

SANTA MONICA BAY AREA MUNICIPAL STORM WATER/ URBAN RUNOFF PILOT PROJECT — EVALUATION OF POTENTIAL CATCHBASIN RETROFITS

Prepared for
Santa Monica Cities Consortium
c/o City of Santa Monica
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Woodward-Clyde Project No. 9653001F-6000

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Exhibit-2231

For this study, the sampling program was designed to collect samples from stormwater before it enters a catchbasin. Most of the previous work performed by other monitoring studies has addressed stormwater that is either in the catchbasin or in a storm drain that is downstream of the catchbasin. Catchbasins may remove material primarily by sedimentation during periods of low flow. For this reason, samples of stormwater in the catchbasin or downstream of the catchbasin may not be representative of the stormwater that enters the catchbasin.

Water quality samples were collected and analyzed for the target contaminants identified in Task 1, and also for a variety of other water quality parameters, as described in Sections 2.1.2 and 2.1.3. This was possible in part because of ongoing programs at UCLA that facilitate stormwater monitoring and analysis. The collected data will be used by students in their research and class projects. Sampling for debris was not performed in this pilot project, due to the difficulty of obtaining enough samples to be confident that the extremely diverse and variable spectrum of litter components was properly characterized. We believe a much longer period would be required to obtain representative debris samples. Some limited observation of debris in stormwater and collection of debris in catchbasins was performed in Task 4, (reported in Section 4 of this report), as a part of field studies of candidate retrofits.

