	75	343	267
Everett	43	76	106	150
Sum for all observed events			449	417

All Northwest Naval Facilities TSS Modeled Concentrations (2006 through 2010 rains)

	modeled TSS (mg/L)		
	average	min	max
Whidbey Is; Everett rain file	56	39	150
Indian Is; Everett rain file	52	47	57
Everett; Everett rain file	59	31	311
Bangor Pier (with pond); Quilcene rain file	13	7	33
Bangor Pier (before pond); Quilcene rain file	38	15	87

Observed and Modeled Cu Concentrations and Yields at Northwest Naval Facility Study Areas

	Total Cu observed average (µg/L)	Total Cu modeled average (µg/L)	Total Cu observed total yield (lbs)	Total Cu modeled total yield (lbs)
Whidbey Island	51	33	146	124
Everett	16	39	52	77
Sum for all observed events			197	201

All Northwest Naval Facilities Total Copper Modeled Concentrations (2006 through 2010 rains)

	modeled total Cu (µg/L)		
	average	min	max
Whidbey Is; Everett rain file	28	13	71
Indian Is; Everett rain file	32	11	129
Everett; Everett rain file	31	13	102
Bangor Pier (with pond); Quilcene rain file	66	14	303
Bangor Pier (before pond); Quilcene rain file	78	18	433

Observed and Modeled Zn Concentrations and Yields at Northwest Naval Facility Study Areas

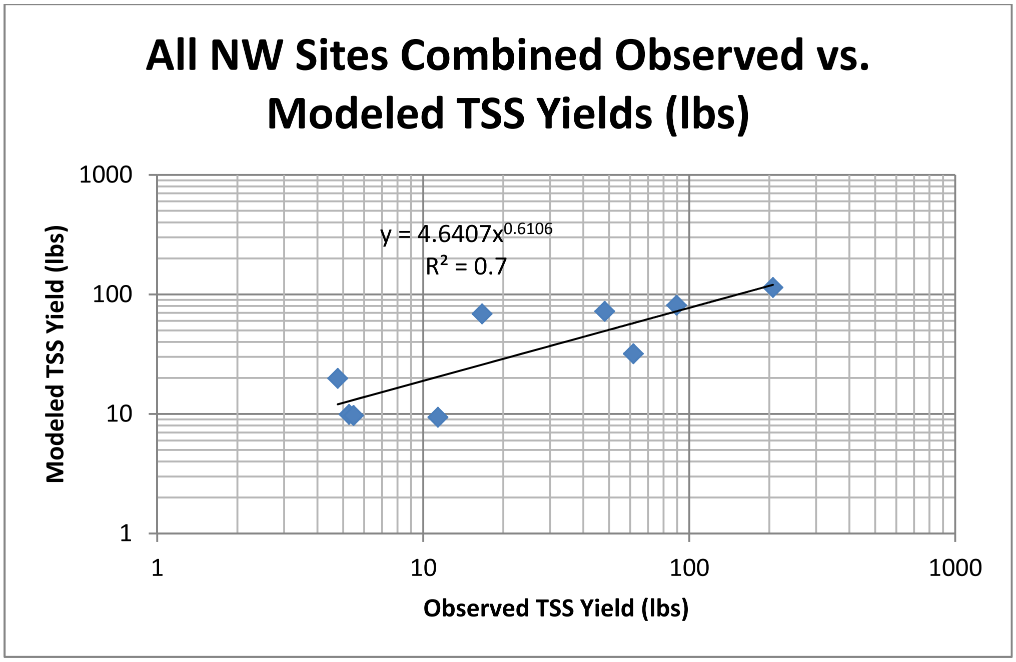
	Total Zn observed average (µg/L)	Total Zn modeled average (µg/L)	Total Zn observed total yield (lbs)	Total Zn modeled total yield (lbs)
Indian Island	150	192	133	127
Whidbey Island	183	156	1,026	636
Everett	80	308	257	646
Sum for all observed events			1,416	1,409

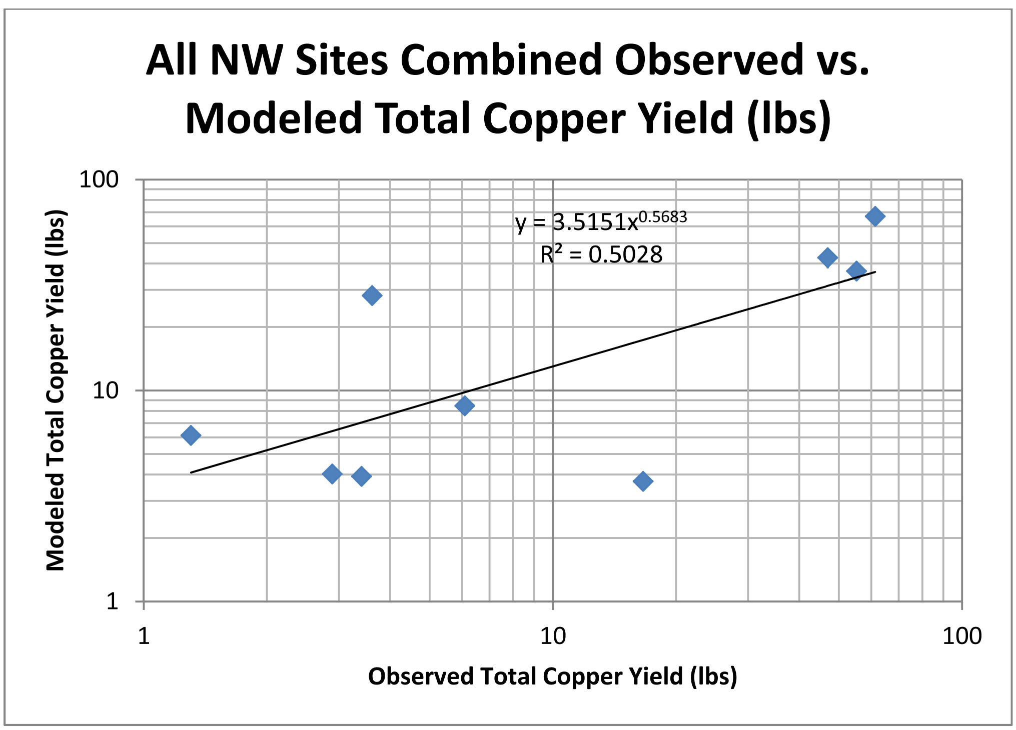
All Northwest Naval Facilities Total Zinc Modeled Concentrations (2006 through 2010 rains)

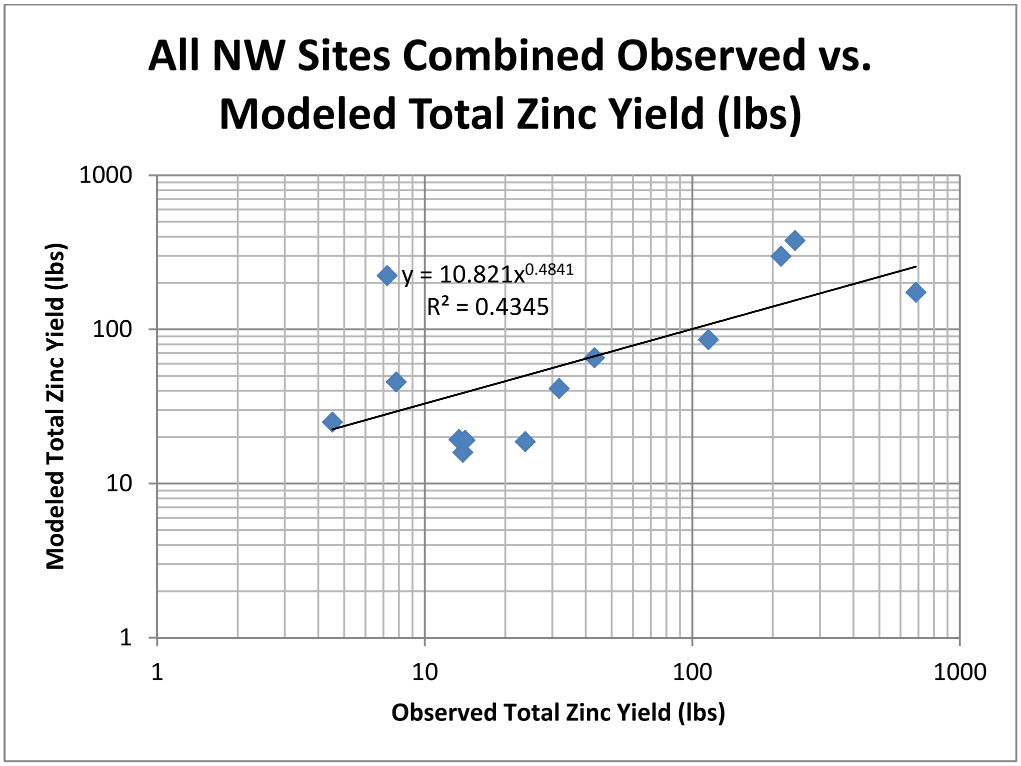
	modeled total Zn (µg/L)		
	average	min	max
Whidbey Is; Everett rain file	132	49	523
Indian Is; Everett rain file	191	72	1,025
Everett; Everett rain file	259	85	1,403
Bangor Pier (with pond); Quilcene rain file	223	53	2,891
Bangor Pier (before pond); Quilcene rain file	301	96	2,330

The following figures are plots of the observed vs. modeled yields for each event (using calculated runoff volume values from WinSLAMM). These scatterplots show wider ranges of data than the earlier San

Diego data, mostly because of the smaller range of observations and the decreased certainty of the rainfall conditions for each event.







Sources of Stormwater Pollutants at Northwest Naval Facilities

The following tables summarize the calculated major pollutant sources for each of the four northwest naval facilities for three major rain categories. Because the sites have little pervious areas, there are generally only small differences in source contributions for the different rain categories. Also, the uncertainly in these calculations may be large due to the limited calibration data. However, the relative source contributions are still likely reasonable and identify the most important source areas that can be targeted for control.

Major flow sources for Bangor Pier sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Oi7 (68%) Oi9 (14%) Oi8 (9%) (total 91%)	Oi7 (69%) Oi9 (14%) Oi8 (9%) (total 92%)	Oi7 (69%) Oi9 (14%) Oi8 (9%) (total 92%)

Major flow sources for Everett sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (45%) Oi9 (28%) Street area (12%) (total 85%)	Paved parking/storage 1 (45%) Oi9 (28%) Street area (12%) (total 85%)	Paved parking/storage 1 (45%) Oi9 (28%) Street area (11%) (total 84%)

Major flow sources for Indian Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (85%)	Paved parking/storage 1 (85%)	Paved parking/storage 1 (85%)

Major flow sources for Whidbey Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (57%) Oi6 (17%) Roofs (15%) (total 89%)	Paved parking/storage 1 (57%) Oi6 (17%) Roofs (14%) (total 88%)	Paved parking/storage 1 (55%) Oi6 (16%) Roofs (13%) (total 84%)

Major TSS sources for Bangor Pier sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Oi7 (77%) Oi8 (18%) (total 95%)	Oi7 (73%) Oi8 (23%) (total 96%)	Oi7 (66%) Oi8 (29%) (total 95%)

Major TSS sources for Everett sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Street area (68%) Paved parking/storage 1 (18%) (total 86%)	Paved parking/storage 1 (44%) Street area (35%) Oi8 (15%) (total 94%)	Paved parking/storage 1 (62%) Street area (20%) Oi8 (12%) (total 94%)

Major TSS sources for Indian Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (75%) Oi8 (23%) (total 98%)	Paved parking/storage 1 (81%) Oi8 (18%) (total 99%)	Paved parking/storage 1 (88%) Oi8 (11%) (total 99%)

Major TSS sources for Whidbey Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (34%) Street area (30%) Oi6 (30%) (total 94%)	Paved parking/storage 1 (55%) Oi6 (27%) Street area (11%) (total 93%)	Paved parking/storage 1 (68%) Oi6 (16%) (total 84%)

Major Cu sources for Bangor Pier sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Oi7 (79%) Oi8 (17%) (total 96%)	Oi7 (78%) Oi8 (18%) (total 96%)	Oi7 (79%) Oi8 (17%) (total 96%)

Major Cu sources for Everett sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Street area (44%) Oi8 (27%) Paved parking/storage 1 (18%) (total 89%)	Oi8 (37%) Paved parking/storage 1 (30%) Street area (21%) (total 88%)	Paved parking/storage 1 (38%) Oi8 (34%) Street area (15%) (total 87%)

Major Cu sources for Indian Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (47%) Oi8 (46%) (total 93%)	Paved parking/storage 1 (52%) Oi8 (42%) (total 94%)	Paved parking/storage 1 (59%) Oi8 (35%) (total 94%)

Major Cu sources for Whidbey Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (32%) Oi6 (27%) Street area (19%) (total 78%)	Paved parking/storage 1 (41%) Oi6 (26%) Roofs4 (11%) (total 78%)	Paved parking/storage 1 (46%) Oi6 (23%) Roofs4 (12%) (total 8%)

Major Zn sources for Bangor Pier sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Oi7 (62%) Oi8 (24%) Oi9 (13%) (total 99%)	Oi7 (55%) Oi8 (26%) Oi9 (17%) (total 98%)	Oi7 (49%) Oi8 (27%) Oi9 (22%) (total 98%)

Major Zn sources for Everett sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Oi9 (36%) Street area (26%) Oi8 (25%)	Oi9 (47%) Oi8 (27%) Paved parking/storage 1 (17%)	Oi9 (52%) Oi8 (23%) Paved parking/storage 1 (19%)

Paved parking/storage 1 (13%) (total 100%)	(total 91%)	(total 94%)

Major Zn sources for Indian Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Oi8 (51%) Paved parking/storage 1 (40%) (total 91%)	Oi8 (47%) Paved parking/storage 1 (45%) (total 92%)	Paved parking/storage 1 (51%) Oi8 (40%) (total 91%)

Major Zn sources for Whidbey Island sub areas:

0 to 0.5 inches	0.5 to 1.5 inches	>1.5 inches
Paved parking/storage 1 (33%) Oi6 (32%) Street area (16%) (total 81%)	Paved parking/storage 1 (44%) Oi6 (28%) (total 78%)	Paved parking/storage 1 (52%) Oi6 (21%) (total 73%)

The following tables identify the sources that make up the majority of the pollutant contributions and the source areas that contribute at least twice the contribution as expected based on their areas. These critical source areas would be the most likely effective areas for source area treatment.

Major source areas for Bangor Pier (10.57 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Other impervious area #7	Medium industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)	7.28 ac (69%)	69%	73%	78%	55%
Other impervious area #8	Heavy industrial storage/laydown area, asphalt (heavy industrial/laydown activities, asphalt)	0.98 ac (9%)	9%	23%	18%	26%
Other impervious area #9	Galvanized metal roofs, flat, directly connected to drainage system	1.52 ac (14%)	14%			17%

Major source areas for Everett (12.68 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Paved parking and storage area	Directly connected paved parking areas	5.55 ac (44%)	45%	44%	30%	17%
Streets	40 ft wide paved streets, intermediate texture	1.29 ac (10%)	12%	35%	21%	
Other impervious area #8	Heavy industrial storage/laydown area, asphalt (heavy industrial/laydown activities, asphalt)	0.82 ac (6%)		15%	37%	27%
Other impervious area #9	Galvanized metal roofs, flat, directly connected to drainage system	3.48 ac (27%)	28%			47%

Major source areas for Indian Island (3.11 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Paved parking and storage area	Directly connected paved parking areas	2.66 ac (86%)	85%	81%	52%	45%
Other impervious area #8	Heavy industrial storage/laydown area, asphalt (heavy industrial/laydown activities, asphalt)	0.26 ac (8%)		18%	42%	47%

Major source areas for Whidbey Island (13.12 ac):

Label	Description	Area (acres and percentage)	Flow sources (%) for medium rains	TSS sources (%) for medium rains	Cu sources (%) for medium rains	Zn sources (%) for medium rains
Roofs	Flat, directly connected roof areas	1.39 ac (11%)	14%		11%	
Paved parking and storage area	Directly connected paved parking areas	6.01 ac (46%)	57%	55%	41%	44%
Streets	42 ft wide paved streets	0.35 ac (3%)		11%		
Other impervious area #6	Light industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)	1.75 ac (13%)	17%	27%	26%	28%

The following lists summarizes the most significant source areas by naval facility (those having at least twice the expected contribution as the area) along with the most critical sources for each contaminant of interest (in order to control the majority of the contaminant):

Bangor Pier (10.57 acres)

- Heavy industrial storage or laydown areas (9% of area, 23% TSS, 78% Cu, 55% Zn sources)

- Runoff volume (medium industrial storage/laydown areas, 69% of area and 69% of runoff sources)
- TSS sources (medium industrial storage/laydown areas, 69% of area and 73% of TSS sources)
- Cu sources (medium industrial storage/laydown areas, 69% of area and 78% of Cu sources)
- Zn sources (medium industrial storage/laydown areas, 69% of area and 55% of Zn sources)

Everett (12.68 acres)

- Streets (10% of area, 35% of TSS and 21% of Cu sources)
- Heavy industrial storage or laydown areas (6% of area, 15% of TSS, 37% of Cu, and 27% of Zn sources)

- Runoff volume (paved parking and storage areas, 44% of area, 45% of runoff sources; and galvanized roofs at 27% of area, 28% of runoff sources)
- TSS sources (paved parking and storage areas, 44% of area, 44% of TSS sources; streets at 10% of area, 35% of TSS sources; and heavy industrial storage/laydown areas at 6% of areas and 15% of TSS sources)
- Cu sources (heavy industrial storage/laydown areas at 6% of areas and 37% of Cu sources; paved parking and storage areas, 44% of area, 30% of Cu sources; and streets at 10% of area, 21% of Cu sources)
- Zn sources (galvanized metal roofs, 27% of area, 47% of Zn sources; and heavy industrial storage/laydown areas at 6% of areas and 27% of Zn sources)

Indian Island (3.11 acres)

- Heavy industrial storage or laydown areas (8% of area, 18% of TSS, 42% of Cu, and 47% of Zn sources)

- Runoff volume (paved parking and storage areas, 86% of area, 85% of runoff sources)
- TSS sources (paved parking and storage areas, 86% of area, 81% of TSS source)
- Cu sources (paved parking and storage areas, 86% of area, 52% of Cu source; and heavy industrial storage/laydown areas, 8% of area, 42% of Cu sources)
- Zn sources (heavy industrial storage/laydown areas, 8% of area, 47% of Zn sources; and paved parking and storage areas, 86% of area, 45% of Zn source)

Whidbey Island (13.12 acres)

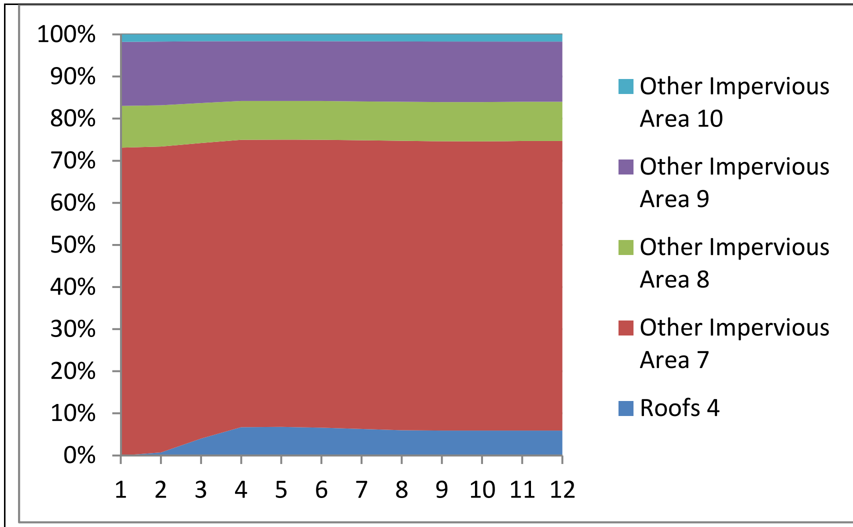
- Streets (3% of area, 11% of TSS sources)
- Light industrial storage/laydown areas (13% of area, 27% of TSS, 26% of Cu, and 28% of Zn sources)

- Runoff volume (paved parking and storage areas, 46% of area, 57% of runoff sources; light industrial storage/laydown area, 13% of area, 17% of runoff; and roofs, 11% of area, 14% of runoff sources)
- TSS sources (paved parking and storage areas, 46% of area, 55% of TSS; light industrial storage/laydown area, 13% of area, 27% of TSS; and streets, 3% of area, 11% of TSS sources)

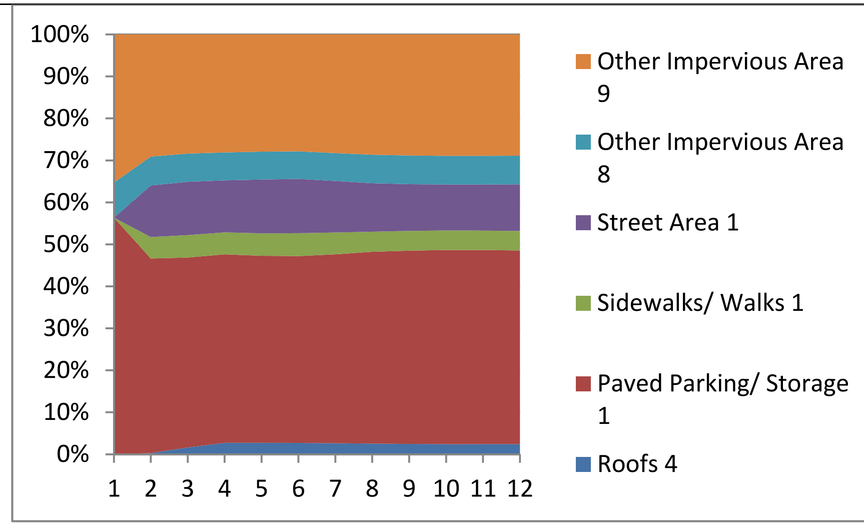
• Cu sources (paved parking and storage areas, 46% of area, 41% of Cu; light industrial storage/laydown area, 13% of area, 26% of Cu; and roofs, 11% of area, 11% of Cu sources)
• Zn sources (paved parking and storage areas, 46% of area, 44% of Zn; and light industrial storage/laydown area, 13% of area, 28% of Zn sources)

The following figures show these major source contributions for the different rain categories listed below.

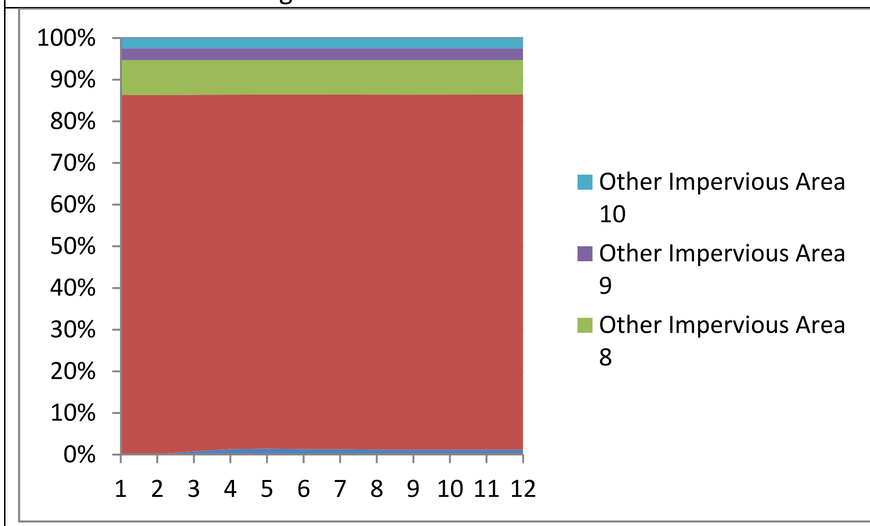
Event number	Rain Total (inches)
1	0.01
2	0.05
3	0.1
4	0.25
5	0.5
6	0.75
7	1
8	1.5
9	2
10	2.5
11	3
12	4



