Port of Seattle

Stormwater Whole Effluent Toxicity (WET) Testing at Seattle-Tacoma International Airport

Final Report

May 2000

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ACKNOWLEDGEMENTS

The Port thanks the staff of Taylor Associates for their diligence, skill and ingenuity in stormwater sample collection, Aquatic Research, Incorporated for their flexibility and availability in handling the analytical work, and Parametrix, Incorporated for their high quality support in WET testing and for assisting with the novel approach for source-tracing.

1 EXECUTIVE SUMMARY

During a twelve month period in 1998-99, the Port of Seattle characterized the whole effluent toxicity (WET) of at least two stormwater samples from four outfalls at Sea-Tac International Airport (STIA.) This WET testing satisfies the requirements of Special Condition S10 of the Port's NPDES permit (WA-002465-1.) The WET tests used two aquatic organisms, a water flea (Daphnia *pulex*.) and the fathead minnow (Pimephales *promelas*) to characterize the acute toxicity of flow-weighted composite stormwater samples taken during two different storm events. Two of these outfalls were sampled on additional occasions to corroborate results from the first two tests. The Port has previously submitted the WET testing data to Ecology. This final report summarizes all results and subsequent information gathered pursuant to the permit requirement.

Subbasins SDE4 (002), SDS3 (005), SDN1 (006) and SDN4 (011) were sampled for WET testing. All test results for outfalls SDS3 and SDN4 met the Washington Department of Ecology performance standards for survival for each organism. These two outfalls drain 79% (492 ac) of the airfield runways and taxiways, or 51% of the total storm drainage area of the airport. Nine of ten test results for outfall SDE4, which drains 149 acres mostly consisting of access roadways and the terminal and cargo building rooftops, also met the performance standards. One of the fathead minnow results for an SDE4 sample fell just below the performance standard. In contrast, seven of nine WET results for outfall SDN1 fell below the performance standards and led to a subsequent source-tracing investigation.

Supplemental sampling and analysis indicated that metals were the primary source of toxicity in the SDN1 samples. After removal of metals by chelation with EDTA, survival improved dramatically. Comparing these results to the available literature indicated that zinc was the likely source of toxicity. Further investigations revealed that about 2 acres of zinc-galvanized metal rooftop on the two AFCO Air Cargo buildings was the principal source of the zinc. Synthetic runoff samples obtained by spraying domestic water on the rooftops also exhibited toxicity and considerable zinc.. The Port is investigating alternatives to remedy the apparent source of toxicity originating from a tenant-owned facility. Follow up sampling will demonstrate the effectiveness of the remedy selected.

2 INTRODUCTION

The Port of Seattle owns and operates Seattle-Tacoma International Airport (STIA) which lies about midway between the cities of Seattle and Tacoma, Washington. The airport was built in the 1940s and expanded throughout the years to become the 18th busiest airport in the U.S. (POS, 1999a.) As the airport grew, the areas surrounding the airport urbanized and incorporated as the cities of Seatac, Des Moines, and Burien.

STIA storm drainage discharges from 14 principal subbasins through a variety of outfalls; four that drain to Miller Creek[1], eight that drain to Des Moines Creek, and two that drain to a City of Seatac stormwater system. The storm drain system (SDS) connected to these outfalls drains a 963 acre area, which contains about 44% impervious surfaces. Another 370 acres of impervious surfaces where aircraft are serviced (terminal gates and ramps) drain to the Industrial Wastewater System (IWS) and the Industrial Wastewater Treatment Plant (IWTP.) The IWTP discharges directly to Puget Sound through a marine outfall that combines discharges from the nearby Midway Sewage Treatment plant. The IWTP was not monitored as part of the WET testing, therefore this report pertains only to SDS discharges.

In 1994, the Port secured a National Pollutant Discharge Elimination System (NPDES) permit for the stormwater and IWTP discharges. The required intensive stormwater monitoring program has been in place since 1994, and has generated a considerable volume of sample data. As another part of this permit, the Port implements a Stormwater Pollution Prevention Plan (SWPPP, POS 1998) and stormwater best management practices (BMPs.) The permit was renewed in 1997 and a revised permit took effect in March 1998. Special

[1] Miller and Des Moines Creeks flow directly to Puget Sound.

Condition S10 of the Port's NPDES permit requires the Port to conduct WET testing on stormwater samples from subbasins SDE4, SDS3, SDN4 and SDN1 for two storm events. These four subbasins encompass 68% of the total SDS service area and contain most of the landside and airfield activity.

2.1 WET Testing Background

In Washington state, only eleven NPDES permittees have performed WET testing on stormwater or a mix of stormwater and industrial wastewater (WDOE, 1998a.) WET testing is a common compliance requirement for point source wastewater discharges such as pulp mills and wastewater treatment plants. WET testing improves upon chemical-specific testing because it measures aggregate toxicity, or lack thereof, addresses unknown toxicants, and takes bioavailability into account.

In accordance with EPA protocols (EPA, 1991), WET testing at STIA was performed on 100% stormwater samples plus a series of samples tested at specific dilutions. Results are expressed as percent survival for the100% sample plus the LC50, NOEC and LOEC estimates generated by the dilution series[2]. Source-tracing in subbasin SDN1 used 100% (undiluted) samples only

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All WET testing was performed by Parametrix, Incorporated, (1999a-e) and followed the state and federal guidelines (WDOE 1998b, EPA 1991.) WET testing and other analyses were initiated within acceptable holding times.

[2] The LC50 is the concentration of sample where 50% survival of the test organism occurred. The no observed effect concentration (NOEC) is the maximum concentration of the test sample that produces no statistically significant harmful effect on the test organisms compared to controls in a specific test. The lowest observed effect concentration (LOEC) is the lowest concentration that has a statistically significant deleterious effect on test organisms compared to controls in a specific test (Rand, 1995.)

Chemical specific analyses were conducted by Aquatic Research, Incorporated, which is an Ecology-accredited laboratory. All WET testing data reports have been previously submitted to Ecology for review.

2.2 Sampling Methods

All samples tested were collected as flow-weighted stormwater composites using ISCO model 3700 automatic samplers and model 4150 or 4230 flowmeters[3]. Samples generally represented the majority of runoff and are thus considered as event-mean concentrations (EMCs), a common term used in the literature to judge intra-event representativeness and inter-event comparability of a stormwater sample. Composite samples taken for the SDN1 source tracing study were collected concurrently using three automatic samplers programmed to sample a similar duration of the hydrograph from each upstream source area. The SDN1 source tracing also used grab samples taken automatically and manually at several of the upstream locations. Quality assurance procedures and quality control samples were adequate to ensure valid results. The results of the Port's routine quality control field blanks and duplicates indicate ongoing effective sampling techniques (POS, 1999c.)

Samples were collected using the "clean techniques" approach for trace metal sampling (EPA method 1669) adapted for stormwater sampling (EPA 1995, POS 1999d.) Results from field equipment blanks indicated that these techniques were generally adequate. Ecology reviewed an outline of the Port's sampling protocol in June 1999 and agreed the sampling procedures satisfied the requirements of clean techniques (POS 1999e.)

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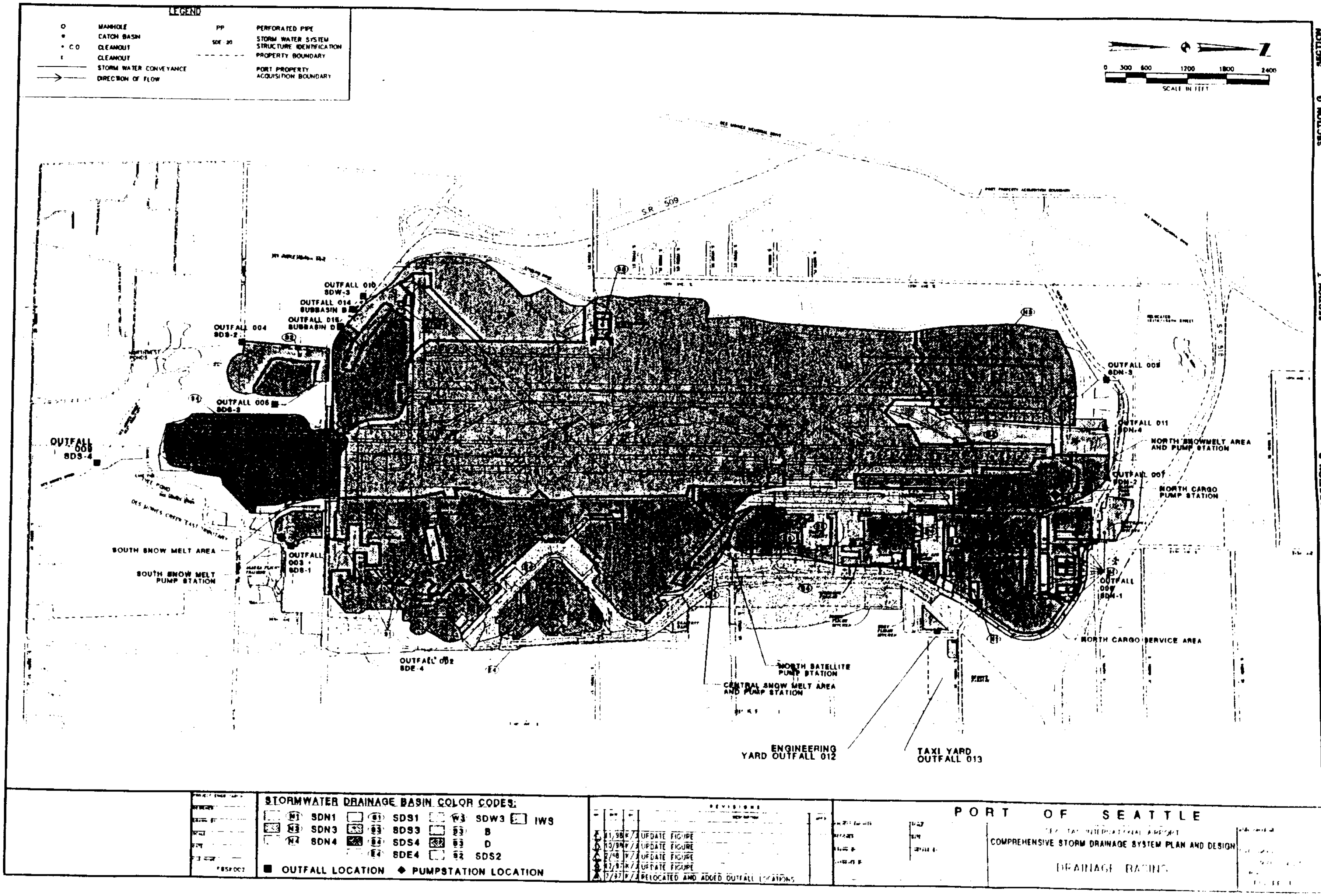
[3] Sampling procedures for WET testing work were consistent with the Port's routine NPDES stormwater monitoring program, described in the Ecology-approved "Procedure Manual for Stormwater Monitoring at Sea-Tac International Airport, revision 6, April 22, 1999" (POS 1999b)

2.3 STIA Storm Drainage Subbasins

The Port codes STIA storm drainage subbasin names according to location, for example, "SDN1" means "storm drain north number 1." The NPDES permit refers to outfalls by number; however, this report refers to subbasins and their outfalls by location names (both identifiers are used in subsequent tables). The Port also identifies manhole or other specific locations within a particular subbasin according to an alphanumeric scheme. Figure 1 shows the stormwater drainage subbasins.