2.1 METHODS

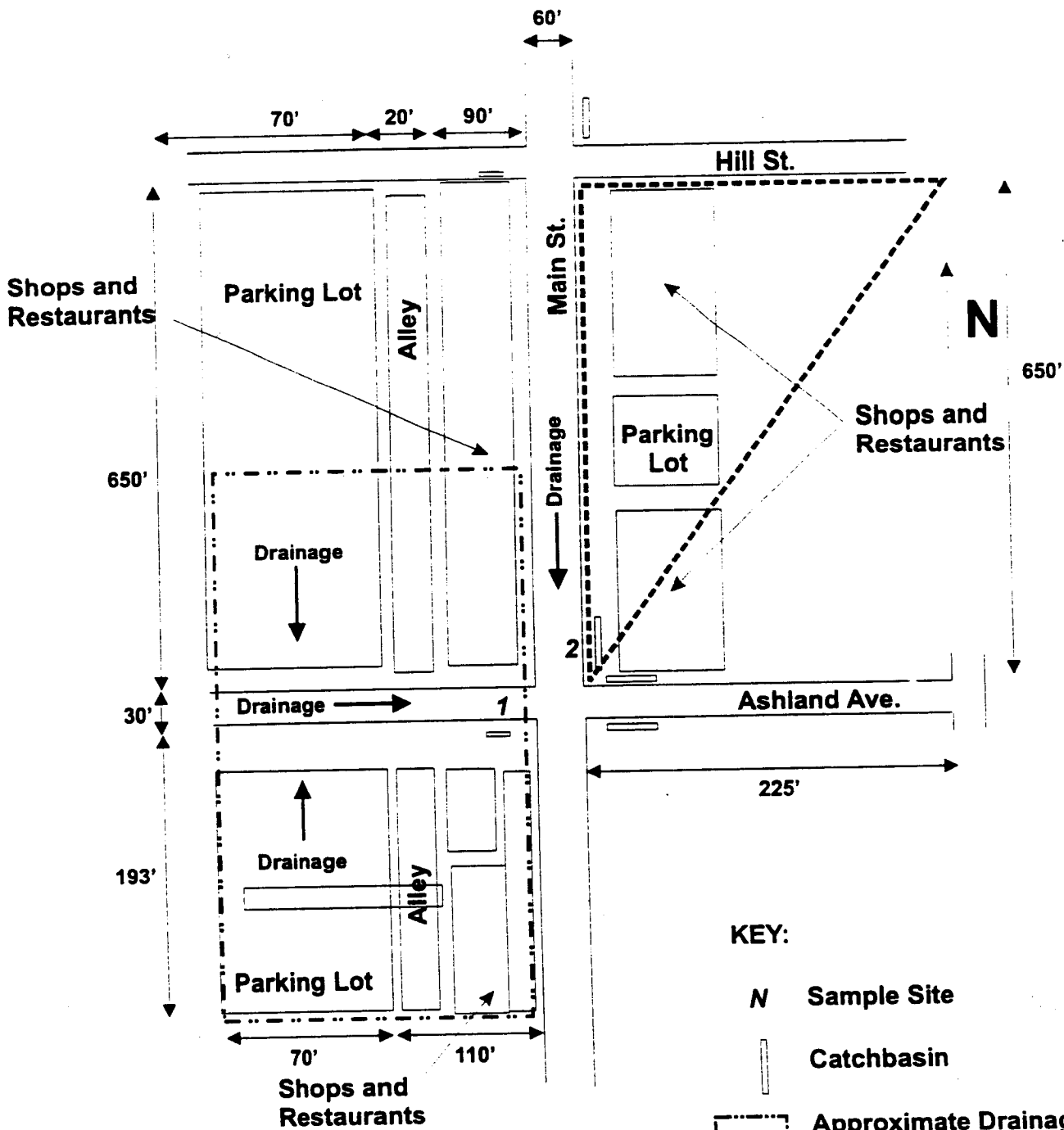
2.1.1 Sample Location and Collection

Stormwater samples were collected at the inlets to four catchbasins during storm events occurring from September to December 1997. The locations of these sampling sites are shown in Figures 2-1 to 2-3. All of the sites were in the City of Santa Monica and were selected based on the following criteria:

- Land use and activities in the area draining into the catchbasin;
- Safety of the personnel, including the ability to avoid street traffic as well as potential crime areas.
- Feasibility of sample collection, including proximity of the sites to each other and to UCLA;

Figure 2-1 shows the locations of Sites 1 and 2, which were catchbasins draining commercial and high traffic volume roadway areas. Site 1 is a 4-foot wide catchbasin on Ashland Avenue that receives runoff from the parking lots, alleys, and streets shown on the figure. Approximately 50% of the runoff from the lot between Hill and Ashland Streets enters Location 1. Virtually all of the flow from the lot south of Ashland Avenue enters Site 1. Runoff from the two alleys enters the site in approximately equal proportions. Roof runoff from the shops also flows to Site 1. Restaurants use trash dumpsters along the alley, which at times were observed to be quite full. None of the dumpsters were observed to be leaking. Overall, Site 1 receives runoff that is primarily associated with vehicular activity. The drainage area is approximately 155,000 sq. ft.

Site 2 is an 18-foot wide catchbasin that receives runoff from Main Street (between Hill and Ashland) and a small parking lot. Parking is permitted along Main Street. Runoff flows down Ashland Avenue towards Main Street from the east, but is intercepted by other catchbasins. Roof



Not to Scale

SAMPLE SITES 1 and 2

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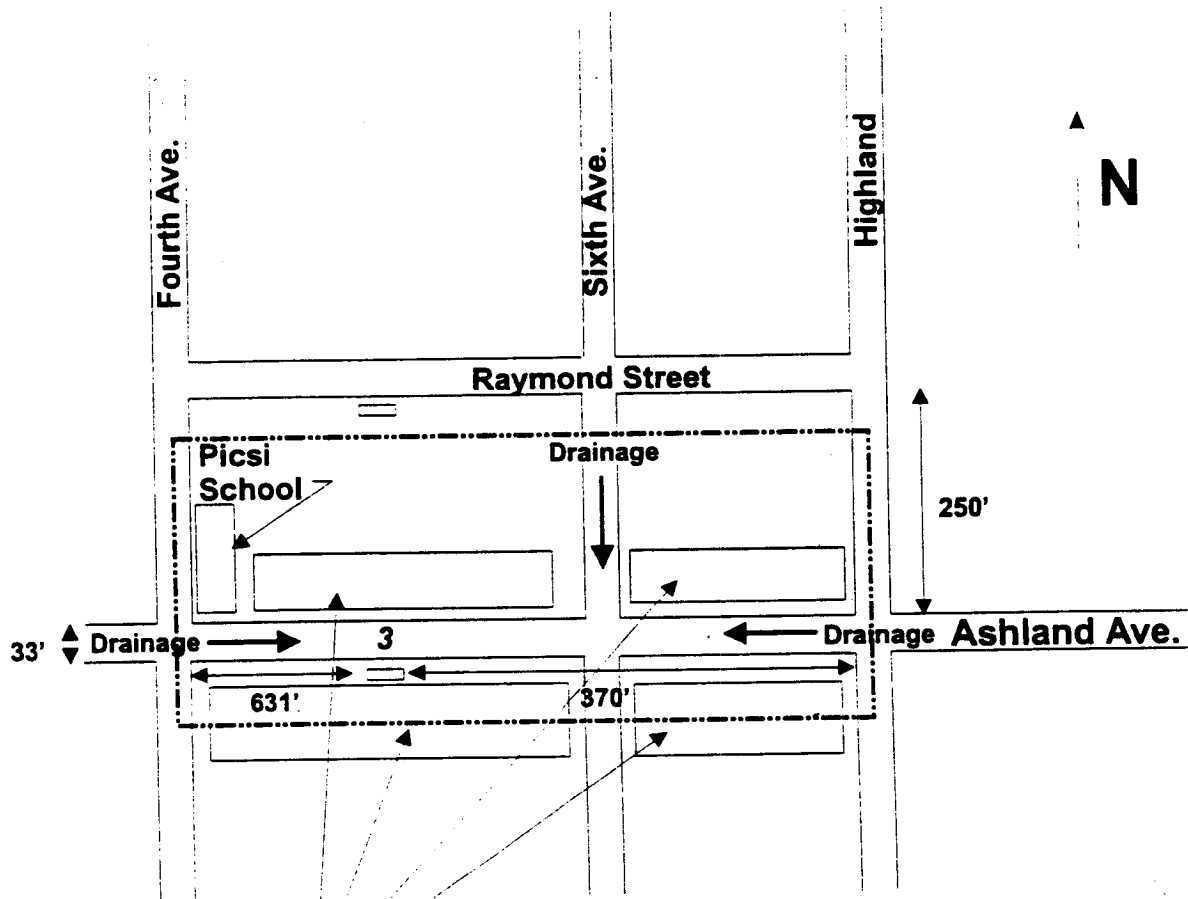
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FIGURE NO: 2-1