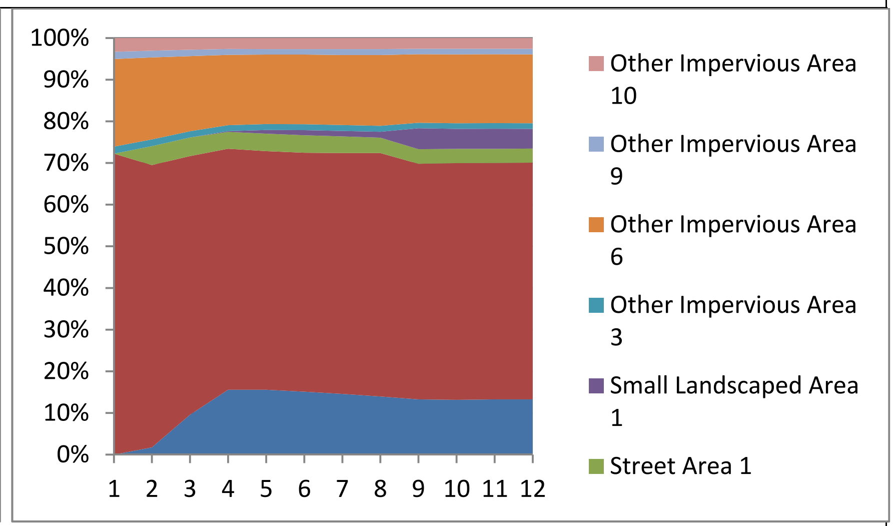
Runoff sources at Bangor Pier



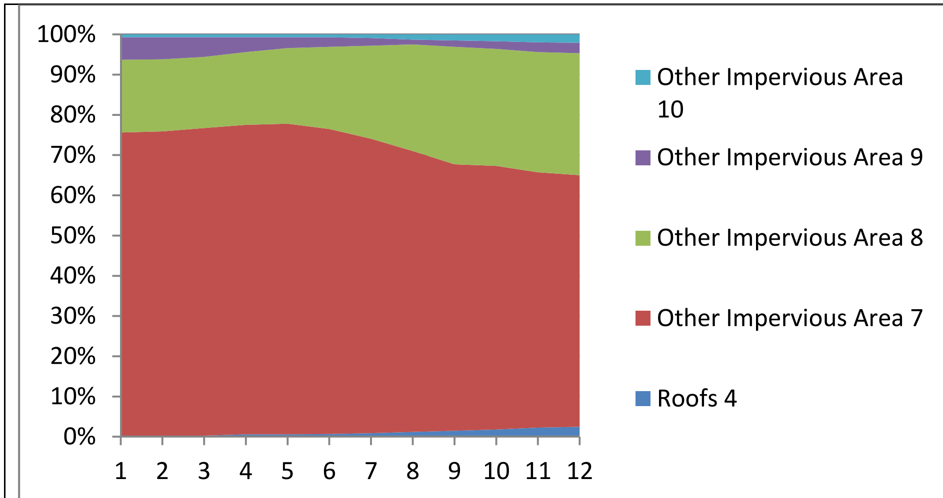
Runoff sources at Everett



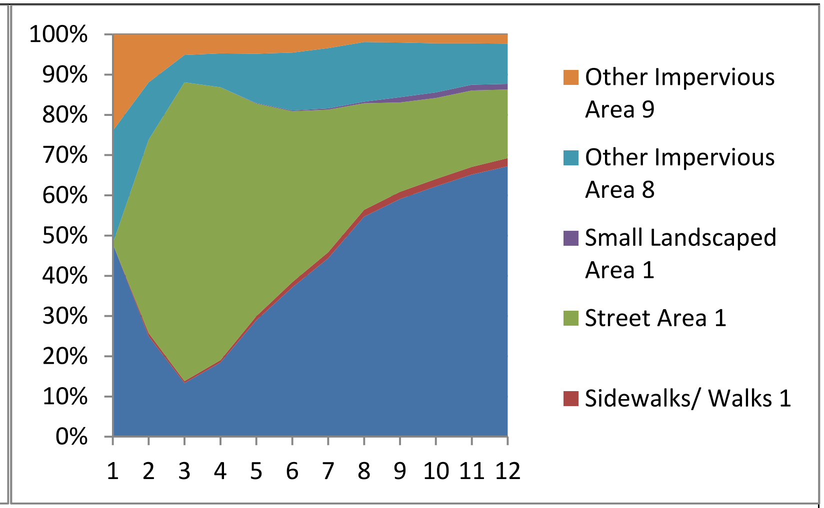
Runoff sources at Indian Island



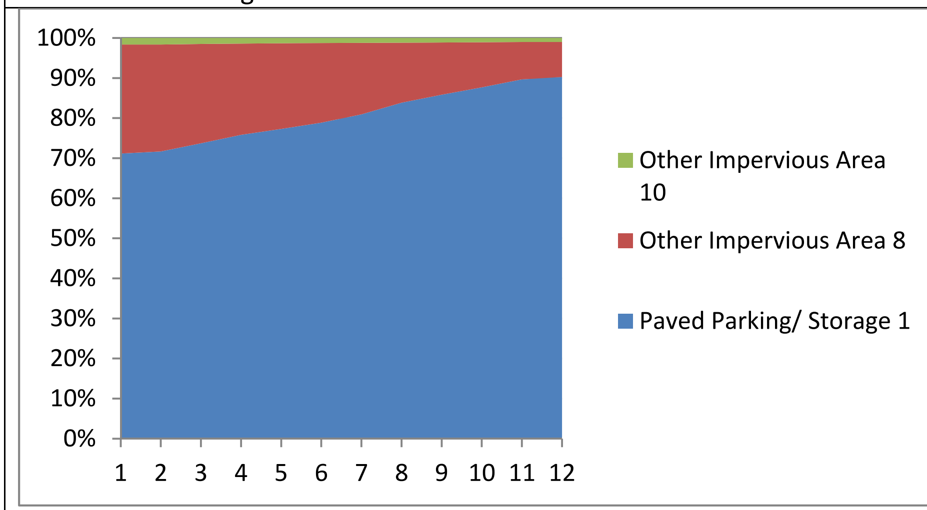
Runoff sources at Whidbey Island



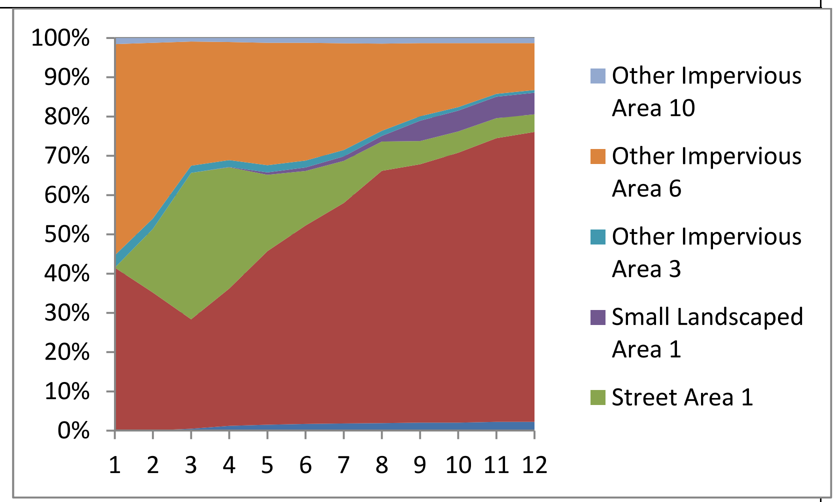
TSS sources at Bangor Pier



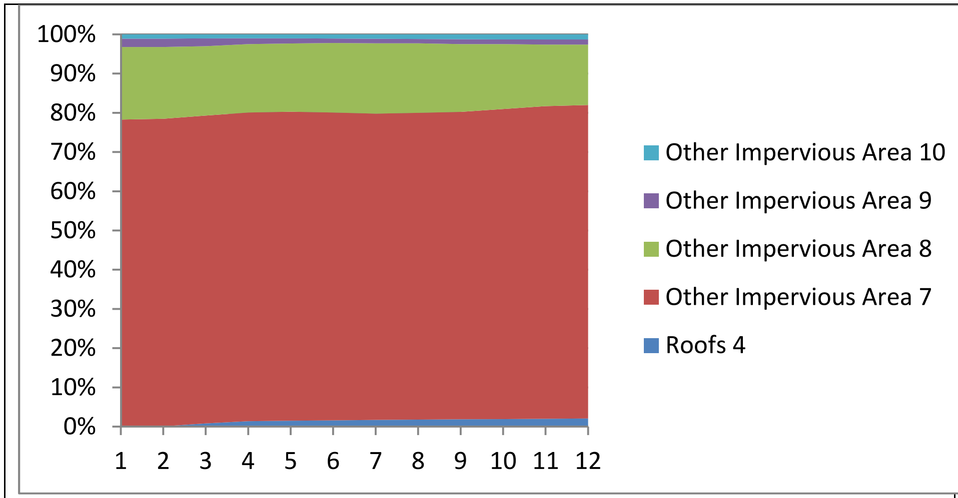
TSS sources at Everett



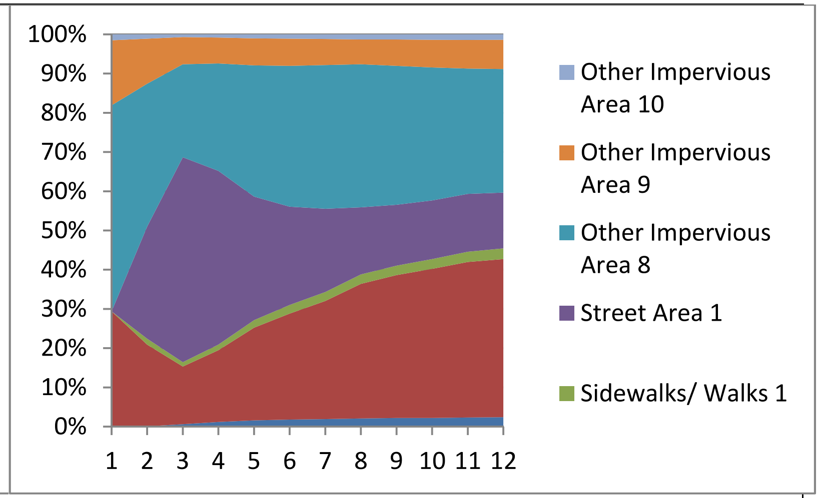
TSS sources at Indian Island



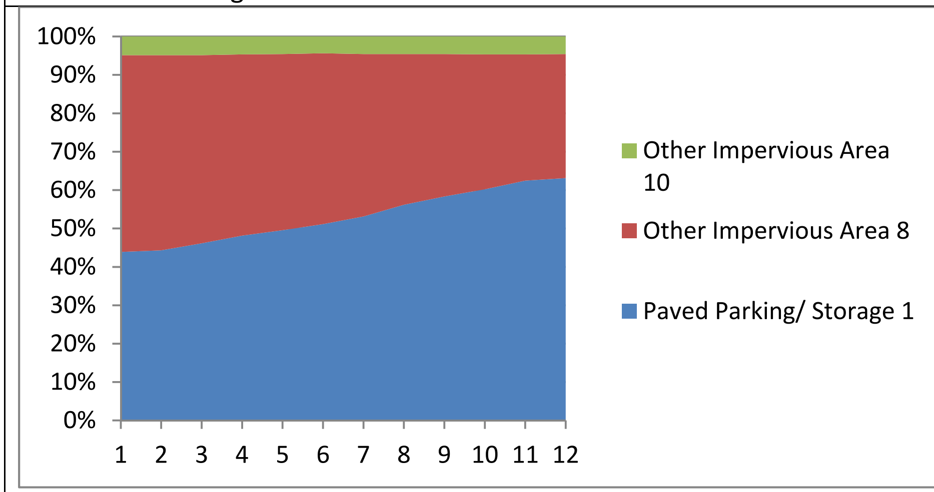
TSS sources at Whidbey Island



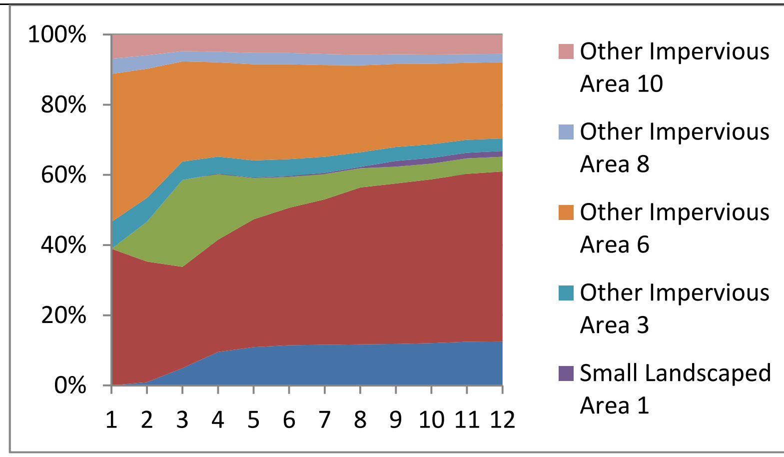
Cu sources at Bangor Pier



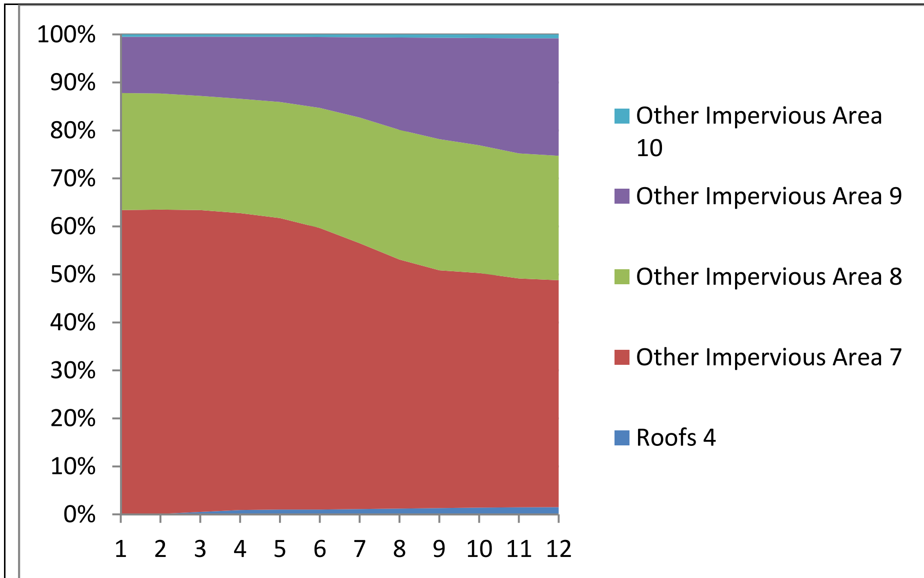
Cu sources at Everett



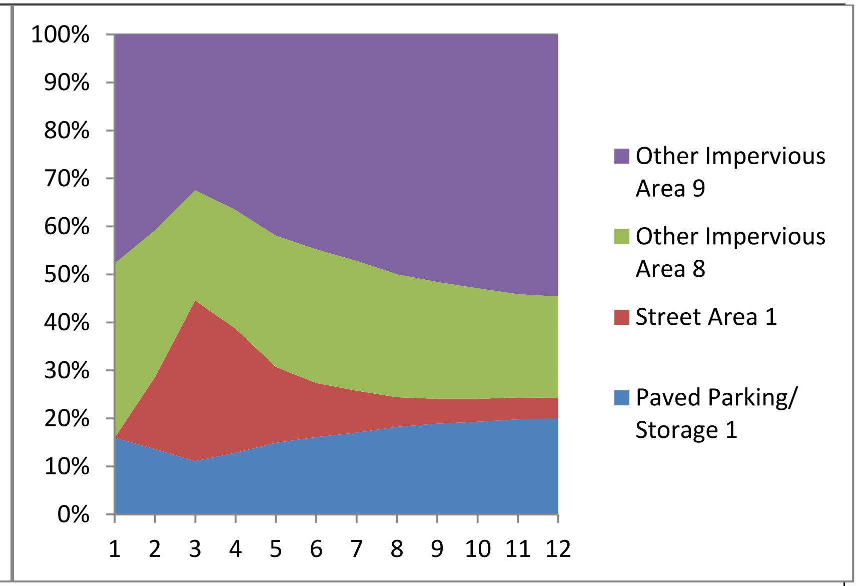
Cu sources at Indian Island



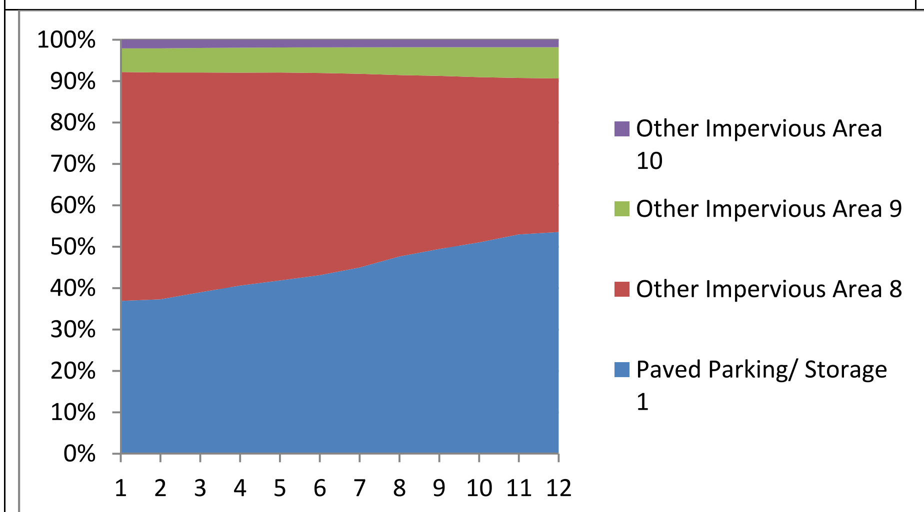
Cu sources at Whidbey Island



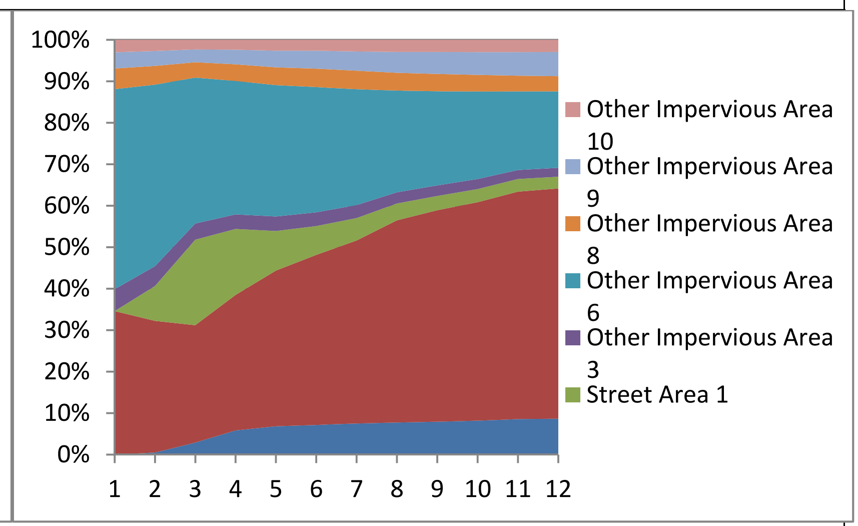
Zn sources at Bangor Pier



Zn sources at Everett



Zn sources at Indian Island



Zn sources at Whidbey Island

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Appendix A: San Diego and Northwest Naval Base Site Survey Information

Naval Base San Diego (NBSD) - Outfall 14

Buildings and Adjacent Areas:

Building/ Area	Roof Area (acres)	Roof Area (square feet)	Description/Material/Location	Area concrete (sq. ft)	Area Sidewalk Concrete (sq. ft.)	Area Walkway Concrete (sq. ft.)	Area Pervious (sq. ft)	Area Brick (sq ft)	Photo #
3304	7.96	346,868	Flat, connected roof. Concrete and metal siding. Catchbasins that appear inside building on outfall map are actually outside of the building and drain the loading dock but are covered under a roof.						1298 & 1299
322	1.64	71,371	Flat roof, Concrete Siding, Connected. Concrete Sidewalk and brick walkway North of bldg.		448			1,982	1296
3478	0.10	4,339	Pitched roof, Metal siding same as roof. *Partially Connected---Roof water drains into planter box adjacent to bldg. 2 ft wide by 85.6 ft long by 1.5 feet deep. Planter will contain first 0.06 inches of rain assuming a rainfall intensity of 0.68 in/hr and a percolation rate of 0.3 mL/sec.		1,290	465	257		1292 & 1293
3509	0.52	22,796	Flat and connected- Concrete walkway West of building and small planter boxes outside building. Siding consists of brick and painted metal.			844	27		
3511	0.78	33,916	Flat and connected--Concrete west of building Concrete and metal siding, shingled roof.						
3638	0.02	1,054	Flat, connected, galvanized roof--Haz waste building East of 3511						

3587	0.02	938	Flat and connected roof. Carwash bldg.						
Tire Storage	0.01	555	Galv. metal roof. Connected. Adjacent to B 3510 and East of 3511						
3434	0.19	8,309	Pitched and Connected Roof.						
3421	0.05	2,365	Pitched and connected blue tile roof.	2,323			1,082		
127	0.47	20,317	Flat and connected roof. Concrete siding.						
319	2.75	119,997	Pitched and connected roof. Metal siding.						
3546	0.22	9,658	Pitched and connected roof. Metal siding.						
3416	0.06	256	Pitched and connected metal roof. Siding is the same material as the roof.			1,030			
3510	0.20	8,514	Flat and Connected roof. Concrete parking West of building and a sliver within OF14 East of Building. Siding brick and painted metal	7,350					
94	0.14	5,995	Flat and connected shingled roof. Wood siding.						
3581	0.81	35,318	Flat and connected roof with concrete siding.- Galvanized awning (accounted for in Contam Sources sheet)			685			
Roofed loading dock	0.21	9,356	Flat and connected roof. No siding.-- southwest of 3304, north of 66						

(southwest of 3304)										
3301	0.68	29,485	*Partially connected roof. Some of water is routed to adjacent planters and some is routed to parking lots. Little storage capacity in planters adjacent to building.		1288	6,393	592		1302 and 1303
3641	0.04	1,710	Flat and connected roof.- Building w/in LD5 (DLA)		423		188		
Totals	16.88	735,423		9,674	3,449	9,416	2,146	1,982	


Photo 1298 Bldg 3304

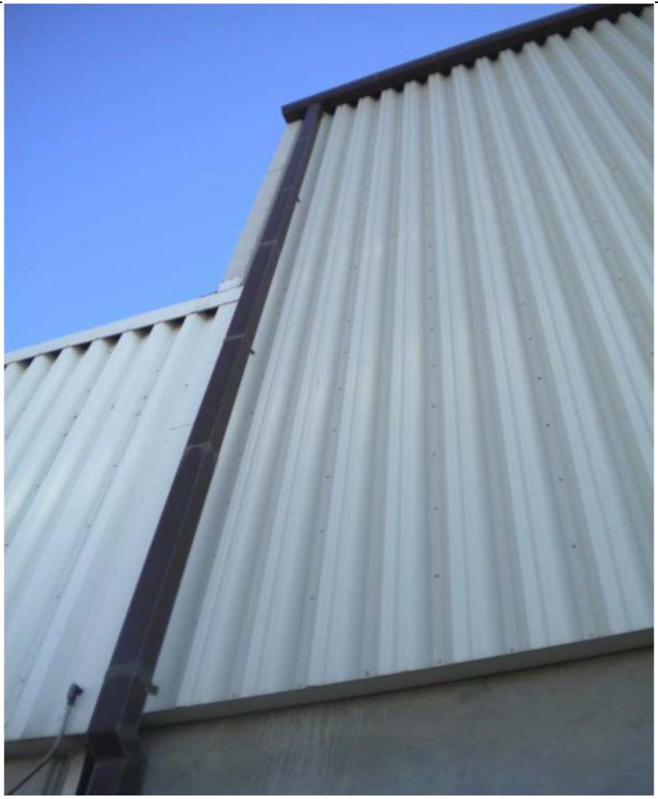


Photo 1299 Bldg 3304

 Photo 1296 Bldg 322	 Photo 1292 Bldg 3478

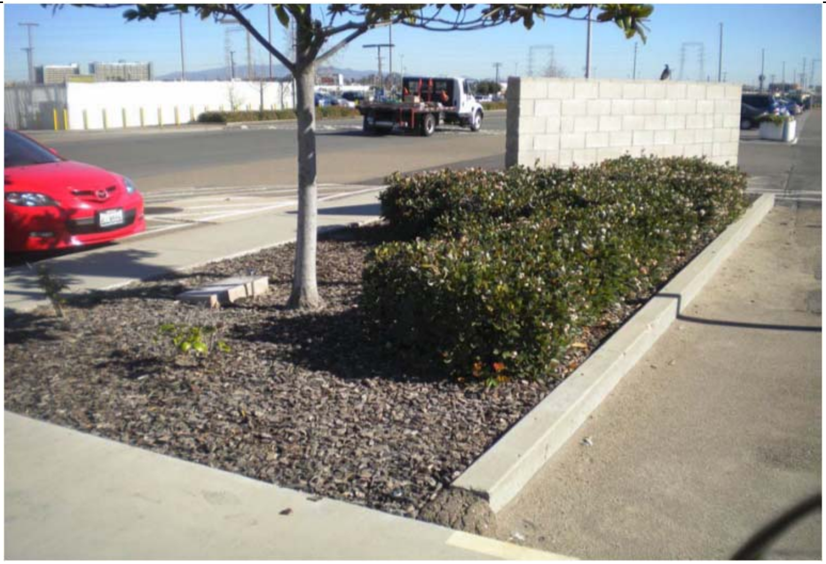


Photo 1293 Bldg 3478

Photo 1302 Bldg 3301

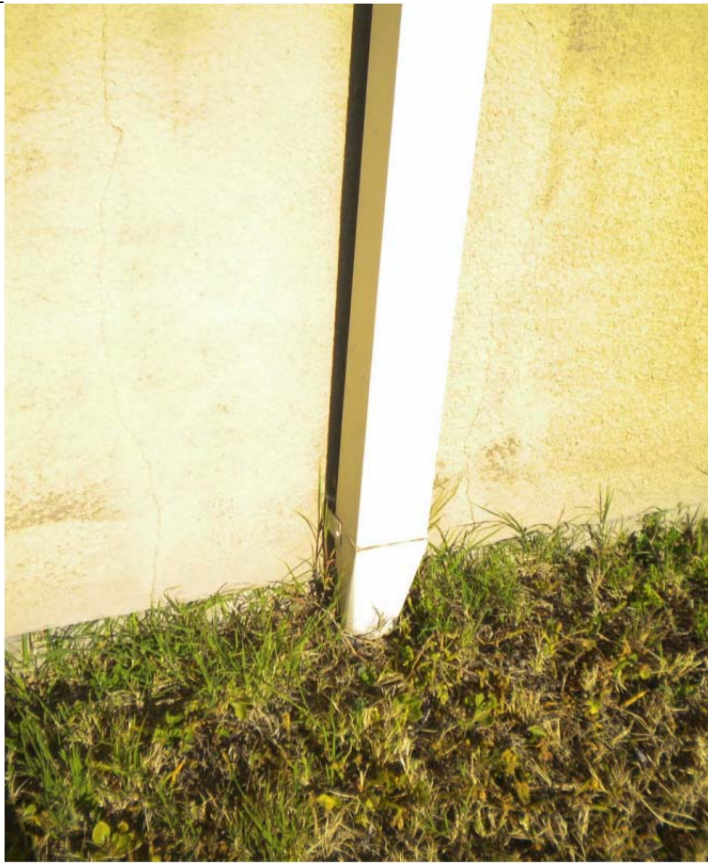


Photo 1303 Bldg 3301

Paved Area Descriptions

Land Use Zone	Area (acres) asphalt, unless noted)	Area (square feet)	Description/Material	Area concrete (sq. ft)	Area Pervious (sq. ft)	Area of Secondary Containment (sq. ft)	Area of Artificial Turf (sq. ft.)	Photo #
Paved Parking 1	0.17	7,199	Asphalt (moderate-good quality)- Westernmost parking area along quay wall. Generally about 90% full.					
Paved Parking 2	5.19	226,294	Asphalt (mod - good quality). Usually 95% full of cars. West of Ward Rd. and North of Woden St.--Triangle of vegetation and gravel at corner of Ward and Woden.		6,940			1,301
Paved Parking 3&4	3.93	171,354	Asphalt (moderate-good quality). Generally about 75% full. West of Cummings and North of Woden. Concrete pad adjacent to Cumings Rd and art. Turf at the corner. Near food court bldg so usually a good amount of traffic.	4,995	778		364	1,297
Paved Parking 5	2.27	98,880	Asphalt in good condition South of Vesta, East of Cummings. Parking lot usually about 35% full. Parking lot mainly used for adjacent office buildings. Secondary containment around Substation 380.			668		
Paved Parking 6&7	1.65	71,975	Asphalt (good quality West of 3434 and poor quality West of 127). Poor quality asphalt accounts for approx. 40% of total area. Parking about 40% full. East of Cummings and North of Woden.					1285, 1286, 1290 & 1287
Paved Parking 8	1.26	54,794	Asphalt (moderate-good quality) parking West of 3511 and 3509. Parking lot about 80% full. Planter boxes West of parking along Cummings. Secondary containment around electrical station west of bldg.	17,672	4,334	596		
Paved Parking 9	0.48	20,863	Good quality asphalt parking lot. Parking about 70% full. East of 3581					1305

Paved Parking 10	2.14	93,008	Moderate quality asphalt parking lot. Parking about 80% full. South of 4th St. and East of Cummings. Used by transportation for gov vehicles. Planter boxes on the west end of lot.		1,032			
Paved Parking 11	0.39	16,842	Asphalt parking East of 322. Poor asphalt quality, parking about 40% full. Secondary containment around a high voltage utility area.			435		1295
Paved Parking 12	0.32	13,873	Asphalt (moderate quality) parking North of 3304 and 322. Parking about 70% full.		3,746			1300
Concrete Parking 1			Concrete parking area North of 127. Concrete is in poor quality (cracks) and parking lot is generally about 80% full.	16,810				1284
Concrete Parking /Road 2	0.01	558	Concrete (moderate-poor quality) driving area. East of 319 and Und1 and Und2. Small amount of poor quality asphalt.	13,365				
Woden St. (West of Cummings)	1.16	50,415	Asphalt in good condition with heavy vehicle traffic. Cars driving to/from parking lots and semi trucks driving to/from DLA.					1304
Woden St. (East of Cummings)	0.03	1,301	Asphalt road in good condition with low (mainly car) traffic.					
Cummings Rd.	1.79	78,058	Good quality asphalt- Area includes intersections. Very high traffic road (cars and large trucks).					
Ward St.	0.36	15,561	Good quality asphalt. High traffic volumes (cars and large trucks).					
S. All St.	0.15	6,684	Good quality asphalt, high traffic volumes (cars and large trucks). Road provides access to piers and parallels the quay wall.					
4th St. West of Cummings	0.59	25,526	Good quality asphalt. Road is within DLA. Moderate- heavy truck traffic (depending on time) to and from loading docks.					

4th St. East of Cummings	0.16	7,163	Good quality Asphalt. Moderate traffic to and from NAVFAC Transportation area.					
Knowlton Williams (off 4th St.)			Moderate quality concrete roadway. Low traffic volumes.	22,992				
Undeveloped/Misc Asphalt 1	0.23	9,944	Area east of 127 and Knowlton Williams. Pervious area with some equipment storage (boats). Asphalt pad within fence in good condition.		7,998			1289 & 1283
Undeveloped 2	0.13	5,775	Area east of 127 and Knowlton Williams. Pervious area with some equipment storage over wood chips. Asphalt and concrete pad in poor, degraded condition.	1,233	12,138			1281 & 1282
Loading dock1, 2, and 3	0.53	23,038	Asphalt loading dock south of 322 and southeast of 3304. Asphalt in good condition. Concrete in good-moderate condition. Light to moderate loading dock traffic.	16,733	1,967			1294
Loading dock 4	0.77	33,581	Asphalt (good quality) Northeast of 3581- Concrete pad (good-moderate quality) East of 3581. Planters east of 3581	16,555	380			1306
Loading Dock/ Laydown area 5	3.14	136,711	Asphalt (good quality) loading dock area Southwest of 3304 w/in DLA. Moderate large truck traffic.	7,221	5,363			
Loading Dock6	0.27	11,616	Loading dock East of 3301. Poor (rough) quality asphalt. Low-moderate truck traffic.	3,406				1288
Loading Dock 7			Loading Dock (concrete pad) West of Und 2 East of 3434. Concrete in poor-moderate condition with low traffic volumes	4,216				
Equip. Storage/Junk yard	2.23	97,017	Asphalt (moderate condition)- Area used for old trucks, equipment, metal cabinets, tool boxes, galvanized fencing (rolled up), trailers, roll off bins. Moderate truck traffic.			1,064		1279 & 1291
Totals	29.339	1,278,028		125,197	44,675	2,763	364	


Photo 1301 Park 2


Photo 1297 Park 3&4


Photo 1285 Park 6&7

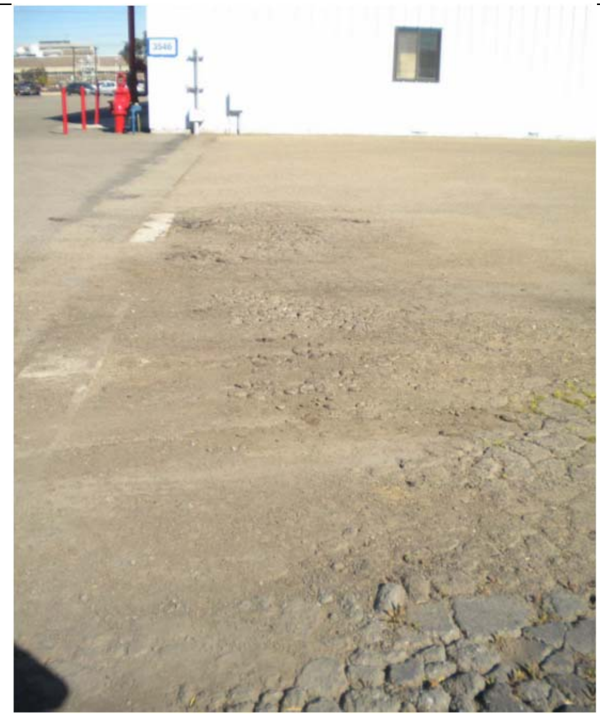


Photo 1286 Park 6&7

 Photo 1290 Park 6&7	 Photo 1287 Park 6&7


Photo 1305 Park 9


Photo 1295 Park 11


Photo 1300 Park 12


Photo 1284 CP1


Photo 1304 Woden St. (West of Cummings Rd.)


Photo 1289 Und1


Photo 1283 Und1


Photo 1281 Und2


Photo 1282 Und2


Photo 1294 Loading Docks 1,2,&3


Photo 1306 Loading Dock 4


Photo 1288 Loading Dock 6

Photo 1279 Equip Storage Parking

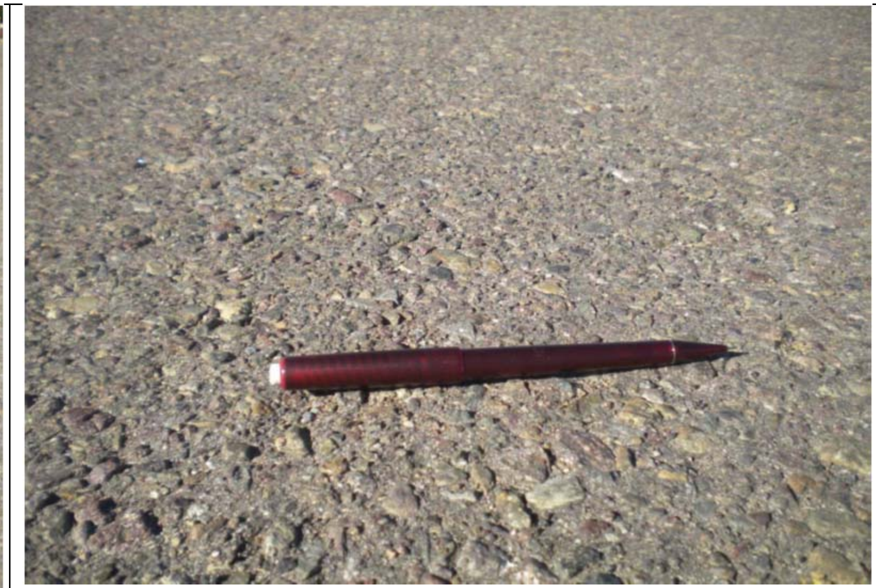


Photo 1291 Equipment Storage Yard

Summary of Aerial Coverage for Outfall 14		
Land Use	Area	
	Sq. Ft.	Acres
Building	735,423	16.9
Asphalt	1,278,028	29.3
Concrete	134,871	3.1
Concrete Sidewalk	3,449	0.1
Concrete Walkway	9,416	0.2
Brick/Pavers	1,982	0.0
Artificial Turf	364	0.0
Pervious Surfaces	46,822	1.1
Secondary Containment	2,763	0.1

Totals	2,213,117	50.8

Possible Contaminant Source Materials	Quantity	Unit
Galv. Roof*	6736.45	sq. ft.
Galv. Fence	4834	LF
Galv. Turnstile	2	ea
Galv. Guard Rails	314	LF
Galv. Light Poles**	29	ea
Galv. Hand Rails	163	LF
Galv. Bike Racks	3	ea
Galv. Picnic Tables	1	ea
Galv Trash Cans	5	ea
Galv. Scaffolding	1	ea
Large Galv. Light (bayside)	1	ea
Galv stop/street pole	19	ea
Metal Cabinets	4	ea
Scrap Metal Bin	5	ea
Conex Boxes	960	sq. ft.
Dumpsters	17	ea
Roll-off Bins	5	ea
Flamm. Lockers	2	ea
Electrical Boxes	20	ea
Generator	1	ea
ASTs	8	ea
Concrete Light Pole	25	ea
Yellow cleats	3	ea
Blue (painted) H2O pump	4	ea
*Many of the roofing material is unknown and could be galvanized		
**Uncertain if light poles are actually galvanized		

Naval Base San Diego - Outfall 1 and 13

Outfall 1 Ceremonial Pier

Possible Contaminant Sources/Materials Present	Description	Quantity	Dimensions	Units
Electrical Cable	Black	1428.4	1705 ft. x3.2 in. diameter	sq. ft.
Electrical Cable, coil	Black, coiled, 5 ft. diameter coils, 15 cables per coil	107.23	128 ft. x 3.2 in. diameter	sq. ft.
Water Hose, Black	1 roll (assume same dimensions as black cable)	197.71	236 ft. x 3.2 in. diameter	sq. ft.
Total cable and water hose area: 1,733 ft^2 (0.04 acres), or 2.8% of area				

Possible Contaminant Sources/Materials Present	Description	Quantity	Dimensions	Units
Aluminum walkway/ramp	Includes entire ramp.	2.5	3'8"W x 4'8"H x 40'L	ea.
Walkway/ramp, painted	Painted galvanized, entire ramp	1	3'8"W x 4'8"H x 40'L	ea.
Aluminum Pedestal/Platform w/Stairs	Includes entire ramp	1	4'3"W x 6'H x 27'L	ea.

Possible Contaminant Sources/Materials Present	Description	Quantity	Dimensions	Units

Painted Galvanized Stairs/Walkway	Painted stairway structure	270	2 ea. 13'6"W x 14"D x 10' H	sq. ft.
Painted Galvanized Stairs/Walkway	Painted stairway structure	270	1 ea. 13'6"W x 14"D x 20' H	sq. ft.
Galvanized Light poles	68" circumference base, estimated height	850	3ea. 50' H.	sq. ft.
Life Ring Stand	Galvanized pipe holding up the life ring.	13.1	5 ea. 2"diameter x 5'H	ea.
Galvanized Fencing	Painted yellow, galvanized fencing. 4 sections at the noted dimensions.	1500	4 ea. 50'L x 7'6"H	sq. ft.
Total galvanized material area: 2,900 ft^2 (0.07 acres), or 4.6% of area				

Possible Contaminant Sources/Materials Present	Description	Quantity	Dimensions	Units
Camera pole, square	Painted pole located at the end of the pier.	1	6" x 6" x 20'	ea.
Utilities structure	Surrounded by a yellow-painted galvanized fence	4	9'W x 5'D x 36'L	ea.
Roll-off Bins	Painted	1	8'W x 19'D x 7'H	ea.
Dumpster	Green painted	6	6' x 6' x 6'	ea.
Scrap Metal Bin	Painted (rusting).	2	7'W x 4'4"D x 5'H	ea.
Scrap wood bin	Painted metal bin.	1	7'W x 6'D x 6'6"H	ea.
Painted/metal Bike racks		2	10' length	ea
Bollards	Painted yellow, large	66	2.5'H x 1.5' W	ea.

Areas of Secondary Containment	Description	Quantity	Dimensions (Subtracts from overall pier footprint)	Units
Secondary Containment	"Waste Water" main	6	6' x 3'6"	ea.
Secondary Containment	"OW"	10	10'6" x 2'	ea.
Secondary Containment	porta-potty	1	3'8" x 3'6"	ea.
Total secondary containment area: 55 ft^2 (0.001 acres), or 0.1% of area				

Outfall 13 Industrial Pier

Hose and Cables	Description	Photo #	Quantity	Dimensions	Units
Electrical Cables	Black electrical cable was found stretched along the length of the pier and wrapped in 5-ft diam coils.	7	13940	16728.39 ft. long, 3.2 in. diam	sq. ft.
Electrical Cables	Yellow electrical cable stretched along the pier and wrapped in 6-ft diameter coils with 12 cables per coil		1035	1,242 ft long, 3.2 in. diameter	sq. ft.
Water Hose	Red		78.5	60 ft. x 5" Diam	sq. ft.
Black water hose			134	102' x 5"	sq. ft.
Total hose and cable area 15,187 ft^2 (0.35 acres) or 8.2% of the total area					


Photo 7: Electrical Cables

Possible Contaminants	Description	Photo #	Quantity	Dimensions	Units
Conex Boxes	Painted metal.		9	18'x20'x8.5'	ea.
Roll-off Bins	Painted metal.		1	8'W x 19'D x 7'H	ea.
Aluminum Walkway/Ramp	Portion of metal ramp over the pier was measured.		3	23'L x 3'8"W x4'8" H	ea.
Aluminum Walkway/Ramp	Entire metal ramp.	4	1	3'8"W x 4'8"H x 40'L	ea.

Photo 4: Aluminum Walkway/Ramp

Galvanized Materials	Description	Photo #	Quantity	Dimensions	Units
Galvanized Stand for Walkway	Painted galvanized metal.		336	4 ea. 12'W x 7'D x 8'H	sq. ft.
Galvanized Stairways	Painted galvanized metal.		571.2	3 ea. 13'6"W x 14"D x 20' H	sq. ft.
Galvanized Stairways	Painted galvanized metal.		255.8	1 ea. 16'6"W x 15'6"D x 30'H	sq. ft.
Galvanized Fencing	Entrance gate to pier. Poles are spaced 9.5' apart.		1,927	Ave Ht 8'	sq. ft.

Galvanized Fencing Rectangles	4 Constructed rectangular frames		73.3	9'2" x 2'	sq. ft.
Rolls of Galvanized Fencing	Rolled up on a pallet		84.8	2 ea. @ 1.5'x6' 1.5 turns per roll	sq. ft.
Galvanized Lights	Estimated 50-foot Tall galvanized light pole		850	3 ea. 68" circumference (at base)	sq. ft.
Galvanized Life Ring Stand	2 Galvanized poles holding up life ring		15.7	6 ea. 2"diameter x 5'H	sq. ft.
Metal Toolbox	Possibly galvanized metal.		8	1 ea. 4'x2'x3'2"	sq. ft.
Galvanized Pallet	Galvanized metal pallet for staging materials		16	4 ea. 2'x2'	sq. ft.
Galvanized Bike Racks			20.6	1 ea. 10'x2'7"	sq. ft.
Galvanized Utility Box	Misc. galvanized utility boxes of approximately similar sizes fit into this category.	2	73.5	7 ea 3'W x 1'9"D x 3'5"H	sq. ft.
Galvanized circuit breaker boxes	Individual breaker boxes	1	4.5	4 ea. 9" x 6" x 18"	sq. ft.
Painted utility structure	Electrical utility, partial unpainted section on top is galvanized (10' x 12' unpainted section)	3	360	3 ea. 46'W x 10'D x 10'6"H	sq. ft.
Total galvanized material area 4,596 ft^2 (0.11 ac) or 2.5% of the total area.					

Photo 1: Galvanized circuit breaker boxes


Photo 2: Galvanized utility box

Photo 3: Painted utility structure

Possible Contaminants	Description	Photo #	Quantity	Dimensions	Units
Dumpster	Painted green metal dumpster		10	6'x6'x6'	ea.
Scrap Metal Bin	Metal bin with a plastic cover. Rusty.		6	7'W x 4'4"D x 5'H	ea.
Scrap Metal Bucket	Metal container looks like it can be unloaded with a tractor/Bobcat.		2	3'5"W x 3'D x 5'H	ea.
Painted metal bike rack			3	10'x2'7"	ea.
Painted Metal Toolbox	Painted metal, some rust.		28	4'x2'x2'	ea.

Engine block, painted	Set on a pallet		1	3' x 3'2" x 2'6"	ea.
Painted Metal Tank	Tank set on a pallet.		1	11' long, 4' diameter	ea.
Scrap Wood Trash Bin	Painted metal		2	7'W x 6'D x 6'6"H	ea.

Laydown Materials	Description	Photo #	Quantity	Dimensions	Units
LayDown Pipes	Shelf with pipes. 33% Copper, 33% Stainless Steel, 33% other	6	1	18'L x 5'W x 3'H	ea.
LayDown Pipes	Contains misc. pipes including copper, steel, other.	5	1	4"D x 6'H x 20'6"L	
Laydown materials	3 piles of mixed galvanized coated steel.	8 (not available)		5'W x 4"D x 2'H	
Bollards	Painted yellow.		44	2.5'H x 1.5' W	ea.
Cleat	Painted yellow.		44	3'3" x 1'2"	ea.
Total laydown material area 70.5 ft^2 (0.002 acres) or 0.04% of the total area.					