Two of the subbasins with discharges tested for WET, SDS3 and SDN4 comprise 51% of the total STIA storm drainage area. These two subbasins drain the majority of the airfield runways, taxiways and aircraft "hardstand" areas that make up the airfield operations area (AOA). In contrast, the other two subbasins with discharges WET-tested, SDE4 and SDN1 drain the "landside" areas and comprise 17% of the SDS. These landside areas are mostly associated with passenger vehicles, including public roads such as the airport access freeway, Air Cargo Road and portions of International Boulevard.

Recent Annual Stormwater Monitoring reports showed that the concentrations of metals and other constituents were lower in airfield outfall samples when compared to results from the landside subbasin outfalls (POS, 1996, 1997.) In the past few years, the Port has constructed a number of source-control best management practices (BMPs) that reroute storm drainage to the IWS for a number of airfield and landside areas, including an entire SDS subbasin (SDN2).


LEGEND
MANHOLE
CATCH BASIN
CLEANOUT
CLEANOUT
STORM WATER CONVEYANCE
DIRECTION OF FLOW
PP PERFORATED PIPE
STORM WATER SYSTEM STRUCTURE IDENTIFICATION
PROPERTY BOUNDARY
PORT PROPERTY ACQUISITION BOUNDARY
0 300 600 1200 1800 2400
SCALE IN FEET
SR 509
OUTFALL 010 SDW-3
OUTFALL 014 SUBBASIN B
OUTFALL 015 SUBBASIN D
OUTFALL 004 SDS-2
OUTFALL 006 SDS-3
OUTFALL 005 SDS-4
SOUTH SNOW MELT AREA
SOUTH SNOW MELT PUMP STATION
OUTFALL 003 SDS-1
OUTFALL 002 SDE-4
OUTFALL 008 SDN-3
OUTFALL 011 SDN-4
NORTH SNOWMELT AREA AND PUMP STATION
OUTFALL 007 SDN-2
NORTH CARGO PUMP STATION
OUTFALL 009 SDN-1
NORTH CARGO SERVICE AREA
NORTH SATELLITE PUMP STATION
CENTRAL SNOW MELT AREA AND PUMP STATION
ENGINEERING YARD OUTFALL 012
TAXI YARD OUTFALL 013
SECTION G
SECTION T
SECTION B
SECTION N
DISCIPLINES
STORMWATER DRAINAGE BASIN COLOR CODES:
N1 SDN1
S1 SDS1
W3 SDW3
IWS
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3 RESULTS AND DISCUSSION

3.1 General results

Results of the WET tests performed on stormwater samples from outfalls SDE4, SDS3, and SDN4 met Ecology's WET testing performance standards[4]. However, results from outfall SDN1 exhibited aquatic toxicity that was subsequently traced to metals leaching from uncoated galvanized sheet metal rooftops. According to the manufacturer's literature, the coating on this common sheet-steel roofing product contains 43% zinc by weight (Bethlehem Steel, 1995.) Because the WET test results from outfalls SDS3 and SDN4 demonstrated no toxicity, sampling requirements for these two outfalls were completed early in the program during the fall and winter months of 1998-1999. All test results for these 2 outfalls met Ecology's performance standards for individual results so that additional testing was not necessary. Outfalls SDE4 and SDN1 were sampled during additional storms to corroborate results from the first two tests. For SDE4, the additional sampling and WET testing met the required standards. As a result, further testing was not necessary. Of the five samples evaluated for WET for outfall SDE4, the average survival of 96% for the daphnid and 85.8% for the fathead minnow met the Ecology performance standards. However, samples collected from SDN1 continued to exhibit toxicity. As a result, the Port engaged in the SDN1 source-tracing study described below.

Table 1 summarizes WET testing results and lists the relative percent rank for each supplemental analytical result (metals, TSS, etc.). Though not required to do so, the Port analyzed these additional chemical-specific parameters to characterize the WET test samples and compare results with the 5-year data history for each outfall. Because the results were within the ranges of the historical data for each outfall, the WET test samples are considered to be comparable to other historical samples. Appendix A lists the individual sample results and ranks. Table 2 lists the other WET metrics reported: NOEC, LOEC and LC50.

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[4] According to WAC 173-205, for acute WET tests the average survival in 100% effluent must be at least 80%, and no single sample must have less than 65% survival. For outfall SDE4, one of ten test results exhibited 63% survival, just below the minimum performance standard of 65% survival for a single test.

Table 1 WET Testing Summary

Outfall (#)	Sample date	WET, % survival		note
		daphnid	fathead	
SDE4	11/19/98	90	100	
(002)	1/21/99	100	98	2
	2/23/99	95	[redacted]	3
	3/24/99	95	98	3
	7/2/99	100	70	3,4
	Average	*96*	*85.8*	
SDS3	11/13/98	90	98	
(005)	1/14/99	80	95	
	Average	*85*	*96.5*	
SDN1	11/13/98	80	[redacted]	
(006)	1/14/99	[redacted]	78	
	3/24/99	[redacted]	[redacted]	3
	5/11/99	[redacted]	not tested	3,6
	7/2/99	not tested	[redacted]	3,4,5
	11/6/99	[redacted]	not tested	3,6
	Average	*37*	*53.5*	
SDN4	11/13/98	75	100	
(007)	1/14/99	100	100	
	Average	*87.5*	*100*	

Shaded values indicate the individual result was below the performance standard of 65% survival.

Notes for Table:

1. all samples were flow-weighted composite stormwater samples
2. SDE4 Jan 20, 1999 sample: fathead test duration was 48-hr instead of 96-hr
3. Retested to corroborate previous results.
4. July 2, 1999 samples: fathead control survival of 72.5% was below the performance standard of >90%.
5. July 2, 1999 SDN1 sample: insufficient # of organisms to start daphnid test.
6. Sample taken for source-tracing

Table 2 Additional WET Test Metrics

Outfall	Sample Date	Test Date	Species	Duration	NOEC	LOEC	LC50	% Survival in 100% Sample
SDN1	11/13/98	11/13/98	*D. pulex*	48 hours	100%	>100%	>100%	80%
(006)	1/14/99	1/15/99	*D. pulex*	48 hours	100%	>100%	85.20%	30%
	3/24/99	3/25/99	*D. pulex*	48 hours	50%	100%	74.00%	10%
	7/2/99	7/3/99	*D. pulex*	*not tested*				
	11/13/98	11/13/98	*P. promelas*	96 hours	50%	100%	89%	40%
	1/14/99	1/15/99	*P. promelas*	96 hours	100%	>100%	>100%	78%
	3/24/99	3/25/99	*P. promelas*	96 hours	50%	100%	>100%	63%
	7/2/99	7/3/99	*P. promelas*	96 hours	50%	100%	88%	33%
SDN4	11/13/98	11/13/98	*D. pulex*	48 hours	100%	>100%	>100%	75%
(011)	1/14/99	1/15/99	*D. pulex*	48 hours	100%	>100%	>100%	100%
	11/13/98	11/13/98	*P. promelas*	96 hours	100%	>100%	>100%	100%
	1/14/99	1/15/99	*P. promelas*	96 hours	100%	>100%	>100%	100%
SDS3	11/13/98	11/13/98	*D. pulex*	48 hours	100%	>100%	>100%	90%
(005)	1/14/99	1/15/99	*D. pulex*	48 hours	100%	>100%	>100%	80%
	11/13/98	11/13/98	*P. promelas*	96 hours	100%	>100%	>100%	98%
	1/14/99	1/15/99	*P. promelas*	96 hours	100%	>100%	>100%	95%
SDE4	11/19/98	11/20/98	*D. pulex*	48 hours	100%	>100%	>100%	90%
(002)	1/21/99	1/22/99	*D. pulex*	48 hours	100%	>100%	>100%	100%
	2/23/99	2/23/99	*D. pulex*	48 hours	100%	>100%	>100%	95%
	3/24/99	3/25/99	*D. pulex*	48 hours	100%	>100%	>100%	95%
	7/2/99	7/3/00	*D. pulex*	48 hours	100%	>100%	>100%	100%
	11/19/98	11/20/98	*P. promelas*	96 hours	100%	>100%	>100%	100%
	1/21/99	1/22/99	*P. promelas*	*48 hours*	100%	>100%	>100%	98%
	2/23/99	2/23/99	*P. promelas*	96 hours	25%	50%	>100%	63%
	3/24/99	3/25/99	*P. promelas*	96 hours	100%	>100%	>100%	98%
	7/2/99	7/3/99	*P. promelas*	96 hours	100%	>100%	>100%	70%*

* in this test, survival in the control of 72.5% did not meet minimum acceptability criterion of 90%

3.2 SDN1 source-tracing

Additional stormwater samples collected from outfall SDN1 continued to exhibit toxicity.. To address this, the Port developed a multiphase source-tracing study using additional stormwater sampling and testing. The approach used concurrent WET testing and chemical-specific analysis of stormwater samples to reveal clues about specific sources of toxicity. Because the first three samples showed that the daphnia were more sensitive, source-tracing samples were tested using only Daphnia *pulex* in 100% sample concentration.

Because stormwater from SDN1 has historically exhibited higher zinc concentrations than other outfalls (see Figure 2), this metal was suspected as a potential source of toxicity. Note the considerable number of historical samples (twenty for SDN1) denoted by "N=" below each boxplot in the figure. Based on this information, this additional effort focused on metals and used a chelation technique to determine if particular metals were responsible for any toxicity observed in these subsequent WET tests[5]. During these additional sampling events in SDN1, upstream source area runoff samples were also tested to determine where and under what conditions the problems occurred. These potential source areas upstream of the SDN1 sampling location isolate runoff from the Transiplex rooftops (a total of 4 buildings), AFCO cargo building rooftops (2 buildings), and Air Cargo Road (which also contains runoff from the recently constructed east expansion of the FedEx building rooftop.)