Photo 5: Miscellaneous pipes


Photo 6: Miscellaneous pipes

Areas of Secondary Containment	Description	Photo #	Subtracts from overall pier footprint	Area	Units
Secondary Containment	Secondary containment around a water main.		13	6'x3.5'	ea.
Secondary Containment	Secondary containment around a water valve. "OW"		12	6'10"x2'	ea.
Secondary Containment	Secondary containment around a generator.		1	10' x 20'6"	ea.
Secondary Containment	Secondary containment around a generator.		3	12'x6'	ea.
Secondary Containment	Secondary containment around a porta potty		10	3'8" x 3'6"	ea.
Secondary Containment	Secondary containment around a high voltage electrical station		1	24.5'x72.5'	ea.
Total secondary containment area: 2,101 ft^2 (0.05 acres), or 1.1% of area					

North Island Complex - Outfall 26

	Land Use Zone	Area of Asphalt (acres)	Asphalt Area (square feet)	Description/Material	Area concrete (sq. ft)	Area Pervious (sq. ft)	Area of Secondary Contain. (sq. ft)	Area of Industrial Equip	Area Galvanized (sq. ft.)	Photo #
Airfield	Asphalt lot	11.026	480,278	18,250 sq. ft of total asphalt is within roadway.						23
	Walkways			Near Bldgs 516 & 700	994					
	Airfield			15,251 sq.ft. of total concrete area is within a roadway.	900,430					
Mixed Use	Grass Circle			Roundabout		37,772				
	Heli grass			Northeast of roundabout		21,669				
	Veg Strip			Northwest edge		35,851				
	Plane/heli grass			West of roundabout		45,259				
	Quentin Roosevelt Rd	0.594	25,873							
	Roundabout, Mccain Blvd, 4th st., Gowan St.	1.702	74,136	Asphalt roadway. Smooth asphalt.						
	Wright Ave			Concrete Road	45,756					
	Parking lot near Bldg 2246*		62,230	Asphalt parking lot by auto hobby. Rough asphalt.						
	Parking lot near Heli grass/ Roundabout		56,910	Asphalt parking lot surrounded by Wright Ave, Tow Way, and Gowan St. Moderate condition asphalt.		14,651				

	Parking lot near Bldg 599		58,879	Approximately 90% moderately smooth asphalt, 10% very rough asphalt.		84,825				18, 21
	Parking Lot- Bldg 699		29,767	Approximately 20% full. Moderately smooth asphalt		45,180				
	Bldg 698 Electric Meter Room			Approximately 10% of surface area is composed of galvanized metal.				1,246		
	Parking Lot-Bldg 698		18,519	Approximately 20% full. Moderately smooth asphalt		2,348				
	Boat Storage Yard-Bldg 139		64,696	Asphalt lot- 50% Rough, 50% very rough						
	Auto Hobby			Concrete in moderate to poor condition.	41,075					
Industrial Southeast	Parking/road- Bldg 690.		7,283	Parking lot moderately rough and approx. 50% full. Concrete road between 690A and 677 in good condition.	3,792	4,061				
	Parking Lot west of Bldg 654		39,663	Moderate asphalt condition and approximately 60% full.						
	Area around 654		5,628	Very rough asphalt and some pervious areas.		9,188				
	Area around 676 &461		18,457	Mix of very rough asphalt and pervious area		3,086				16
	Asphalt around cylinders		4,681	Asphalt in moderate condition.						
	Concrete Circle			Concrete in good condition. One area of secondary containment outside concrete circle.	16,523		1,439			11, 19

	Area around 653		43,512	Asphalt in moderate condition. Concrete in moderate condition. Some pervious areas.	5,120	3,546	3,546			
	Steam generation Plant		23,426	Mix of moderate asphalt and pervious gravel. Heavy industrial zone. Approx. 25% of total surface area is composed of galvanized metals.		7,873		29,166		
Industrial West	Tow Way		65,532	Asphalt in good condition, heavy traffic road.						
Industrial West	Southern Parking Lot around 343B and east		82,789	Parking 75% full. Asphalt 80% rough, 20% very rough.						
Industrial West	2nd St. and other roads		58,852	Very rough asphalt, low traffic volumes						
Industrial West	Truck Storage Yard Undeveloped			Completely Pervious		10,531				
Industrial West	Truck Storage Yard		8,324	Semi-pervious--Undeveloped w/metal ties on ground to reduce mud. Some rough asphalt as well.		8,294				7 & 8
Industrial West	Parking lot around 315 and C149		10,053	50% Concrete, 30% rough asphalt, 20% very rough asphalt	10,053					
Industrial West	Pervious strip			East side of boundary		48,304				
Industrial West	Asphalt around 399		12,605	Asphalt moderate condition						6
Industrial North	Parking Lot Bldg 66		32,191	Parking Lot 95% full. 3-5% slope. 80% rough asphalt, 20% very rough and degraded asphalt.						2 & 3

	Miscelaneous Concrete			Mixed concrete and asphalt roads between buildings. Rough, degraded condition	19,392					
	Undeveloped/Pervious areas					6,028				
	Secondary Containment			17' x 5' and 9' x 8'			157			
SUM		13.322	1,284,284		1,043,136	388,467	5,143	30,411		

Photo 23: Asphalt lot- Airfield

Photo 18: Parking lot near bldg 599- Very rough asphalt- Mixed Use Area

Photo 21: Asphalt parking lot near Bldg 599- Mixed Use Area

Photo 16: Rough asphalt around Bldg 461- Industrial Southeast

Photo 11: Enclosed concrete circle area with storage containers- Industrial Southeast

Photo 19: Concrete in good condition inside "concrete circle"- Industrial Southeast

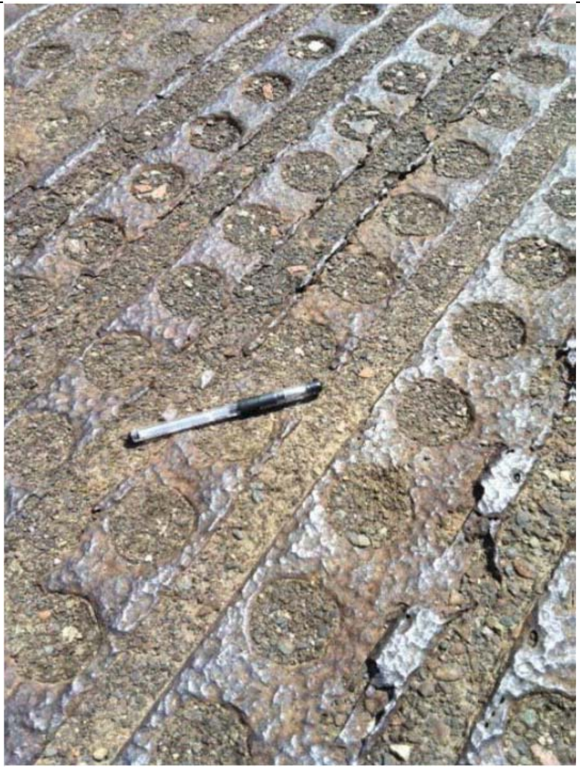
 Photo 7: Truck storage yard- Semi pervious- Metal on ground to reduce mud. Industrial West	 Photo 8: Truck Storage Yard- Semi Pervious and Asphalt- Industrial West

Photo 6: Rough asphalt around building 399- Industrial West

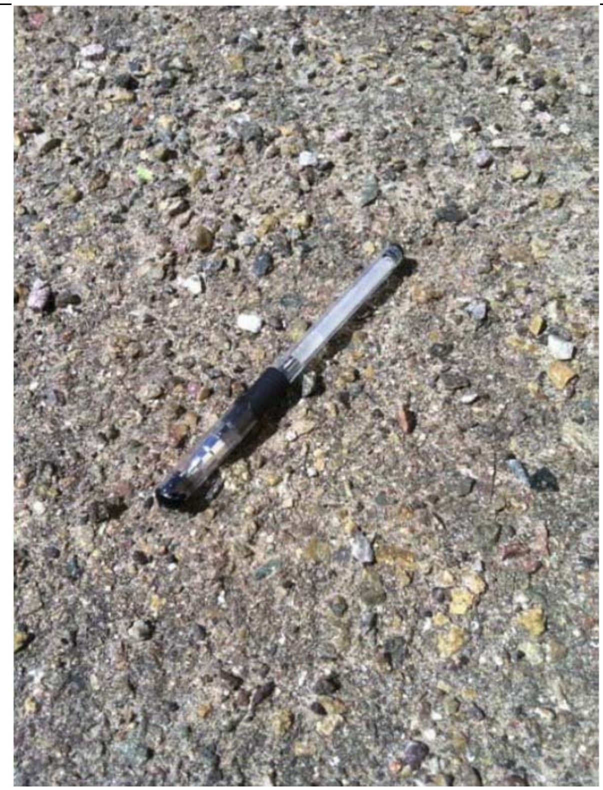


Photo 2: Rough Asphalt- Industrial North

Photo 3: Very rough, degraded asphalt- Industrial North

	Building/ Area	Roof Area (acres)	Roof Area (square feet)	Description/Material/Location	Area concrete (sq. ft)	Area Sidewalk Concrete (sq. ft.)	Area Walkway Concrete (sq. ft.)	Area Pervious (sq. ft)	Area Galvanized (sq. ft.)	Photo #
Airfield	516	0.112	4,873	Flat concrete roof drains to pervious area.				5,337		
	700	0.173	7,535	Painted metal roof drains to pavement	3,357					

	568	0.009	410	Adjacent/east of Bldg 700. Flat roof drains to pavement						
	569	0.005	197	Adjacent/east of Bldg 700. Flat roof drains to pavement						
	770	0.190	8,288	Flat concrete roof drains to pavement.						
Mixed Use	599	0.736	32,069	Cross-shaped bldg. Metallic roof and concrete siding. Pitched roof flows to pavement.		2,469	1,470			
	698	0.825	35,928	Entire roof drains to pervious area. Painted galv roof. Concrete siding.	2,859					22
	699	0.089	3,872	McDonald's. Flat roof drains to pavement. Appears to be concrete roof.	1,205	1,074				
	505	0.028	1,218	Pitched tile roof drains to pervious						
	505A	0.034	1,478	Pitched tile roof drains to pervious	879			10,404		
	2246*	0.160	6,980	Skinny s- shaped bldg	35,272	3,183		8,467		
	HW25	0.006	251	Flat roof						
	825		12,750	255' x 50' Drains into OF 26						
	Electric Meter Room			Galv piping and materials in structure. 10% of area galvanized					60	
	500	0.059	2,549							
Industrial Southeast	690	0.531	23,131	Pitched roof. 85% drains to pavement, 15% of roof drains to pervious area.			3,005			
	690A		3,820	Pitched roof, drains to pavement. Painted metal roof and brick siding.						
	654	0.292	12,732	Flat roof. 90% of roof run-off drains to pervious area adjacent to building.						
	676	0.079	3,454	Pitched roof, drains to pavement. Painted metal roof in poor condition.						
	683	0.027	1,177	Flat container. Painted metal.						

	461	0.090	3,902	Slightly pitched roof. Drains to pavement/concrete. Roof made of tar paper w/ gravel. Minor copper and galv pipes associated w/ building						
	653	0.214	9,327	Flat roof, concrete and brick. Minor galv piping. Steel racks around bldg. Runoff drains to pavement		435				
	Cylinders	0.053	2,307	6 cylindrical structures						
	Industrial	0.505	22,015	Industrial structures northeast portion of area.						
	Single Cylinder	0.011	474	Painted metal flat top cylinder.						
	2652*	0.036	1,579	Flat roof, drains to pavement						
	2651*	0.023	1,003	Flat roof, drains to pavement						
Industrial West	C149		1,581	Painted steel roof drains to pavement						
	343B	0.081	3,509	East of veg strip and Gowan st. Drains to ground		228		431		
	M-6		4,565	Wood Bldg pitched. drains underground.						
	M-7		1,601	Wood bldg, pitched, drains to pavement						
	688		940	Slightly pitched, drains to pavement						
	689A		1,943	Slightly pitched, drains to pavement						
	376		2,717	Slightly pitched, drains to pavement						
	814		1,519	Flat metal roof, drains to pavement						
	305		1,506	Pitched metal roof, drains to pavement						
	790		8,070	Flat metal roof, drains to pavement						
	789		1,727	Pitched painted galv metal roof drains to pavement. Concrete loading dock in moderate condition.	3,670					12
	788		1,381	Slightly pitched painted metal roof drains to pavement						
	315A		1,380							

	Unknown		1,564	North of 315A						
	399		13,665	Corrugated asbestos-containing roof and siding. Painted galv door.						
	171		2,480	Painted galvanized roof and siding.						
	2009		5,061	Bldg along quay wall on 2nd st. Flat roof drains to pavement						
Industrial North	Bldg 384		20,648	Flat painted metal roof with rocks and painted galv material. Approx. 33% surface area contains galv metals. Runoff directly connected.					6,814	
	1209		615	Flat painted metal roof with rocks and painted galv material. Approx. 33% surface area contains galv metals. Runoff directly connected.					203	
	66		22,691	Flat painted metal roof with rocks and painted galv material. Approx. 33% surface area contains galv metals. Runoff directly connected.					7,488	
	94		4,618	Painted galvanized metal. Runoff directly connected.					1,524	5
SUM		4.368	307,102		47,241	7,389	4,475	24,639	16,089	


Photo 22: Bldg 698- Entire roof drains to pervious area- Mixed Use Area


Photo 12: Concrete loading dock near bldg 789- Industrial West


Photo 5: Building 94 runoff directly connected- Industrial North

	Possible Contaminants	Description	Dimensions	Sq. ft.	Total Galvanized Materials (sq. ft.)	Total Copper Materials (sq. ft.)	Total Misc. Metals (sq. ft.)	Photo #
Airfield	Galvanized Roof	Shed Roof	20' x 20'	400				
	Galv. Bike Rack		5' x 2' x 2'H	10				
	Galv Light Pole		30'H x 5"x5" base	25				
	Galv parking sign poles		14 ea. 4'H x 2"D	29				
	Galv Fence		219' x 8'H, 979' x 4'H	5,668				
	Galv Utility Box		6' x 4' x 1'W	6				
	Galv Trash cans		2ea. 3' x 2'D	38	6,176			
Mixed Use	Galvanized Railing	Double Railing	1"D 3'Hx 58'L	30				
	Galvanized Pipe	Associated with Bldg 599	2"D x 15'L	8				
	Galvanized Switch Box		3 ea. 1' x 2' x 0.5' W	6				
	Galvanized fencing	Around electrical area	33' x 15'	495				
	Galvanized Picnic Tables	Contains galv pipes	7 ea. 20' L x 2"D	73				
	Galvanized Ladder	Leads to roof	2' x 20'H	40				
	Painted galvanized railing	Near McDonald's	35' x 3'H x 2"D	18				
	Dumpster		2 ea. 5' x 6' x 4'H	60				
	Galv Roof	By auto hobby	10' x 15'	150				
	Galv posts	Supporting wood fence	60 ea. 8'x 2"D	251				
	Galv Fencing		1004' x 8'	8,032				
	Galv Trash cans		3ea. 2.5'H x 2'D	47				
	Galv boat trailers	Galv pipe. Trailer 6' x 20'	5 ea. 70' 4"x4"	467				
	Painted Galv fence	Around auto hobby	418' x 7'H	2,926				
	Tires		20ea. 3'D	188				
	Galv Roof	Roof on shed	10' x 8'	80				
	Painted Galv structure	On roof of Bldg 698	15' x 15' x 8'H	225	12,849			

Industrial Southeast	Galvanized structures		3 ea. 18' x 15' x 15'H	810				Ernies photo
	Galvanized piping	Around bldg 653	1"D 500'L, 2"D x 200'L	236				20
	Copper piping	Around bldg 653	100' x 2" Diam.	52				20
	Copper piping	Around Bldg 461	1"D x 50', 2"D x 50', 4"Dx150'	196				
	Industrial Galv Structure	Steam Generation plant. Approx. 25% surface area was galvanized	25'H x 102'L x 25'W	638			1,913	
	Galv Steel Diamond plate	Around Bldg 653	5' x 5'	25				
	Galv Structure w/ wood roof		15' x 12' x 10'H	180				
	Galvanized awning		33' x 5', 4' x 5', 10' x 10'	285				
	Galvanized pallets		6 ea. 3'x3'	54				
	Galv Diamond Plate		4' x 4'	16				
	Galvanized Fence post signs		96' x 8'					
	Miscellaneous storage	Mixed metals laydown- Aprox 10% Galvanized	3 ea. 150' x 150'	6,750			60,750	13, 14 & 17
	Galvanized roof		20' x 55'	1,100				
	Painted Galv Fence		177' x 7.5'H	1,328				
	Galvanized Fence		1557.4' x 7.5'H, 317.5' x 6'H	13,586				
	Galv Fence over pervious		275.5' x 6'H	1,653				
	Galvanized Rack	Galvanized piping	50'x 2"D	26				
	Galvanized Railing		141' x 1'W					
	Galvanized Turnstile		5'Dx 8'H	79				
	BAC A/C Chiller Unit	Possibly galvanized	3 ea. 6' x 8' x 15'H	144				15

	Galv metal frame		12 ea. 4' x 5'	240				
	Galvanized Frame Structure	Wood roof over galv frame	15' x 12' x 10'H	180				
	Galvanized Industrial Equip.	Large galv cylinder with a base	20' x 20' base, 10'D, 50'H	2,542				
	Dumpster		6' x 6' x 6'	36				
	Scrap Metal Bin		6' x 6' x 6'	36				
	Painted Flammable Lockers		3 ea. 5' x 6' x 8'H	90	22,898			
Industrial West	Galv Fencing		94'x 8'H, 37' x 5.5'H, 39' x 6'H	1,190				
	Galv Fencing	Around Bldg 399. Approx 50% drains to pervious area.	319' x 6'H	957				
	Galv Fencing	Around truck storage yard	400' x 6'H	2,400				
	Galv Fencing		223' x 7'H, 105' x 8'H,	2,471				
	Galv Fencing gates	Over pervious surface	5 ea. 7' x 3'	105				
	Galv Fencing Roll	Over pervious surface	9' L x 2' Diam	57				
	Galv Shed	Roof and sides are galvanized. Near truck storage yard.	11' x 11.5'	127				
	Galv shed	Covering Haz Waste area	26' x 43'	1,118				
	Galv Shed	Galv roof	23' x 6'	138				
	Galv roof cover on wheels	In front of bldg 789	9' x 17' x 8'H	153				
	Galv Railing	50% over pervious surface	307' L x 3'H, 2"Diam	80				
	Cables	reels of cables exposed	4ea. 5'D, 20 wraps ea. Roll 3"D cables	987				9

	Hose	Bundles of hosing	4ea. 2"D, bundles 3'H x 3'D	355				
	A/C Units	Painted metal	14 ea. 6' x 7.5' x 4'H	630				
	A/C Units	Painted metal	2 ea. 6' x 4' x 4'H	48				
	Haz Waste Conex Boxes		9'x 21' x 10'H	189				
	Drying Racks for painted Material	Painted metal structure	15 ea. 6' x 7.5' x 4' Approx. 74' of 2"rectangular metal per rack	5				10
	Galvanized Fence post signs		12 ea. 7' x 4"	88				
	Picnic Table	Galv pipe	Approx 30'L x 2"D	16	8,899			
Industrial North	Galvanized guard rail	Over gravel, but eventually drains to ground.	1' H x 604' L	604				
	Miscellaneous galvanized pipe		2"D x 80' L	42				
	Painted galvanized structure		6' x 80'	480				
	Galvanized Roof		12' x 37'	444				
	Laydown galv metals and wood	Approximately 10% of material is galvanized	24' x 15' area	36				4
	Galvanized vents		6 ea. 10" D x 2'H	18				
	Minor Galv Gutter		0.5' x 10'	5				
	Galvanized fencing		94' x 6' H and 15' x 5'H	639				
	Painted galv fencing	Painted but worn. Around utility area	96'L x 6' H	576				
	Galv Picnic Tables	Contains galv pipes	7 ea. 20' L x 2"D	73				
	Galv Fence	Around transportation yard	207' x 8'H	1,656	4,574			
				SUM	46,496	249	2,961	

Photo 20: Galvanized and copper piping near BAC chiller unit and bldg 653- Industrial Southeast

Photo 13: Laydown Area- Mixed Metals- Industrial Southeast

Photo 14: Laydown Area- Mixed Metals- Industrial Southeast

Photo 17: Laydown Area- Mixed Metals- Industrial Southeast

Photo 15: BAC A/C Chiller Units- Industrial Southeast


Photo 9: Cables in laydown area near truck storage yard- Industrial West


Photo 10: Galvanized drying rack for painted materials. Near Building 814 Industrial West


Photo 4: Miscellaneous metals lay-down area- Industrial North

Summary of Aerial Coverage			Percentage of total Area
Land Use	Area		
	Sq. Ft.	Acres	
Building	307,102	7.1	9.8%
Asphalt	1,284,284	29.5	40.9%
Concrete	1,090,377	25.0	34.7%
Concrete Sidewalk	7,389	0.2	0.2%
Concrete Walkway	4,475	0.1	0.1%
Industrial Equipment	30,411	0.7	1.0%
Pervious Surfaces	413,106	9.5	13.1%
Secondary Containment	5,143	0.1	0.2%
Totals	3,142,286	72.1	100.0%

Summary of Materials	Sq. Ft.	Acres
Area of Galvanized	46,496	1.07
Area of Copper	249	0.01
Area of Miscellaneous Metals	2,961	0.07

North Island Complex (Naval Amphibious Base) - Outfall 9


Photo 11: Catchment basin that conveys stormwater to Outfall 9

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area
Galvanized Materials Over Grass	Galvanized Utility Stand	Galvanized pipe over grass.		2 ea. 3"D x 6'H	9	sq. ft.	0.000	0.000
	Painted Galvanized pipe parking barrier	Over grass.	1	5 ea. 2"D x 6'L	16	sq. ft.	0.000	0.000
	Galvanized Fence	Partially painted, over grass		1ea. 12'Hx 49'L	588	sq. ft.	0.013	0.003
	Total Area of Galvanized Materials Over Grass				613	sq. ft.	0.014	0.003

Photo 1: Galvanized pipe parking barrier over grass

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area
als Over Imper	Galvanized Fence	Approximately 35' is over a pervious surface.		6'Hx 215'L	1,290	sq. ft.	0.030	0.006

	Galvanized Storage Cage	Loaded with metal chairs		5ea. 4'x9'x6.5'	180	sq. ft.	0.004	0.001
	Galvanized Scaffolding		6	2 ea. 9'x5'x10'H	90	sq. ft.	0.002	0.000
	Galvanized ladders			2 ea. 13'x1.5'	39	sq. ft.	0.001	0.000
	Painted galvanized fence	Freshly painted galvanized fence with plastic longitudinal inserts		110'x8'H	880	sq. ft.	0.020	0.004
	Galvanized stand for pipe storage	Galvanized A-frame (painted) stand with pipes. Approx. 10% Cu pipes.	13	1ea. 16'x8'x10'H	128	sq. ft.	0.003	0.001
	Galvanized fence	Fence surrounding an electrical utility area		108'x8'H	864	sq. ft.	0.020	0.004
	Total Area of Galvanized Materials				3,471	sq. ft.	0.080	0.016

Photo 6: Galvanized scaffolding

Photo 13: Painted galvanized A-frame stand containing approximately 10% copper pipes

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area

Laydown/Staging Materials	Gas Cylinder Storage		3	8'x14' area	112	sq. ft.	0.003	0.001
	Gas Cylinder Storage Racks	Gas cylinder storage		3'x14' area	42	sq. ft.	0.001	0.000
	Laydown Materials: Plywood			8'x20' area	160	sq. ft.	0.004	0.001
	Laydown Materials: Pipes	Miscellaneous pipes		1 ea. 21'x 9'	189	sq. ft.	0.004	0.001
	Rack with sheet metal	Aluminum sheet metal, very little galvanized metal		1 ea. 13'x15'	195	sq. ft.	0.004	0.001
	Container	Painted metal container		13 ea. 7'x7'x8'	637	sq. ft.	0.015	0.003
	Painted Metal Lockers			2 ea. 4'x4'x6.5'H	32	sq. ft.	0.001	0.000
	Tire Storage/Racks	4'D Tires on an axel structure. 15 Tires total	9	2ea. 4'x12'L	96	sq. ft.	0.002	0.000
	Rubber from barges	Rubber set on pallets	10	1 ea. 8'x4'x4'H	32	sq. ft.	0.001	0.000
	Scrap Metal	Scrap metal heap. Lots of sediment under and around the metal.	12	1 ea. 28'x9'x4'H	252	sq. ft.	0.006	0.001
	Wooden Crates	Painted		77ea. 8'x4'x4'	2,464	sq. ft.	0.057	0.011
	Pipe storage area			11'x10'	110	sq. ft.	0.003	0.001
	Total Laydown/Staging Materials Area				4,321	sq. ft.	0.099	0.020

 Photo 3: Gas cylinder storage	 Photo 9: Tire storage

Photo 10: Rubber from barges

Photo 12: Rusty scrap metal set on asphalt with a good amount of sediment on the ground

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area

Miscellaneous Materials	Metal Supports	Metal cube supports	5	4 ea. 4'x7'x5'H	112	sq. ft.	0.003	0.001
	Metal Painted Stands	Newly painted barge support stands	8	8ea. 4.5'x4.5'x4'H	162	sq. ft.	0.004	0.001
	Barge/ Barge paint	Painted with copper-containing hull paint (1-ft. high)	7	2ea. 76'x25'x9'H	3,800	sq. ft.	0.087	
	Metal Scrubber	Connected to outside of building to capture paint fumes and particles	14	2 ea. 34'x16'x10'H	1,088	sq. ft.	0.025	0.005
	Metal light pole	Painted metal		2 ea. 5"x5"x15'H	50	sq. ft.	0.001	0.000
	Platform support	Painted platform support with rubber	18	6 ea. 24'x11'x4.5'H	1,584	sq. ft.	0.036	0.007
	Dumpster	Blue painted dumpster		1 ea. 6'x6'x7'	36	sq. ft.	0.001	0.000
	Dumpster	Painted, slightly rusted metal dumpster		1 ea. 25'x9'x8'H	225	sq. ft.	0.005	0.001
	Utility vault/structure	Metal, painted green		7ea. 5'x7'x10'H	245	sq. ft.	0.006	0.001
	Total Miscellaneous Materials Area				7,302	sq. ft.	0.168	0.033

Photo 5: Metal cube supports

Photo 8: Painted metal barge support stands

Photo 7: Barge supported by stands

Photo 14: Metal scrubber vault to capture paint fumes and particles


Photo 18: Painted metal platform support with rubber

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area

Asphalt Surfaces	Asphalt road	Rough Asphalt Road	2	48'W	14,613	sq. ft.	0.335	0.067
	Asphalt parking lot	Contained approximately ***cars			17,156	sq. ft.	0.394	0.078
	Asphalt Loading Dock	West of Bldg 350			2,356	sq. ft.	0.054	0.011
	Asphalt Loading Dock	North and East of Bldg 332			4,300	sq. ft.	0.099	0.020
	Total Asphalt Area				38,426	sq. ft.	0.882	0.175

Photo 2: Rough asphalt roadway

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area

Concrete Surfaces	Concrete Loading Dock	In between bldgs 350 and 332			43,530	sq. ft.	0.999	0.198
	Concrete Loading Dock	North of Bldg 350			21,271	sq. ft.	0.488	0.097
	Total Concrete Area				64,801	sq. ft.	1.488	0.295

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area
Buildings	Building 350				14,081	sq. ft.	0.323	0.064
	Building 332				7,616	sq. ft.	0.175	0.035
	Unnamed Building	Northwest of Building 350			1,247	sq. ft.	0.029	0.006
	Total Building Area				22,944	sq. ft.	0.527	0.104

	Possible Contaminant Sources/Materials	Description	Photo #	Dimensions	Quantity	Units	Acres	Percentage of Total Drainage Area
Pervious Surfaces	Pervious Area	Landscaping around Bldg 332		5'x35' & 5'x43'	390	sq. ft.	0.009	0.002
	Pervious Area	Baseball field		336'x268'	90,048	sq. ft.	2.067	0.410
	Total Pervious Area				90,438	sq. ft.	2.076	0.412
	Total Drainage Area				216,608	sq. ft.	4.973	0.986

Naval Station Everett - Outfall B

Areas:

	Land Use Zone	Asphalt Area (square feet)	Description/Material	Area concrete (sq. ft)	Area Pervious (sq. ft)
Area 1	Asphalt	119199	Texture, moderately smooth. (entire asphalt area), encompasses Bldgs. 2310, 2320, 2330, 2331. Parking = 100% full.		
	Pervious		Grassy area,(153.0+199.5+89.6+140.1) x 10.5'.		6113
Area 2	Asphalt	53928	Texture, moderately smooth. Surrounding Bldg. 2300.		
	Sidewalk		565.6' x 21'	11878	
	Pervious		Grassy area separates B. 2300 from sidewalk.		1220
	Pervious		Grassy area, 391.2' x 8.5'.		3325
	Road	29212	Moderately rough, concrete gutter and drain, 618.9' x 47.2'.		
	Pervious		Grassy area, 560.0' x 9.5'.		5320
Area 3	Asphalt 1	34851	Texture, moderately smooth. Northwest side Bldg. 2200.		
	Parking/Asphalt	19567	Texture, moderately smooth. South side Bldg. 2200. Parking - 18 spaces, 75% full.		
	Sidewalk		556.6' x 21'	11689	
	Road	26791	Moderately rough, concrete gutter and drain, 567.6' x 47.2'.		
	Pervious		Grassy area, 7x5 Pe'.		228
	Pervious		Grassy area, 495.9' x 10.4'.		5157
SUM		283548		23566	21363

Buildings:

	Building/ Area	Roof Area (square feet)	Description/Material/Location	Area concrete (sq. ft)	Area Pervious (sq. ft)
Area 1					
	Bldg. 2331	8524	Recycling center, 1/2 (east side) directly connected, 1/2 (west side) indirectly connected. (110.7' x77.0')		
	Bldg. 2330	8496	Canvas building/shed, 1/2 indirectly connect, flow to asphalt; 1/2 flow to rock landscaping. (116.7'x72.8')		2872
	Bldg. 2320	4328	1/2 indirectly connected (east side, flow to pavement), 1/2 flow to impervious (west side, rock landscape). (82.6'x52.4')		1150
	Bldg. 2310	4291	1/2 indirectly connected (east side, flow to pavement), 1/2 flow to impervious (west side, rock landscape). (82.2'x52.2')		2405
Area 2	Bldg. 2300	15148	Brick building, painted green metal roof, pitched. Indirect connection, drains to surrounding asphalt.		
		156	Small building adjacent to 2300 (no number), Painted green metal roof, pitched. Indirectly connected, drains to asphalt. (6x4 Pe)		
Area 3	Bldb. 2200	107736	Pitched painted (green) roof, drainage directly connected to stormwater conveyance.		24294
	Concrete		Around Bldg. 2200, smooth. 25x46 Pc	8534	
	Concrete		Same. 25x6 Pc	1113	
	Concrete		Same. 6x60 Pc	2672	
	Concrete		Same. 4x34 Pc	1009	
	Concrete		Same. 8x11 Pc	653	
	Shed	5425	Grren painted metal roof, pitched, drains to asphalt, 12x42 Pe x 24'(H).		
SUM		154104		13981	30720

Material Storage Areas:

	Possible Contaminants	Description	Dimensions	Sq. ft.	Total Galvanized Materials (sq. ft.)	Total Copper Materials (sq. ft.)	Total Misc Metals (sq. ft.)
Area 1	Galvanized Roof						
	Galvanized fence	Fence sections, 12 ea.	8 Pe x 12' (H)	2937.6	2937.6		
	Galvanized platform	Raised platform, 2 ea.	6x4 Pe x 6' (H)	156.1	156.1		
	Galvanized trailer		3x8 Pe	156.1	156.1		
	Shed, metal		5x5 Pe x 10'(H)	162.6			162.6
	Dumpster, large	5 ea. + 4 ea. + 3 ea.	22'x10'	2420			2420
	Laydown area	concrete barriers, yellow	17 Pe x 4'	173.4			
	Tailer, metal		2.5x6 Pe	97.5			97.5
	Dumpster, small	5 ea. + 23 ea.	5'x6'	840			560
	Gangplank, aluminum		26 Pe x 4'	265.2			265.2
	Gangplank, aluminum		20 Pe x 4'	204			204
	Laydown area	Misc. aluminum/galvanized steel	8x4 Pe x 3' (H)	208.1			208.1
	Conex box	6 ea.	20'x10'	1200			1200
	Bumper, large	Ship bumpers, black, 14 ea.	6'D x 5 Pe	1071			
	Laydown area	Aluminum platforms and walkways (gangplanks)	18x10 Pe x 10'H	1170.4			1170.4
	Storage box, metal	Painted metal	3x6 Pb x 10'H	117			117
	Air filter unit w/stair frames		5x3 Pb x 20'H	97.5			97.5
	Laydown area	Recycle bins, small blue	4x14 Pb	364.1			364.1
	Trailer, medium		8'x15'	120			120
	Metal crates	Painted metal, 2 ea.	5'x6'	60			60
	Reels w/plastic hose	2 ea.	5'D	31.4			

	Laydown area	Hoses, wood, metal, partially covered	5' x 33 Pe	420.8			420.8
	Blocks, concrete		2.5' x 17 Pb x 2'H	108.4			
	Laydown area	Painted concrete blocks, hose reel, wood, copper/galvanized pipe	9x29 Pe	1697.2			1697.2
	Racks w/rubber cables	Aluminum racks, 3" diameter cables, 50% full (average all), 21 ea.	4' x 6 Pe x 3'H	1285.2			1285.2
	Recycle area	laydown - wood chip, shell, dirt, plastic trash cans	34x6 Pe	1326.5			
Area 2	Galvanized Stairs	Against Bldg. 2300, painted railing.	4x12 Pe	312.1	312.1		
	Galvanized Grate		2' x 2', 2 ea.	8	8.0		
	Utility box		2 x 7 Pe x 6'H	91			91
	Medium dumpsters	2 ea.	15'x8'x6'H	240.0			240
	Light pole, concrete	1 ea.	8"Dx40'H	83.77573333			
	Laydown area	rubber hoses, metal storage - (1:1)	6x3 Pe	117.0			117
	Fencing, green coated	Dark green, thick coating	1728' x 7'	12096			12096
	Holding tank	Aluminum siding	5.5 Pe D x 20' H	881.2			881.2
Area 3							
	Galvanized fence		504 Pe x 7' (H)	9596.0	9596.0		
	Galvanized rails/walkway, painted red, 50% galvanized metal exposed	4 ea., connected to Bldg. 2200	5' x 8 Pe	204.0	204.0		

	Copper piping	On rack, see below.	2' x 1'	2		2	
	Conex boxes	10 ea.					
	Rack for pipes	Misc. pipes inc. copper (partially exposed)	5' x 8 Pe	102			102
	Laydown area	Misc. metal, wood, equip.	7x10 Pe	455.2			455.2
	Utility/electrical box		5' x 11 Pe x 8'H	140.2			140.2
	Small trailer	1 ea.	8'x12'	96			
	Laydown area	Covered boats, golf cart and trailers, behind 2200.	27x5 Pe	877.8			877.8
	Laydown area	wooden pallets	3x5 Pe	97.5			
	Laydown area	Steel drums (4), wood shipping crates	13x2 Pe	169.1			169.1
	Laydown area	Tires (11) on pallet	4'x4'	16			
	Trailer w/boat		14x4 Pe	364.1			364.1
	Trailer	White	9'x13'	117			117
	Ramp, steel		12x2.5 Pe	195.1			195.1
	Laydown area	misc. metal, misc. equipment	10x5 Pe x 8'(H)	325.1			325.1
	Light pole, concrete	8 ea.					
	Laydown area	wooden pallets	5x9 Pe	292.6			
	Dumpster, medium	7 ea.	15'x8'x6'H	240.0			240
	Wood shed, small painted		4.5x3 Pe	87.8			87.8
	Metal shed, painted green	Grren painted metal roof, pitched, drains to asphalt	12x42 Pe x 24'(H)	2377			2377
	Tractors, yellow w/18 attached carts	2 ea.,		1066.6			1066.6
	Trailer, steel		2.5x13 Pe	211			211

	Laydown area	Gray steel, rope spools (3), wood reels w/electrical cable.	22x2.5 Pe	357.6			357.6
	Storage shed, painted metal	Drains to asphalt	3x6 Pe x 10'(H)	117			117
	Locker, painted metal	Yellow, 5 ea., drains to asphalt.	6'x2'x4'	60			60
	Storage shed, painted metal	Green, drains to asphalt.	10'x7'x7' (H)	70			70
	Trailer, gray		9'x13'	117			117
	Shed, metal		6x6.5 Pe x 10' (H)	253.6			253.6
	Laydown area	Scrap metal, wood	17x6 Pe x 3'(H)	663.2			663.2
					13369.9	2	32241.2

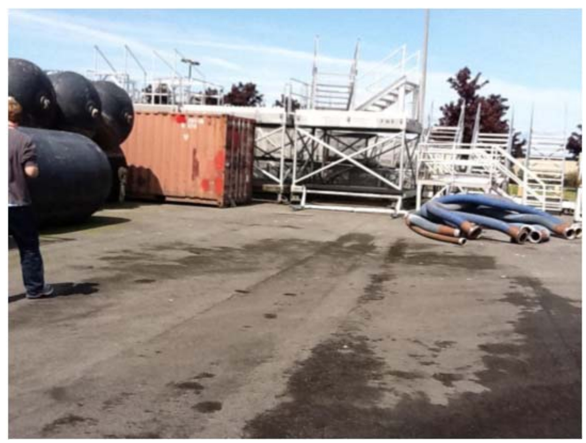
 Roof drain to pervious area. Pervious rock landscape adjacent to Bldgs. 2320/2330/2310.	 Directly connected roof drain. Rear Bldg. 2202 showing concrete pad, directly connected drainage and painted galvanized walkway/stairs.
 Directly connected roof drain. Drainage rear of Bldg. 2202 representative of entire 2200/2202 complex.	 Paved parking area. Photo 11: Asphalt texture real Bldg. 2200.

Paved parking area. Photo 20:
Storage and parking adjacent to Bldg. 2320.

Paved parking area. Photo 24:
Parking area north of Bldg. 2310.

Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 5: Laydown area Bldg. 2200.

Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 8: Rear Bldg. 2202 laydown area.

 Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 9: Misc. materials laydown area.	 Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 10: Misc. materials laydown area rear Bldg. 2200.
 Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 17: Laydown area east side of drainage.	 Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 19: Storage/laydown area south of Bldgs. 2300/2301, include rubber bumpers, aluminum stairs/walkways (some galvanized materials, conex and hoses.

 Other galvanized material area (other impervious area #10). Photo 14: Rear Bldg. 2300 showing painted galvanized stairway, drainage connection and misc. materials.	 Other galvanized material area (other impervious area #10). Photo 15: Painted galvanized stairs/walkway rear of Bldg. 2202, note wear of paint.

Naval Submarine Base Bangor - Outfall 3A (pier 3A)

Areas:

	Land Use Zone	Asphalt Area (square feet)	Description/Material
Area 1	Pier surface	18050	Entire pier surface is asphalt, moderately rough.
Area 2	Pier surface	52236	Entire pier surface is asphalt, moderately rough.
Area 3	Pier surface	80511.5	Entire pier surface is asphalt, moderately rough.

Area 4	Pier surface	111556.7	Entire pier surface is asphalt, moderately rough.
Area 5	Pier surface	54537.6	Entire pier surface is asphalt, moderately rough.
SUM		316891.8	

Roofs:

	Building/ Area	Roof Area (square feet)	Description/Material/Location	Area Galvanized (sq. ft.)
Area 1	Office	967	Painted wood sides, flat roof drains to pavement (26 x 6 Pb)	
	Bathrooms		Galvanized and aluminum walkway and steps, yellow painted rails (20 x 4 Pc)	520
Area 2	7410	2179	Flat roof (painted sheet metal), directly connected.	
	7415	3799	Roof flat (material unknown, appears painted sheet metal), directly connected to drainage.	
	7417	978	Flat roof (painted concrete structure), no drainage, flows to grouind	
	Offices	370	Small office stuctures, flat roofs, drain to ground. 2 ea. (5x5 Pc)	
Area 3	T45	743	Flat roof, painted concrete. Flows to ground.	
	7419	3967	Flat roof, painted steel, directly connected to drainage.	
	7418	2163	Roof flat, sheet metal, directly connected to drainage.	
	7432	922	Flat roof, concreted building, drains to ground, indirectly connected.	
	7462	185	Guard building, painted steel building (5 x 5 Pb x 18"H)	

	7460	610	Flat roof, painted steel, drains to ground. (15 x 5.5 Pe x 12'H)	
	7437	156	Galvanized building, indirectly connected, drains to ground. (6 x 4 Pe x 15'H)	
Area 4	7450	25208	Roof flat, drains to pavement, roof material unknown. Painted metal sides.	
	7416	2802	Flat roof, painted steel. Connected drains.	
	7441	220	Flat roof, painted steel. Flows to concrete.	
	7423	450	Pitched roof, painted galvanized. Flows to ground.	
	7425	5948	Flat roof, shop. Indirectly connected, drains to ground.	
	7436	1266	Brown painted steel, drains to ground, indirectly connected.	
	7427	409	Flat roof, painted steel. Flows to ground.	
	7431	925	Flat roof, painted steel. Flows to ground, indirectly connected.	
	Office	364	Flat roof, drains to ground. Painted metal. (7 x 8 Pe)	
	7413	819	Flat roof, concrete building. (7 x 18 Pe x 15'H)	
Area 5	7420	11494	Flat roof, painted steel, brown. Flows to ground, indirectly connected to drainage.	
	7421	1418	Flat roof, painted steel. Flows to ground.	
	7426	6477	Pitched roof, painted galvanized. Flows to ground.	
	7489	1807	Slightly pitched roof, painted steel. Flows to ground.	
	7429	925	Flat roof, painted steel. Flows to ground, indirectly connected.	
	7448	717	Pitched roof, painted galvanized. Flows to ground.	
	T29	807	Flat roof, painted steel. Flows to ground.	
	7428	688	Flat roof, painted steel. Drains to ground, indirectly connected.	

	7420b	11164	Flat roof, painted steel, brown. Flows to ground, indirectly connected to drainage.	
	7409	2340	Flat roof, painted metal. Drains to ground, indirectly connected. (36 x 10 Pe x 20'H)	
SUM		93288		520

Material Storage Areas:

	Possible Contaminants	Description	Dimensions	Sq. ft.	Total Galvanized Materials (sq. ft.)	Total Copper Materials (sq. ft.)	Total Misc Metals (sq. ft.)
Area 1							
	Galvanized pipe	misc. metal	9'x3'	27	27		
	Conex box	office/storage	7.5x3 Pe x 9'H	146			146
	Pallet	1" black cable, 2 ea.	6'x4'x2'H	24			
	Pallet	Possible copper treated wood	5'x5'x2'H	25			
	Pallets	mis. Scrap metal, 6 ea.	4'x5'	120			120
Area 2	Galvanized Boxes	electric meter, 40 ea.	2' x 3' x 4' H	240	240		
	Galvanized grating/gangplant	w/aluminum duct tubing	3' W x 10 Pc x 2' H	82	82		
	Conex box	green, white, misc. 11 ea.	20'x10'	2200			2200
	Dumpster, medium	2 ea.	15'x8'x6'	240			240
	Dumpster, sm.		5'x6'x4'	30			30
	Pallet	wood, 10 ea.	4'x4'x4'	160			
	Transfer cradle	painted yellow	10'x2'x4'H	20			20
	Gangway	steel painted	3'x10'x3'H	30			30
	Utility/electrical box	gray painted	13 Pc x 2.5 Pe x 1'H	225			225
	Laydown area	8 pallets 4' H, steel, Al	6x6 Pc	266			266
	Dumpster	Al or Steel, for zinc storage	5'x6'x4'	30			30
	Fork lift storage roof	Al painted side	5 Pb x 6 Pb x 6' H	186			186

	Laydown area	misc. metal(steel + Al)	12 Pc x 2 Pc	178			178
	Hose, liquid transfer	good condition	22 Pc	60			
	crane	170K lbs., 2 ea.	24 Pe(base) x 13 Pe	2029			2029
	Steel box	painted steel	13 Pc x 5 Pc	481			481
	Refrig. Units	fair condition	4 Pe x 4 Pe x 10'H	104			104
	Lockers	painted green, 2 ea.	(2x3 Pc + 2x2 Pc) 8'H	74			74
	Treated plywood	Possibly copper painted, 2 ea.	3 Pc x 3 Pc x 3' H	133			
	Treated plywood	Possibly copper painted	9 Pc x 1 Pc x 1' H	67			
	Dumpster, sm.	white painted	5'x6'x4'	30			30
	Cable holders	hose/elec. Al	21 Pc x 4 Pc	621			
	Painted light poles	light poles, painted, 11 ea.	8"Dx40'H	922			922
	Deck plating	Submarine deck, 10"D w/4' circular opening in center.		264			264
	Stair well	painted	2 Pc x 8 Pc	118			118
	Generator box	blue painted	8 Pc x 2 Pc x 10" H	118			118
Area 3	Gavanized shed	heating/cooling unit w/cables (17 Pc x 4 section cables)	17 Pc x 4'	185	185		
	Galvanized shed	open, 5 ea.	6 Pc x 12 Pc x 12'H	2663	2663		
	Galvanized shed	galv. Shed wsteel drums	8 x 4 Pe	208	208		
	Galvanized steel	misc.	4 Pc x 3 Pc	89	89		
	Conex box	11 ea.	20'x10'	2200			2200
	Fuel tank	diesel	4'x10'x4.5'H	40			40
	Refrig. Units	painted fiberglass, qty. 4	4 Pe x 4 Pe x 10'H	104			
	Crane	older, yellow steel	24 Pe(base) x 13 Pe	2029			2029

	Haz. Storage locker	green painted steel	3 Pc x 2 Pc x 8'H	44			44
	Laydown area	mixed wood, metal	26 x 8 Pc	566			
	storage locker	1 painted green, 1 rusted	3 Pc x 2 Pc x 8'H	89			89
	Laydown area	w/Zn dust, misc. metal	21 Pe x 6 Pe	321			321
	Dumpster, med.	std. green, med., 2 ea.	15'x8'x6'	240			240
	treatment plant	painted steel, sm.	7 Pc x 10 Pc	518			518
	ducting	Al, housed in steel grate	10 Pe x 5' x 4' H	128			128
	Laydown area	misc. metal	31 Pc x 8 Pc	1835			1835
	Cooling systems	3 ea.	32 x 10 Pe x 15'	2081			2081
	Laydown area	misc metals	5 Pc x 13 Pc	481			481
	crane	yellow, sm.	24 Pe(base) x 13 Pe	2029			2029
	fuel truck	yellow	3 Pc x 15 Pc	333			333
	Laydown area	misc. metals	5 Pc x 5 Pc	185			185
	gas tank storage	steel, 2 ea.	4'x4'x5'	80			80
	gang plank	w/galv. Side fencing 5.5'	15 Pc x 2 Pc	222			222
	Laydown area(triangle)	misc. steel, some galv.	42 Pe x 45 Pe x 39 Pe	756			756
	Galvanized shed	w/staging boxes 5' width	16 Pe x 12 Pe	1248	1248		
	Galvanized walkway		16 Pe x 10 Pe	1040	1040		
Area 4	BBQ area	galv.frame+deck,steel roof	5 Pe x 5 Pe	163	163		163
	Galvanized Roof	uncoated	8 Pe x 4 Pe	208	208		
	Copper tubing	1 pallet	4' x 4'	16		16	
	dumpster	large metal painted, 2 ea.	3 Pe x 8.5 Pe x 6'H	293			293
	scrap metal bins	misc. material, 6 ea.	3' x 5' x 4'H	90			90
	storage lockers	painted blue, 4 ea.	4' x 3' x 3'H	48			48

	laydown area	w/lots of zinc anodes	5 Pe x 10 Pe	325			325
	steel boxes	painted	2 Pe x 3 Pe x 8'H	39			39
	Laydown area	blast hoses, 8 pallets	10 Pe x 5 Pe	325			
	Conex boxes	12 ea.	20'x10'	2400			2200
	pallets	misc. metal, 3ea.	5'x5'x2'H	75			75
	gas storage shed	sheet metal, Al, open front	5 Pe x 9 Pe x 10'	293			293
	laydown area	misc. storage boxes	55'x4'	220			
	Laydown area	misc. metal equip.	6 Pe x 8 Pe	312			312
	steel lockers	yellow painted	6'x10'x8'H + 4'x4'x3'H	76			76
	pallets	unpainted elec. Tubing, 5 ea	4'x4'x2'H	80			
	laydown area	yellow metal storage boxes	17 Pe x 8 Pe	884			884
	laydown area	scaff., galv. Pcs, pipes	12 Pe x 8 Pe	624			624
	gang plank	w/ Al ducting	10 Pe x 5 Pe	128			128
Area 5							
	Galvanized laydown	unpainted	8 Pe x 9 Pe x 15'H	468	468		
	Galvanized stairway	stairs concrete, 5 ea.	3'x7'	105	105		
	Galvanized pallets	stack	2 Pc x 2 Pc x 6.5'H	30	30		
	Galvanized shelf	w/rubber hoses, 4 stacks	2 Pc x 24 Pc x 24' H	355	355		
	Treated plywood	possibly preserved with copper.	8 Pe x 4 Pe x 2.5'H	208			
	storage cabinet	green	5'x5'x8'H	25			25
	conex box	23 ea.	20'x10'	4600			4600
	storage box	misc., 7 ea.	5'x4'x3'H	140			140
	pallets	of black cable 3"dia, 33 ea?	4'x4'x2'H	528			

	Dumpster, med.	green, med., 2 ea.	15'x8'x6'	240			240
	Power cables	painted, poor cond.	6 Pe x 4 Pe	156			
	Laydown area	misc. Al storage	6 Pe x 11 Pe	429			429
	Al bins	w/3"neoprene cable, 12 ea.	2 ? x 4 Pb x 6 Pb(L)	149			149
	metal fans	painted	14 Pe x 10 Pe	910			910
	scaffolding	5 stories, 4 ea.	5 Pc x 5 Pc	185			185
	hosing	2", 9 ea.	39 Pc	159			
	transformer boxes	painted	7 Pb x 7 Pb	304			304
	steel material	painted	6 Pe x 9 Pe	351			351
	storage shed	painted metal roof, open	9 Pe x 24 Pe	1405			1405
	pallets	of rubber fire hose, 2 ea.	2'x2'x2'H	8			
	storage area		18 Pe x 30 Pe	3511			3511
				49828	7111	16	39220

Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 1: Laydown area including misc. steel parts, pallets, ducting material and shipping crates.

Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 14: Laydown area.

Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 2: Crane tracks, industrial equip. and trailer.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 6: Treated (copper?) wood, laydown area.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 7: Electrical cables on gangplank with large crane on track in background, misc. laydown.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 9: Deck plating.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 10: Mobile offices, electical cable on gangplank, note crane tracks.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 22: Scrap metal and garbage bins.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 23: Cable laydown area.

Galvanized metal roofs (other impervious area #9). Photo 5: Building 7414, painted galvanized w/significant paint peeling of wall. Note broken drainage, connected.

Galvanized metal roofs (other impervious area #9).Photo 11: Galvanized storage sheds, drains to ground.

Other galvanized material areas (other impervious area #10). Photo 8: Galvanized utility box, 40 boxes on site.

Other galvanized material areas (other impervious area #10). Photo 28: Galvanized material laydown.

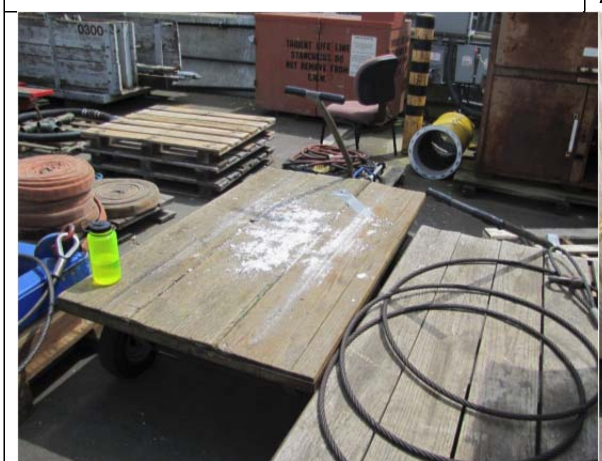
Other galvanized material areas (other impervious area #10). Photo 29: Galvanized stairway structure.

Other galvanized material areas (other impervious area #10). Photo 3: Small dumpster with zinc waste. Note zinc particles on surface.

Other galvanized material areas (other impervious area #10). Photo 4: Zinc anodes in dumpster.

Other galvanized material areas (other impervious area #10). Photo 8: Galvanized utility box, 40 boxes on site.

Other galvanized material areas (other impervious area #10). Photo 12: Galvanized shed, lead waste Hazardous Waste Accumulation Area.



Other galvanized material areas (other impervious area #10). Photo 13: Laydown area with miscellaneous items (note zinc debris on table).

Other galvanized material areas (other impervious area #10). Photo 15: Cable reel, note zinc particles from corroded anodes.

Other galvanized material areas (other impervious area #10). Photo 20: Storage and laydown including zinc anodes. Note corroded anode material on ground.

Other galvanized material areas (other impervious area #10). Photo 21: Residue on ground is zinc.

Whidbey Island Seaplane Base - Outfall 3D

Areas:

	Land Use Zone	Asphalt Area (square feet)	Description/Material	Area concrete (sq. ft)	Area Pervious (sq. ft)
Area 1	Asphalt	14372	Moderate texture.		
	Asphalt/parking	41199	Moderate texture. 13 trucks, 3 boats/trailers, 5 pickups, 8 convoy. Slopes toward grate/drain.		
	Asphalt road	3649	Curb and gutter drainage.		
	Concrete		Smooth texture. Unoccupied area.	31114	
	Pervious		Grassy area		8618
	Pervious		Grassy area		2141
	Pervious		Grassy area and soil		13194
	Pervious		Grassy area		3379
	Pervious		Gravel cover north of B. 2795		3511
Area 2	Asphalt	37939	Rough, no visible slope. Parking minimally occupied; 90 spaces, 7 occupied.		

	Concrete/parking		Moderately smooth texture, non-occupied area. Even surface, no visible slope.	48061	
	Concrete, loading area		Moderate/smooth texture. Loading dock Norwest of Bldg. 18.	6298	
	Pervious		Grass. North and west of Fire Dept. building.		11690
	Pervious		Grass/gravel Southwest of Bldg. 18.		3715
	Pervious		Grass area adjacent to Bldg. 18 south side.		2463
	Concrete		East side Fire Dept. Building. Smooth textrure, no slope, surrounded by pervious grassy areas.	977	
Area 3	Asphalt	51173	Moderate texture. Some of Area 2 asphalt (south side of bldg. 18 included).		
	Asphalt road	11662	Curb and gutter drainage.		
	Pervious		Grassy area southwest Fire Dept. Creeps in area 2.		1853
	Pervious		Grassy area southeast Fire Dept.		2630
	Pervious		Grass. Main feature in area.		40180
	Concrete/sidewalk		Smooth texture, surrounded by grass. To Fire Dept. building.	511	
	Concrete		Concrete pad.	1179	
	Concrete		Concrete pad.	264	
Area 4	Asphalt	76090	Area west of Building 22. Minimal parking, laydown areas.		
	Concrete		Concrete surface, little parking, around and between Build. 21 and 22.	35479	
	Concrete/sidewalk		North of Bldg. 21	628	
	Pervious		Grassy area west building 21.		10012
	Pervious		Grassy area north building 21.		1724
	Pervious		Grassy area between Bldg. 22 and 2795.		1113
SUM		236083		124511	106225

Buildings:

	Building/ Area	Roof Area (square feet)	Description/Material/Location
Area 1			

	Bldg. 2795	4162	Flat roof. Painted metal roof, drains to asphalt - indirectly connected. 16x55 Pe
Area 2	Bldg. 18	16134	Flat roof. Painted yellow shingles on side of building. 50% drains to asphalt - indirect connection; 50% drains to grassy area south side of building (estimate). 20' H.
	Fire Dept.	4124	Flat roof, drains to grassy, pervious area.
Area 3			
Area 4	Bldg. 21	27702	Flat roof, black-rubbery material. 50% drains to concrete , remaining 50% drains to pervious grassy areas North and east of building. Yellow, shingle siding, composite/asbestos, 20'H. Some galvanized pipes on roof (8 pipes, 6"D x 3'H)
	Bldg. 22	38569	Flat roof, plastic material. Drains to asphalt, indirect connection to stormwater conveyance system.
SUM		90691	

Material Storage Areas:

	Possible Contaminants	Description	Dimensions	Total Galvanized Materials (sq. ft.)	Total Misc Metals (sq. ft.)
Area 1					
	Galvanized fence	Fence perimeter of Bldg. 2795.	645.2'x 7'H	4516	
	Galvanized fence	Fence perimeter around boat yard.	214.2'x 7'H	1499	
	Parking area	Navy green. 13 trucks, 3 boats/trailers, 5 pickups, 8 convoy.			
	Laydown area	Truck rails, misc. metal pieces/parts	3x4.5 Pb		84
	Laydown area	Pallets, scrap metal, truck rails	3x4.5 Pb		84
	Laydown area	53 truck tires	19 x 5 Pe		
	Storage sheds, metal	2 ea.	7x2 Pe x 8'H		91
	Transformetr box	Metal, painted green	6'x6'x4.5'H		36
				6016	294
Area 2	Laydown area	Treated wood, misc. metal, misc. parts	7x5 Pc		260
	Laydown area	scrap bins	8x2.5 Pe		130
	Secondary containment	Motor oil storage, fuel tank	7x11 Pc		
	Laydown area	Metal framing material, wood	5'x6 Pe		77
					466
Area 3					

Area 4	Galvanized fence	Fenced area west of Bldg. 22 (90+63+90+30+26 Pe x 7'H)	329 Pe x 7'H	5873	
	Laydown area	Metal framing material	5'x 18 Pe		230
	Laydown area	Pallets, painted blue, south end Bldg. 22	10' x 10		100
	Laydown area	Boat trailers (12), 20' boats (3), oil booms	6x20 Pe		306
	Laydown area				
				5873	636
Totals				11888	1396

 Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 4: Laydown area adjacent to truck yard.	 Asphalt, medium industrial storage/laydown area (other impervious area #7). Photo 7: Bldg. 18 loading area and laydown of pervious grassy area.

Naval Magazine Indian Island - Outfall SW120

Areas:

	Land Use Zone	Area of Asphalt (acres)	Asphalt Area (square feet)	Description/Material
SW120	Asphalt	3	115739	Asphalt over entire surface, rough. Entire area uneven with no continuous slope. 31 passenger vehicles, parking = 50% full.
SUM		3	115739	

Buildings:

	Building/ Area	Roof Area (square feet)	Description/Material/Location	Area Galvanized (sq. ft.)
Area 1				
	Bldg. 854		Pitched roof. Galvanized. 1/2 roof indirectly connected, 1/2 flows to pervious outside of drainage area.12x6 Pe	234
	Bldg. 834	3121	Flat roof. Flows to asphalt - indirectly connected. Fire Dept. building. 15x32 Pe.	
	Shed	1951	Shed, roof only. Flat roof, painted steel. Indirectly connected - flows to asphalt. 5x60 Pe.	
SUM		5072		234

Material Storage Areas:

	Possible Contaminants	Description	Dimensions	Sq. ft.	Total Galvanized Materials (sq. ft.)	Total Misc Metals (sq. ft.)	Total Misc Non-metals (sq. ft.)
Area 1	Galvanized Roof						
	Galvanized bins	Storage area, 4'x4'x4', 3 levels	12x12 Pe x10'H	2809	2809		
	Galvanized trailer deck	Aluminum frame, galv. Deck	13x2 Pe	169	169		
	Galvanized light pole	3 ea., 6"D x 40'H		188	188		
	Galvanized platform	2 ea., use as raised decks	4x4 Pe x 10'H	208	208		
	Trailer	w/black electrical hose	15x3.5 Pe	341		341	
	Dumpster, large	1 ea.	3 Pe x 8.5 Pe x 6'H	146		146	
	Trailer	flat bed w/ pallets of misc. tubing	19x3 Pe	371		371	
	Dumpster, small		5'x6'	30		30	
	Crane truck		14x3 Pe	273			273
	Trailer	flat bed w/painted steel structure	11 x 3.5 Pe	250			
	Fuel tank	Diesel	8'D x 11 Pe	705		705	
	Conex box	4 ea. + 5ea.	20'x10'	1800		1800	
	Trailer	Painted galvanized	3x13 Pe	254		254	
	Gangplank	Aluminum, 3 ea.	4' x 4' x 6 Pe	122		122	
	Barge, metal	Poor condition	9x3 Pe	176		176	

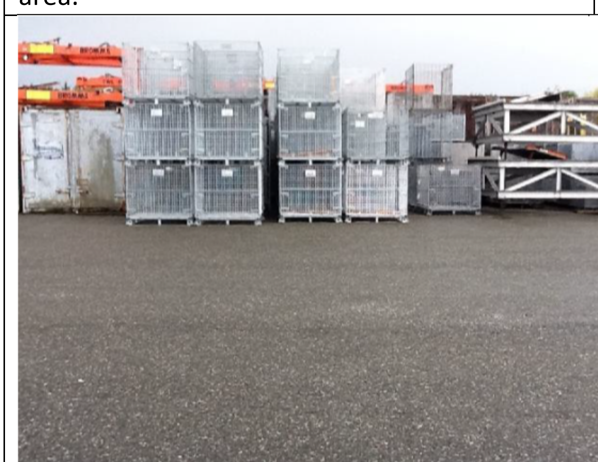
	Laydown area	Aluminum, portable steps and gangplanks	30x14 Pe	2731		2731	
	Laydown area	Steel test weights, yellow painted	12x12 Pe	936		936	
	Rubber bumpers	Large, black., 4 ea.	8'D x 6 Pe	1538			1538
	Wooden box	Large w/steel support, 8 ea.	6'x12' x 4'H	576			576
	Staging area	wooden boxes w/steel reinforced edges.	5x11 Pe	358			358
	Laydown area	Misc. aluminum and wood parts/equipment.	5x15 Pe	488		488	
	Laydown area	Steel carts, misc. containers.	5x5 Pe	163		163	
Totals				14633	3375	8263	2745

Paved parking area. Photo 1: North side of drainage, mostly parking lot.

Paved parking area. Photo 6: Pavement texture.

Paved parking area. Photo 3: Outfall sample collection site, southwest corner of drainage area.

Asphalt, heavy industrial storage/laydown area (other impervious area #8). Photo 4: Wooden boxes with steel reinforced edges.



Other galvanized material areas (other

impervious area #10). Photo 2: Laydown and storage area, baskets are uncoated galvanized steel construction.	

Appendix B: Water Quality from First Flush vs. Composite Samples

First Flush Stormwater Comparisons using National Data

Maestre, *et al.* (2004) examined 417 pairs of first flush and full storm composite sampled events for 22 stormwater constituents, using data from the National Stormwater Quality Database (NSQD) (Maestre and Pitt 2007). All the samples were obtained from end-of the pipe outfall locations in separate storm drainage systems. The following table shows the results of the analysis. The "≠" sign in the results column, R, indicates that the medians of the first flush and the composite data set were found to be statistically significantly different. The "=" sign indicates that there is not enough information to reject the null hypothesis at the desired level of confidence (at least at the 95 percent level). Events without enough data are represented with an "X".

Presence of Significant First Flushes (ratio of first flush to composite median concentrations)

Parameter	Commercial				Industrial				Institutional			
	n	**sc**	**R**	**ratio**	**n**	**sc**	**R**	**ratio**	**n**	**sc**	**R**	**ratio**
Turbidity, NTU	11	11	=	1.32			X				X	
pH, S.U.	17	17	=	1.03	16	16	=	1.00			X	
COD, mg/L	91	91	≠	2.29	84	84	≠	1.43	18	18	≠	2.73
TSS, mg/L	90	90	≠	1.85	83	83	=	0.97	18	18	≠	2.12
BOD5, mg/L	83	83	≠	1.77	80	80	≠	1.58	18	18	≠	1.67
TDS, mg/L	82	82	≠	1.83	82	81	≠	1.32	18	18	≠	2.66
O&G, mg/L	10	10	≠	1.54			X				X	
Fecal Coliform, col/100mL	12	12	=	0.87			X				X	
Fecal Streptococcus, col/100 mL	12	11	=	1.05			X				X	
Ammonia, mg/L	70	52	≠	2.11	40	33	=	1.08	18	16	≠	1.66
$NO_2 + NO_3$, mg/L	84	82	≠	1.73	72	71	≠	1.31	18	18	≠	1.70
N Total, mg/L	19	19	=	1.35	19	16	=	1.79			X	
TKN, mg/L	93	86	≠	1.71	77	76	≠	1.35			X	
P Total, mg/L	89	77	≠	1.44	84	71	=	1.42	17	17	=	1.24
P Dissolved, mg/L	91	69	=	1.23	77	50	=	1.04	18	14	=	1.05
Ortho-P, mg/L			X		6	6	=	1.55			X	
Cadmium Total, μg/L	74	48	≠	2.15	80	41	=	1.00			X	
Chromium Total, μg/L	47	22	≠	1.67	54	25	=	1.36			X	
Copper Total, μg/L	92	82	≠	1.62	84	76	≠	1.24	18	7	=	0.94
Lead Total, μg/L	89	83	≠	1.65	84	71	≠	1.41	18	13	≠	2.28
Nickel, μg/L	47	23	≠	2.40	51	22	=	1.00			X	
Zinc, μg/L	90	90	≠	1.93	83	83	≠	1.54	18	18	≠	2.48

Presence of Significant First Flushes (ratio of first flush to composite median concentrations) (continued)

Parameter	Open Space				Residential				All Combined			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU			X		12	12	=	1.24	26	26	=	1.26
pH, S.U.			X		26	26	=	1.01	63	63	=	1.01
COD, mg/L	28	28	=	0.67	140	140	≠	1.63	363	363	≠	1.71
TSS, mg/L	32	32	=	0.95	144	144	≠	1.84	372	372	≠	1.60
BOD5, mg/L	28	28	=	1.07	133	133	≠	1.67	344	344	≠	1.67
TDS, mg/L	31	30	=	1.07	137	133	≠	1.52	354	342	≠	1.55
O&G, mg/L			X				X		18	14	≠	1.60
Fecal Coliform, col/100mL			X		10	9	=	0.98	22	21	=	1.21
Fecal Streptococcus, col/100 mL			X		11	8	=	1.30	26	22	=	1.11
Ammonia, mg/L			X		119	86	≠	1.36	269	190	≠	1.54
$NO_2 + NO_3$, mg/L	30	21	=	0.96	121	118	≠	1.66	324	310	≠	1.50
N Total, mg/L	6	6	=	1.53	31	30	=	0.88	77	73	=	1.22
TKN, mg/L	32	14	=	1.28	131	123	≠	1.65	335	301	≠	1.60
P Total, mg/L	32	20	=	1.05	140	128	≠	1.46	363	313	≠	1.45
P Dissolved, mg/L	32	14	=	0.69	130	105	≠	1.24	350	254	=	1.07
Ortho-P, mg/L			X		14	14	=	0.95	22	22	=	1.30
Cadmium Total, µg/L	30	15	=	1.30	123	33	≠	2.00	325	139	≠	1.62
Chromium Total, µg/L	16	4	=	1.70	86	31	=	1.24	218	82	≠	1.47
Copper Total, µg/L	30	22	=	0.78	144	108	≠	1.33	368	295	≠	1.33
Lead Total, µg/L	31	16	=	0.90	140	93	≠	1.48	364	278	≠	1.50
Nickel, µg/L			X		83	18	=	1.20	213	64	≠	1.50
Zinc, µg/L	21	21	=	1.25	136	136	≠	1.58	350	350	≠	1.59

Note: n = number of events. sc = number of selected events with detected values. R = result: not enough data (X); not enough evidence to conclude that median values are different (=); median values are different (≠).

Also shown on this table are the ratios of the medians of the first flush and the composite data sets for each constituent and land use. Generally, a statistically significant first flush was associated with a median concentration ratio of the first flush to composite concentration of about 1.4, or greater (the exceptions are when the number of samples in a specific category was much smaller). The largest ratios are about 2.5, indicating that for these conditions, the first flush sample concentrations are about 2.5 times greater than the composite sample concentrations. More of the larger ratios are found for the commercial and institutional land use categories, areas where larger paved areas are likely to be found. The smallest ratios are associated with the residential, industrial, and open spaces land uses, locations where there may be larger areas of unpaved surfaces.

About 70% of the constituents in the commercial land use category had elevated first-flush concentrations, while about 60% of the constituents in the residential, institutional and the mixed (mostly commercial and residential) land use categories had elevated first flushes, and about 45% of the constituents in the industrial land use category had elevated first flushes. In contrast, no constituents were found to have elevated first-flushes in the open space land use category. COD, BOD_5. TDS, TKN and Zn all had first flushes in all areas (except for the open space category). In contrast, turbidity, pH, fecal coliform, fecal streptococcus, total N, dissolved and ortho-P never showed a statistically significant first flush in any category.

It is expected that peak concentrations generally occur during periods of peak flows (and highest rain energy). On relatively small paved areas, however, it is likely that there will always be a short initial period of relatively high concentrations associated with washing off of the most available material (Pitt 1987). This peak period of high concentrations may be overwhelmed by periods of high rain intensity that may occur later in the event. In addition, in more complex drainage areas, the routing of these short periods of peak concentrations may blend with larger flows and may not be observable. A first flush in a separate storm drainage system is therefore most likely to be seen if a rain occurs at a relatively constant intensity over a small paved area having a simple drainage system. If the peak flow (and highest rain energy) occurs later in the event, then there likely will not be a noticeable first flush. However, if the peak rain intensity occurs at the beginning of the event (such as is common in the southeast during intense summer thunderstorms), then the effect is exaggerated.

This data review of first flush conditions indicated that a first flush effect was not present in all of the land uses, and certainly not for all constituents. Commercial and residential areas were more likely to show this phenomenon, especially if the peak rainfall occurred near the beginning of the event. It is expected that this effect will be more likely to occur in a watershed with a high level of imperviousness, but the data indicated first flushes less than 50% of the time for the most impervious areas. Groups of constituents showed different behavior for different land uses. All the heavy metals evaluated showed higher concentrations at the beginning of the events in the commercial land use category. Similarly all the nutrients show a higher concentration in the residential land use, except for total nitrogen and ortho-P. Conventional constituents (TSS, turbidity, COD, etc.) showed elevated first-flush concentrations in commercial, residential and institutional land uses.

Comparisons of First Flush and Composite Stormwater Concentrations at San Diego Naval Facilities

Thirteen sets of composite and first-flush samples were analyzed at 10 locations during four separate storm events at the San Diego naval facilities. The following tables show the available data organized into total sample analyses and filtered sample analyses. The site notations are:

NAV= Naval Base San Diego
NAB= Naval Amphibious Base
NI= North Island Naval Air Station
SUB= Subbase

OF= Outfall
PR= Pier

Simple statistical summaries are also shown on these tables, including the probability that the first flush sample results are significantly different (at the 90% confidence level using the paired T-test) from the composite sample results. Seven analytes for the total samples and seven analytes for the filtered samples had significant differences in concentrations. For these analytes being used in the model (and calibrated), the average composite to first flush ratio will be used as a conversion factor to modify the available first flush sample results. These tables summarize the sample conditions and analytes that were found to have significant differences, while the figures are scatterplots showing the relationships between the composite and first flush sample concentrations for these significantly different analytes.