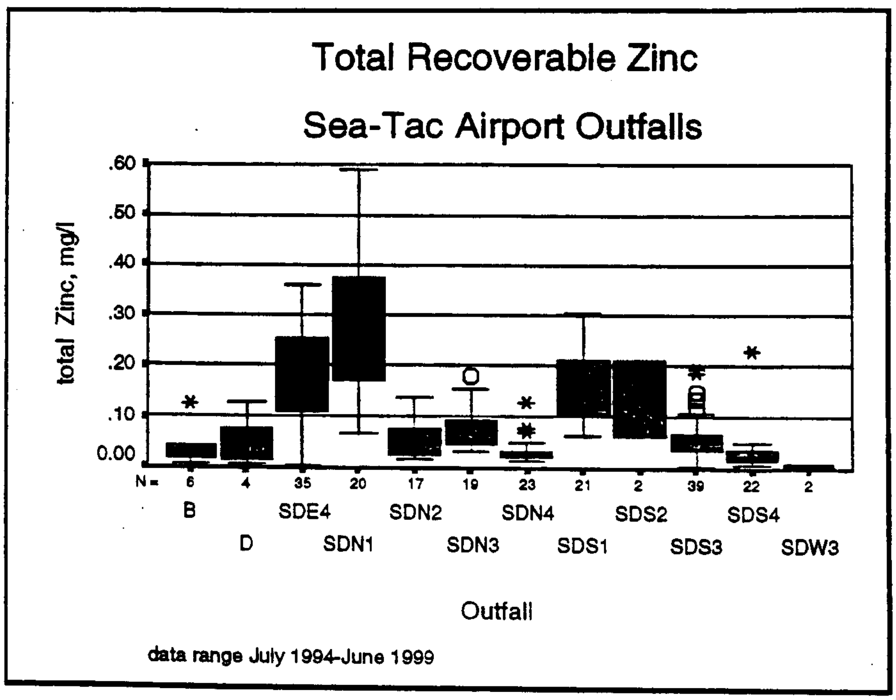

Figure 2 Boxplot of Zinc in STIA Stormwater Samples

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[5] Chelation is the chemical process whereby ions, free metals in this case, are rendered non-bioavailable by binding to a host molecule that forms a stable complex. Free metal ions that are "bioavailable" are the form generally considered to be responsible for toxicity to aquatic organisms.

3.2.1 Summary of source-tracing results

Initial source-tracing and metals chelation confirmed that zinc was the principal, if not sole toxicant present. Total recoverable (TR) zinc concentrations ranged from 120 to 487 µg/l which were within the 11^{th} to 78^{th} percentiles of historical data for SDN1. In four composite samples tested, dissolved zinc ranged from 33 to 117 µg/l, and comprised 18 to 58% of the total zinc. These SDN1 samples generally had higher dissolved zinc than samples from the other outfalls subject to WET testing where dissolved zinc ranged from 12 to 49 µg/l (see Appendix A.) The discussions below focus on metals, because in general other constituents were not associated with survival. Appendix C summarizes the source tracing sample results.

Treating the SDN1 samples with chelating agents that bind dissolved metals confirmed that metals were the principal source of toxicity, with specific indications for zinc. Samples taken from SDN1 drainage isolated from specific rooftops and other contributory areas indicated that the zinc was primarily associated with uncoated galvanized rooftops of the AFCO cargo buildings, but not the nearby non-metal rooftops of the five nearby Transiplex buildings. Synthetic storm runoff samples obtained after spraying domestic water on the AFCO rooftops showed zinc concentrations and toxicity similar to the actual storm samples. The domestic water was not toxic and had about 15 times less zinc than the synthetic runoff sample. These results indicated that the AFCO rooftops were the principal source of zinc. However, other, less significant sources may exist in the SDN1 subbasin. Once the primary source of toxicity (AFCO rooftops) is eliminated, additional sampling should be preformed to determine the effectiveness of the solution. If SDN1 discharges continue to fall below the WET performance standards, additional sampling and source tracing should be undertaken.

The following sections provide details on the sampling, analysis and results of the source tracing as well as a discussion of the potential sources of toxicity.

3.2.2 Field Investigations

Plans and field investigations verified that only reinforced concrete pipe (RCP) and plastic (PVC) piping is used in the SDN1 drainage area studied. None of this drainage passed through corrugated metal pipe (CMP), a potential source of zinc due to galvanized coatings. Also, unlike the other subbasins evaluated for WET, drainage maps and field conditions show that SDN1 runoff receives little to no contact with vegetation and soils; runoff flows directly from the impervious surfaces into the constructed drainage system. Appendix B contains photographs showing the general layout of the SDN1 area under study.

AFCO Cargo Buildings and Their Drainage

Building plans indicated that the two AFCO buildings were constructed about 1989. The plans[6] called for roofing material using uncoated galvanized sheet-steel roofing (POS 1990, Bethlehem Steel, 1995.) Field reconnaissance verified that indeed the roofing material on AFCO building #2 was galvanized and uncoated. According to STIA drainage maps the total roof area is about 2.2 acres, which is similar to the building plans. Because both buildings were designed and built as part of the same project, the as-built conditions of the roofing material on AFCO building #2 are assumed to be the same as that on building #1.

These rooftops represent 25% of the total SDN1 area draining to manhole SDN1-41, the current subbasin SDN1 sampling station for NPDES permit compliance (see Figure 3 and Figure 4.) Other field inspections verified that drainage from these rooftops was the principal discharge present in the 10 inch RCP inlet to manhole SDN1-41 from SDN1-34. The rooftop is in good condition, and has about eight small ventilation stacks, a single air conditioning unit, and no other equipment installed. See the photographs in Appendix B.

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[6] STIA drawing 9029 indicates that the building fabricator was Ruffin Pre-Fab, Inc., of Oak Grove, LA. During a telephone call to this company, a Ruffin employee indicated his familiarity with the AFCO building (previously known as "Avia") project and supplied the material specification cited above.

Other minor amounts of runoff from an area of about 500 square feet of pavement along the East side of this building at loading dock numbers E9 to E13 (see Appendix B) also combines with the AFCO Air Cargo building rooftop drainage. To prevent this drainage from influencing the subsequent samples taken in this study, the outlet of the trench drain that receives this runoff was blocked beginning in June 1999. Ponding due to this blockage did not occur because the affected runoff flows immediately to the adjacent trench drain along loading docks E7 to E9. This second trench drain connects to the IWS, unlike the former which should be considered for a drainage reroute from SDN1 to the IWS. These drainage connections were verified during dry-weather flow and/or dye testing in March 1999.