Total Sample Analyses of First Flush vs. Composite Event Concentrations

site	Sample Date	Cu comp	Cu ff	Cu comp/ff	Zn comp	Zn ff	Zn comp/ff	TSS (mg/L) comp	TSS ff	TSS comp/ff	%Survival in 100% comp	% survival ff	tox comp/ff
NAB-OF18	2/10/2005	44.4	43.7	1.02	214	137	1.56	20	6	3.48			
NAB-OF18	4/27/2005	108.0	67.1	1.61	752	601	1.25	234	46	5.14	90	90	1.00
NAB-OF9	4/27/2005	108.0	33.3	3.24	1832	519	3.53	60	12	5.16	60	85	0.71
NAV-OF11	2/24/2003	46.9	68.4	0.69	298	555	0.54				100	0	
NAV-OF14	2/24/2003	28.9	72.6	0.40	200	797	0.25				100	100	1.00
NAV-OF14	10/26/2004	38.0	45.3	0.84	220	362	0.61	79	61	1.29	80	63	1.26
NAV-OF9	2/24/2003	36.1	54.2	0.67	233	433	0.54				100	90	1.11
NAV-PR5	2/24/2003	104.0	84.7	1.23	391	521	0.75				100	0	
NAV-PR6	2/24/2003	66.2	183.0	0.36	249	314	0.79				90	33	2.70
NI-OF26	2/10/2005	41.0	33.4	1.23	87	129	0.68	22	15	1.48	100	95	1.05
SUB-OF11B	2/2/2004	24.9	20.4	1.22	123	130	0.94	97	37	2.60	80	77	1.04
SUB-OF23CE	2/2/2004	37.3	27.1	1.38	792	967	0.82	55	45	1.21	87	77	1.13
SUB-OF26	2/2/2004	194.8	94.1	2.07	477	384	1.24	21	39	0.55	70	90	0.78
	min	24.9	20.4	0.36	87	129	0.25	20	6	0.55	60	0	0.71
	max	194.8	183.0	3.24	1832	967	3.53	234	61	5.16	100	100	2.70
	avg	67.6	63.6	1.23	451	450	1.04	73	33	2.61	88	67	1.18
	st dev	48.8	42.4	0.77	469	252	0.83	71	20	1.81	13	36	0.56
	COV	0.72	0.67	0.63	1.04	0.56	0.80	0.97	0.60	0.69	0.15	0.54	0.47
	number	13	13	13	13	13	13	8	8	8	12	12	10
	ratio comp/ff avg	1.06			1.00			2.26			1.32		
	P (paired T test)	0.40			0.50			0.06			0.05		

Total Sample Analyses of First Flush vs. Composite Event Concentrations (continued)

site	Sample Date	Ag comp	Ag ff	Ag comp/ff	Pb comp	Pb ff	Pb comp/ff	Hg comp	Hg ff	Hg comp/fe	Al comp	Al ff	AL comp/ff
NAB-OF18	2/10/2005												
NAB-OF18	4/27/2005												
NAB-OF9	4/27/2005												
NAV-OF11	2/24/2003	0.11	0.18	0.61	14	22	0.63	0.054	0.051	1.06	777	1690	0.46
NAV-OF14	2/24/2003	0.07	0.23	0.30	15	44	0.34	0.031	0.054	0.59	1270	2640	0.48
NAV-OF14	10/26/2004	0.06	0.07	0.85	22	22	1.00	0.069	0.063	1.10	2618	1322	1.98
NAV-OF9	2/24/2003	0.19	0.17	1.10	16	23	0.70	0.015	0.017	0.87	1050	1840	0.57
NAV-PR5	2/24/2003	0.25	0.19	1.29	23	21	1.14	0.021	0.006	3.84	1025	320	3.20
NAV-PR6	2/24/2003	0.13	0.05	2.53	15	4	3.60	0.019	0.019	1.01	722	179	4.03
NI-OF26	2/10/2005												
SUB-OF11B	2/2/2004												
SUB-OF23CE	2/2/2004												
SUB-OF26	2/2/2004												
	min	0.06	0.05	0.30	14	4	0.34	0.015	0.006	0.59	722	179	0.46
	max	0.25	0.23	2.53	23	44	3.60	0.069	0.063	3.84	2618	2640	4.03
	avg	0.13	0.15	1.11	17	23	1.23	0.035	0.035	1.41	1244	1332	1.79
	st dev	0.07	0.07	0.78	4	13	1.19	0.022	0.024	1.20	702	943	1.55
	COV	0.53	0.47	0.70	0	1	0.96	0.63	0.68	0.85	0.56	0.71	0.87
	number	6	6	6	6	6	6	6	6	6	6	6	6
	ratio comp/ff avg	0.90			0.77			1.01			0.93		
	P (paired T test)	0.35			0.20			0.49			0.42		

Total Sample Analyses of First Flush vs. Composite Event Concentrations (continued)

site	Sample Date	As comp	As ff	As comp/fe	Cd comp	Cd ff	Cd comp/ff	Cr comp	Cr ff	Cr comp/ff	Fe comp	Fe ff	Fe comp/ff
NAB-OF18	2/10/2005												
NAB-OF18	4/27/2005												
NAB-OF9	4/27/2005												
NAV-OF11	2/24/2003	1.3	1.2	1.13	0.78	1.23	0.63	4.7	5.6	0.85	1390	2250	0.62
NAV-OF14	2/24/2003	2.0	2.9	0.69	0.67	2.59	0.26	7.2	13.7	0.53	1870	3940	0.47
NAV-OF14	10/26/2004	2.4	3.2	0.75	0.87	1.18	0.74	12.9	6.9	1.86	4481	2138	2.10
NAV-OF9	2/24/2003	1.4	1.6	0.90	0.66	0.99	0.67	8.6	6.6	1.30	1610	2390	0.67
NAV-PR5	2/24/2003	1.8	1.5	1.19	2.27	5.49	0.41	7.2	3.3	2.16	1417	515	2.75
NAV-PR6	2/24/2003	1.4	1.7	0.82	1.12	1.37	0.82	6.7	4.2	1.57	1149	426	2.70
NI-OF26	2/10/2005												
SUB-OF11B	2/2/2004												
SUB-OF23CE	2/2/2004												
SUB-OF26	2/2/2004												
	min	1.3	1.2	0.69	0.66	0.99	0.26	4.7	3.3	0.53	1149	426	0.47
	max	2.4	3.2	1.19	2.27	5.49	0.82	12.9	13.7	2.16	4481	3940	2.75
	avg	1.7	2.0	0.91	1.06	2.14	0.59	7.9	6.7	1.38	1986	1943	1.55
	st dev	0.4	0.8	0.21	0.62	1.74	0.21	2.8	3.7	0.62	1246	1316	1.08
	COV	0.25	0.42	0.22	0.58	0.81	0.36	0.35	0.55	0.45	0.63	0.68	0.70
	number	6	6	6	6	6	6	6	6	6	6	6	6
	ratio comp/ff avg	0.86			0.50			1.17			1.02		
	P (paired T test)	0.10			0.04			0.27			0.47		

Total Sample Analyses of First Flush vs. Composite Event Concentrations (continued)

site	Sample Date	Mn comp	Mn ff	Mn comp/ff	Ni comp	Ni ff	Ni comp/ff	Se comp	Se ff	Se comp/ff	Sn comp	Sn ff	Sn comp/ff
NAB-OF18	2/10/2005												
NAB-OF18	4/27/2005												
NAB-OF9	4/27/2005												
NAV-OF11	2/24/2003	56	76	0.73	4.5	9.3	0.48	0.11	0.17	0.64	0.87	0.92	0.94
NAV-OF14	2/24/2003	57	131	0.43	5.3	15.7	0.34	0.04	0.15	0.24	0.95	1.44	0.66
NAV-OF14	10/26/2004	72	66	1.08	4.8	7.2	0.67	0.53	1.30	0.41	0.54	0.66	0.81
NAV-OF9	2/24/2003	50	93	0.54	7.9	12.5	0.63	0.07	0.19	0.35	1.12	1.00	1.12
NAV-PR5	2/24/2003	32	22	1.41	11.2	7.7	1.45	0.10	0.67	0.15	1.13	0.72	1.58
NAV-PR6	2/24/2003	33	84	0.39	7.3	17.2	0.43	0.16	1.08	0.15	0.82	0.21	3.98
NI-OF26	2/10/2005												
SUB-OF11B	2/2/2004												
SUB-OF23CE	2/2/2004												
SUB-OF26	2/2/2004												
	min	32	22	0.39	4.5	7.2	0.34	0.04	0.15	0.15	0.54	0.21	0.66
	max	72	131	1.41	11.2	17.2	1.45	0.53	1.30	0.64	1.13	1.44	3.98
	avg	50	79	0.76	6.8	11.6	0.67	0.17	0.59	0.32	0.90	0.82	1.51
	st dev	15	35	0.40	2.5	4.2	0.40	0.18	0.51	0.19	0.22	0.41	1.25
	COV	0.31	0.45	0.53	0.37	0.36	0.61	1.09	0.86	0.58	0.24	0.50	0.82
	number	6	6	6	6	6	6	6	6	6	6	6	6
	ratio comp/ff avg	0.63			0.59			0.28			1.10		
	P (paired T test)	0.04			0.04			0.02			0.32		

Filtered Sample Analyses of First Flush vs. Composite Event Concentrations

site	Sample Date	Cu comp	Cu ff	Cu comp/ff	Zn comp	Zn ff	Zn comp/ff	Ag comp	Ag ff	Ag comp/ff	Pb comp	Pb ff	Pb comp/ff
NAB-OF18	2/10/2005	26.2	38.2	0.69	101	134	0.75						
NAB-OF18	4/27/2005	31.2	31.8	0.98	149	313	0.48						
NAB-OF9	4/27/2005	40.0	37.5	1.07	356	197	1.81						
NAV-OF11	2/24/2003	37.8	17.6	2.15	709	308	2.31						
NAV-OF14	2/24/2003	15.1	33.9	0.45	179	393	0.46	0.013	0.029	0.44	0.2	0.5	0.46
NAV-OF14	10/26/2004	7.2	22.1	0.33	110	310	0.35	0.010	0.027	0.37	0.3	0.9	0.36
NAV-OF9	2/24/2003	9.9	18.9	0.52	68	175	0.39	0.004	0.006	0.63	0.4	0.5	0.89
NAV-PR5	2/24/2003	9.9	25.8	0.38	112	218	0.51	0.010	0.020	0.49	0.2	0.4	0.42
NAV-PR6	2/24/2003	14.2	69.4	0.20	81	458	0.18	0.008	0.015	0.54	0.5	11.8	0.05
NI-OF26	2/10/2005	29.1	22.2	1.31	37	101	0.36						
SUB-OF11B	2/2/2004	15.2	15.1	1.01	37	59	0.63						
SUB-OF23CE	2/2/2004	18.0	16.8	1.07	505	679	0.74						
SUB-OF26	2/2/2004	122.8	27.9	4.40	338	104	3.24						
	min	7.2	15.1	0.20	37	59	0.18	0.004	0.006	0.37	0.2	0.4	0.05
	max	122.8	69.4	4.40	709	679	3.24	0.013	0.029	0.63	0.5	11.8	0.89
	avg	29.0	29.0	1.12	214	265	0.94	0.009	0.019	0.50	0.3	2.8	0.44
	st dev	30.2	14.4	1.11	205	173	0.93	0.003	0.009	0.10	0.2	5.0	0.30
	COV	1.04	0.50	0.99	0.96	0.65	0.99	0.38	0.48	0.19	0.44	1.78	0.70
	number	13	13	13	13	13	13	5	5	5	5	5	5
	ratio comp/ff avg	1.00			0.81			0.46			0.12		
	P (paired T test)	0.5			0.2			0.01			0.16		

Filtered Sample Analyses of First Flush vs. Composite Event Concentrations (continued)

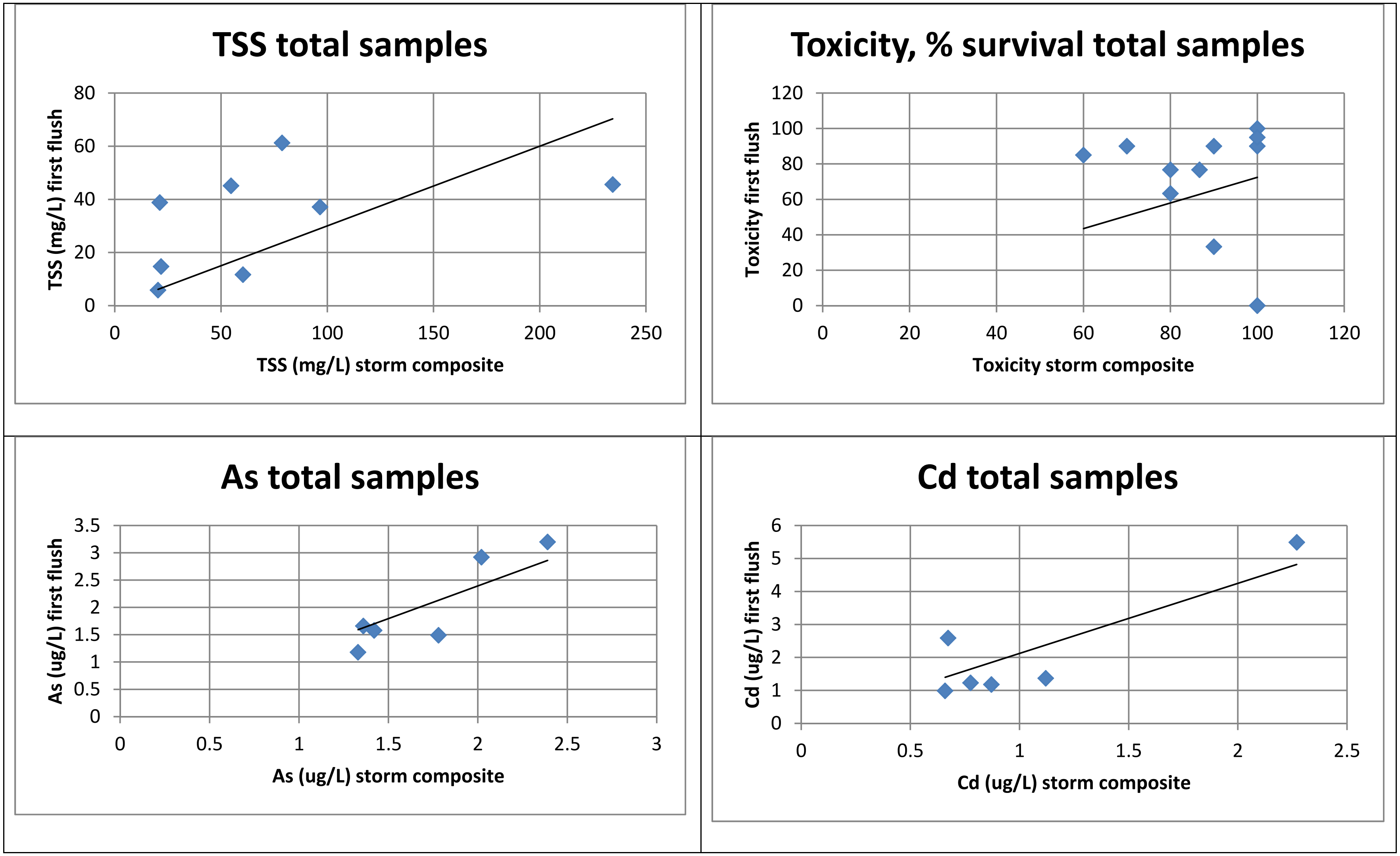
site	Sample Date	Hg comp	Hg ff	Hg comp/fe	Al comp	Al ff	AL comp/ff	As comp	As ff	As comp/fe	Cd comp	Cd ff	Cd comp/ff
NAB-OF18	2/10/2005												
NAB-OF18	4/27/2005												
NAB-OF9	4/27/2005												
NAV-OF11	2/24/2003												
NAV-OF14	2/24/2003	0.0031	0.0061	0.52	19	18	1.04	0.8	0.4	2.22	0.67	0.76	0.88
NAV-OF14	10/26/2004	0.0018	0.0037	0.47	40	11	3.80	1.2	0.8	1.59	0.53	0.98	0.54
NAV-OF9	2/24/2003	0.0033	0.0060	0.55	18	15	1.20	1.7	2.0	0.84	0.24	0.49	0.50
NAV-PR5	2/24/2003	0.0019	0.0037	0.51	8	17	0.50	0.8	0.7	1.18	0.39	0.39	0.99
NAV-PR6	2/24/2003	0.0022	0.0027	0.80	15	40	0.38	1.2	1.2	0.96	0.30	4.97	0.06
NI-OF26	2/10/2005												
SUB-OF11B	2/2/2004												
SUB-OF23CE	2/2/2004												
SUB-OF26	2/2/2004												
	min	0.0018	0.0027	0.47	8	11	0.38	0.8	0.4	0.84	0.24	0.39	0.06
	max	0.0033	0.0061	0.80	40	40	3.80	1.7	2.0	2.22	0.67	4.97	0.99
	avg	0.0025	0.0044	0.57	20	20	1.38	1.2	1.0	1.36	0.43	1.52	0.60
	st dev	0.0007	0.0015	0.13	12	11	1.39	0.4	0.6	0.56	0.17	1.94	0.37
	COV	0.29	0.34	0.23	0.60	0.57	1.01	0.32	0.63	0.41	0.41	1.28	0.62
	number	5	5	5	5	5	5	5	5	5	5	5	5
	ratio comp/ff avg	0.55			1.00			1.13			0.28		
	P (paired T test)	<0.01			0.5			0.21			0.15		

Filtered Sample Analyses of First Flush vs. Composite Event Concentrations (continued)

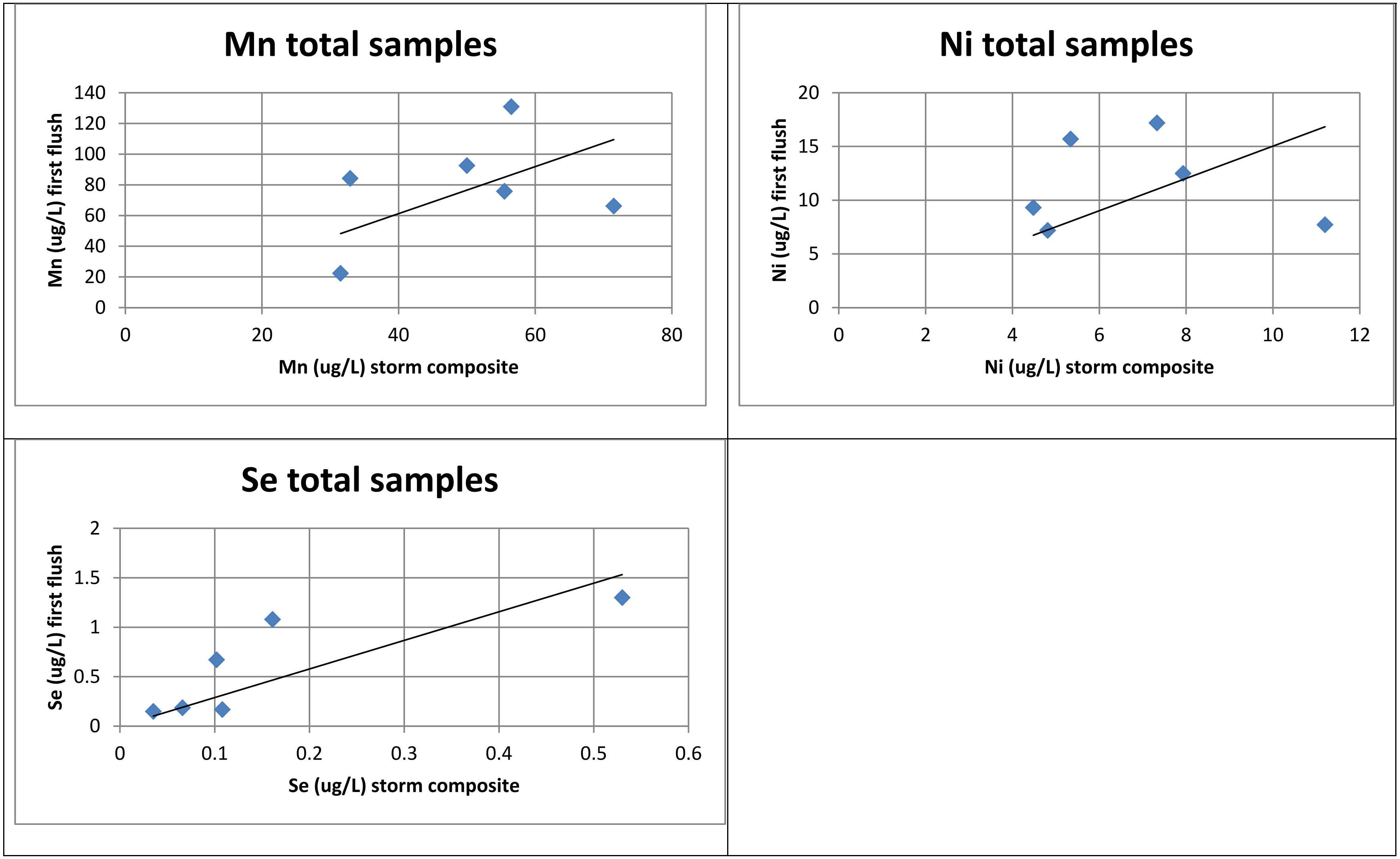
site	Sample Date	Cr comp	Cr ff	Cr comp/ff	Fe comp	Fe ff	Fe comp/ff	Mn comp	Mn ff	Mn comp/ff	Ni comp	Ni ff	Ni comp/ff
NAB-OF18	2/10/2005												
NAB-OF18	4/27/2005												
NAB-OF9	4/27/2005												
NAV-OF11	2/24/2003												
NAV-OF14	2/24/2003	1.2	0.8	1.49	69	31	2.20	25	35	0.72	2.2	5.3	0.42
NAV-OF14	10/26/2004	1.7	0.8	2.15	71	19	3.81	16	32	0.50	1.8	5.8	0.31
NAV-OF9	2/24/2003	10.0	2.2	4.50	25	26	0.95	13	29	0.45	1.7	3.7	0.45
NAV-PR5	2/24/2003	2.3	1.2	1.90	62	19	3.36	12	29	0.41	2.8	7.0	0.41
NAV-PR6	2/24/2003	1.1	1.3	0.86	18	23	0.77	6	14	0.41	1.9	5.2	0.36
NI-OF26	2/10/2005												
SUB-OF11B	2/2/2004												
SUB-OF23CE	2/2/2004												
SUB-OF26	2/2/2004												
	min	1.1	0.8	0.86	18	19	0.77	6	14	0.41	1.7	3.7	0.31
	max	10.0	2.2	4.50	71	31	3.81	25	35	0.72	2.8	7.0	0.45
	avg	3.3	1.3	2.18	49	24	2.22	14	28	0.50	2.1	5.4	0.39
	st dev	3.8	0.6	1.38	25	5	1.37	7	8	0.13	0.5	1.2	0.06
	COV	1.2	0.5	0.63	0.52	0.23	0.62	0.49	0.28	0.26	0.23	0.22	0.14
	number	5	5	5	5	5	5	5	5	5	5	5	5
	ratio comp/ff avg	2.58			2.08			0.52			0.39		
	P (paired T test)	0.12			0.05			<0.01			<0.01		

Filtered Sample Analyses of First Flush vs. Composite Event Concentrations (continued)

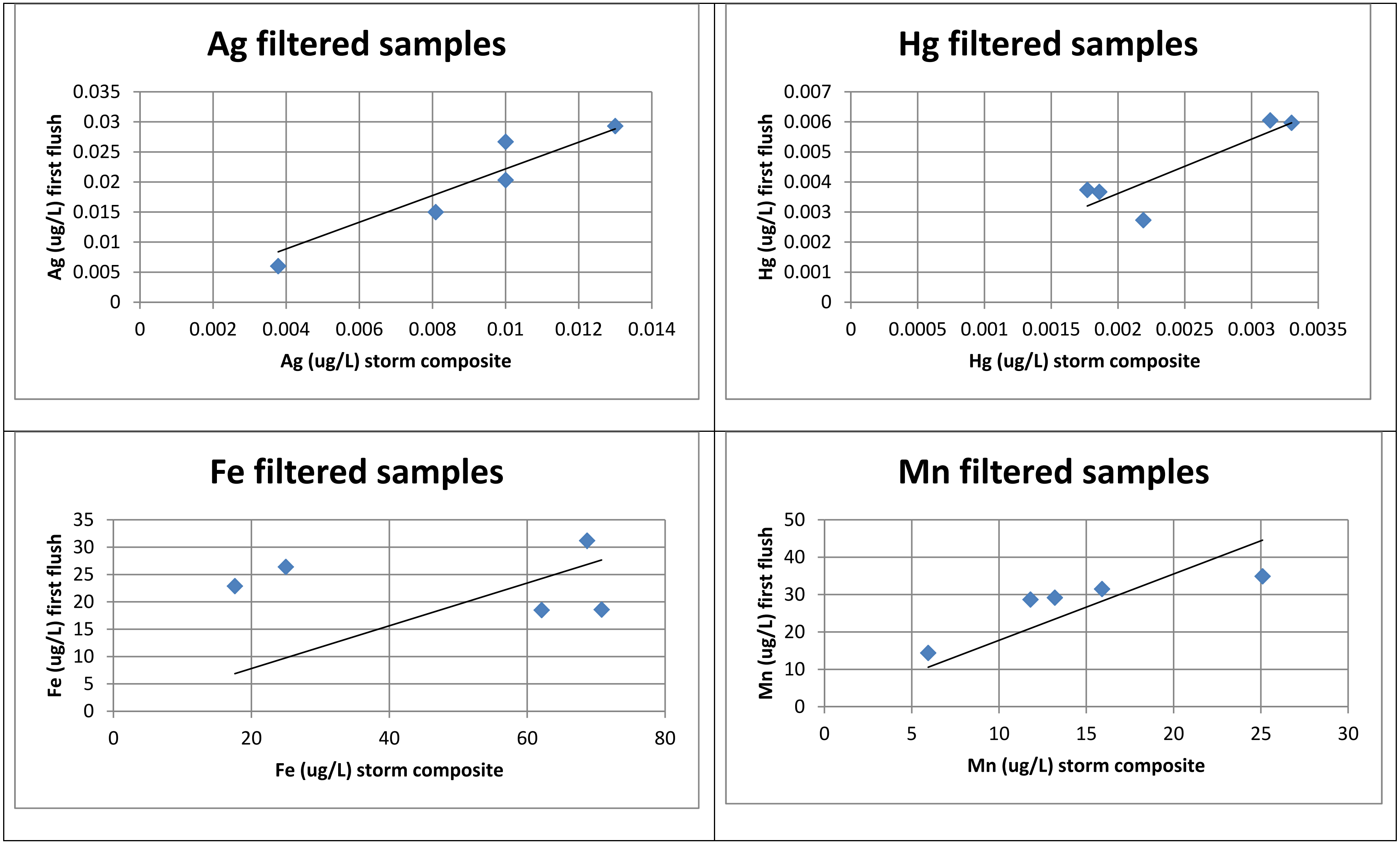
site	Sample Date	Se comp	Se ff	Se comp/ff	Sn comp	Sn ff	Sn comp/ff
NAB-OF18	2/10/2005						
NAB-OF18	4/27/2005						
NAB-OF9	4/27/2005						
NAV-OF11	2/24/2003						
NAV-OF14	2/24/2003	0.07	0.09	0.76	0.23	0.12	1.86
NAV-OF14	10/26/2004	0.04	0.09	0.40	0.12	0.09	1.31
NAV-OF9	2/24/2003	0.36	0.85	0.42	0.50	0.50	1.00
NAV-PR5	2/24/2003	0.04	0.13	0.27	0.27	0.17	1.61
NAV-PR6	2/24/2003	0.25	0.37	0.67	0.06	0.09	0.70
NI-OF26	2/10/2005						
SUB-OF11B	2/2/2004						
SUB-OF23CE	2/2/2004						
SUB-OF26	2/2/2004						
	min	0.04	0.09	0.27	0.06	0.09	0.70
	max	0.36	0.85	0.76	0.50	0.50	1.86
	avg	0.15	0.31	0.50	0.24	0.19	1.30
	st dev	0.15	0.32	0.20	0.17	0.17	0.46
	COV	0.98	1.06	0.41	0.72	0.90	0.36
	number	5	5	5	5	5	5
	ratio comp/ff avg	0.49			1.22		
	P (paired T test)	0.07			0.09		



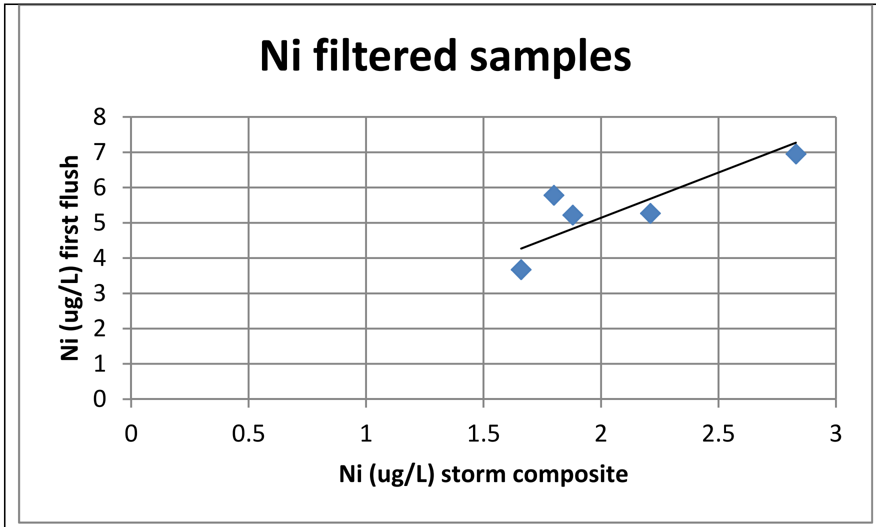
First flush vs. composite sample concentration comparisons (total samples).

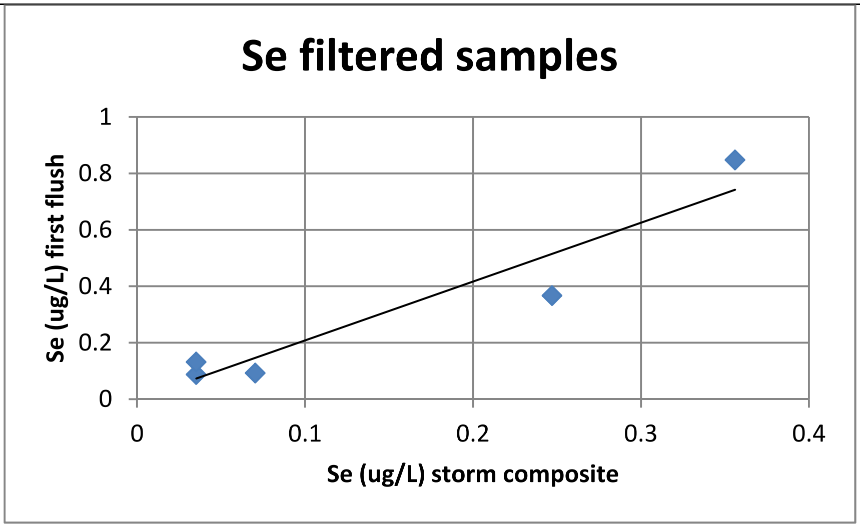


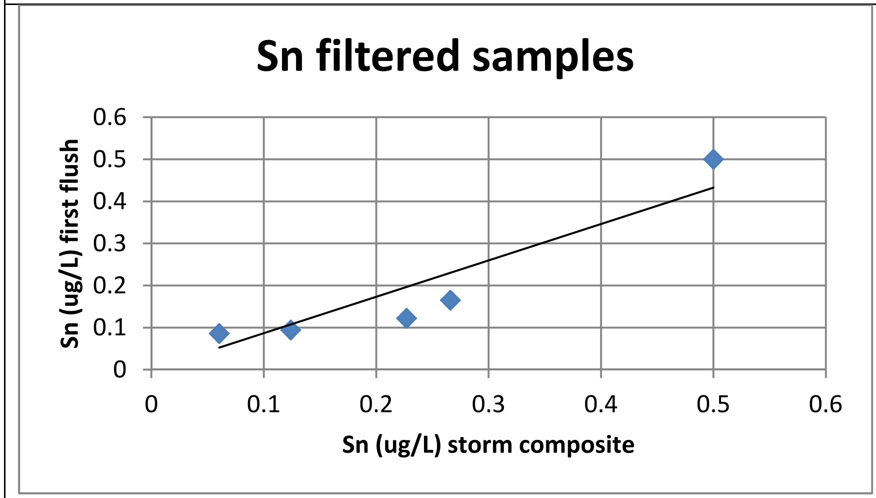
First flush vs. composite sample concentration comparisons (total samples) (continued).



First flush vs. composite sample concentration comparisons (filtered samples).







First flush vs. composite sample concentration comparisons (filtered samples) (continued).

Summary of Analytes in Total and Filtered San Diego Navy Samples having Significantly Different Concentrations

Analytes having significant differences between composite and first-flush concentrations	Average composite concentration	Average first flush concentration	Ratio of composite to first flush concentration ("conversion factor")	First flush to composite concentration factor ("enrichment factor")
Total Sample Results				
TSS (mg/L)	73	33	2.26	0.44
% survival	88	67	1.32	0.77
Arsenic (µg/L)	1.7	2.0	0.86	1.17
Cadmium (µg/L)	1.06	2.14	0.50	2.00
Manganese (µg/L)	50	79	0.63	1.59
Nickel (µg/L)	6.8	11.6	0.59	1.69
Selenium (µg/L)	0.17	0.59	0.58	1.72
Filtered Sample Results				
Silver (µg/L)	0.009	0.019	0.46	2.17
Mercury (µg/L)	0.0025	0.0044	0.55	1.82
Iron (µg/L)	49	24	2.08	0.48
Manganese (µg/L)	14	28	0.52	1.92
Selenium (µg/L)	0.15	0.31	0.49	2.04
Tin (µg/L)	0.24	0.19	1.22	0.82

* Only TSS, Cu, and Zn are being used in these modeling efforts; therefore only TSS first flush values will be adjusted using the conversion factor to convert to equivalent composite event TSS concentrations

The following analytes were tested in both composite and first-flush total samples, but did not have significantly different concentrations (due to too few data) and therefore do not require any conversion factors to be applied to the total sample first flush data: copper, zinc, silver, lead, mercury, aluminum, chromium, iron, and tin. The following analytes were tested in both composite and first-flush filtered samples, but did not have significantly different concentrations (due to too few data) and therefore do not require any conversion factors to be applied to the filtered sample first flush data: copper, zinc, lead, aluminum, arsenic, cadmium, and chromium. Therefore, not all analytes were found to be significantly different in the first flush vs. the composite Navy stormwater samples. Contrary to expectations, the TSS (along with the toxicity, the filtered iron, and the filtered tin) concentrations in the composite samples were significantly larger than in the first flush samples, indicating increasing concentrations as the storms continued.

Analytes that were found to have significantly different first flush vs. composite total sample concentrations at industrial sites (the most similar land use to the monitored Navy areas) from the NSQD included: COD, BOD_5, TDS, nitrates, TKN, copper, lead, and zinc. The Navy data only included metal analyses, but did not identify copper, lead, or zinc as having significantly different values in the first flush vs. the composite samples.

Analytes not having significant differences (due to too few data) at the industrial NSQD areas included: pH, TSS, ammonia, TN, TP, dissolved P, ortho-P, cadmium, chromium, and nickel. In contrast, the San Diego Navy samples found that cadmium concentrations in the unfiltered first flush samples were significantly different than for the composite samples.

The maximum enrichment ratio observed (first flush to composite concentration ratios) for the significantly different analytes was 2.2 for the Navy samples, similar to the maximum ratio observed from the significant NSQD industrial area analytes (1.5), both being much smaller than the first flush enrichment ratios usually assumed.

First Flush Stormwater Samples from Naval Air Station North Island (NASNI), Outfall 26 (naval air base)

Date Sampled	TSS (mg/L)	Copper (µg/L)	Zinc (µg/L)
1/10/1995	78	69	510
3/21/1995	7	14	62
1/25/1996	0	17	50
1/31/1996	115	54	113
4/3/1997	54	53.4	
3/11/1999	123		
2/12/2000	8		
4/17/2000	9		
10/27/2000	130	85.1	389
1/8/2001	28	50.2	185
11/29/2001	56	39.5	411
12/14/2001	6	0	23.2
3/15/2003	13	44	240
4/1/2004	23	26	130
4/17/2004	380	230	1500
1/28/2005	42	19	68
2/11/2005	180	38	280
10/17/2005	77	110	520
3/10/2006	130	66	330
12/27/2006	11	24	75
4/20/2007	120	170	1000
2/14/2008	140	48	440
11/4/2008	18	39	180
12/15/2008	230	51	310
12/7/2009	120	71	510
1/18/2010	590	140	820
average	103	63	370
minimum	0	0	23
maximum	590	230	1500
st dev	132	54	356
COV	1.27	0.85	0.96
count	26	23	22

First Flush Stormwater Samples from Naval Base San Diego (NAV/NBSD), Outfall 14 (mixed industrial activities)

Date Sampled	TSS (mg/L)	Copper (µg/L)	Zinc (µg/L)
2/17/1994	220	88	390
3/5/1995	20	8.2	140
4/18/1995	22	14	68
1/21/1996	37		
2/21/1996		47	220
3/13/1996	87	43	196
12/9/1996	106	40	170
1/15/1997		33.7	173
11/26/1997	63	72	
1/9/1998	32	29	
11/8/1998	2	20	
2/4/1999	41	30	
2/10/2000	96	96.2	
4/17/2000	33	18.9	
1/8/2001	75	143	1490
1/24/2001	36	74.2	1060
11/24/2001	20	53.7	813
4/24/2002	196	206	3700
3/15/2003	80	12	100
2/18/2004	67	32	550
4/17/2004	240	92	1200
1/28/2005	18	11	45
2/11/2005	25	16	160
10/17/2005	160	180	2300
3/10/2006	38	19	310
12/27/2006	27	38	190
4/20/2007	66	350	3600
2/14/2008	41	100	600
11/4/2008	29	68	450
12/15/2008	97		
12/7/2009	48	42	540
1/18/2010	290	88	530
average	77	69	791
minimum	2	8	45
maximum	290	350	3700
st dev	73	72	1027
COV	0.95	1.05	1.30
count	30	30	24

First Flush Stormwater Samples from Naval Base San Diego (NAV/NBSD), Piers, Point Loma, Outfall 1 (ceremonial pier)

Date Sampled	TSS (mg/L)	Copper (µg/L)	Zinc (µg/L)
10/27/2000	40	80.1	233
1/8/2001	72	235	1040
11/24/2001	57	39.8	80.7
4/24/2002	64	68.5	202
3/15/2003	49	130	360
4/1/2004	120	50	450
4/17/2004	910	260	720
1/28/2005	44	62	2200
2/10/2005	60	39	1500
10/17/2005	550	170	1800
4/14/2006	400	110	1300
12/27/2006	27	220	1700
4/20/2007	180	330	2300
2/14/2008	160	65	930
11/4/2008	180	230	800
	40		
12/7/2009	110	48	240
1/18/2010	220	200	1200
average	182	137	1003
minimum	27	39	81
maximum	910	330	2300
st dev	228	92	713
COV	1.25	0.67	0.71
count	18	17	17

First Flush Stormwater Samples from Naval Base San Diego (NAV/NBSD), Piers, Point Loma, Outfall 13 (heavy industrial pier)

Date Sampled	TSS (mg/L)	Copper (µg/L)	Zinc (µg/L)
10/27/2000	149	320	1790
1/24/2001	17	234	642
11/24/2001	184	151	478
4/24/2002	460	195	470
3/15/2003	35	460	950
2/18/2004	650	120	360
4/17/2004	51	93	340
1/28/2005	95	140	680
2/10/2005	190	200	1400
10/17/2005	400	860	3900
3/10/2006	820	390	1600
12/27/2006	50	150	310
4/20/2007	320	180	550
2/14/2008	250	250	670
11/4/2008	240	1300	4200
12/15/2008	97		
12/7/2009	52	60	310
1/18/2010	250	710	5800
average	239	342	1438
minimum	17	60	310
maximum	820	1300	5800
st dev	222	329	1629
COV	0.93	0.96	1.13
count	18	17	17

First Flush Stormwater Samples from Naval Amphibious Base (NAB), Outfall 9

Date Sampled	TSS (mg/L)	Copper (µg/L)	Zinc (µg/L)
1/31/1996	740	61	1060
2/21/1996	76	212	5450
1/15/1997	353	137	5590
2/10/1997	934	284	3260
11/13/1997	10	53	837
12/6/1997	10	40	660
1/25/1999	40	103	462
3/11/1999	63	390	3310
2/12/2000	12	369	1860
4/17/2000	17	73.2	588
10/27/2000	75	25.4	180
1/8/2001	20	505	3320
11/24/2001	4	95.8	673
12/14/2001	0	63.3	378
3/15/2003	19	140	1300
4/1/2004	250	290	4400
4/17/2004	110	440	5600
1/28/2005	9.6	29	230
2/10/2005	16	20	310
11/4/2008			
2/14/2008			
12/7/2009	110	71	770
1/18/2010	16	22	220
average	137	163	1927
minimum	0	20	180
maximum	934	505	5600
st dev	250	154	1946
COV	1.82	0.94	1.01
count	21	21	21

Appendix C: Dissolved Constituent Concentrations

An important characteristic affecting stormwater treatability and the fate of the stormwater pollutants is the fraction of the pollutants that are particulate-bound vs. filterable. The following tables show the available data for the samples analyzed for both total forms and filterable forms of the heavy metals from the San Diego navy facilities. Thirteen samples are available for copper and zinc, while six samples are available for the other metals (silver, lead, mercury, aluminum, arsenic, cadmium, chromium, iron, manganese, nickel, selenium, and tin). Three samples were taken at the Naval Amphibious Base (NAB), six from the Naval Base San Diego (NAV), one from North Island (NI) and three from the Sub Base (SUB). The table lists the observed concentrations, separated by full storm composite (filtered and total sample) and first flush (filtered and total sample). Another column also shows the calculated percentage of the metal associated with the filtered sample. Summary statistics are also shown along with probability values comparing some of the paired sets of data (using a basic paired Student's T-test). Yellow high-lighted values indicate probability values that are 0.05 or less, indicating a likely significant difference in the comparison test.

Filterable Fraction of San Diego Naval Facility Stormwater Samples

site	Sample Date	Cu comp d	Cu comp t	Cu comp % diss	Cu ff d	Cu ff t	Cu ff % diss	Zn comp d	Zn comp t	Zn comp % diss	Zn ff d	Zn ff t	Zn ff % diss
NAB-OF18	2/10/2005	26.2	44.4	59.0	38.2	43.7	87.5	101	214	47	134	137	98
NAB-OF18	4/27/2005	31.2	108.0	28.9	31.8	67.1	47.5	149	752	20	313	601	52
NAB-OF9	4/27/2005	37.8	108.0	35.0	17.6	33.3	52.9	709	1832	39	308	519	59
NAV-OF11	2/24/2003	15.1	46.9	32.2	33.9	68.4	49.6	179	298	60	393	555	71
NAV-OF14	2/24/2003	7.2	28.9	25.0	22.1	72.6	30.4	110	200	55	310	797	39
NAV-OF14	10/26/2004	9.9	38.0	26.0	18.9	45.3	41.7	68	220	31	175	362	48
NAV-OF9	2/24/2003	9.9	36.1	27.4	25.8	54.2	47.6	112	233	48	218	433	50
NAV-PR5	2/24/2003	14.2	104.0	13.7	69.4	84.7	81.9	81	391	21	458	521	88
NAV-PR6	2/24/2003	33.0	66.2	49.8	177.0	183.0	96.7	78	249	31	288	314	92
NI-OF26	2/10/2005	29.1	41.0	71.0	22.2	33.4	66.4	37	87	42	101	129	79
SUB-OF11B	2/2/2004	15.2	24.9	61.0	15.1	20.4	73.8	37	123	30	59	130	45
SUB-OF23CE	2/2/2004	18.0	37.3	48.3	16.8	27.1	62.1	505	792	64	679	967	70
SUB-OF26	2/2/2004	122.8	194.8	63.0	27.9	94.1	29.7	338	477	71	104	384	27
average		28.4	67.6	41.6	39.8	63.6	59.1	192.7	451.4	43.0	272.3	450.0	63.0
minimum		7.2	24.9	13.7	15.1	20.4	29.7	36.6	87.3	19.8	59.3	128.9	27.1
maximum		122.8	194.8	71.0	177.0	183.0	96.7	709.0	1832.0	70.9	679.2	966.7	97.7
st dev		30.03	48.78	18.05	43.62	42.42	21.24	203.85	469.26	16.28	171.63	252.45	21.77
COV		1.06	0.72	0.43	1.10	0.67	0.36	1.06	1.04	0.38	0.63	0.56	0.35
count		13	13	13	13	13	13	13	13	13	13	13	13
P that diss not = total		0.00*			0.00			0.00			0.00		
P that comp % diss not = ff % diss		0.01			n/a			0.02			n/a		
P that comp d not = ff d		0.22			n/a			0.09			n/a		
P that comp t not = ff t		0.40			n/a			0.50			n/a		

* yellow high-lighted values are probability values <0.05 indicating statistical significance for the comparison (paired Student's T-test).

Note:

comp = composite whole event sample; ff = first flush sample taken at the beginning of the event; d = dissolved (filtered) sample portion; t = total sample analysis

Filterable Fraction of San Diego Naval Facility Stormwater Samples (continued)

site	Sample Date	Ag comp d	Ag comp t	Ag comp % diss	Ag ff d	Ag ff t	Ag ff % diss	Pb comp d	Pb comp t	Pb comp % diss	Pb ff d	Pb ff t	Pb ff % diss
NAV-OF11	2/24/2003	0.013	0.107	12.1	0.029303	0.175	16.7	0.247	14.1	1.8	0.541	22.4	2.4
NAV-OF14	2/24/2003	0.01	0.068	14.7	0.026701	0.229	11.7	0.33	15	2.2	0.916	43.8	2.1
NAV-OF14	10/26/2004	0.00378	0.0632	6.0	0.00601	0.0741	8.1	0.441	21.6	2.0	0.493	21.7	2.3
NAV-OF9	2/24/2003	0.01	0.185	5.4	0.020328	0.168	12.1	0.156	15.9	1.0	0.369	22.7	1.6
NAV-PR5	2/24/2003	0.00809	0.247	3.3	0.015	0.192	7.8	0.533	23.4	2.3	11.8	20.5	57.6
NAV-PR6	2/24/2003	0.0119	0.132	9.0	0.0266	0.0522	51.0	0.281	14.6	1.9	0.879	4.06	21.7
average		0.0	0.1	8.4	0.0	0.1	17.9	0.3	17.4	1.9	2.5	22.5	14.6
minimum		0.0	0.1	3.3	0.0	0.1	7.8	0.2	14.1	1.0	0.4	4.1	1.6
maximum		0.0	0.2	14.7	0.0	0.2	51.0	0.5	23.4	2.3	11.8	43.8	57.6
st dev		0.00	0.07	4.37	0.01	0.07	16.52	0.14	4.01	0.47	4.56	12.64	22.45
COV		0.34	0.53	0.52	0.43	0.47	0.92	0.41	0.23	0.25	1.82	0.56	1.54
count		6	6	6	6	6	6	6	6	6	6	6	6
P that diss not = total		0.00			0.00			0.00			0.01		
P that comp % diss not = ff % diss		0.11			n/a			0.11			n/a		
P that comp d not = ff d		0.00			n/a			0.14			n/a		
P that comp t not = ff t		0.35			n/a			0.20			n/a		

Filterable Fraction of San Diego Naval Facility Stormwater Samples (continued)

site	Sample Date	Hg comp d	Hg comp t	Hg comp % diss	Hg ff d	Hg ff t	Hg ff % diss	Al comp d	Al comp t	Al comp % diss	Al ff d	Al ff t	Al ff % diss
NAV-OF11	2/24/2003	0.00314	0.0541	5.8	0.00605	0.0508	11.9	18.7	777	2.4	18	1690	1.1
NAV-OF14	2/24/2003	0.00177	0.0314	5.6	0.00374	0.0536	7.0	39.9	1270	3.1	10.5	2640	0.4
NAV-OF14	10/26/2004	0.0033	0.0694	4.8	0.00597	0.0629	9.5	17.7	2618	0.7	14.7	1322	1.1
NAV-OF9	2/24/2003	0.00186	0.0151	12.3	0.00367	0.0173	21.2	8.25	1050	0.8	16.6	1840	0.9
NAV-PR5	2/24/2003	0.00219	0.0213	10.3	0.00273	0.00555	49.2	15.1	1025	1.5	39.6	320	12.4
NAV-PR6	2/24/2003	0.00412	0.0189	21.8	0.0133	0.0188	70.7	32.2	722	4.5	30.4	179	17.0
average		0.0	0.0	10.1	0.0	0.0	28.3	22.0	1243.7	2.2	21.6	1331.8	5.5
minimum		0.0	0.0	4.8	0.0	0.0	7.0	8.3	722.0	0.7	10.5	179.0	0.4
maximum		0.0	0.1	21.8	0.0	0.1	70.7	39.9	2618.0	4.5	39.6	2640.0	17.0
st dev		0.00	0.02	6.46	0.00	0.02	25.94	11.75	702.10	1.47	11.05	943.48	7.28
COV		0.34	0.63	0.64	0.65	0.68	0.92	0.53	0.56	0.68	0.51	0.71	1.33
count		6	6	6	6	6	6	6	6	6	6	6	6
P that diss not = total		0.01			0.02			0.00			0.01		
P that comp % diss not = ff % diss		0.04			n/a			0.14			n/a		
P that comp d not = ff d		0.03			n/a			0.48			n/a		
P that comp t not = ff t		0.48			n/a			0.42			n/a		

Filterable Fraction of San Diego Naval Facility Stormwater Samples (continued)

site	Sample Date	As comp d	As comp t	As comp % diss	As ff d	As ff t	As ff % diss	Cd comp d	Cd comp t	Cd comp % diss	Cd ff d	Cd ff t	Cd ff % diss
NAV-OF11	2/24/2003	0.814	1.33	61.2	0.366	1.18	31.0	0.669	0.776	86.2	0.756	1.23	61.5
NAV-OF14	2/24/2003	1.24	2.02	61.4	0.781	2.92	26.7	0.533	0.673	79.2	0.983	2.59	38.0
NAV-OF14	10/26/2004	1.72	2.39	72.0	2.04	3.2	63.8	0.244	0.871	28.0	0.492	1.18	41.7
NAV-OF9	2/24/2003	0.82	1.42	57.7	0.69542	1.58	44.0	0.386	0.659	58.6	0.388	0.987	39.3
NAV-PR5	2/24/2003	1.18	1.78	66.3	1.23	1.49	82.6	0.303	2.27	13.3	4.97	5.49	90.5
NAV-PR6	2/24/2003	1.04	1.36	76.5	1.41	1.66	84.9	0.265	1.12	23.7	1.23	1.37	89.8
average		1.1	1.7	65.8	1.1	2.0	55.5	0.4	1.1	48.2	1.5	2.1	60.1
minimum		0.8	1.3	57.7	0.4	1.2	26.7	0.2	0.7	13.3	0.4	1.0	38.0
maximum		1.7	2.4	76.5	2.0	3.2	84.9	0.7	2.3	86.2	5.0	5.5	90.5
st dev		0.34	0.43	7.18	0.60	0.84	25.40	0.17	0.62	30.78	1.74	1.74	24.78
COV		0.30	0.25	0.11	0.55	0.42	0.46	0.42	0.58	0.64	1.19	0.81	0.41
count		6	6	6	6	6	6	6	6	6	6	6	6
P that diss not = total		0.00			0.01			0.03			0.01		
P that comp % diss not = ff % diss		0.13			n/a			0.29			n/a		
P that comp d not = ff d		0.38			n/a			0.10			n/a		
P that comp t not = ff t		0.10			n/a			0.04			n/a		

Filterable Fraction of San Diego Naval Facility Stormwater Samples (continued)

site	Sample Date	Cr comp d	Cr comp t	Cr comp % diss	Cr ff d	Cf ff t	Cr ff % diss	Fe comp d	Fe comp t	Fe comp % diss	Fe ff d	Fe ff t	Fe ff % diss
NAV-OF11	2/24/2003	1.2	4.7	25.5	0.803	5.55	14.5	68.7	1390	4.9	31.2	2250	1.4
NAV-OF14	2/24/2003	1.73	7.24	23.9	0.804	13.7	5.9	70.8	1870	3.8	18.6	3940	0.5
NAV-OF14	10/26/2004	9.99	12.9	77.4	2.22	6.93	32.0	25	4481	0.6	26.4	2138	1.2
NAV-OF9	2/24/2003	2.32	8.56	27.1	1.22	6.56	18.6	62.1	1610	3.9	18.5	2390	0.8
NAV-PR5	2/24/2003	1.12	7.19	15.6	1.3	3.33	39.0	17.6	1417	1.2	22.9	515	4.4
NAV-PR6	2/24/2003	1.69	6.67	25.3	3.58	4.24	84.4	27.5	1149	2.4	161	426	37.8
average		3.0	7.9	32.5	1.7	6.7	32.4	45.3	1986.2	2.8	46.4	1943.2	7.7
minimum		1.1	4.7	15.6	0.8	3.3	5.9	17.6	1149.0	0.6	18.5	426.0	0.5
maximum		10.0	12.9	77.4	3.6	13.7	84.4	70.8	4481.0	4.9	161.0	3940.0	37.8
st dev		3.45	2.76	22.40	1.08	3.68	28.17	24.40	1245.74	1.69	56.33	1316.10	14.82
COV		1.15	0.35	0.69	0.65	0.55	0.87	0.54	0.63	0.60	1.21	0.68	1.93
count		6	6	6	6	6	6	6	6	6	6	6	6
P that diss not = total		0.00			0.02			0.01			0.01		
P that comp % diss not = ff % diss		0.50			n/a			0.23			n/a		
P that comp d not = ff d		0.18			n/a			0.48			n/a		
P that comp t not = ff t		0.27			n/a			0.47			n/a		

Filterable Fraction of San Diego Naval Facility Stormwater Samples (continued)

site	Sample Date	Mn comp d	Mn comp t	Mn comp % diss	Mn ff d	Mn ff t	Mn ff % diss	Ni comp d	Ni comp t	Ni comp % doss	Ni ff d	Ni ff t	Ni ff % diss
NAV-OF11	2/24/2003	25.1	55.5	45.2	34.9	75.8	46.0	2.21	4.48	49.3	5.27	9.32	56.5
NAV-OF14	2/24/2003	15.9	56.5	28.1	31.5	131	24.0	1.8	5.34	33.7	5.78	15.7	36.8
NAV-OF14	10/26/2004	13.2	71.5	18.5	29.2	66.2	44.1	1.66	4.81	34.5	3.67	7.19	51.0
NAV-OF9	2/24/2003	11.8	50	23.6	28.7	92.6	31.0	2.83	7.93	35.7	6.95	12.5	55.6
NAV-PR5	2/24/2003	5.94	31.5	18.9	14.4	22.4	64.3	1.88	11.2	16.8	5.22	7.72	67.6
NAV-PR6	2/24/2003	14.1	32.9	42.9	81.5	84.2	96.8	4.11	7.33	56.1	17.2	17.2	100.0
average		14.3	49.7	29.5	36.7	78.7	51.0	2.4	6.8	37.7	7.3	11.6	61.3
minimum		5.9	31.5	18.5	14.4	22.4	24.0	1.7	4.5	16.8	3.7	7.2	36.8
maximum		25.1	71.5	45.2	81.5	131.0	96.8	4.1	11.2	56.1	17.2	17.2	100.0
st dev		6.27	15.29	11.81	23.04	35.48	26.35	0.93	2.54	13.71	4.94	4.21	21.44
COV		0.44	0.31	0.40	0.63	0.45	0.52	0.38	0.37	0.36	0.67	0.36	0.35
count		6	6	6	6	6	6	6	6	6	6	6	6
P that diss not = total		0.00			0.02			0.00			0.01		
P that comp % diss not = ff % diss		0.04			n/a			0.02			n/a		
P that comp d not = ff d		0.03			n/a			0.02			n/a		
P that comp t not = ff t		0.04			n/a			0.04			n/a		

Filterable Fraction of San Diego Naval Facility Stormwater Samples (continued)

site	Sample Date	Se comp d	Se comp t	Se comp % diss	Se ff d	Se ff t	Se ff % diss	Sn comp d	Sn comp t	Sn comp % diss	Sn ff d	Sn ff t	Sn ff % diss
NAV-OF11	2/24/2003	0.0703	0.108	65.1	0.0927	0.169	54.9	0.227	0.872	26.0	0.122	0.924	13.2
NAV-OF14	2/24/2003	0.0352	0.0352	100.0	0.0873	0.149	58.6	0.124	0.945	13.1	0.0945	1.44	6.6
NAV-OF14	10/26/2004	0.356	0.53	67.2	0.848	1.3	65.2	0.5	0.536	93.3	0.5	0.663	75.4
NAV-OF9	2/24/2003	0.0352	0.066	53.3	0.132	0.187	70.6	0.266	1.12	23.8	0.165	1	16.5
NAV-PR5	2/24/2003	0.247	0.102	242.2	0.367	0.671	54.7	0.0603	1.13	5.3	0.0859	0.715	12.0
NAV-PR6	2/24/2003	0.257	0.161	159.6	1.33	1.08	123.1	0.101	0.816	12.4	0.289	0.205	141.0
average		0.2	0.2	114.6	0.5	0.6	71.2	0.2	0.9	29.0	0.2	0.8	44.1
minimum		0.0	0.0	53.3	0.1	0.1	54.7	0.1	0.5	5.3	0.1	0.2	6.6
maximum		0.4	0.5	242.2	1.3	1.3	123.1	0.5	1.1	93.3	0.5	1.4	141.0
st dev		0.14	0.18	73.44	0.51	0.51	26.20	0.16	0.22	32.43	0.16	0.41	53.89
COV		0.82	1.09	0.64	1.07	0.86	0.37	0.75	0.24	1.12	0.77	0.50	1.22
count		6	6	6	6	6	6	6	6	6	6	6	6
P that diss not = total		0.50			0.14			0.00			0.02		
P that comp % diss not = ff % diss		0.10			n/a			0.27			n/a		
P that comp d not = ff d		0.06			n/a			0.47			n/a		
P that comp t not = ff t		0.02			n/a			0.32			n/a		

The first row of probability values compares the dissolved (filtered) concentrations with the corresponding total sample concentrations. All analytes (both total event and first flush samples) had significant differences in these paired values, except for selenium. Neither composite nor first flush samples had significant fractions that were filterable for selenium; the filterable fraction was high for all samples, with some filtered concentrations even being greater than the unfiltered (total) sample concentrations. This can occur when an analyte concentration is close to the detection limit and the analytical results are more uncertain than normal, especially for compounds that have small differences between the two paired sets of data (large filterable fraction).

The second row of probability values compares the paired calculated percentage filtered values for the composite samples vs. the first flush samples. The following analytes had significantly different filterable fractions for the two sample sets: first flush samples had larger filterable fraction than composite samples (preferential washoff of “dissolved” pollutants at the beginning of the storm event): copper, zinc, manganese, mercury, and nickel. No analyte had a significant difference with the composite sample fraction greater than the first flush fraction.

The third and fourth rows of probability values are comparisons of the composite vs. first-flush samples for the filterable fraction and the total storm composite fraction (similar to the earlier analyses on first flush effects, but these are for samples also obtained at other locations than the five being studied).

- Samples having significant differences between filterable composite and filterable first-flush samples: silver, mercury, manganese, and nickel.
- Samples having significant differences between unfiltered (total sample) composite and unfiltered first-flush samples: cadmium, manganese, nickel, and selenium.

Copper and zinc, the metals of interest in this analysis, do not have significant differences observed between the composite and first-flush concentrations for their filtered fractions.

Appendix D: Observed and Modeled Stormwater Concentrations for the San Diego Naval Facilities

Observed and Modeled TSS Concentrations

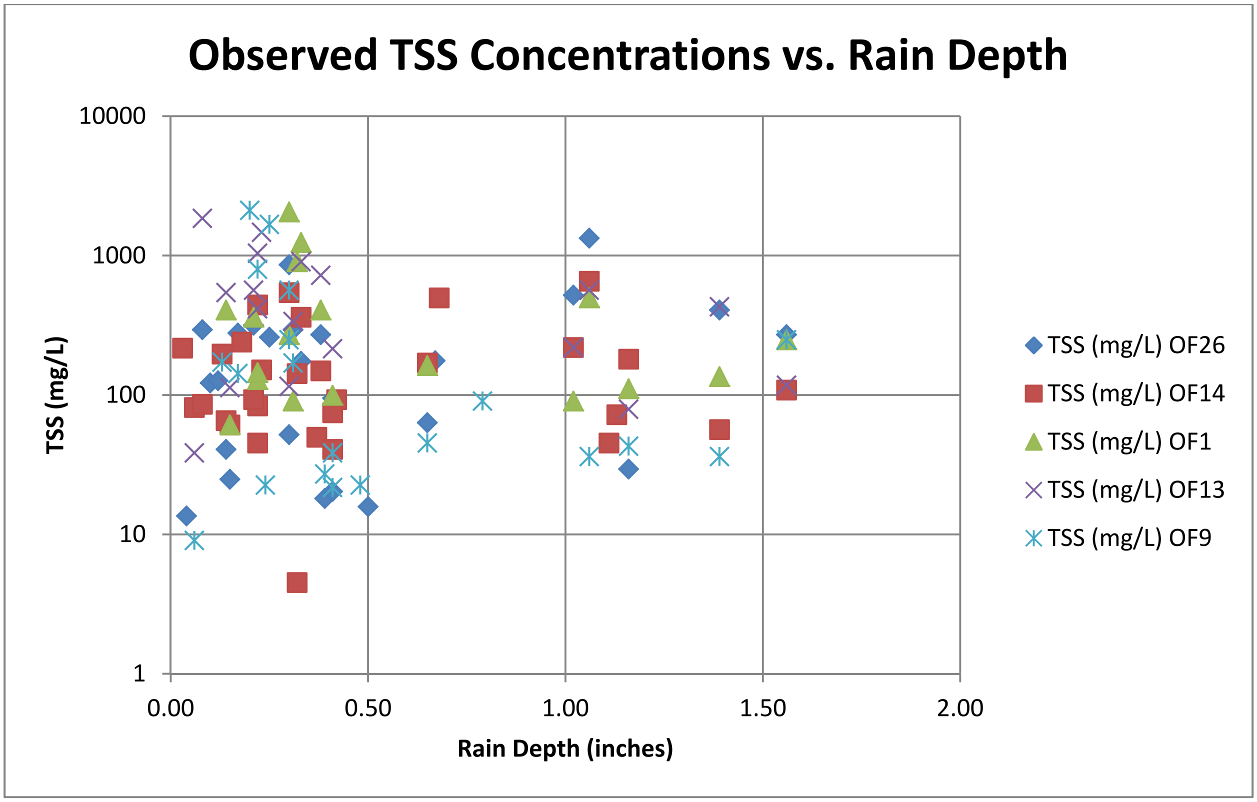
The following table summarizes the observed TSS concentrations for each of the monitored events at each of the monitoring locations. Also shown on this table are the likely rainfall characteristics for each of these monitored events, as measured at the San Diego airport.

Observed TSS Concentrations (adjusted)

Date Sampled	rain depth (in)	rain duration (hrs)	peak rain hourly intensity (in/hr)	antecedent dry period (days)	TSS (mg/L) OF26	TSS (mg/L) OF14	TSS (mg/L) OF1	TSS (mg/L) OF13	TSS (mg/L) OF9
2/17/1994	0.68	10.00	0.07	5.92		497			
1/10/1995	0.67	9.00	0.07	2.33	176				
3/5/1995	1.11	30.00	0.04	0.92		45			
3/21/1995	0.50	7.00	0.07	9.33	16				
4/18/1995	0.37	10.00	0.04	1.46		50			
1/21/1996	0.22	2.00	0.11	2.38		84			
1/25/1996	0.06	5.00	0.01	3.13					
1/31/1996	0.25	8.00	0.03	2.67	260				1672
2/21/1996	0.13	15.00	0.01	8.33					172
3/13/1996	0.13	3.00	0.04	0.50		197			
12/9/1996	0.18	6.00	0.03	17.33		240			
1/15/1997	0.22	8.00	0.03	2.46					798
2/10/1997	0.20	3.00	0.07	14.42					2111
4/3/1997	0.10	2.00	0.05	1.13	122				
11/13/1997	0.48	14.00	0.03	1.33					23
11/26/1997	0.32	2.00	0.16	12.67		142			
12/6/1997	0.24	7.00	0.03	5.54					23
1/9/1998	1.13	25.00	0.05	4.58		72			
11/8/1998	0.32	8.00	0.04	9.13		5			
1/25/1999	0.79	25.00	0.03	3.83					90
2/4/1999	0.42	14.00	0.03	3.71		93			
3/11/1999	0.17	2.00	0.09	4.04	278				142
2/10/2000	0.03	2.00	0.02	4.67		217			
2/12/2000	0.39	7.00	0.06	1.00	18				27
4/17/2000	0.41	4.00	0.10	2.42	20	75			38
10/27/2000	0.31	4.00	0.08	0.29	294		90	337	170
1/8/2001	0.65	18.00	0.04	27.00	63	170	163		45
1/24/2001	0.06	5.00	0.01	11.71		81		38	9

11/24/2001	0.22	2.00	0.11	11.79		45	129	416	
11/29/2001	0.12	4.00	0.03	4.97	127				
12/14/2001	0.04	1.00	0.04	3.83	14				
4/24/2002	0.22	4.00	0.06	7.08		443	145	1040	
3/15/2003	1.16	17.00	0.07	10.46	29	181	111	79	43
2/18/2004	0.23	4.00	0.06	4.08		151		1469	
4/1/2004	0.30	6.00	0.05	6.25	52		271		565
4/17/2004	0.30	3.00	0.10	15.46	859	542	2057	115	249
1/28/2005	0.41	4.00	0.10	1.58	95	41	99	215	22
2/10/2005	1.39	35.00	0.04	3.21	407	57	136	429	36
10/17/2005	0.33	3.00	0.11	1.25	174	362	1243	904	
3/10/2006	0.08	2.00	0.04	3.04	294	86		1853	
4/14/2006	0.32	23.00	0.01	8.92			904		
12/27/2006	0.15	2.00	0.08	4.92	25	61	61	113	
4/20/2007	0.38	12.00	0.03	28.75	271	149	407	723	
2/14/2008	0.21	8.00	0.03	10.29	316	93	362	565	
11/4/2008	0.14	3.00	0.05	30.54	41	66	407	542	
12/15/2008	1.02	17.00	0.06	0.38	520	219	90	219	
12/7/2009	1.56	14.00	0.11	8.33	271	108	249	118	249
1/18/2010	1.06	3.00	0.35	0.63	1333	655	497	565	36
				count:	25	30	18	18	20
				average	243	174	412	541	326
				median	174	101	206	423	68
				st dev	299	165	515	502	576
				COV	1.2	0.9	1.2	0.9	1.8
				min	14	5	61	38	9
				max	1333	655	2057	1853	2111

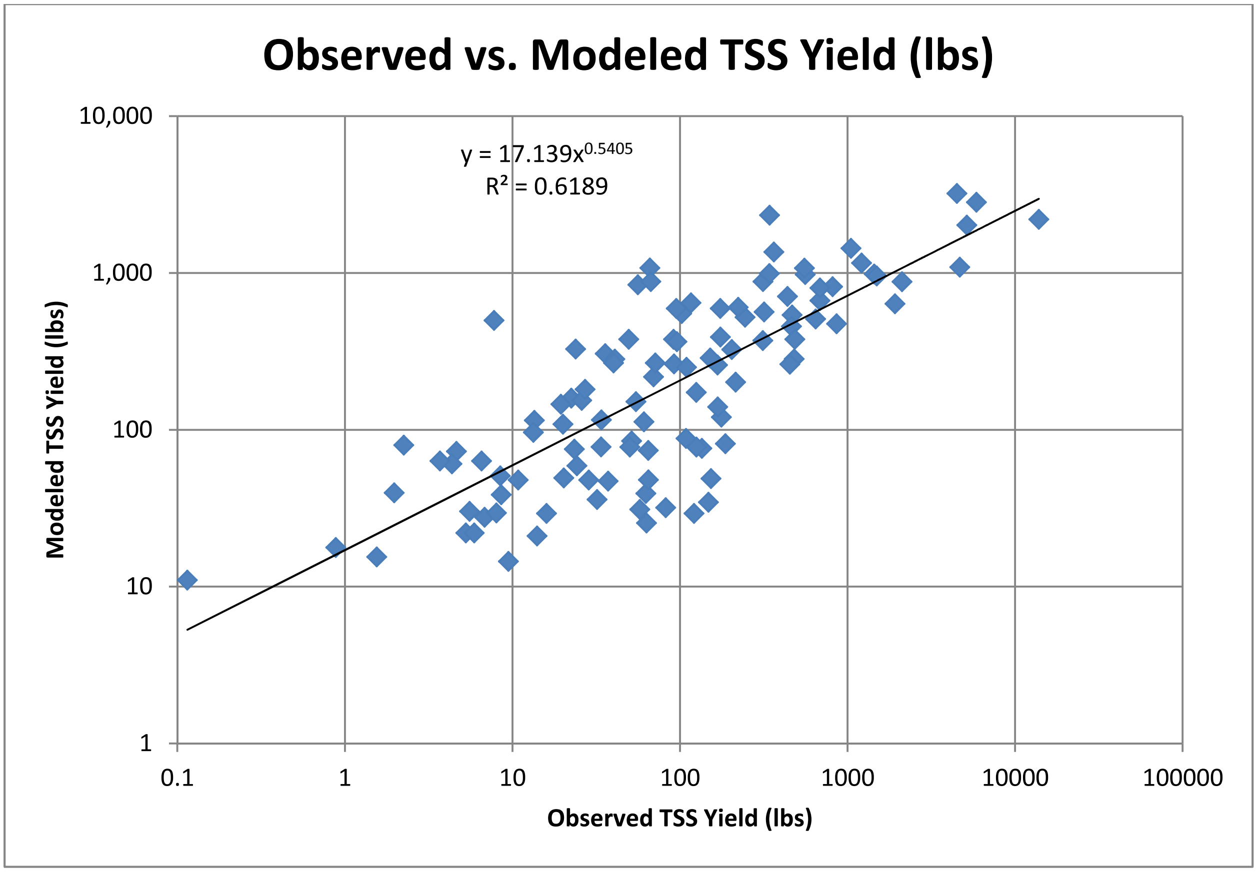
The following scatterplot displays all of the observed TSS concentrations vs. rainfall depth.



In addition to the scatterplots of concentrations vs. rain depth, statistical tests were conducted for each site to determine the significance of possible relationships of the observed concentrations with the rain characteristics. The first step was to conduct a regression analysis, with ANOVA and residual analyses comparing the concentrations as a function of rain depth. For the TSS data (and for the following Cu and Zn data also), none of the slope coefficients, nor the overall equations, were significant at the $p<0.05$ level. Further analyses were conducted using full-factorial tests for each site examining rain depth, interevent length, and their interactions. No data at any of the sites indicated any significant effects of these rain characteristics on TSS concentrations (and for Cu and Zn data also). The following table summarizes the observed and modeled average TSS concentrations and loads for each of the five San Diego naval facility sites.

	TSS observed average (mg/L)	TSS modeled average (mg/L)	TSS observed total yield (lbs)	TSS modeled total yield (lbs)
OF26	243	289	37,200	25,300
OF14	174	315	17,100	17,200
OF1	412	437	736	783
OF13	541	554	2340	2443
OF9	326	422	848	1530

The following figure is a scatterplot showing the observed and modeled yields (using the modeled runoff volumes for both sets of data as observed runoff volumes were available) for each of the events for all of the sites.



The following sections of this appendix present similar data and analyses for copper and zinc.