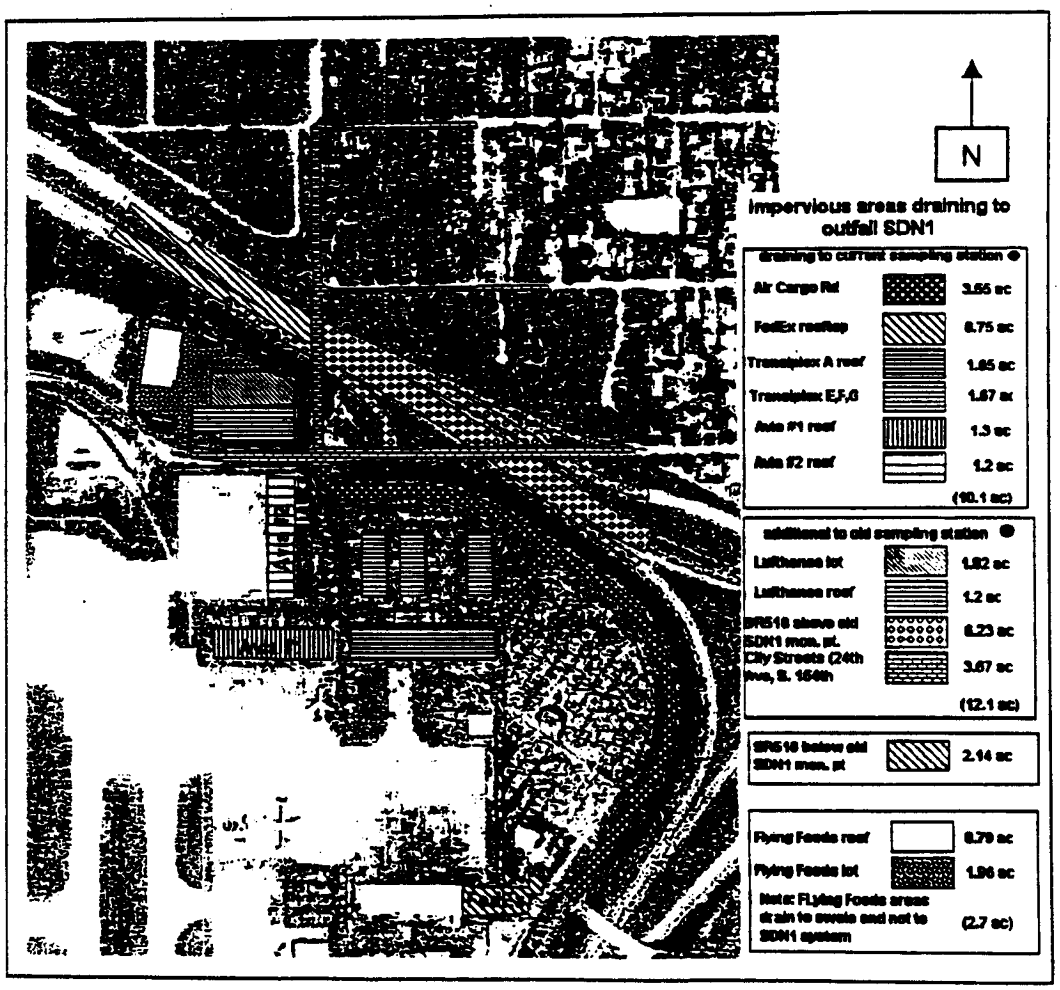

Figure 3 SDN1 Subbasin Map

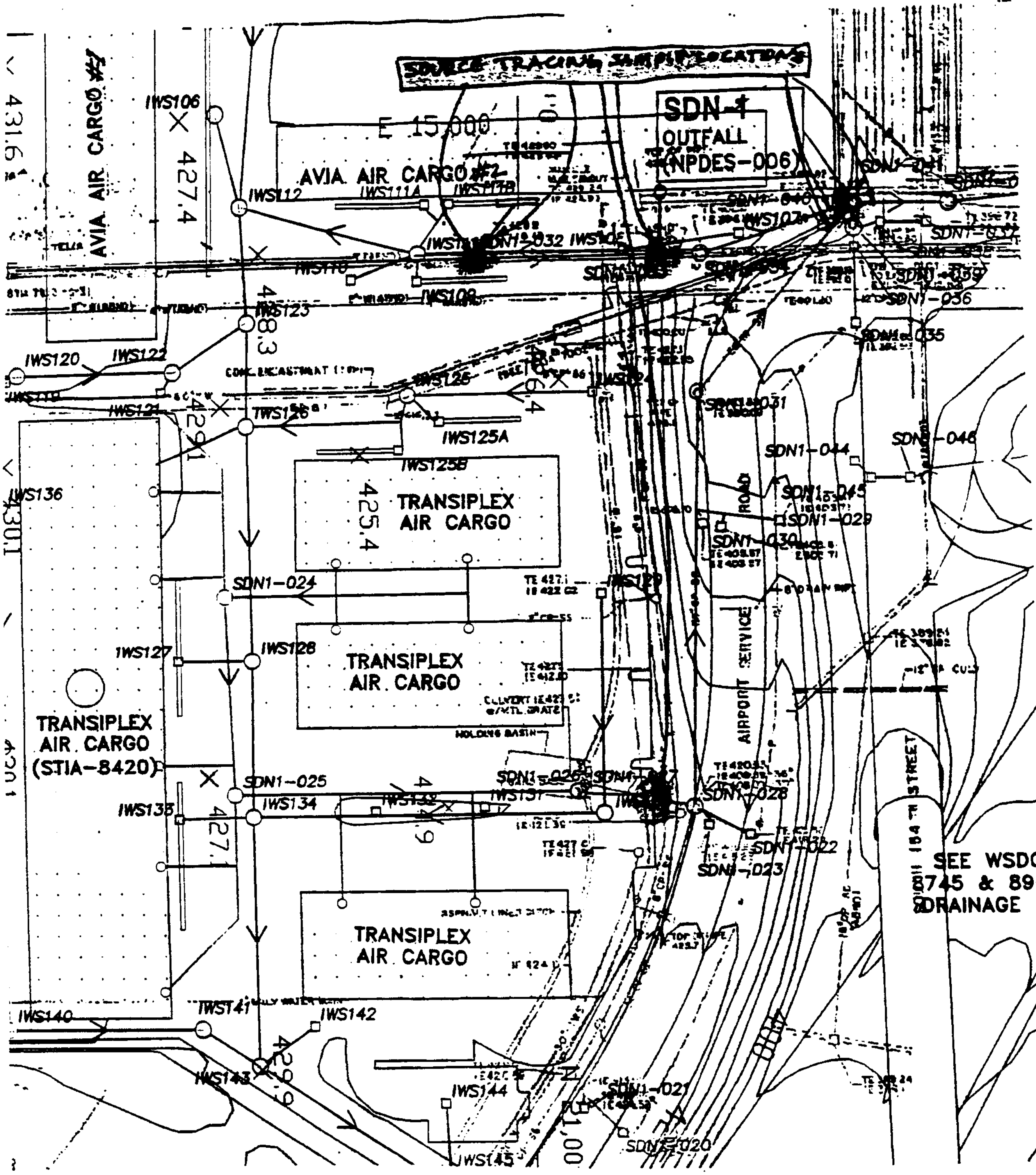

Figure 4 SDN1 Source Tracing Sampling Locations

(SDN1 piping shown in blue)

3.2.3 Sampling Locations

Samples were collected primarily in the three pipes in manhole SDN1-41 that aggregate drainage from various source areas. Grab samples were also taken at other manholes further upstream in the system to isolate drainage from specific source areas and determine their relative metals concentrations. These locations are summarized below and shown in Figure 3 and Figure 4.

1. SDN1-41 manhole: 36" RCP outlet to SDN1-042:
   - This is the routine NPDES compliance sampling location for SDN1 that aggregates all upstream POS drainage. Initial indications of toxicity were found here.
2. SDN1-41 manhole: 36" RCP inlet from SDN1-31
   - This pipe aggregates drainage from Air Cargo Road, and the Transiplex and FedEx rooftops, called "road aggregate" below (labeled "41-31" in Appendix C)
3. SDN1-41 manhole: 10" RCP inlet from SDN1-34
   - This pipe aggregates drainage from locations 5, 6, and 7 below (the two AFCO cargo buildings and the loading dock mentioned below (labeled "41-34" in Appendix C))
4. SDN1-27 manhole: 24" RCP inlet from SDN1-26
   - This location isolates drainage from the four Transiplex buildings A, E,F and G rooftops (about 3.3 acres of rooftops)
5. SDN1-32 manhole: 6" PVC inlet about 3 feet below the manhole rim (not shown on Figure 4)
   - This location isolates drainage from the loading dock trench drain along the east side of AFCO building #2 (about 500 square feet of pavement)
6. SDN1-32 manhole: 10" RCP inlet from the south, bottom of structure
   - This location isolates drainage from AFCO building #1 rooftop only
7. SDN1-33 manhole: 6" PVC inlet about 3 feet below the manhole rim
   - This location isolates drainage from AFCO building #2 rooftop only

3.2.4 Initial Screening Samples

To determine the relative concentrations of metals originating from the various source areas, grab samples were collected during an initial screening of runoff the seven locations listed above. Note that locations 2 and 3 aggregate runoff from the multiple source areas upstream of the sampling location where toxicity was indicated during the initial WET testing. Three storm events were sampled in early 1999: January 13 (1.07"), March 8 (0.28") and March 24 (0.28".) During the first and last of these three storms, grab samples were taken during the rising and falling limbs of the runoff event to determine the relative degree of temporal variation. Appendix C contains the sample results that are plotted in Figure 5 and Figure 6 below. For relative comparisons, these figures show historical interquartile ranges (dashed lines for the 25th and 75th percentile) for SDE4, a comparable landside subbasin with considerable roadway and rooftop drainage, but one that did not exhibit WET toxicity. Working left to right in the figures, the results indicate the following[7].

1. Concentrations of copper and zinc in Transiplex rooftop runoff samples showed:
   - consistently lower concentrations than other locations sampled,
   - dissolved zinc generally an order of magnitude below results from the other rooftops,
   - little difference between samples taken at different times during the discharge (denoted by a sequence number after the sample date),
   - little difference among all samples from the three storm events, and
   - results less than the interquartile range from landside outfall SDE4.

2. Runoff from the loading dock trench drain generally had higher copper and zinc than the other source areas tested, and was higher than the median for SDE4.

3. Comparing samples of runoff isolated from each of the two AFCO building rooftops indicates:
   - copper and zinc were similar between the two buildings among the different events,

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[7] Because dissolved lead was generally less than detection limits, it is not shown in the figures.

- the second sample of the March 24, 1999 event had more than double the zinc of the earlier sample, and
- despite the presence of the minor runoff from the loading dock trench drain, metals in the aggregate runoff of both AFCO rooftops ("AFCO roofs") were similar to and approximated an average of the samples of runoff isolated from each rooftop ("AFCO #1, AFCO #2".)

4. Comparing the Road and AFCO roofs aggregate samples, results indicate:
   - TR copper was similar and within or below the interquartile range for SDE4,
   - in the Road aggregate samples, TR zinc was within the interquartile range for SDE4, and varied less than the rooftop samples
   - in the AFCO rooftop runoff, TR zinc varied to a greater degree than the road aggregate samples. Two rooftop samples had considerably higher TR zinc than the road samples and exceeded the SDE4 interquartile range.

5. In general, metals were mostly present in the dissolved form in all samples. Dissolved to total recoverable metals ratios for copper and zinc ranged from 0.21 to 0.91, with an average of about 61% dissolved. Total recoverable zinc results from the AFCO building rooftops during the March 24, 1999 event ranged from 66 to 92% dissolved.

6. Overall, hardness was low in all samples, which is not surprising given that the runoff has little to no contact with soil surfaces. In general, lower hardness causes metals to be more toxic at lower concentrations.

Based on these initial findings of the source tracing study, the ensuing work incorporated the following considerations:

- it was unlikely that the Transiplex rooftops contributed toxic concentrations of metals,
- the loading dock trench drain was blocked to exclude this drainage from mixing with the AFCO rooftop drainage during the next source-tracing steps. A permanent BMP should be instituted to remove this drainage from SDN1 as part of the SWPPP (POS 1998), and

- subsequent WET testing and chelation evaluations in this project focused on samples from three locations in manhole SDN1-41: 1) the 10" RCP inlet that aggregates the AFCO rooftop runoff, 2) the 36" RCP inlet that aggregates runoff from Air Cargo Road, and the Transiplex and the FedEx rooftops, and 3) the 36" RCP outlet because it is the NPDES compliance sampling location. Samples taken at this outlet measure the net effect of the combined runoff from the two inlets.

3.2.5 Subsequent WET Testing and Chelation Results

Later in 1999, flow-weighted composite samples were collected from the three pipes (two inlets, one outlet) in manhole SDN1-41 during three storm events and analyzed for WET and specific chemical constituents. Two of these sets of samples were processed using chelation to determine if and to what extent metals were associated with toxicity. Samples of runoff produced by spraying the rooftops with domestic water were also tested for WET and the chelation associations.

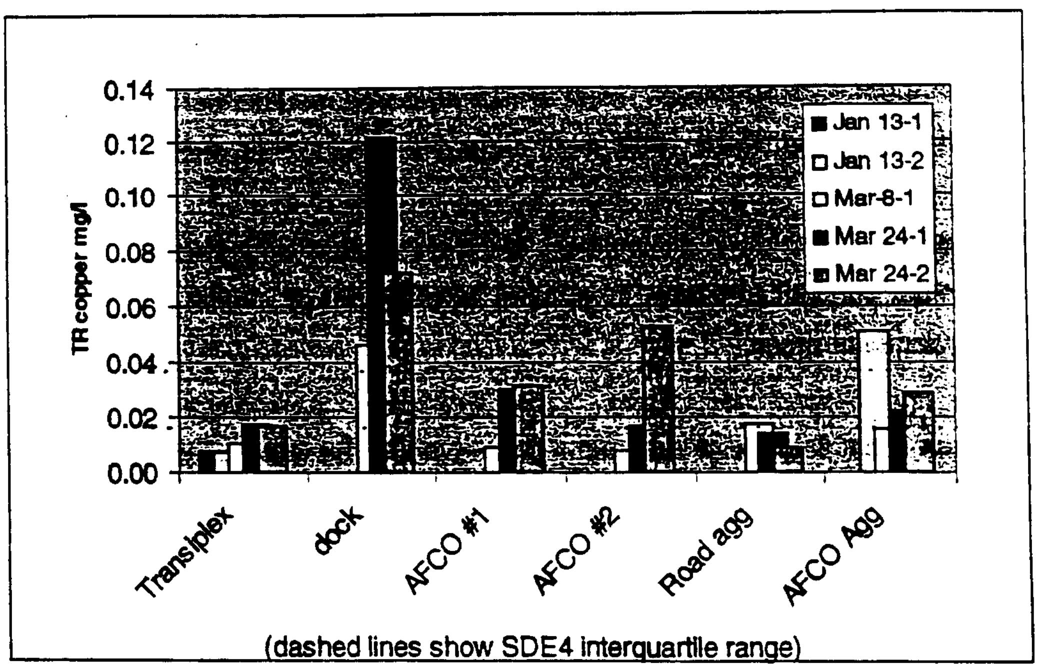

Figure 5 Copper in Initial Screening Grab Samples

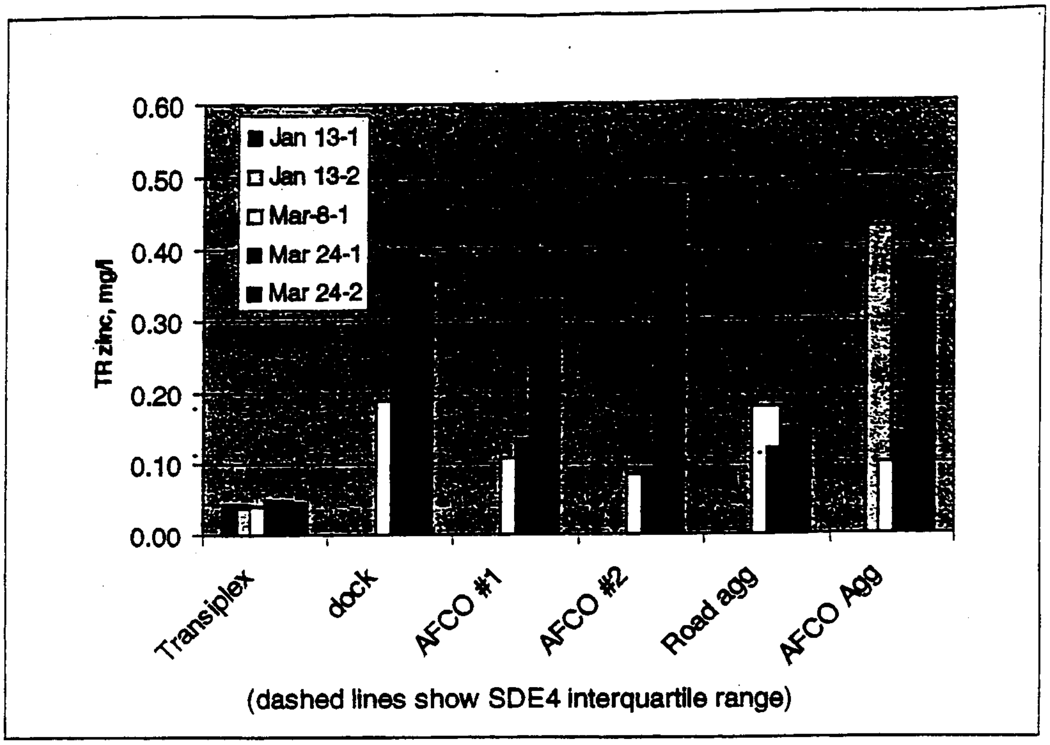

Figure 6 Zinc in Initial Screening Grab Samples

Chelation testing results

Chelation testing on the stormwater yielded interesting and meaningful results. After reducing the bioavailability of metals using two different chelating agents, test organisms had higher survival rates. Therefore, metals were confirmed as the source of toxicity. Furthermore, based on the methods of Hockett and Mount (1996), the pattern of toxicity reduction following chelation confirmed that zinc[8] was indeed the most likely source of toxicity. These tests use EDTA (ethylenediaminetetraacetic acid) and sodium thiosulphate (STS) as chelating agents. Comparing bioassay results before and after adding these agents indicates if and to what degree metals influence toxicity. According to the matrix developed for this method, strong

[8] Hockett and Mount's approach also suggests lead or nickel as potential toxicants, however, historic concentrations of lead and nickel in SDN1 samples were below levels that might have caused toxicity. Lead concentrations analyzed in samples taken during this study were similarly low, and generally not detected. Therefore, this approach indicated zinc as the principal metal attributable for toxicity.

toxicity removal by EDTA coupled with weak removal by STS indicates zinc as a likely source (see Appendix D.)

Other parameters analyzed, such as surfactants and ammonia were not correlated with survival. For samples with low pH, adjusting pH to within acceptable ranges produced little to no toxicity reduction. Survival in laboratory blanks was unaffected by the chelation testing. Table 3 summarizes test results documented by Parametrix, Incorporated (1999f,g,h) with details described below.

In the May 11, 1999 samples, survival was 5% in the SDN1 sample. Subsequent chelation with EDTA dramatically improved survival to 85 to 100%. Because there was limited improvement in survival after the STS additions, results suggest zinc as the source of toxicity. In other words, there were little to no toxic effects due to bioavailable forms of other metals, such as copper, that tend to bind with the STS. In both the road and AFCO rooftop aggregate samples survival was zero, indicating sources of toxicity in drainage from each of these source areas. Because chelation testing was not performed on samples from these source areas, the origins of metals and associated toxicity in the SDN1 sample during this event are not clear. It is important to note that this storm was relatively small (0.14") and that composite samples taken during this event would not meet the minimum rainfall depth criteria (0.20") for NPDES reporting (POS, 1999b.)

Because of problems associated with the WET testing for the July 2, 1999 event, chelation was not pursued[9]. However, the metals results were still valid. There were few other suitable storms for sampling until early fall 1999.

The November 6, 1999 samples tested were from a more typical storm of 0.68 inches. The SDN1 sample and AFCO roof sample each showed a strong improvement in survival after treatment with EDTA. In contrast, the STS additions yielded little to no improvements in

[9] In the July 2, 1999 WET samples, there was an insufficient number of organisms to start the daphnid test. Also, the fathead minnow survival of 72.5% in the control was below the acceptability criterion of ≥90% for control survival.

survival for these two samples. The sample of aggregate runoff from Air Cargo road, and the Transiplex and FedEx rooftops behaved similarly, though initial survival was higher (70%) and chelation results less dramatic. Note that this particular sample would have passed the Ecology performance standards for WET testing. Nonetheless, the chelation results indicate a mild degree of toxicity associated with metals in this aggregate sample of road and other rooftop runoff, predominantly zinc, and possibly copper. Total recoverable zinc was similar between the roads and AFCO runoff samples, yet, the dissolved fraction in the roof sample (0.097 mg/l) was nearly twice as high the road sample (0.056 mg/l.) Copper concentrations were near or below levels suspected to cause toxicity (less than 0.010 mg/l.)

Synthetic runoff

Samples of synthetic runoff produced by spraying the rooftop of the AFCO #2 building also exhibited toxicity, while the source water did not. See Table 4. Two sets of screening tests were conducted on 100% roof runoff sample, the domestic source water, and a control. The domestic source water used for this test was sampled at the outlet of the hose on the tank truck used in the test. The rooftop area tested was well away from the single air-conditioning unit, a potential source of metals associated with exposed cooling coils. Because sample values fell within acceptable test ranges, no pH adjustments were necessary prior to WET testing these samples.

Copper and zinc were generally 2 orders of magnitude higher in the synthetic runoff than the domestic water. Dissolved copper and zinc fractions were 58% and 52% of the total metals measured in the roof runoff. Lead was not detected in either the roof runoff or source water samples. The source water showed non-detectable copper, lead and dissolved zinc. Total recoverable zinc was about 16 times greater in the roof runoff than in the source water. Therefore, these samples show that the roofing material readily leaches metals, particularly zinc. And because about half the total zinc was dissolved in this test, the results indicate that the AFCO roofing generated some degree of metals in particulate form. It is unlikely that this particulate fraction was due to atmospheric deposition considering that runoff samples from nearby rooftops of different construction (the four Transiplex building rooftops' material is a non-metal, single-ply membrane) had much lower metals, especially zinc (see Figures 5 and 6).

Metals Sources Indicated

The WET testing and chelation point to the AFCO Air Cargo building rooftops as at least one distinct source of toxicity with zinc as the likely toxicant. The chemical-specific results indicate that zinc is associated with the building materials, namely the uncoated galvanized metal steel roofing. Other tests have shown that dissolved zinc is higher in this roof runoff than for other locations. Because of the limited number of samples, inconsistent toxicity responses and indications after chelation, it is not clear whether the aggregate runoff from Air Cargo Road, and the Transiplex and FedEx rooftops is problematic, yet a limited degree of toxicity associated with metals is suggested. Recent reconnaissance found the FedEx cargo building rooftop materials to also be uncoated, galvanized metal similar to the AFCO rooftops. This eastern portion of the FedEx facility was added in 1997 and drains to SDN1, unlike the existing western portion that drains to the IWS. However, corrective actions for the AFCO metal roof runoff situation should be pursued as a first step as it appears to be the more significant source of toxicity due to zinc. The Port has already initiated discussions with AFCO and the roofing material manufacturer to determine alternatives for correcting the situation. If subsequent verification WET testing of SDN1 runoff yields acceptable test results no other actions would be indicated.

Table 3 Chelation Testing Results

					Percent survival					
					EDTA addition			STS addition		
			pH	pH	0.5	3	8	1	5	10
Date	Station	pH	unadjusted	adjusted	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
5/11/99	SDN1	7.1	5%	NA	85%	100%	100%	0%	40%	15%
5/11/99	Road agg	6.1	0%	0%	NA	NA	NA	NA	NA	NA
5/11/99	AFCO Roofs	5.4	0%	25%	NA	NA	NA	NA	NA	NA
5/11/99	Blanks	8.3	100%	NA	100%	100%	100%	100%	100%	95%
11/6/99	SDN1	6.7	60%	NA	95%	90%	90%	65%	60%	75%
11/6/99	Road agg	6.8	70%	NA	100%	100%	85%	90%	70%	60%
11/6/99	AFCO Roofs	4.9	0%	0%	5%	0%	55%	0%	0%	0%
11/6/99	Control	7.5	100%	NA	NA	NA	NA	NA	NA	NA