Observed and Modeled Copper Concentrations

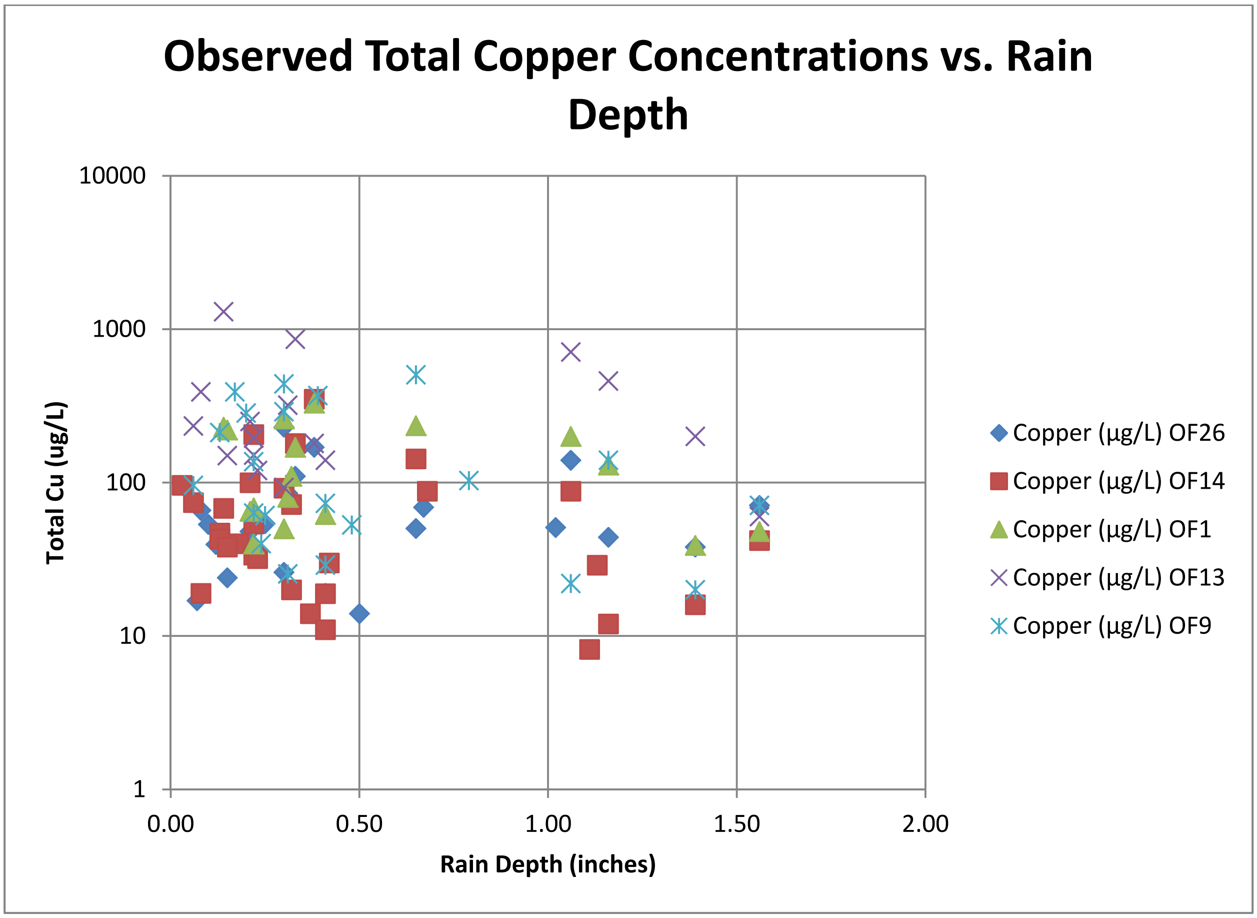
Observed Total Copper Concentrations (adjusted)*

Date Sampled	rain depth (in)	rain duration (hrs)	peak rain hourly intensity (in/hr)	antecedent dry period (days)	Copper (µg/L) OF26	Copper (µg/L) OF14	Copper (µg/L) OF1	Copper (µg/L) OF13	Copper (µg/L) OF9
2/17/1994	0.68	10.00	0.07	5.92		88			
1/10/1995	0.67	9.00	0.07	2.33	69				
3/5/1995	1.11	30.00	0.04	0.92		8			
3/21/1995	0.50	7.00	0.07	9.33	14				

4/18/1995	0.37	10.00	0.04	1.46		14			
1/21/1996	0.22	2.00	0.11	2.38					
1/25/1996	0.07	5.00	0.01	3.13	17				
1/31/1996	0.25	8.00	0.03	2.67	54				61
2/21/1996	0.13	15.00	0.01	8.33		47			212
3/13/1996	0.13	3.00	0.04	0.50		43			
12/9/1996	0.18	6.00	0.03	17.33		40			
1/15/1997	0.22	8.00	0.03	2.46		34			137
2/10/1997	0.20	3.00	0.07	14.42					284
4/3/1997	0.10	2.00	0.05	1.13	53				
11/13/1997	0.48	14.00	0.03	1.33					53
11/26/1997	0.32	2.00	0.16	12.67		72			
12/6/1997	0.24	7.00	0.03	5.54					40
1/9/1998	1.13	25.00	0.05	4.58		29			
11/8/1998	0.32	8.00	0.04	9.13		20			
1/25/1999	0.79	25.00	0.03	3.83					103
2/4/1999	0.42	14.00	0.03	3.71		30			
3/11/1999	0.17	2.00	0.09	4.04					390
2/10/2000	0.03	2.00	0.02	4.67		96			
2/12/2000	0.39	7.00	0.06	1.00					369
4/17/2000	0.41	4.00	0.10	2.42		19			73
10/27/2000	0.31	4.00	0.08	0.29	85		80	320	25
1/8/2001	0.65	18.00	0.04	27.00	50	143	235		505
1/24/2001	0.06	5.00	0.01	11.71		74		234	96
11/24/2001	0.22	2.00	0.11	11.79		54	40	151	63
11/29/2001	0.12	4.00	0.03	4.97	40				
12/14/2001	0.04	1.00	0.04	3.83					
4/24/2002	0.22	4.00	0.06	7.08		206	69	195	
3/15/2003	1.16	17.00	0.07	10.46	44	12	130	460	140
2/18/2004	0.23	4.00	0.06	4.08		32		120	
4/1/2004	0.30	6.00	0.05	6.25	26		50		290
4/17/2004	0.30	3.00	0.10	15.46	230	92	260	93	440
1/28/2005	0.41	4.00	0.10	1.58	19	11	62	140	29
2/10/2005	1.39	35.00	0.04	3.21			39	200	20
2/11/2005	1.39	35.00	0.04	3.21	38	16			
10/17/2005	0.33	3.00	0.11	1.25	110	180	170	860	
3/10/2006	0.08	2.00	0.04	3.04	66	19		390	
4/14/2006	0.32	23.00	0.01	8.92			110		
12/27/2006	0.15	2.00	0.08	4.92	24	38	220	150	
4/20/2007	0.38	12.00	0.03	28.75	170	350	330	180	
2/14/2008	0.21	8.00	0.03	10.29	48	100	65	250	

11/4/2008	0.14	3.00	0.05	30.54	39	68	230	1300	
12/15/2008	1.02	17.00	0.06	0.38	51				
12/7/2009	1.56	14.00	0.11	8.33	71	42	48	60	71
1/18/2010	1.06	3.00	0.35	0.63	140	88	200	710	22
				count:	22	30	17	17	21
				average	66	69	137	342	163
				median	51	43	110	200	96
				st dev	53	72	92	329	154
				COV	0.8	1.1	0.7	1.0	0.9
				min	14	8	39	60	20
				max	230	350	330	1300	505

*Filterable fraction of total copper is about 42%, with a COV of 0.43

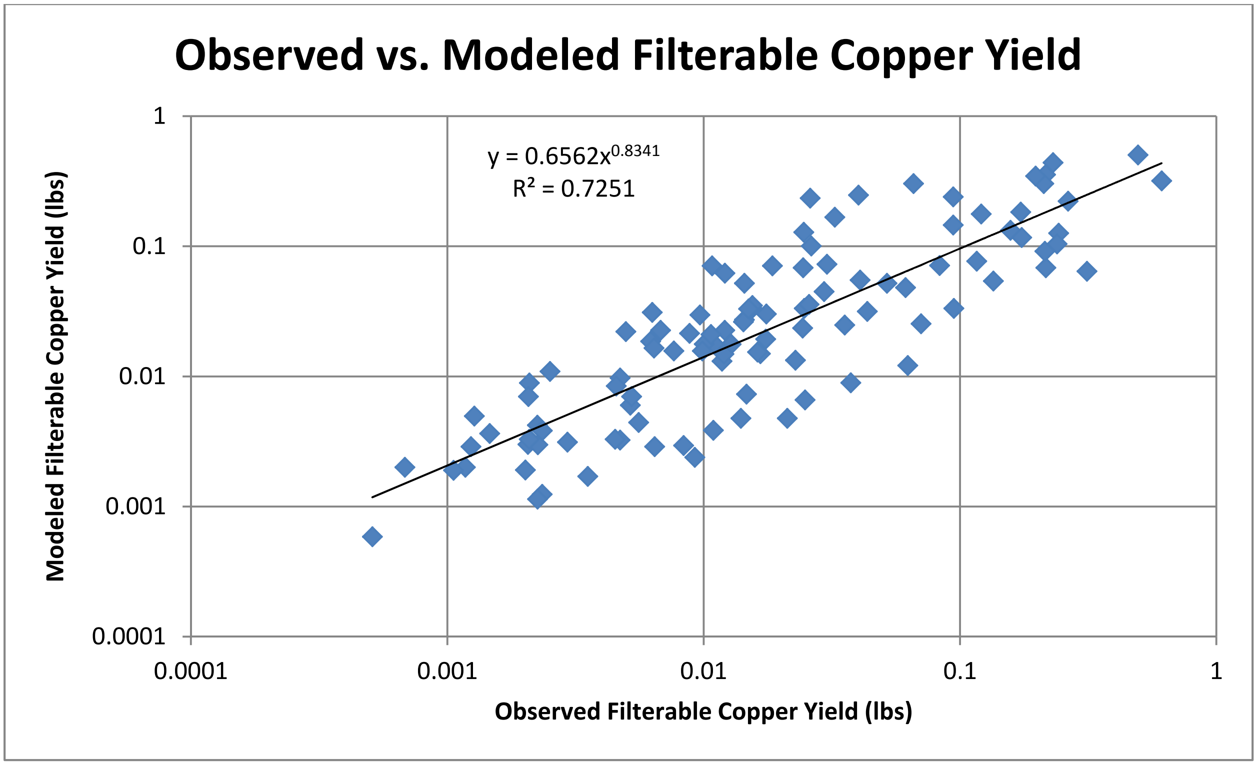


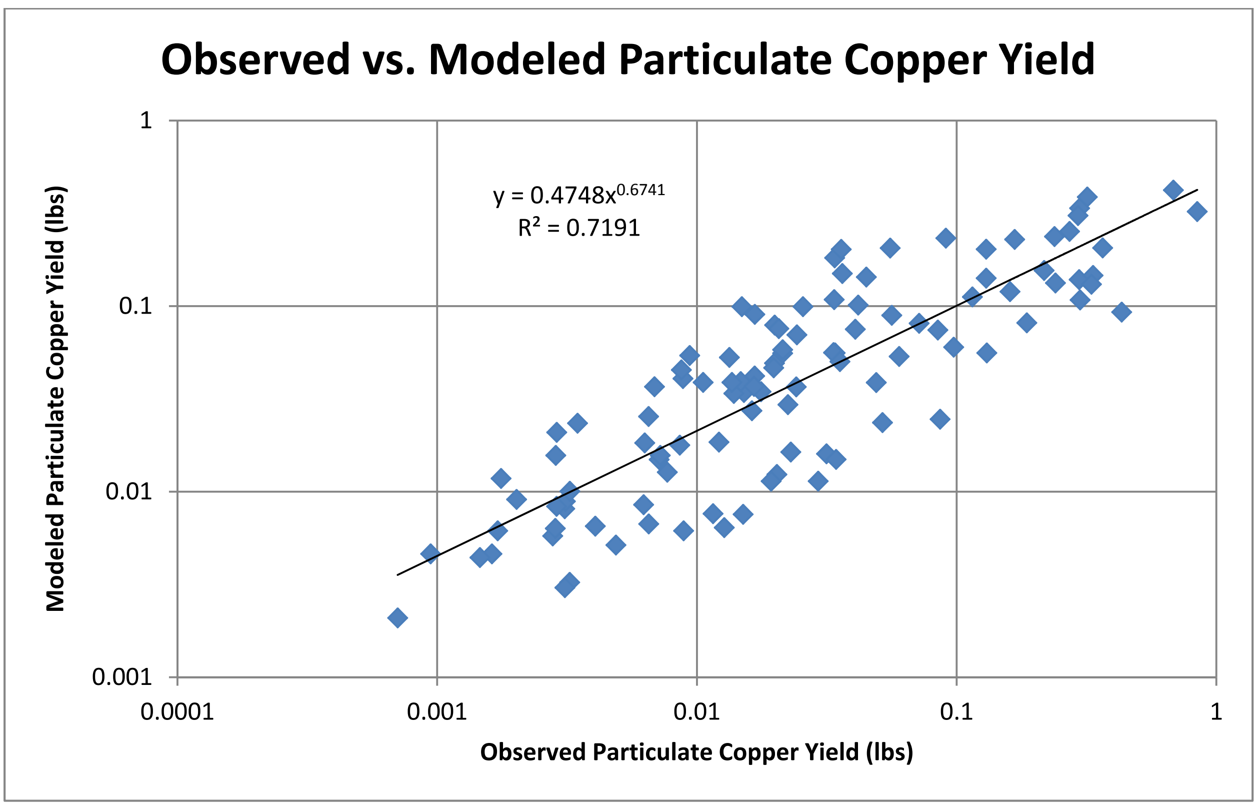
	Total Cu observed	Total Cu modeled	Total Cu observed	Total Cu modeled

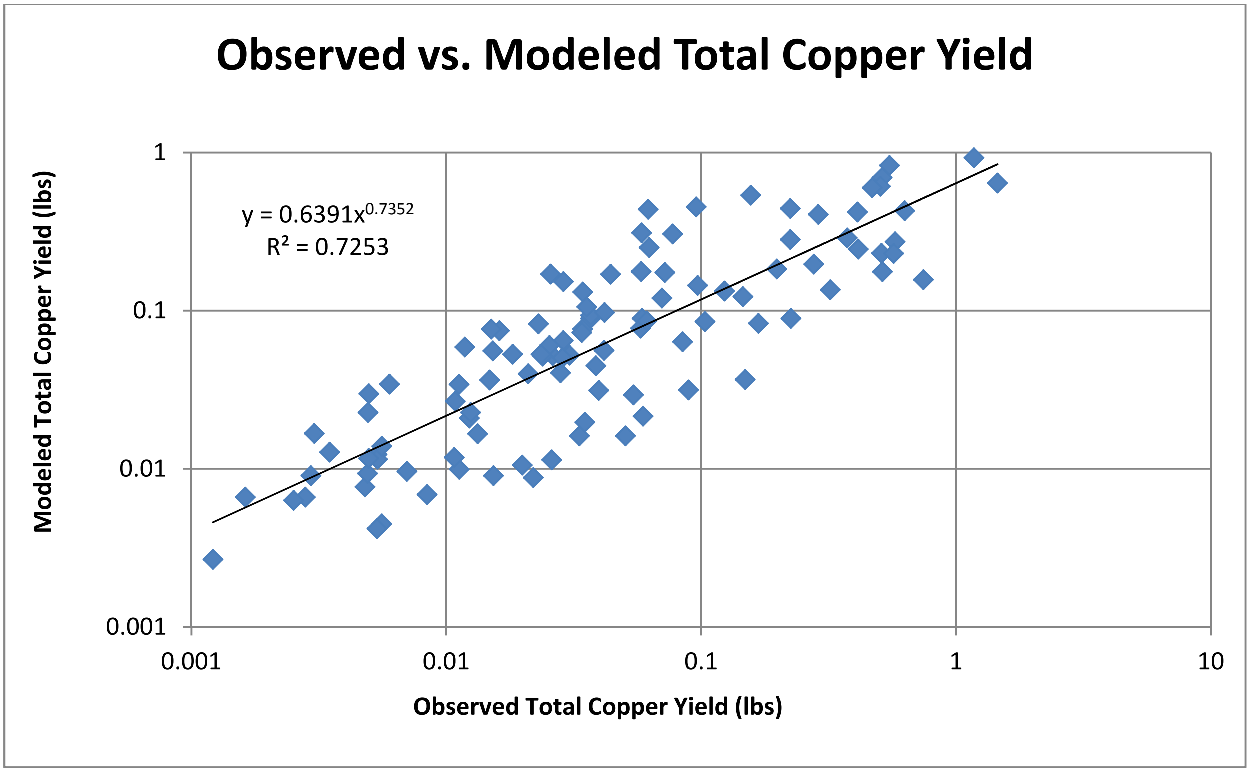
	average (µg/L)	average (µg/L)	total yield (lbs)	total yield (lbs)
OF26	66	77	6.9	6.7
OF14	67	80	4.8	5.6
OF1	137	143	0.26	0.26
OF13	342	402	1.8	1.8
OF9	163	138	0.61	0.59

	Particulate Cu observed average (µg/L)	Particulate Cu modeled average (µg/L)	Particulate Cu observed total yield (lbs)	Particulate Cu modeled total yield (lbs)
OF26	38	46	4.0	3.6
OF14	40	49	2.8	2.9
OF1	80	94	0.15	0.15
OF13	198	283	1.0	1.1
OF9	95	96	0.35	0.38

	Filterable Cu observed average (µg/L)	Filterable Cu modeled average (µg/L)	Filterable Cu observed total yield (lbs)	Filterable Cu modeled total yield (lbs)
OF26	28	31	2.9	3.1
OF14	29	31	2.0	2.7
OF1	58	49	0.11	0.11
OF13	144	130	0.76	0.76
OF9	68	42	0.26	0.21


Observed vs. Modeled Filterable Copper Yield
y = 0.6562x^0.8341
R² = 0.7251
Modeled Filterable Copper Yield (lbs)
Observed Filterable Copper Yield (lbs)
1
0.1
0.01
0.001
0.0001
0.0001
0.001
0.01
0.1
1


Observed vs. Modeled Particulate Copper Yield
y = 0.4748x^0.6741
R² = 0.7191
Modeled Particulate Copper Yield (lbs)
Observed Particulate Copper Yield (lbs)
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1



Observed and Modeled Zinc Concentrations

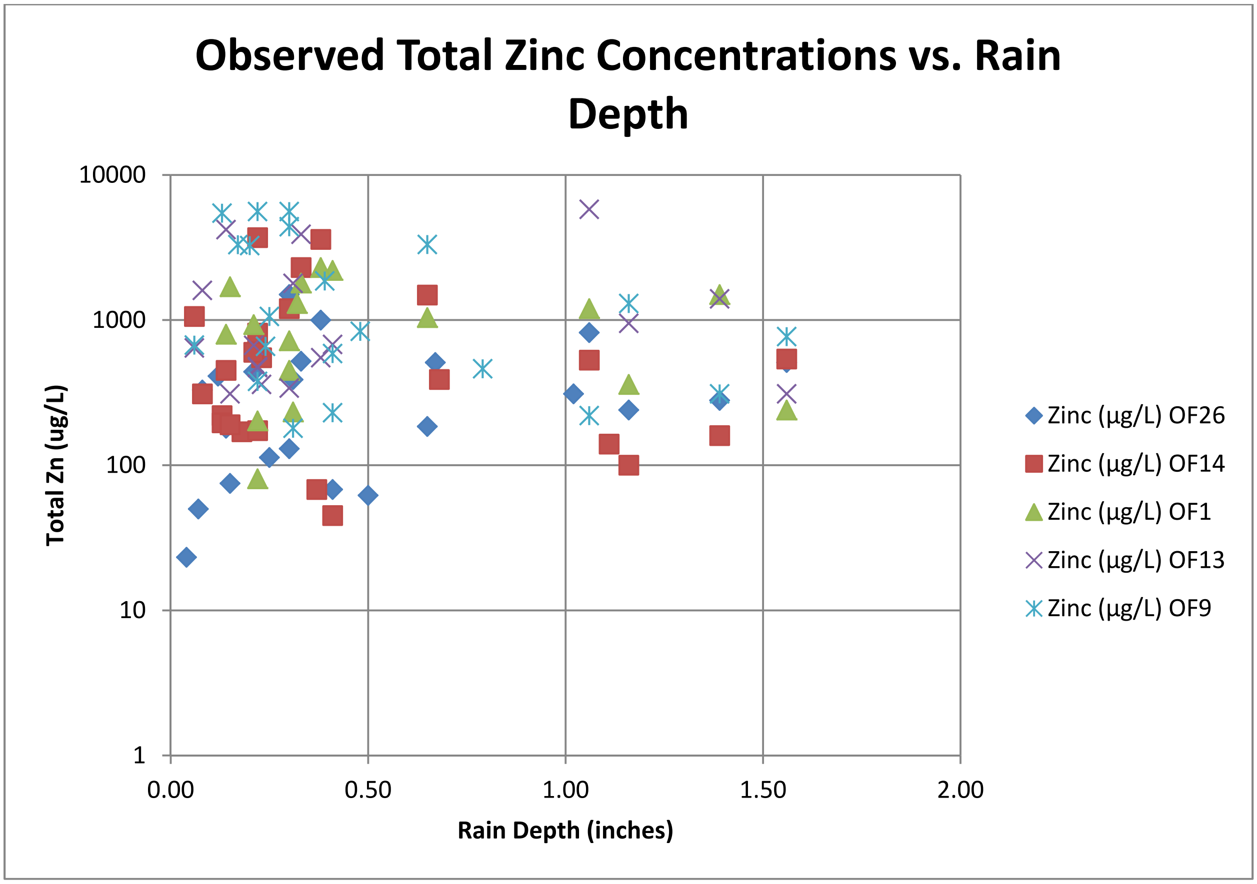
Observed Total Zinc Concentrations (adjusted)*

Date Sampled	rain depth (in)	rain duration (hrs)	peak rain hourly intensity (in/hr)	antecedent dry period (days)	Zinc (μg/L) OF26	Zinc (μg/L) OF14	Zinc (μg/L) OF1	Zinc (μg/L) OF13	Zinc (μg/L) OF9
2/17/1994	0.68	10.00	0.07	5.92		390			
1/10/1995	0.67	9.00	0.07	2.33	510				
3/5/1995	1.11	30.00	0.04	0.92		140			
3/21/1995	0.50	7.00	0.07	9.33	62				
4/18/1995	0.37	10.00	0.04	1.46		68			
1/21/1996	0.22	2.00	0.11	2.38					
1/25/1996	0.07	5.00	0.01	3.13	50				
1/31/1996	0.25	8.00	0.03	2.67	113				1060
2/21/1996	0.13	15.00	0.01	8.33		220			5450
3/13/1996	0.13	3.00	0.04	0.50		196			
12/9/1996	0.18	6.00	0.03	17.33		170			
1/15/1997	0.22	8.00	0.03	2.46		173			5590
2/10/1997	0.20	3.00	0.07	14.42					3260

4/3/1997	0.10	2.00	0.05	1.13					
11/13/1997	0.48	14.00	0.03	1.33					837
11/26/1997	0.32	2.00	0.16	12.67					
12/6/1997	0.24	7.00	0.03	5.54					660
1/9/1998	1.13	25.00	0.05	4.58					
11/8/1998	0.32	8.00	0.04	9.13					
1/25/1999	0.79	25.00	0.03	3.83					462
2/4/1999	0.42	14.00	0.03	3.71					
3/11/1999	0.17	2.00	0.09	4.04					3310
2/10/2000	0.03	2.00	0.02	4.67					
2/12/2000	0.39	7.00	0.06	1.00					1860
4/17/2000	0.41	4.00	0.10	2.42					588
10/27/2000	0.31	4.00	0.08	0.29	389		233	1790	180
1/8/2001	0.65	18.00	0.04	27.00	185	1490	1040		3320
1/24/2001	0.06	5.00	0.01	11.71		1060		642	673
11/24/2001	0.22	2.00	0.11	11.79		813	81	478	378
11/29/2001	0.12	4.00	0.03	4.97	411				
12/14/2001	0.04	1.00	0.04	3.83	23				
4/24/2002	0.22	4.00	0.06	7.08		3700	202	470	
3/15/2003	1.16	17.00	0.07	10.46	240	100	360	950	1300
2/18/2004	0.23	4.00	0.06	4.08		550		360	
4/1/2004	0.30	6.00	0.05	6.25	130		450		4400
4/17/2004	0.30	3.00	0.10	15.46	1500	1200	720	340	5600
1/28/2005	0.41	4.00	0.10	1.58	68	45	2200	680	230
2/10/2005	1.39	35.00	0.04	3.21			1500	1400	310
2/11/2005	1.39	35.00	0.04	3.21	280	160			
10/17/2005	0.33	3.00	0.11	1.25	520	2300	1800	3900	
3/10/2006	0.08	2.00	0.04	3.04	330	310		1600	
4/14/2006	0.32	23.00	0.01	8.92			1300		
12/27/2006	0.15	2.00	0.08	4.92	75	190	1700	310	
4/20/2007	0.38	12.00	0.03	28.75	1000	3600	2300	550	
2/14/2008	0.21	8.00	0.03	10.29	440	600	930	670	
11/4/2008	0.14	3.00	0.05	30.54	180	450	800	4200	
12/15/2008	1.02	17.00	0.06	0.38	310				
12/7/2009	1.56	14.00	0.11	8.33	510	540	240	310	770
1/18/2010	1.06	3.00	0.35	0.63	820	530	1200	5800	220
				count:	22	24	17	17	21
				average	370	791	1003	1438	1927
				median	295	420	930	670	837
				st dev	356	1027	713	1629	1946
				COV	1.0	1.3	0.7	1.1	1.0

				min	23	45	81	310	180
				max	1500	3700	2300	5800	5600

*Filterable fraction of total zinc is about 43%, with a COV of 0.38

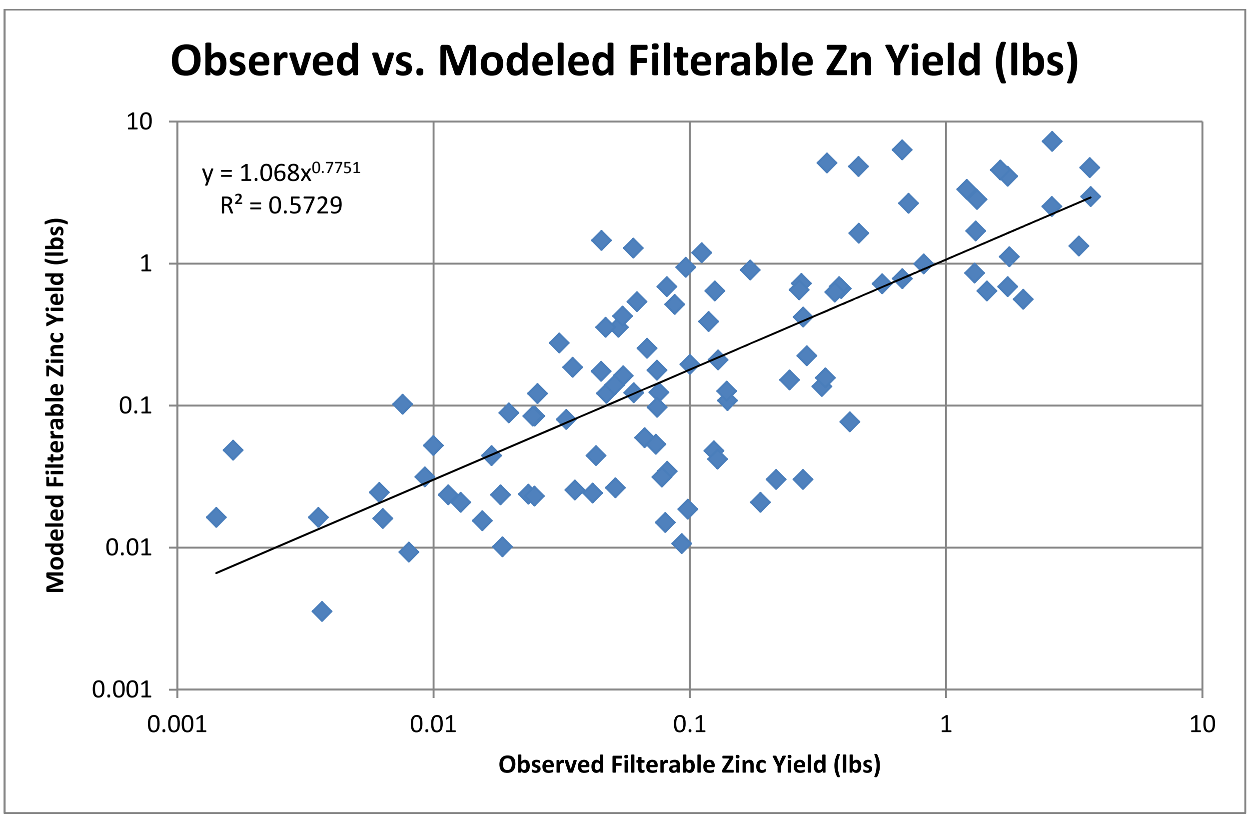


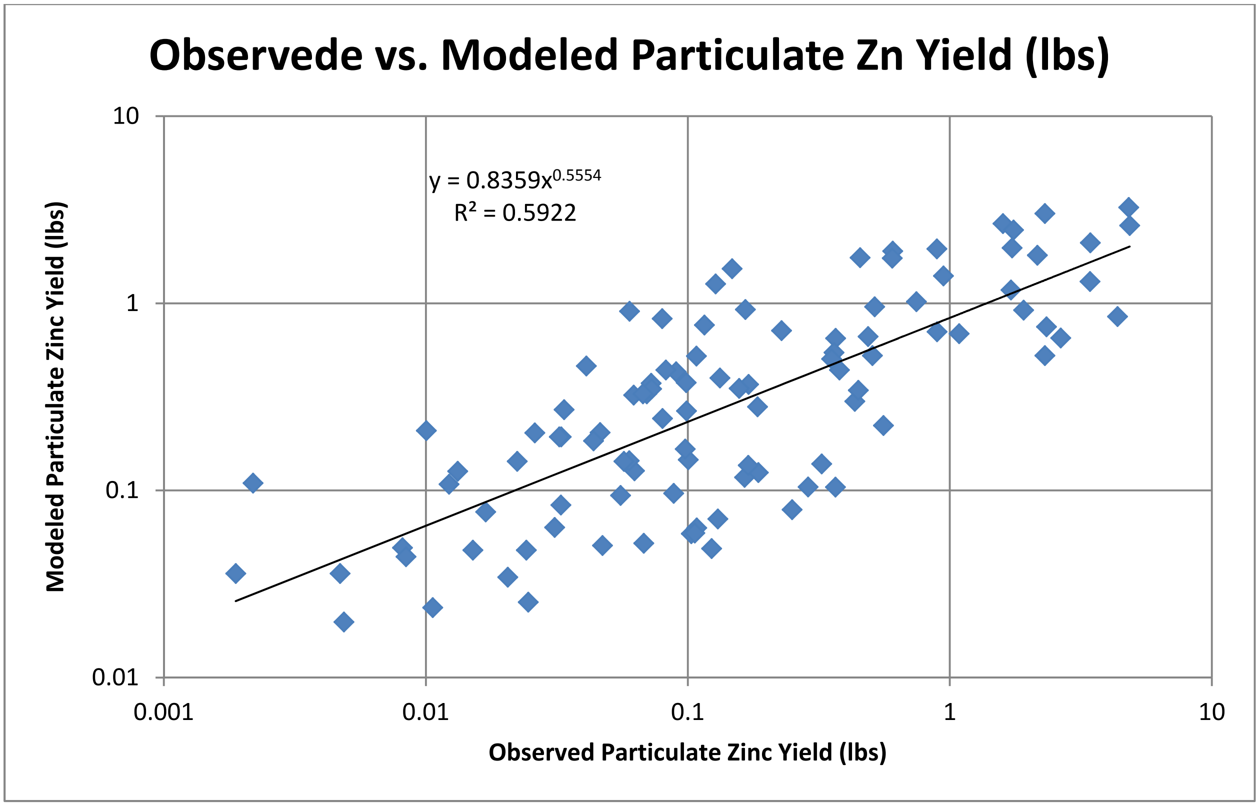
	Total Zn observed average (µg/L)	Total Zn modeled average (µg/L)	Total Zn observed total yield (lbs)	Total Zn modeled total yield (lbs)
OF26	370	685	42	58
OF14	791	1086	42	66
OF1	1003	1128	2.0	2.0
OF13	1438	2110	9.5	9.5
OF9	1926	1148	6.0	4.7

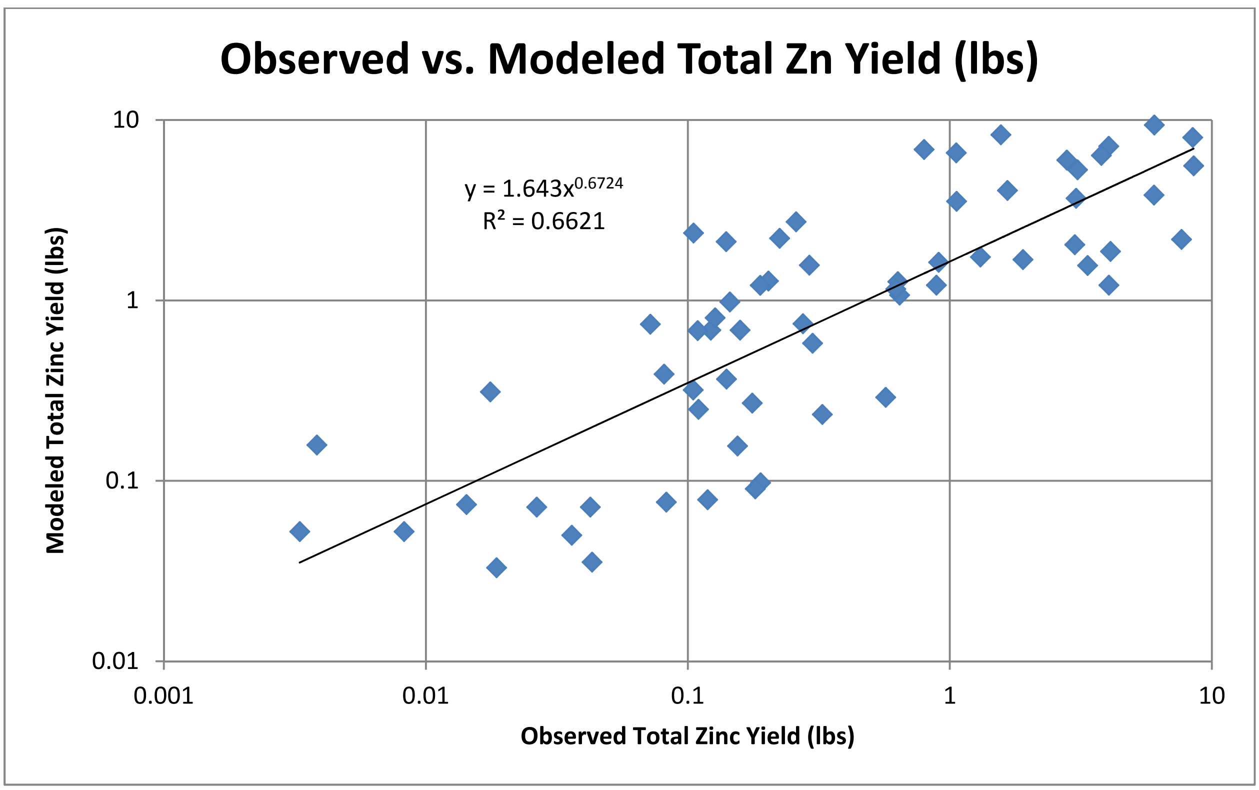
	Particulate Zn observed average	Particulate Zn modeled average	Particulate Zn observed total yield	Particulate Zn modeled total yield