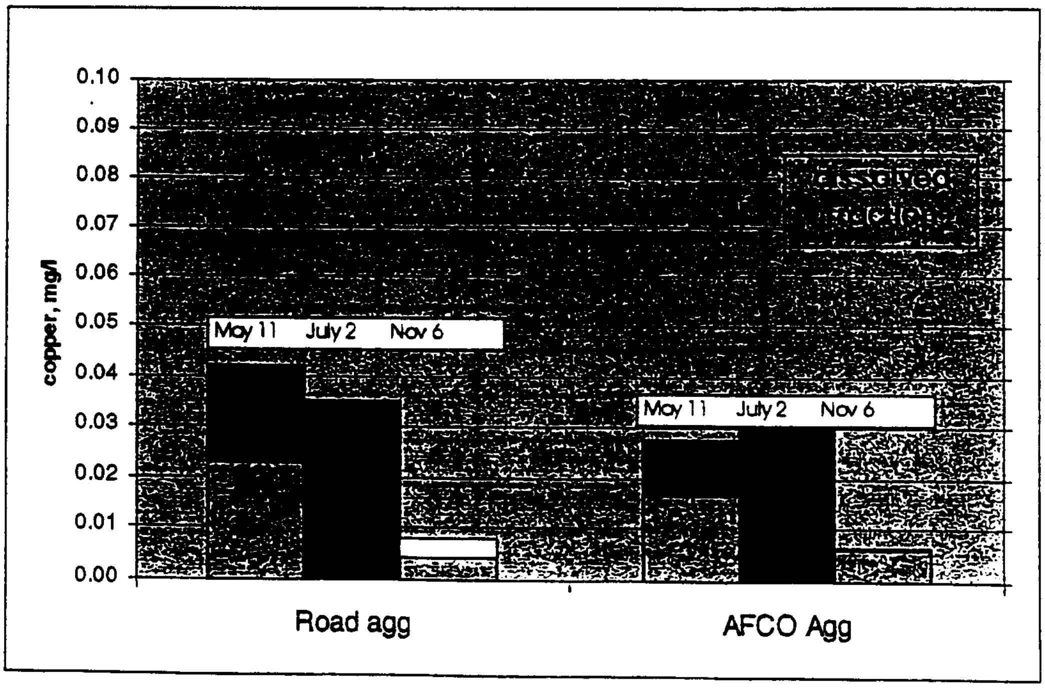

Figure 7 Copper in composite Samples

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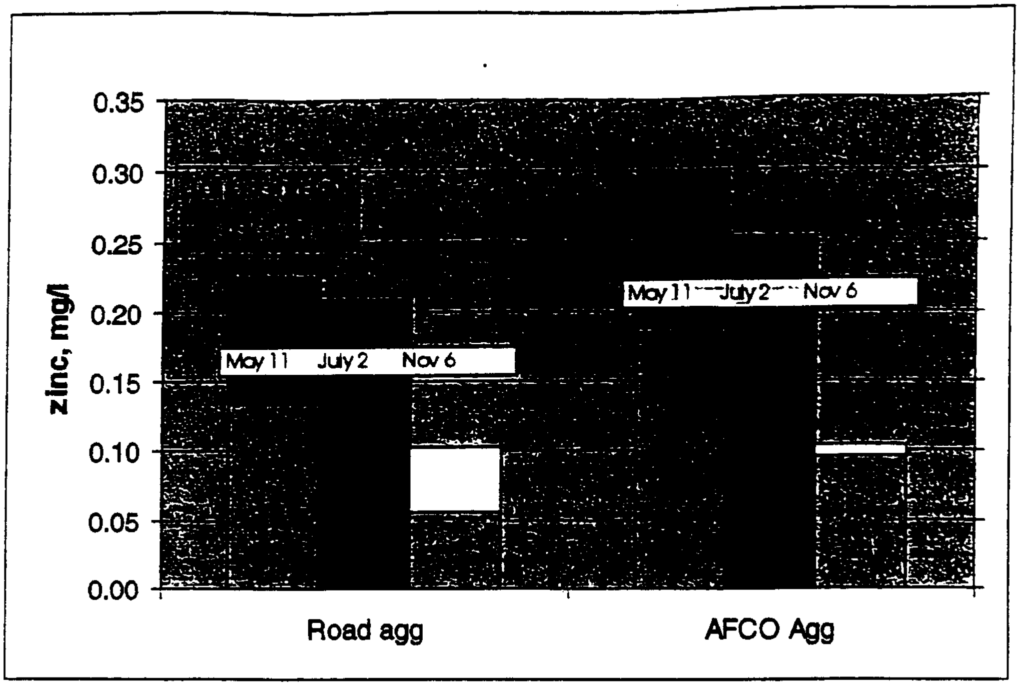

Figure 8 Zinc in composite samples

Table 4 Synthetic Runoff WET Test Results

Sample	pH	Percent Survival
Test 1		
Control	8.0	95%
Roof runoff	6.7	0%
Source water	6.7	90%
Test 2		
Control	7.8	100%
Roof runoff	6.8	0%
Source Water	6.8	100%

Table 5 Synthetic Runoff Metals Concentrations (mg/l)

Sample	TR Cu	Diss Cu	TR Pb	Diss Pb	TR Zn	Diss Zn	hardness
Roof runoff	0.034	0.023	<0.002	<0.002	0.286	0.148	27.4
Source water	<0.002	<0.002	<0.002	<0.002	0.018	<0.005	23.8

4 CONCLUSIONS

The samples collected and tested to satisfy the NPDES permit condition for WET testing support the following conclusions.

1. No further WET testing is necessary for outfalls SDS3 (005) and SDN4 (011) because samples of these stormwater discharges met Ecology's WET testing performance standards.
2. No further WET testing is necessary for outfall SDE4 (002) because the repeat testing (2 samples) met performance standards and did not indicate a continuation of the slightly below-standard survival for only the fathead minnow observed in the February 1999 sample.
3. The source tracing of problematic WET test results for SDN1 yielded meaningful results indicating the need for BMP actions. Specifically, this source-tracing showed that:
   - toxicity was caused by metals, principally zinc, that originated from uncoated galvanized metal roofing on two cargo buildings (AFCO Air Cargo),
   - runoff samples from the other major cargo building rooftops in the area that had non-metal roofing material (Transiplex) had much lower metals that are not suspected to cause toxicity, and
   - there may be other, less significant sources of runoff toxicity in the SDN1 subbasin that may warrant further investigation if corrective actions for the AFCO Air Cargo rooftop do not result in SDN1 discharges that meet performance standards.

Based on the findings of the source-tracing study for SDN1, the following recommendations should be considered.

1. Mitigate the runoff from the 2 AFCO Air Cargo building rooftops. Alternatives include coating, sealing, or removing and replacing the galvanized roofing material. Treating the runoff to remove metals may not be cost effective over the long term. Rerouting the rooftop drainage to the IWS is not consistent with IWS management strategies. Note that the AFCO buildings are tenant-owned facilities not operated by the Port of Seattle.
2. Follow up after mitigating the AFCO rooftop runoff by evaluating SDN1 stormwater for WET. Investigate the other potential sources if these follow-up results are unfavorable.

3. Prevent future use of uncoated galvanized roofing without coating, or require material leaching tests.
4. Correct the inappropriate connection of the trench drain near AFCO building #2 loading docks E9-E11.
5. Update drainage maps to include the roof and trench drain connections found in the study.

5 REFERENCES

Bethlehem Steel, 1995. Spec-Data Sheet for Manufactured Roofing and Siding, Coated Sheet Steel. Descriptive Sheet 2874-95. Bethlehem Steel Corporation, May 1995.

EPA 1991. Methods for aquatic toxicity identifications: Phase 1 toxicity characterization procedures. Second Edition. EPA/600/6-91/003. U.W. Environmental Protection Agency, Environmental Research Laboratory, Duluth Minnesota.

EPA 1995. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels. U.S. Environmental Protection Agency, EPA 821-R-95-034, April 1995.

Good, J. C. 1993. Roof Runoff as a Diffuse Source of Metals and Aquatic Toxicity in Storm Water. Water Sci. Tech., Vol. 28, No. 3-5, 317-321.

Hockett, J. R. and Mount, D. R. 1996. Use of Metal Chelating Agents to Differentiate Among Sources of Acute Aquatic Toxicity. Environ. Toxicol. Chem., Vol 15, No. 10, 1687-1693.

Mason, Y. et.al. 1999. Behavior of Heavy Metals, Nutrients, and Major Components during Roof Runoff Infiltration. Environ. Sci. and Tech. Vol. 33, No. 10, 1588-1597.

Parametrix, 1998. Toxicity Evaluation of Outfalls 005, 006, 011, and 002 to Daphnia pulex and Pimephales promelas. Final Report, dated December 1998. Parametrix, Incorporated.

Parametrix, 1999a. Toxicity Evaluation of Outfalls 005, 006, and 011 to Daphnia pulex and Pimephales promelas. Final Report, dated January 1999. Parametrix, Incorporated.

Parametrix, 1999b. Toxicity Evaluation of Outfall 002 to Daphnia pulex and Pimephales promelas. Final Report, dated March 1999. Parametrix, Incorporated.

Parametrix, 1999c. Toxicity Evaluation of Outfall 002 to Daphnia pulex and Pimephales promelas. Final Report, dated March 1999. Parametrix, Incorporated.

Parametrix, 1999d. Toxicity Evaluation of Outfalls 002 and 006 to Daphnia pulex and Pimephales promelas. Final Report, dated April 1999. Parametrix, Incorporated.

Parametrix, 1999e. Toxicity Evaluation of Outfalls 002 and 006 to Daphnia pulex and Pimephales promelas. Final Report, dated July1999. Parametrix, Incorporated.

Parametrix 1999f. Memorandum dated August 2, 1999. "Toxicity testing following chelation of SDN1 Stormwater." Parametrix, Incorporated.

Parametrix 1999g. Memorandum dated September 20, 1999. "STIA Outfall SDN1: Toxicity testing of simulated stormwater samples." Parametrix, Incorporated.

Parametrix 1999h. Memorandum dated November 29, 1999. "Toxicity testing with Daphnia pulex, following chelation of SDN1 Stormwater collected 6 November, 1999." Parametrix, Incorporated.

POS, 1996. Annual Stormwater Monitoring Report for Seattle-Tacoma International Airport for the Period July 1, 1995 through June 30, 1996. Scott Tobiason, Port of Seattle. Nov 18, 1996.

POS, 1997. Annual Stormwater Monitoring Report for Seattle-Tacoma International Airport for the Period July 1, 1996 through May 31, 1997. Scott Tobiason, Port of Seattle. Sept 29, 1997.

POS 1998. Stormwater Pollution Prevention Plan for Seattle-Tacoma International Airport. November 1998.

POS 1999a. Airport Activity Report, 1998 for Seattle-Tacoma International Airport http://www.portseattle.org/factstat/stats/air/ar98.pdf

POS 1999b. Procedure Manual for Stormwater Monitoring at Sea-Tac International Airport, revision 6, April 22, 1999
POS, 1999c. Annual Stormwater Monitoring Report for Seattle-Tacoma International Airport for the Period July 1, 1998 through June 30, 1999. Port of Seattle. October 1999.

POS 1999d. Adapting Clean Sampling Techniques for POS NPDES Stormwater and other Stormwater Monitoring Project Needs. Scott Tobiason, Port of Seattle, Aviation Environmental Programs. Draft 6/5/99

POS 1999e. Email response from Washington Department of Ecology (Gary Bailey) to Port of Seattle (Scott Tobiason). Dated June 28, 1999.

POS 1990. As-built Drawing numbers STIA 9028 "Avia Air Cargo Complex" dated 6/20/88, and STIA 9029, dated 7/15/89. Available from Port of Seattle Archives. This facility is now owned by "AFCO."

Rand, 1995. **Fundamentals of Aquatic Toxicology,** Second Edition. Gary M. Rand, editor. Taylor and Francis publishers, Washington D.C., 1995.

WDOE 1998a. Whole Effluent Toxicity (WET) Evaluation Summary. Publication # 98-03. Washington Department of Ecology. February 1998.

WDOE 1998b. Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria. Publication #WQ-R-95-80. Washington Department of Ecology. December 1998.

6 APPENDICES

6.1 *Appendix A WET Testing Data Summary*

1998-99 WET Testing Sample Data

SDE4	sample	storm characteristics							concentration, mg/l															WET, % survival		
	type	depth rep	rain	dur	maxint	48hr ai	dryant	pH	TSS	Turb	BOD	NH3	Surf	glycols	TRCu	TRPb	TRZn	Dcu	DPb	DZn	Hard	cond	avg rank	daphnid	fathead	Comment
11/19/98	SMC	0.40	2.34	66	0.18	0	73	8.1	66	52	6.8	0.5	n/a	2	0.032	0.0314	0.163	not analyzed			16	37		90	100	
% rank									82%	88%	54%				64%	81%	58%						71%			
1/20/99	EMC	0.35	0.42	28	0.09	0.95	22	8.2	92	52	5.8	0.10	0.06	2	0.022	0.013	0.168	0.006	0.001	0.012	14.5	34		100	96'	1
% rank									96%	88%	41%				35%	28%	61%	0.25	0.08	0.07			58%			
2/22/99	EMC	0.55	0.56	34	0.14	0.04	9	7.2	53	44	2	0.5	n/a	2	0.015	0.022	0.108	0.004	0.001	0.042	10	36		95	63	
% rank									60%	81%	0%				19%	52%	22%	0.29	0.05	0.39			39%			
3/24/99	EMC	0.26	0.28	19	0.08	0.15	40	6.3	41	32	5.9	0.57	0.26	2	0.020	0.017	0.134	not analyzed			10	31		95	98	
% rank									32%	74%	45%				29%	39%	41%						43%			
7/2/99	EMC	0.27	0.30	6	0.11	0	103	6.2	45	39	6.8	1	n/a	n/a	0.026	0.013	0.141	not analyzed			14	41		100	70'	2
% rank									46%	76%	55%				47%	29%	46%						50%			
average							average result	7.1	54	40	5.3	0.5	0.1	2	0.037	0.017	0.139	0.005	0.001	0.041	13	36		96	87	
							average % rank		63%	81%	39%				39%	46%	46%						52%			
			SDE4		Historical data (7/94-6/99)			count	29	28	32			31	32	33	32									
								max	131	57	29			49	0.078	0.076	0.337									
								min	8.8	1.5	2.0			2.0	0.003	0.001	0.003									
								median	49	27	6.4			2.0	0.028	0.021	0.150									

SDS3	sample	storm characteristics							concentration, mg/l															WET, % survival		
	type	depth rep	rain	dur	maxint	48hr ai	dryant	pH	TSS	Turb	BOD	NH3	Surf	glycols	TRCu	TRPb	TRZn	Dcu	DPb	DZn	Hard	cond	avg rank	daphnid	fathead	Comment
11/13/98	SMC	0.52	0.98	62	0.15	0.05	31	7.5	24	29	17.6	0.5	n/a	11.5	0.022	0.004	0.189	0.014	0.001	0.038	24	69		90	98	
% rank									96%	96%	85%			87%	22%	68%	100%	0.61	0.25	0.20			79%			
1/13/99	EMC	0.65	1.07	22	0.16	0	85	6.8	22	16	7.8	0.5	n/a	11	0.023	0.004	0.030	0.013	0.001	0.012	20	52		80	95	
% rank									93%	87%	39%			83%	25%	65%	13%	0.55	0.26	0.40			58%			
average							average	7.1	23	23	13	0.5		11	0.023	0.004	0.110	0.013	0.001	0.025	22	61		85	97	
			SDS3		Historical data (7/94-6/99)			count	33	33	36			25	37	39	37									
								max	33	42	38			32	0.087	0.016	0.134									
								min	1	1	2			2	0.004	0.001	0.003									
								median	7	6	8			5	0.032	0.002	0.045									

SDN1	sample	storm characteristics							concentration, mg/l															WET, % survival		
	type	depth rep	rain	dur	maxint	48hr ai	dryant	pH	TSS	Turb	BOD	NH3	Surf	glycols	TRCu	TRPb	TRZn	Dcu	DPb	DZn	Hard	cond	avg rank	daphnid	fathead	Comment
11/13/98	EMC	0.61	0.98	62	0.15	0.05	31	8.0	53	46	2	0.5	n/a	n/a	0.024	0.0253	0.487	0.006	0.001	0.110	16	20		60	40	
% rank									63%	100%	0%				67%	79%	94%	0.23	0.04	0.23			67%			
1/13/99	EMC	0.65	1.07	22	0.16	0	85	7.0	78	31	2	0.5	n/a	n/a	0.024	0.048	0.182	0.005	0.001	0.033	8	22		30	78	
% rank									94%	75%	0%				61%	100%	33%	0.19	0.02	0.16			61%			
3/24/99	EMC	0.28	0.28	19	0.08	0.15	40	6.6	61	40	4.86	1	n/a	n/a	0.015	0.010	0.175	not analyzed			16	22		10	63	
% rank									69%	88%	53%				30%	44%	28%						52%			
5/11/99	EMC	0.13	0.14	10	0.08	0	50	7.1		26		0.238	0.246	n/a	0.046	0.004	0.276	0.043	0.001	0.117	14.2			5		4
% rank										53%					86%	10%	74%	0.94	0.29	0.42			56%			
7/2/99	EMC	0.30	0.30	6	0.11	0	103	6.1	69	25	4.26	0.3	n/a	n/a	0.036	0.009	0.236	not analyzed			10	21		not tested	33'	2, 3
% rank									83%	52%	36%				63%	32%	69%						59%			
11/6/99	SMC		0.68	12	0.11	0.05	44		26	20	4.1	0.06	0.06	n/a	0.106	0.009	0.120	0.005	0.001	0.069	11.3			60	not tested	
average							average	6.9	57	32	3.5	0.48	0.06	n/a	0.042	0.020	0.240	0.005	0.001	0.071	12	21		40	60	
							average rank		77%	79%	22%				60%	64%	56%						60%			
			SDN1		Historical data (1/97-6/99)			count	17	17	18				19	20	19									
								max	85	46	29				0.062	0.048	0.540									
								min	9.7	6.4	2				0.003	0.001	0.066									
								median	43	24	5				0.019	0.011	0.218									

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1998-99 WET Testing Sample Data

SDN4	sample	storm characteristics							concentration, mg/l															WET, % survival		
	type	depth rep	rain	dur	maxint	48hr ai	dryant	pH	TSS	Turb	BOD	NH3	Surf	glycols	TRCu	TRPb	TRZn	Dcu	DPb	DZn	Hard	cond	avg rank	daphnid	fathead	Comment
11/13/98	EMC	0.80	0.98	62	0.15	0.05	31	7.5	22	15	2	1	n/a	2	0.025	0.0012	0.127	0.021	0.001	0.049	24	75		75	100	
% rank									94%	89%	0%				23%	81%	100%	0.8379	0.83	0.39			65%			
1/13/99	EMC	0.85	1.07	22	0.16	0	85	6.8	7	9.2	2	0.5	n/a	2	0.020	0.001	0.034	0.014	0.001	0.027	28	56		100	100	
% rank									57%	78%	0%				9%	27%	77%	0.7065	n/a	0.79			41%			
	average						average	7.1	15	12	2	0.8		2	0.023	0.001	0.061	0.018	0.001	0.038	26	66		88	100	
SDN4 Historical data (7/94-6/99)								count	20	20	22			16	22	23	23									
								max	27	23	36			34	0.091	0.003	0.127									
								min	2	2	2			2	0.015	0.001	0.014									
								median	4	5	4			2	0.035	0.001	0.025									

comments

1. SDE4 Jan 20, 1999 sample: fathead test duration was 48-hr instead of 96-hr
2. July 2, 1999 samples: control failed at 72.5% survival (criterion is >90%)
3. July 2, 1999 SDN1 sample: insufficient # of organisms to start daphnid test.
4. May 11, 1999 SDN1 sample taken for source tracing (was a non-storm) only, not to explicitly satisfy permit condition S10

<MDL, value shown is 1/2 MDL
exceeds single value and/or average criterion for survival

notes

1. pH, ammonia, hardness, and conductivity measured at Parametrix toxicology lab
2. Dissolved metals not routinely analyzed, therefore, no summary statistics provided
3. Summary statistics for each outfall are relative trimmed data set July 1994 through June 30, 1999
4. All data for SDN1 are from "up" station located in manhole SDN1-22
5. Ammonia values <1 analyzed at Aquatic Research unless shown as shaded in table

Blanks	sample	storm characteristics							concentration, mg/l															WET, % survival		
	type	depth rep	rain	dur	maxint	48hr ai	dryant	pH	TSS	Turb	BOD	NH3	Surf	glycols	TRCu	TRPb	TRZn	Dcu	DPb	DZn	Hard	cond	avg rank	daphnid	fathead	Comment
11/6/99	bottle blank										<4	<0.01	<0.025	n/a	<0.002	<0.002	<0.005	<0.002	<0.002	<0.005	1.17					
11/6/99	eqpt blank										<4	<0.01	<0.025	n/a	<0.002	<0.002	<0.005	<0.002	<0.002	<0.005	1.17					