	(µg/L)	(µg/L)	(lbs)	(lbs)
OF26	211	398	24	29
OF14	451	444	24	21
OF1	572	728	1.2	1.2
OF13	820	1410	5.4	5.4
OF9	1098	884	3.4	3.4

	Filterable Zn observed average (µg/L)	Filterable Zn modeled average (µg/L)	Filterable Zn observed total yield (lbs)	Filterable Zn modeled total yield (lbs)
OF26	159	287	18	29
OF14	340	642	18	45
OF1	431	400	0.87	0.87
OF13	618	700	4.1	4.1
OF9	828	264	2.6	1.3




Observede vs. Modeled Particulate Zn Yield (lbs)
y = 0.8359x^0.5554
R² = 0.5922
Modeled Particulate Zinc Yield (lbs)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
Observed Particulate Zinc Yield (lbs)


Observed vs. Modeled Total Zn Yield (lbs)
y = 1.643x^0.6724
R² = 0.6621
Modeled Total Zinc Yield (lbs)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
Observed Total Zinc Yield (lbs)

Source Area Runoff Quality for TSS, Cu, and Zn

Area 1: Airfield apron/runway paved areas
Area 2: Other airfield paved areas
Area 3: Light pier/laydown area, concrete (ceremonial, light industrial/laydown activity, concrete)
Area 4: Moderate industrial pier/laydown area, concrete (moderate industrial/laydown activities, concrete)
Area 5: Heavy industrial pier/laydown area, concrete (heavy industrial/laydown activities, concrete)
Area 6: Light industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)
Area 7: Moderate industrial storage/laydown area, asphalt (light industrial/laydown activity, asphalt)
Area 8: Heavy industrial pier/laydown area, asphalt (heavy industrial/laydown activities, asphalt)
Area 9: Galvanized metal roofs, flat, directly connected to drainage system
Area 10: Other

Industrial Source Areas	TSS (mg/L) at 0.04" rain	TSS (mg/L) at 0.39" rain	TSS (mg/L) at 1.2" rain	TSS (mg/L) at 3.2" rain	Cu, part. (mg/kg and COV)	Cu, filt. (µg/L and COV)	Zn, part. (mg/kg and COV)	Zn, filt. (µg/L and COV)
AT 1: roofs (OF9? OF14 OF26)	200	75	10	10	74 0.86	5 1.05	710 1.18	165 1.68
AT 2: paved parking (OF9 OF14? OF26)	200	150	125	100	371 0.80	26 0.81	1776 0.48	192 1.63
AT 3: unpaved parking, driveways, and walkways	500	350	250	200	371 0.80	26 0.81	1776 0.48	192 1.63
AT 4: paved playgrounds	150	125	100	75	19 1.04	18 0.74	266 0.48	27 2.68
AT 5: paved driveways (OF14)	800	300	75	10	74 1.04	17 0.74	888 0.48	165 2.68
AT 6: paved sidewalks and walks (OF14 OF26)	121	100	80	50	19 1.04	17 0.61	888 0.42	27 2.68
AT XX street areas					74 0.43	78 0.61	888 0.42	265 0.51
AT 7: large landscaped areas (OF9 OF26)	30	100	475	700	11 0.42	22 0.51	178 1.28	110 0.58
AT 8: small landscaped areas (OF9 OF26)	30	100	475	700	11 0.42	22 0.51	178 1.28	110 0.58
AT 9: undeveloped areas (OF14)	25	25	25	50	4 0.42	11 0.51	107 1.28	11 0.58
AT XX: isolated areas					4 0.42	11 0.51	107 1.28	11 0.58
AT 10: other pervious areas (OF14 OF26)	30	100	475	700	11 0.42	22 0.51	178 1.28	110 0.58
AT 11: other directly connected impervious areas	200	150	125	100	371 0.80	26 0.81	1776 0.48	192 1.63
AT 12: other partially connected impervious areas	200	150	125	100	371 0.80	26 0.81	1776 0.48	192 1.63
AT 13: paved lane and shoulder areas (only in freeway land use)	n/a	n/a	n/a	n/a	19 0.43	29 0.61	1691 0.42	265 0.51
AT XX: large turf areas	30	100	475	700	11 0.42	22 0.51	178 1.28	110 0.58

Industrial Other Impervious Areas	TSS (mg/L) at 0.04“ rain	TSS (mg/L) at 0.39“ rain	TSS (mg/L) at 1.2“ rain	TSS (mg/L) at 3.2“ rain	Cu, part. (mg/kg and COV)	Cu, filt. (µg/L and COV)	Zn, part. (mg/kg and COV)	Zn, filt. (µg/L and COV)
AT 14, Area 1: airfield apron/runway paved areas (OF26)	35	110	215	1000	37 1.04	5 0.81	320 0.48	110 2.68
AT 15, Area 2: other airfield paved areas	200	150	125	100	37 1.04	10 0.74	888 0.48	165 2.68
AT 16, Area 3: light pier/laydown/storage/loading dock concrete areas (OF1)	800	450	250	100	210 1.04	49 0.67	1635 0.48	400 2.68
AT 17, Area 4: moderate pier/laydown/storage/loading dock concrete areas (OF13 OF9?)	800	600	290	100	480 1.04	130 0.96	2490 0.48	700 2.68
AT 18, Area 5: heavy pier/laydown/storage/loading dock and scrapyard concrete areas	1000	750	500	250	260 0.82	62 0.82	2664 0.48	384 0.82
AT 19, Area 6: light pier/laydown/storage/loading dock asphalt areas	800	450	250	100	93 1.04	26 0.74	888 0.48	274 2.68
AT 20, Area 7: moderate pier/laydown/storage/loading dock asphalt areas (OF9?)	800	600	290	100	186 1.04	67 0.74	1776 0.48	549 2.68
AT 21, Area 8: heavy pier/laydown/storage/loading dock and scrapyard asphalt areas	1000	750	500	250	260 0.82	62 0.82	2664 0.48	1920 1.65
AT 22, Area 9: galvanized metal roofs, directly connected (OF14? OF9? OF26?)	200	75	10	10	93 1.04	5 0.74	533 1.5	1920 1.5
AT 23, Area 10: other impervious areas	200	150	125	100	371 0.80	26 0.81	1776 0.48	192 1.63

Short-term galvanized steel gutter and pipe sample exposures

	Filt. Cu (µg/L)	Filt. Cu (mg/m²)	Filt. Zn (µg/L)	Filt. Zn (mg/m²)
Galvanized pipes and gutters in river water, 1 hr exposure	<20	n/a	650	25
Galvanized pipes and gutters in Bay water, 1 hr exposure	<20	n/a	1,000	40
Galvanized pipes and gutters in 5 pH roof runoff, 1 hr exposure	<20	n/a	3,000	140
Galvanized pipes and gutters in 8 pH parking lot runoff, 1 hr exposure	<20	n/a	170	6

	Cu (ug/L)	Zn (ug/L)
Galvanized metal roofing PSH tests	3	5,500
Asphalt shingle roofing PSH tests	25	100

Metal scrapyard data

	TSS (mg/L)	Filterable Cu (ug/L) average and COV	Particulate Cu (mg/kg) average and COV	Filterable Zn (ug/L) average and COV	Particulate Zn (mg/kg) average and COV
Metal scrapyard data	2,930	120 (0.82)	700 (0.67)	3,780 (1.65)	520 (0.15)

Cu was 34% filterable based on the total NSQD dataset (and 24% filtered for just the industrial data)
Zn was mostly filterable using the NSQD data (esp the industrial data, open space was about 30% filterable)

Average Total Metal Concentrations in Stormwater for Open Space, Undeveloped Land, Bare Soil, and Landscaped Areas

Average (COV)	Copper (µg/L)	Zinc (µg/L)
Undeveloped areas (Pitt, *et al.* 2005 WI and MN)	5	n/a
Small landscaped areas in developed land uses (Pitt, *et al.* 2005 WI and MN)	12 (0.4)	67 (0.4)
Open space outfall (NSQD national data)	14.1 (1.5)	109 (1.1)
Landscaped areas in developed land uses (Pitt 1983, Ottawa; Pitt and Bozeman 1982, San Jose; Pitt and McLean 1986, Toronto)	<20	10

Residential dirt walks in developed areas (Pitt and McLean 1986 Toronto)	20	40
Undeveloped areas (Denver Regional Council of Governments 1983; Pitt 1983, Ottawa; Pitt and Bozeman 1982, San Jose; Pitt and McLean 1986, Toronto)	30	100
Landscaped areas in developed land uses (Pitt, *et al*. 1995 Birmingham)	81	230

* Average value followed by coefficient of variation, if available.

Open Space, Undeveloped Land, Bare Soil Samples Particulate Strengths

	Copper (mg Cu/kg SS)	**Zinc (mg Zn/kg SS)**
SSFL background soil samples (MWH 2005)	11 (0.5)*	57 (0.3)
Small landscaped areas (Pitt 2004 WI and MN sheetflow)	14 (0.4)	160 (1.3)
Resid./Commer. dirt path (Pitt and McLean 1986, Toronto, Ontario 125μm)	15	50
SSFL ISRA soil samples in watershed 009 (MWH 2009)	20 (0.04)	n/a
California benchmark soils (Kearney 1996)	29 (9.1 to 96)	150 (88 to 240)
Resid./Commer. garden soil (Pitt and McLean 1986, Toronto, Ontario 125μm)	30	120
Industrial bare ground (Pitt and McLean 1986, Toronto, Ontario 125μm)	91	270
Open Space NSQD outfalls	188 (1.2)	789 (1.2)

* Average and coefficient of variation values (where available). In some cases (XX to YY), the parenthetical values show the range.

Average Total Metal Concentrations in Stormwater for Residential Areas

Average (COV)	**Copper (μg/L)**	**Zinc (μg/L)**
Residential roofs (Bannerman, *et al.* 1983, Milwaukee, WI; Pitt 1983 Ottawa; Pitt and Bozeman 1982, San Jose; Pitt and McLean 1986 Toronto)	5	390
Residential streets (Pitt, *et al.* 2005 WI and MN)	18 (0.6)	151 (0.7)
Residential paved sidewalks (Pitt and McLean 1986 Toronto)	20	60
Residential roofs (Pitt, *et al.* 2005 WI and MN)	21 (1.6)	185 (1.1)

Residential outfall, NSQD	27.3 (1.8)	125 (2.8)
Residential streets (Pitt and Bozeman 1982 San Jose; Pitt and McLean 1986 Toronto)	35	160
Driveways (Pitt, *et al.* 2005 WI and MN)	37 (1.0)	164 (0.8)
Residential paved parking/storage (Pitt and McLean 1986 Toronto)	60	450
Roof runoff (Pitt, *et al.* 1995 Birmingham)	110	250
Residential paved driveways (Pitt and McLean 1986 Toronto)	210	1000
Street runoff (Pitt, *et al*. 1995 Birmingham)	280	58

* Outfall 008 and 009 data are also shown on this table as a reference.
** Average value followed by coefficient of variation, if available.

Residential Area Samples Particulate Strengths

	Copper (mg Cu/kg SS)	**Zinc (mg Zn/kg SS)**
Resid./Commer. road shoulder (Pitt and McLean 1986, Toronto, Ontario 125μm)	35	120
Residential streets (Pitt 2004 WI and MN sheetflow)	39 (0.6)*	350 (0.6)
Resid./Commer. pvd sidewalk (Pitt and McLean 1986, Toronto, Ontario 125μm)	44	430
Resid./Commer. unpvd parking (Pitt and McLean 1986, Toronto, Ontario 125μm)	45	170
Paved driveways (Pitt 2004 WI and MN sheetflow)	89 (1.0)	650 (0.5)
Resid./Commer. roofs (Pitt and McLean 1986, Toronto, Ontario 125μm)	130	1900
Resid./Commer. pvd parking (Pitt and McLean 1986, Toronto, Ontario 125μm)	145	420
Residential roofs (Pitt 2004 WI and MN sheetflow)	160 (1.3)	2900 (0.6)
Resid./Comer. pvd driveways (Pitt and McLean 1986, Toronto, Ontario 125μm)	170	800
Street Dirt Residential (Pitt 1979, San Jose, CA <45 μm; Pitt 1985, Bellevue, WA) <63 μm; Pitt and McLean 1986, Toronto, Ontario <125 μm, Pitt and Sutherland 1982, Reno/Sparks, NV <63 μ)	230	431
Residential NSQD outfalls	431 (2.6)	1262 (1.4)

* Average and coefficient of variation values (where available).

Average Total Metal Concentrations in Stormwater for Commercial Areas

Average (COV)	Copper (µg/L)	Zinc (µg/L)
Commercial roofs (Pitt, *et al.* 2005 WI and MN)	19 (0.8)	322 (0.54)
Commercial parking (Pitt, *et al.* 2005 WI and MN)	30 (0.8)	292 (0.9)
Commercial streets (Pitt, *et al.* 2005 WI and MN)	34 (0.6)	302 (1.0)
Commercial outfall (NSQD)	36.7 (2.3)	197 (1.4)
Commercial streets (Pitt and McLean 1986 Toronto)	40	180
Commercial paved parking (Bannerman, *et al.* 1983 Milwaukee, WI; Denver Regional Council of Governments 1983; Pitt 1983 Ottawa; Pitt and Bozeman 1982 San Jose; Pitt and McLean 1986 Toronto; STORET*** Site #590866-2954309 Shop-Save-Durham, NH; STORET Site #596296-2954843 Huntington-Long Island, NY)	65	290
Commercial roofs (Bannerman, *et al.* 1983 Milwaukee, WI; Pitt and Bozeman 1982 San Jose)	110	200
Commercial paved parking (Pitt, *et al.* 1995 Birmingham)	116	110
Commercial vehicle service areas (Pitt, *et al.* 1995 Birmingham)	135	105

* Outfall 008 and 009 data are also shown on this table as a reference.
** Average value followed by coefficient of variation, if available.
*** STORET data are from the EPA's STORET water quality database. These sites were NURP 1983 monitoring locations.

Commercial Area Samples Particulate Strengths

	Copper (mg Cu/kg SS)	Zinc (mg Zn/kg SS)
Commercial parking (Pitt 2004 WI and MN sheetflow)	100 (0.7)*	802 (0.6)
Commercial streets (Pitt 2004 WI and MN sheetflow)	140 (1.3)	1150 (1.2)
Street Dirt Commercial (Bannerman, *et al*. 1983, Milwaukee, WI <31µm; Pitt 1979, San Jose, CA <45 µm; Pitt and Sutherland 1982, Reno/Sparks, NV <63 µm; Terstrip, *et al*. 1982, Champaign/Urbana, IL <63 µm)	175	975
Commercial roofs (Pitt 2004 WI and MN sheetflow)	180 (1.0)	3500 (1.0)
Commercial NSQD outfalls	358 (1.8)	1218 (1.4)

* Average and coefficient of variation values (where available).

Average Total Metal Concentrations in Stormwater for Industrial Areas

Average (COV)	Copper (µg/L)	Zinc (µg/L)
Industrial roofs (Pitt, *et al.* 2005 WI and MN)	9 (0.6)	319 (1.5)
Industrial roofs (Pitt and McLean 1986 Toronto)	<20	70
Industrial loading docks (Pitt, *et al*. 1995 Birmingham)	22	55
Industrial streets (Pitt, *et al.* 2005 WI and MN)	22 (0.6)	593 (0.5)
Industrial paved sidewalks (Pitt and McLean 1986 Toronto)	30	60
Industrial parking (Pitt, *et al.* 2005 WI and MN)	33 (0.5)	228 (0.7)
Industrial outfall (NSQD)	36.3 (2.1)	382 (3.5)
Industrial paved driveways (Pitt and McLean 1986 Toronto)	40	310
Galvanized metal runoff (Clark 2000)	41	10,200
Industrial unpaved storage (Pitt and McLean 1986 Toronto)	120	410
Industrial unpaved driveways (Pitt and McLean 1986 Toronto)	140	690
Industrial streets (Pitt and McLean 1986 Toronto)	220	910
Industrial storage areas (Pitt, *et al.* 1995 Birmingham)	290	1730
Industrial paved parking/storage (Pitt and McLean 1986 Toronto; STORET*** Site #590866-2954309 Shop-Save-Durham, NH)	370	480

* Average value followed by coefficient of variation, if available.

Industrial Area Samples Particulate Strengths

	Copper (mg Cu/kg SS)	Zinc (mg Zn/kg SS)
Industrial streets (Pitt 2004 WI and MN sheetflow)	74 (0.4)*	540 (0.4)
Industrial parking (Pitt 2004 WI and MN sheetflow)	83 (0.5)	490 (0.5)
Industrial pvd path (Pitt and McLean 1986, Toronto, Ontario 125µm)	280	1300
Industrial NSQD outfalls	281 (0.6)	7147 (1.6)
Industrial street dirt (Pitt and McLean 1986, Toronto, Ontario <125 µm)	360	500
Industrial pvd parking (Pitt and McLean 1986, Toronto, Ontario 125µm)	1110	930

Industrial unpvd parking (Pitt and McLean 1986, Toronto, Ontario 125μm)	1120	1120

* Average and coefficient of variation values (where available).

Appendix E: Regional Calibration of WinSLAMM

The following is a summary of regional calibrations of WinSLAMM using information obtained from specific research projects and from the National Stormwater Quality Database. Detailed land use characteristics were available from several older and current stormwater research projects. The projects and locations where these land use characteristics were available included:

• Jefferson County, AL (high density residential; medium density residential <1960, 1960 to 1980 and >1980; low density residential; apartments; multi-family; offices; shopping center; schools; churches; light industrial; parks; cemeteries; golf courses; and vacant land). These areas were inventoried as part of regional stormwater research and included about 10 single land use neighborhoods for each land use category. Local NPDES data were available to calibrate WinSLAMM for regional conditions using the specific monitored areas. The sites are described in several publications, including:

- Bochis, C., R. Pitt, and P. Johnson. "Land development characteristics in Jefferson County, Alabama." In: *Stormwater and Urban Water Systems Modeling*, Monograph 16. (edited by W. James, E.A. McBean, R.E. Pitt and S.J. Wright). CHI. Guelph, Ontario, pp. 249 – 282. 2008.

• Bellevue, WA (medium density residential <1960). These data were from test and control watersheds that were extensively monitored as part of the Bellevue project of the EPA's Nationwide Urban Runoff Program (NURP). Much monitoring data from these sites are available for calibration of WinSLAMM. These areas are described in:

- Pitt, R. and P. Bissonnette. *Bellevue Urban Runoff Program Summary Report*, U.S. Environmental Protection Agency, Water Planning Division. PB84 237213. Washington, D.C. 173 pgs. 1984.
- Pitt, R. *Characterizing and Controlling Urban Runoff through Street and Sewerage Cleaning*. U.S. Environmental Protection Agency, Storm and Combined Sewer Program, Risk Reduction Engineering Laboratory. EPA/600/S2-85/038. PB 85-186500. Cincinnati, Ohio. 467 pgs. June 1985.

• Kansas City, MO (medium density residential <1960). These descriptions are from the test watershed in the current EPA green infrastructure demonstration project being conducted in Kansas City. Detailed inventories were made of each of the approximately 600 homes in the area. Currently, no runoff quality data are available for these areas. These are summarized in the following:

- Pitt, R., J. Voorhees. "Modeling green infrastructure components in a combined sewer area." Monograph 19. ISBN 978-0-9808853-4-7. *Modeling Urban Water Systems*. *Cognitive Modeling of Urban Water Systems*. James, W., K.N. Irvine, James Y. Li, E.A. McBean, R.E. Pitt, and S.J. Wright (editors). Computational Hydraulics International. Guelph, Ontario. 2011. pp. 139 – 156.
- Pitt, R. and J. Voorhees. "Green infrastructure performance modeling with WinSLAMM." *2009 World Environmental and Water Resources Congress* Proceedings, Kansas City, MO, May 18 - 22, 2009.

• Downtown Central Business Districts (Atlanta, GA; Chicago, IL; Los Angeles, CA; New York, NY; and San Francisco, CA). These were not monitored locations, but were selected as part of this project report, as this land use was not well represented in the available research projects. Five example areas in the high density downtown areas of each of these five cities were examined in detail using Google maps. The areas associated with each land cover in a several block area were manually measured and described. No runoff quality or quantity data are available for these areas.

• Millburn, NJ (medium density residential 1961-80). Nine homes are being monitored during this current EPA research project investigating the effects of dry-well disposal of stormwater from individual homes, and the potential for irrigation use of this water. Google map aerial photographs and site surveys were conducted at each home to determine the land covers and characteristics. Site stormwater data are not available yet for these areas. Preliminary results will be presented at the following upcoming conferences:

- Talebi, L. and R. Pitt. "Stormwater Non-potable Beneficial Uses: Modeling Groundwater Recharge at a Stormwater Drywell Installation." ASCE/EWRI World Environment and Water Resources Congress. Palm Springs, CA, May 22-26, 2011.
- Talebi, L. and R. Pitt. "Stormwater Non-potable Beneficial Uses and Effects on Urban Infrastructure." 84th Annual Water Environment Federation Technical Exhibition and Conference (WEFTEC), Los Angeles, CA, October 15–19, 2011.

• San Jose, CA (medium density residential 1961-80; downtown central business district). Two residential and one downtown area were characterized as part of this early stormwater research project. Stormwater characterization data are available for these areas. These areas are described in the following report:

- Pitt, R. *Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices*, EPA-600/2-79-161, U.S. Environmental Protection Agency, Cincinnati, Ohio. 270 pgs. 1979.

• Toronto, Ontario (medium density residential 1961-80; medium industrial). These two areas were characterized and monitored as part of a research project conducted for the Toronto Area Wastewater Management Strategy Study (TAWMS). Stormwater characterization data are also available for these areas. The areas are described in the following reports:

- Pitt, R. and J. McLean. *Humber River Pilot Watershed Project*, Ontario Ministry of the Environment, Toronto, Canada. 483 pgs. June 1986.
- Pitt, R. *Small Storm Urban Flow and Particulate Washoff Contributions to Outfall Discharges*, Ph.D. Dissertation, Civil and Environmental Engineering Department, University of Wisconsin, Madison, WI, November 1987.

• Tuscaloosa, AL (parking lot at city park; City Hall). These two sites were characterized and monitored as part of the pilot-scale and full-scale monitoring projects of the Up-Flo™ filter. The pilot-scale tests were conducted as part of an EPA SBIR project and were conducted at the Tuscaloosa City Hall. The full-scale tests were conducted at the Riverwalk parking lot. Stormwater quality and quantity data are available from both of these sites for model calibration. These sites are described in the following reports:

- Pitt, R. and U. Khambhammettu. *Field Verification Tests of the UpFlow™ Filter. Small Business Innovative Research, Phase 2 (SBIR2) Report*. U.S. Environmental Protection Agency, Edison, NJ. 275 pages. March 2006.
- Khambhammettu. U., R. Pitt, R. Andoh, and S. Clark "UpFlow filtration for the treatment of stormwater at critical source areas." Chapter 9 in: *Contemporary Modeling of Urban Water Systems*, ISBN 0-9736716-3-7, Monograph 15. (edited by W. James, E.A. McBean, R.E. Pitt, and S.J. Wright). CHI. Guelph, Ontario. pp 185 – 204. 2007.
- Togawa, N., R. Pitt. R. Andoh, and K. Osei. "Field Performance Results of UpFlow Stormwater Treatment Device." ASCE/EWRI World Environment and Water Resources Congress. Palm Springs, CA, May 22-26, 2011. Conference CD.

• Wisconsin (downtown central business district; duplex residential; high density residential with alleys; high density residential without alleys; high rise residential; hospital; fairgrounds; light industry; low density residential; medium density residential; medium industry; mobile homes; multi-family residential; open space; schools; shopping center; strip commercial; and suburban residential). These areas are the standard land use areas studied and described by the Wisconsin Department of Natural

Resources and the USGS to support WinSLAMM modeling in the state. These area descriptions are based on locations studied throughout the main urban areas in Wisconsin, including Milwaukee, Madison, Green Bay, etc. Generally, about 10 homogeneous areas representing each land use category were examined in each study area to develop these characteristic descriptions. Much stormwater characterization data are available for these areas and calibrated versions of the WinSLAMM parameter files are maintained by the USGS for use by state stormwater managers and regulators. Descriptions of these projects and the source water quality data are summarized in the following:

- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 1) – Older monitoring projects." In: *Effective Modeling of Urban Water Systems*, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 465 – 484 and 507 – 530. 2005.
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 2) – Recent sheetflow monitoring results." In: *Effective Modeling of Urban Water Systems*, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 485 – 530. 2005.
- Pitt, R., D. Williamson, and J. Voorhees. "Review of historical street dust and dirt accumulation and washoff data." *Effective Modeling of Urban Water Systems*, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp 203 – 246. 2005.

• Lincoln, NE (low density residential; medium density residential <1960; 1960-80; >1980; light industry; strip malls; shopping centers; schools; churches; hospitals). These site descriptions are from an on-going project in Lincoln, NE examining pollutant sources and controls. About ten homogeneous examples representing each land use were studied to develop these land use descriptions. Regional NPDES stormwater data are available for this area. There are no project reports available yet for this on-going project.

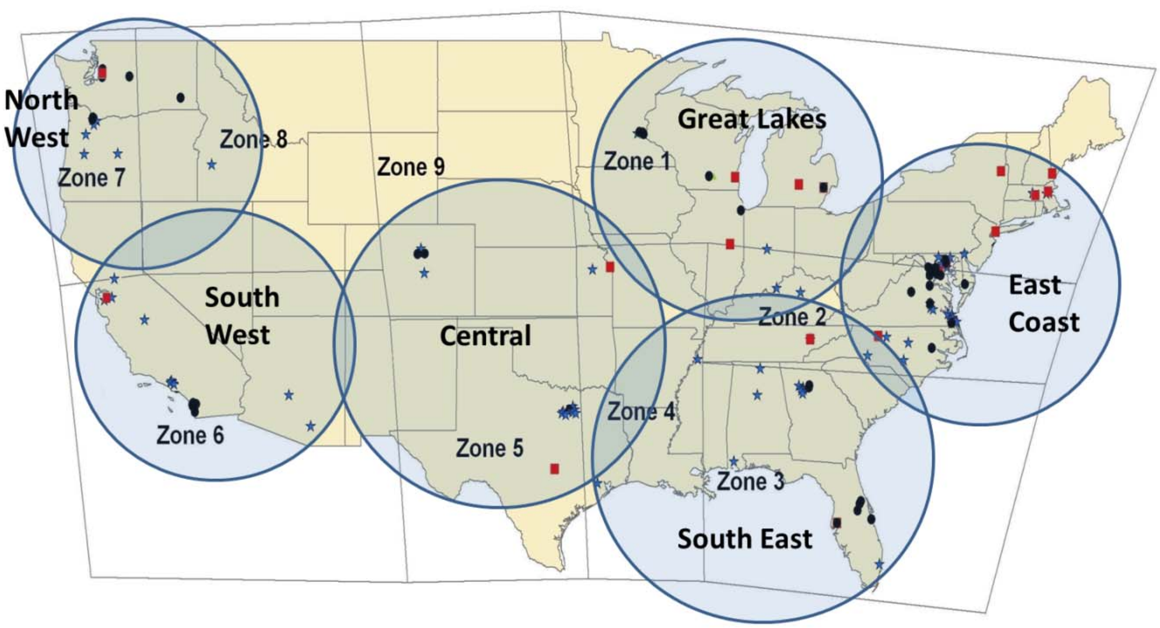
There are many land uses described from many locations throughout the country. The Wisconsin standard land use files represent the broadest range of land uses and the most observations. The Birmingham, AL and Lincoln, NE areas also have data representing a broad range of land uses. Several other study areas are also available that represent other geographical areas of the county. The individual data were initially grouped into six major land use categories: commercial, industrial, institutional, open space, residential, and freeway/highway land uses. The following table summarizes the breakdown of these categories into directly connected impervious areas (DCIA), partially connected impervious areas, and pervious areas.

Summary of Major Land Use Characteristics (average and COV)

Land Use Category (# of example areas)	Total directly connected impervious areas (DCIA)	total partially connected impervious areas	Total pervious areas
Commercial (16)	79.5 (0.3)	1.8 (2.8)	18.6 (1.0)
Industrial (5)	54.3 (0.3)	21.4 (0.4)	24.3 (0.5)
Institutional (8)	50.0 (0.4)	9.1 (0.9)	40.8 (0.3)
Open Space (5)	10.2 (1.2)	10.6 (1.3)	79.1 (0.3)
Residential (25)	24.0 (0.6)	12.1 (0.5)	63.8 (0.2)
Freeway and Highway (4)	31.9 (1.2)	27.4 (1.2)	40.7 (0.3)

The directly connected impervious areas are most closely related to the runoff quantities. The partially connected impervious areas contribute runoff at later portions of larger rains, while the pervious areas may only contribute flows after substantial rain has occurred. As expected, most of the data represent residential areas, with commercial areas next, and the other areas having fewer than 10 detailed area descriptions.

In order to examine geographical variations in stormwater characteristics, these land uses were sorted into six areas: Northwest; Southwest; Central; Southeast; Great Lakes; and East Coast. Model calibration was performed in each of these six geographical areas for all of the land uses in each area. If a land use was not represented in an area, the overall average land use characteristics were used. As noted in a previous submittal, stormwater quality data from the National Stormwater Quality Database (NSQD) was sorted into groups representing major land use and geographical categories. The following figure shows the EPA Rain Zones (not to be confused with the EPA administrative regions), the locations for the NSQD stormwater data, and the general calibration set regions. The modeled concentrations were compared to the observed concentrations, as described in the following section.



Sampling locations for data contained in the National Stormwater Quality Database (NSQD), version 3, showing EPA Rain Zones and general calibration set regions.

Modeled Stormwater Characteristics Compared to Observed Data

As noted above, the land use characteristics were used to create a range of standard land use files for evaluation with WinSLAMM. Six geographical areas and six major land use categories were examined. Many of the locations where the site characteristics were available also had stormwater monitoring data available that was used for regional calibration. If sites did not have site-specific data, NSQD regional data were used instead.

The first task was to sort all of the land use files into these six major land use categories. The following table lists the number of sites that were available for each group. As noted, most of the data were available for residential, then commercial areas, with less data available for institutional, industrial, open space, and highway/freeway areas. Overall site characteristics (averaged) were determined for each of these six categories. These six overall averaged files were then used in each of the six geographical areas, to complement available data for each location and land use data set. Some of the area and land use combinations only had this one file available, if no areas were monitored. A total of 114 files were used, with most in the residential and commercial areas, as previously noted, and with most of the files located in the Great Lakes region (due to the large number of Wisconsin observations) and in the Southeast (due to the large number of Birmingham, AL area observations).

Number of Land Use Files Used for Each Category

	Commercial	Industrial	Institutional	Open Space	Residential	Freeways/ Highways	Total by Location
Central	4	2	4	1	5	3	19
East Coast	3	1	1	1	2	3	11
Great Lakes	6	4	4	2	11	4	31
Northwest	2	1	1	1	3	3	11
Southeast	7	2	3	5	8	4	29
Southwest	5	1	1	1	2	3	13
Total by Land Use	27	11	14	11	31	20	114

Each of these 114 files was associated with stormwater characteristic data, with preference given to site-specific monitoring data. If local observations were not available, then NSQD data was used. As noted in the earlier NSQD project memo, those observations were separated into land use and regional EPA rain zone categories. The NSQD data associated with the land use-area category were used if at least 30 events were monitored; if not, then the overall land use values for the constituent were used. Infrequently, the overall land use data did not have at least 30 event observations, so the overall average concentration was used.

The original WinSLAMM calibrated parameter files for Wisconsin developed and maintained by the USGS were used for all of the areas, except for the Southeast region. The Southeast region used the Birmingham area previously calibrated parameter files. The characteristics and constituents examined included: Rv (the volumetric runoff coefficient, the ratio of runoff depth to rain depth), TSS, TDS, COD, TP, filtered P, TKN, NO_3+NO_2, Cu, Pb, Zn, and fecal coliforms. The bacterial data was not available for the WI locations, so the NSQD was used for the Great Lakes locations. In addition, calculated peak flow (CFS/100 acres) was also examined. It was hoped that *E. coli* could also be used in these analyses, but the few data available did not allow suitable calibrations.

Initially, each of the 114 standard land use files were used in WinSLAMM using these original calibrated parameter files. The source area concentration data used in these files are described and summarized in the following publications (previously listed as the sources of the WI data, but these also include data from most of the source areas examined):

- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 1) – Older monitoring projects." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 465 – 484 and 507 – 530. 2005.
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 2) – Recent sheetflow monitoring results." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 485 – 530. 2005.
- Pitt, R., D. Williamson, and J. Voorhees. "Review of historical street dust and dirt accumulation and washoff data." Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp 203 – 246. 2005.

Area rain files were selected for each of the regions. The averaged land use files were evaluated using the following rain data for 4 or 5 years (1995 through 1999, except for Lincoln, NE that started in 1996 due to missing rain records): Great Lakes: Madison, WI; East Coast: Newark, NJ; Central: Lincoln, NE; Northwest: Seattle, WA; Southeast: Birmingham, AL; and Southwest: Los Angeles, CA. The sites having site-specific observations used the rain records associated with the sites and for the period of record. The Great Lakes region recognized a winter period (Dec 3 to March 12) as did the Central region (Dec 20 to Feb 10). During these winter periods, no stormwater calculations were made.

The calculated long-term averaged modeled concentrations were compared to the monitored concentrations for each site and for the land use category combined. Factors were applied uniformly to each land use-area pollutant parameter file to adjust the long-term modeled concentrations to best match the monitored/observed values. The WI and AL location files were not changed as they were associated with previously calibrated conditions (except for the constituents that were not measured locally). In addition, the runoff parameter files were not modified as they have been shown to compare well to observed conditions under a wide range of situations.

The following table summarizes the results of the comparisons of the modeled to the observed values for all of the 114 files (91 for Rv, as some areas did not have suitable comparison data) for each constituent. As noted in this summary table, the regression statistics were all excellent (the P-values of the regression equations and for the slope terms were all highly significant), and the regression slope terms were all close to 1.0, with a few exceptions. The residual behaviors were all very good, except for total and filtered phosphorus that showed a strong bias, with modeled concentrations being too high for small observed concentrations. The Rv plot also showed a similar, but much less severe bias. All of the other constituents had random variations about the best fit lines with small variabilities.

Summary of Observed vs. Modeled Concentrations

	Regression Slope (intercept = 0) and 95% CI	P-value of slope term	P-value of regression	Adjusted R^2	Number of Observations	Residual Behavior Comments
Volumetric Runoff Coefficients	0.93 (0.87, 0.99)	<0.0001	<0.0001	0.90	91	Some modeled values high for small observed RV
Total Suspended Solids	0.90 (0.83, 0.97)	<0.0001	<0.0001	0.85	114	Good
Total Dissolved Solids	0.62 (0.53, 0.70)	<0.0001	<0.0001	0.63	114	Good
Chemical Oxygen Demand	1.00 (0.92, 1.04)	<0.0001	<0.0001	0.93	114	Good
Total Phosphorus	0.88 (0.68, 1.08)	<0.0001	<0.0001	0.40	114	Most modeled values high for small observed TP concentrations
Filterable Phosphorus	0.95 (0.81, 1.09)	<0.0001	<0.0001	0.61	114	Most modeled values high for small observed filterable P concentrations
Total Kjeldahl Nitrogen	1.06 (0.96, 1.15)	<0.0001	<0.0001	0.80	114	Good
Nitrites plus Nitrates	0.70 (0.62, 0.78)	<0.0001	<0.0001	0.71	114	Good
Total Copper	0.59 (0.50, 0.67)	<0.0001	<0.0001	0.60	114	Good
Total Lead	0.99 (0.93, 1.05)	<0.0001	<0.0001	0.90	114	Good
Total Zinc	0.96 (0.92, 1.00)	<0.0001	<0.0001	0.95	114	Good
Fecal Coliform Bacteria	0.74 (0.65, 0.83)	<0.0001	<0.0001	0.68	114	Good