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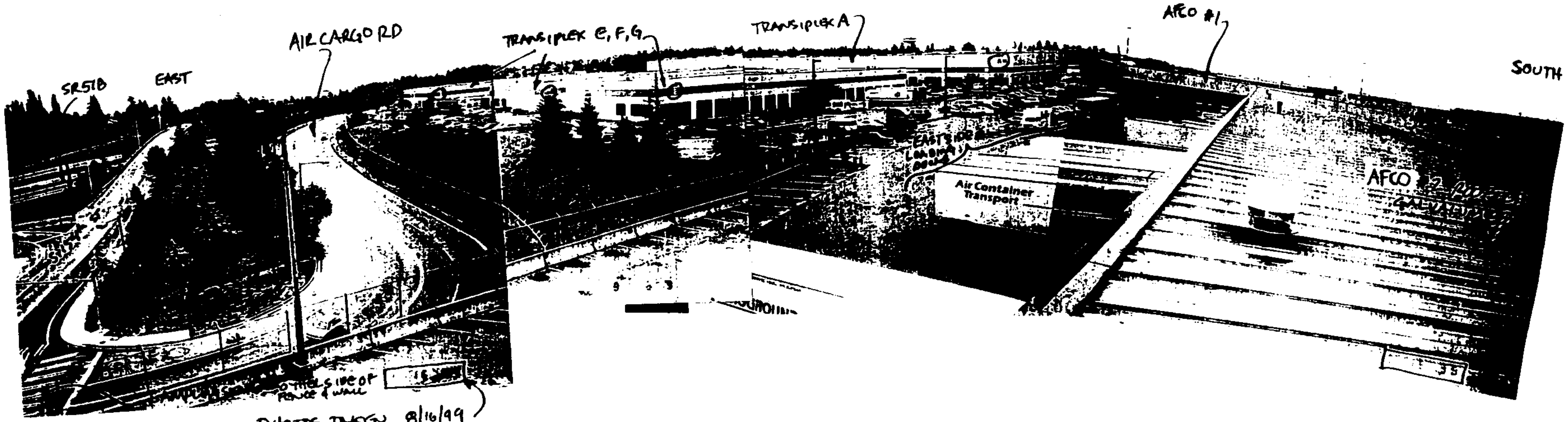
AR 044515

6.2 Appendix B Photographs



LOOKING NORTHEAST   PHOTO TAKEN SEPT 1997

H3

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6.3 Appendix C Source Tracing Results

1999 SDN1 Source Tracing in Multiple Upstream Manholes

event	rain in.	maxInt in/hr	dryant hr	LF	SDN1 manhole	name	seq	type	pH	TR Cu	TR Pb	TR Zn	Diss Cu	Diss Pb	Diss Zn	Diss/TR ratios Cu	Diss/TR ratios Pb	Diss/TR ratios Zn	Hard	surf	NH3	turb	comment
13-Jan-99	1.07	0.16	85	13.6	26	Transiplex 1/13	1	GRAB	6.83	0.008	0.001	0.044	0.005	0.001	0.021	0.68		0.48					Transiplex rooftops
13-Jan-99	1.07	0.16	85	13.6	26	Transiplex 1/13	2	GRAB	7.49	0.007	0.001	0.038	0.005	0.001	0.022	0.69		0.58					Transiplex rooftops
8-Mar-99	0.28	0.05	96	4.8	26	Transiplex 3/8		GRAB		0.011	0.001	0.040	0.005	0.001	0.012	0.44		0.30	4.29				Transiplex rooftops
24-Mar-99	0.28	0.08	40	3.2	26	Transiplex 3/24	1	GRAB		0.017	0.001	0.048	0.012	0.001	0.046	0.68		0.96	2.98				Transiplex rooftops
24-Mar-99	0.28	0.08	40	3.2	26	Transiplex 3/24	2	GRAB		0.017	0.001	0.046	0.014	0.001	0.036	0.81		0.78	6.53				Transiplex rooftops
8-Mar-99	0.28	0.05	96	4.8	32 dock	dock 3/8		GRAB		0.046	0.012	0.188	0.034	0.008	0.134	0.75	0.66	0.71	3.92				loading dock drain (Avia #2, doors E9-E13)
24-Mar-99	0.28	0.08	40	3.2	32 dock	dock 3/24	1	GRAB		0.121	0.023	0.400	0.111	0.019	0.320	0.92	0.84	0.80	5.6				loading dock drain (Avia #2, doors E9-E13)
24-Mar-99	0.28	0.08	40	3.2	32 dock	dock 3/24	2	GRAB		0.072	0.014	0.389	0.066	0.011	0.263	0.91	0.78	0.68	10.4				loading dock drain (Avia #2, doors E9-E13)
8-Mar-99	0.28	0.05	96	4.8	32	AFCO#1 3/8		GRAB		0.009	0.001	0.108	0.007	0.001	0.034	0.78		0.31	1.49				AFCO Bldg #1 rooftop
24-Mar-99	0.28	0.08	40	3.2	32	AFCO#1 3/24	1	GRAB		0.030	0.003	0.133	0.013	0.001	0.122	0.42	0.29	0.92	2.24				AFCO Bldg #1 rooftop
24-Mar-99	0.28	0.08	40	3.2	32	AFCO#1 3/24	2	GRAB		0.032	0.001	0.330	0.020	0.001	0.217	0.63		0.66	2.8				AFCO Bldg #1 rooftop
8-Mar-99	0.28	0.05	96	4.8	33	AFCO#2 3/8		GRAB		0.008	0.001	0.083	0.005	0.001	0.033	0.65		0.40	1.31				AFCO Bldg #2 rooftop
24-Mar-99	0.28	0.08	40	3.2	33	AFCO#2 3/24	1	GRAB		0.017	0.001	0.091	0.013	0.001	0.074	0.78		0.81	3.92				AFCO Bldg #2 rooftop
24-Mar-99	0.28	0.08	40	3.2	33	AFCO#2 3/24	2	GRAB		0.053	0.003	0.484	0.033	0.001	0.333	0.62	0.38	0.69	4.1				AFCO Bldg #2 rooftop
8-Mar-99	0.28	0.05	96	4.8	41-31	Road agg 3/8		GRAB		0.017	0.021	0.180	0.001	0.001	0.037	0.06	0.05	0.21	6.34				Air Cargo Rd+Transiplex+new FedEx
24-Mar-99	0.28	0.08	40	3.2	41-31	Road agg 3/24	1	GRAB		0.014	0.016	0.121	0.006	0.001	0.046	0.41	0.06	0.38					Air Cargo Rd+Transiplex+new FedEx
24-Mar-99	0.28	0.08	40	3.2	41-31	Road agg 3/24	2	GRAB		0.009	0.003	0.149	0.007	0.001	0.092	0.76	0.33	0.62	8.39				Air Cargo Rd+Transiplex+new FedEx
11-May-99	0.14	0.08	50	4	41-31	Road agg 5/11		ffgrab		0.062	0.017	0.347	0.040	0.001	0.278	0.64	0.06	0.80				2.1	Air Cargo Rd+Transiplex+new FedEx
11-May-99	0.14	0.08	50	4	41-31	Road agg 5/11 comp		comp		0.042	0.002	0.226	0.023	0.001	0.134	0.55	0.42	0.60	12.9	0.329	0.252	31	Air Cargo Rd+Transiplex+new FedEx
20-Jun-99	0.21	0.03	48	1.44	41-31	Road agg 6/20		ffgrab		0.082	0.005	0.525	0.060	0.001	0.394	0.73	0.20	0.75					Air Cargo Rd+Transiplex+new FedEx
2-Jul-99	0.3	0.11	103	11.3	41-31	Road agg 7/2	1	GRAB	6.44	0.032	0.001	0.200											Air Cargo Rd+Transiplex+new FedEx
2-Jul-99	0.3	0.11	103	11.3	41-31	Road agg 7/2	2	GRAB	6.25	0.026	0.001	0.205											Air Cargo Rd+Transiplex+new FedEx
2-Jul-99	0.3	0.11	103	11.3	41-31	Road agg 7/2 comp		COMP		0.035	0.009	0.209							16				Air Cargo Rd+Transiplex+new FedEx
6-Nov-99	0.68	0.11	44	4.84		Road agg11/6 comp		comp		0.008	0.005	0.103	0.005	<0.002	0.056	0.58	na	0.54	11.9	0.067	0.08	18	Air Cargo Rd+Transiplex+new FedEx
13-Jan-99	1.07	0.16	85	13.6	41-34	AFCO agg 1/13		GRAB	7.2	0.051	0.001	0.428	0.013	0.001	0.227	0.26		0.53					total AFCO rooftops
8-Mar-99	0.28	0.05	96	4.8	41-34	AFCO agg 3/8		GRAB		0.016	0.001	0.099	0.008	0.001	0.062	0.54		0.63	6.53				total AFCO rooftops
24-Mar-99	0.28	0.08	40	3.2	41-34	AFCO agg 3/24	1	GRAB		0.022	0.001	0.141	0.016	0.001	0.128	0.74		0.91	4.48				total AFCO rooftops
24-Mar-99	0.28	0.08	40	3.2	41-34	AFCO agg 3/24	2	GRAB		0.029	0.001	0.379	0.019	0.001	0.207	0.64		0.55	3.17				total AFCO rooftops
11-May-99	0.14	0.08	50	4	41-34	AFCO agg 5/11		ffgrab		0.022	0.001	0.649	0.016	0.001	0.210	0.70		0.32				39	total AFCO rooftops
11-May-99	0.14	0.08	50	4	41-34	AFCO agg 5/11 comp		comp		0.028	0.001	0.300	0.017	0.001	0.188	0.61		0.63	4.85	<0.025	0.07	2	total AFCO rooftops
20-Jun-99	0.21	0.03	48	1.44	41-34	AFCO agg 6/20		ffgrab		0.062	0.001	0.449	0.051	0.001	0.388	0.82		0.86					total AFCO rooftops
2-Jul-99	0.3	0.11	103	11.3	41-34	AFCO agg 7/2	1	GRAB	6.06	0.028	0.001	0.251											total AFCO rooftops
2-Jul-99	0.3	0.11	103	11.3	41-34	AFCO agg 7/2	2	GRAB	7.06	0.042	0.001	0.422											total AFCO rooftops
2-Jul-99	0.3	0.11	103	11.3	41-34	AFCO agg 7/2 comp		COMP		0.030	0.001	0.254							3.91				total AFCO rooftops
6-Nov-99	0.68	0.11	44	4.84	41-34	AFCO agg 11/6 comp		comp		0.006	<0.002	0.104	0.006	<0.002	0.097	0.95	na	0.93	2.16	<0.025	0.023	0.63	total AFCO rooftops

Indicates result <MDL, value shown is 1/2 MDL

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6.4 Appendix D Matrix for Interpreting Chelation Test Results

Toxicty Removal by EDTA

Toxicity Removal by Thiosulfate

	Strong	Weak	None
Strong	Copper chloride Cadmium chloride Mercury [II] chloride (24h)	Silver Chloride	
Weak	Zinc chloride Lead nitrate Nickel chloride	Manganese chloride Mercury [II] chloride (48h)	Sodium selenate
None			Iron [II] chloride Chromium [III] chloride Potassium dichromate Sodium arsenate Sodium arsenite Sodium selenite Aluminum chloride

Modified from Hockett and Mount, 1996