Woodward-Clyde

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Single Family
Houses and Small
Apt. Buildings

KEY:

N Sample Site

 Catchbasin

 Approximate Drainage
Area \approx 250,000 sq. ft.

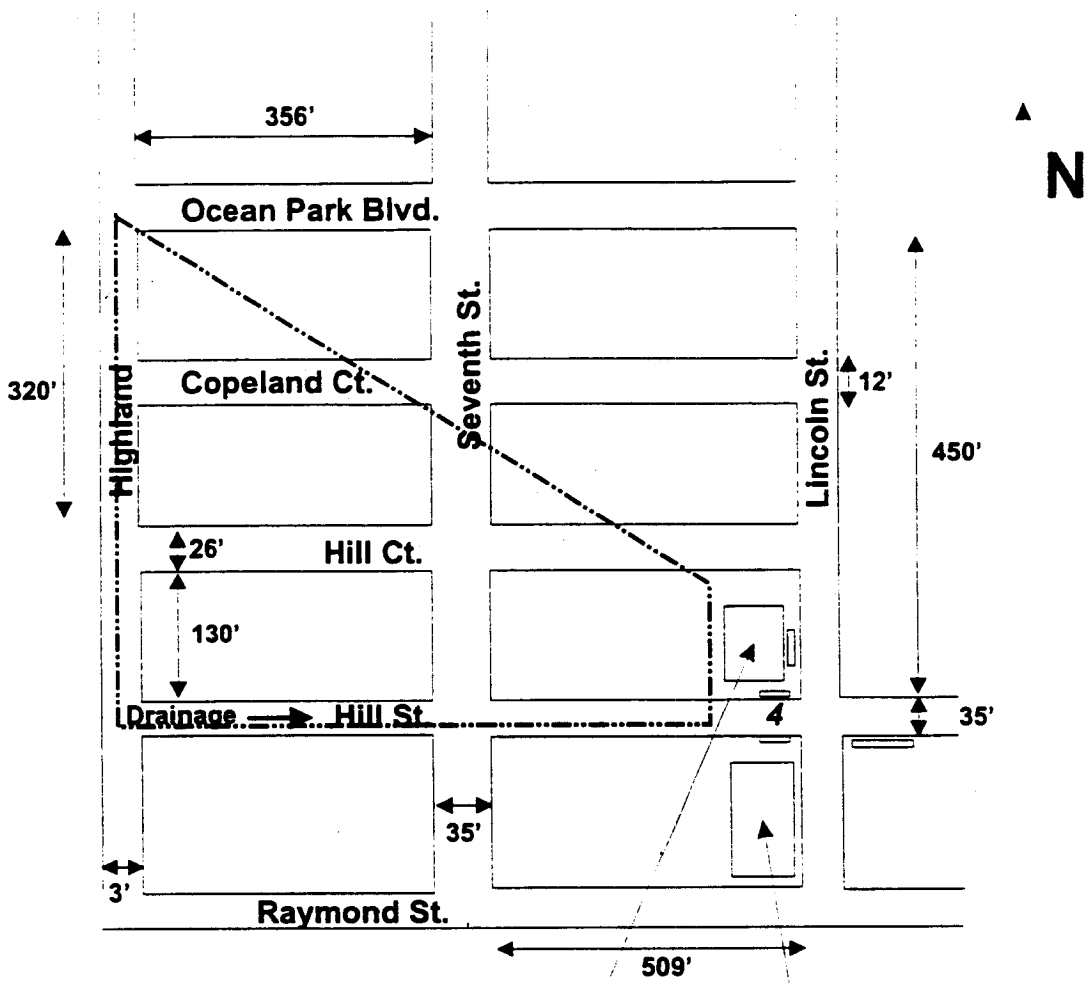
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SAMPLE SITE 3

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Auto Dealer

Auto Repair Facility

KEY:

N Sample Site

--- Catchbasin

--- Approximate Drainage Area \cong 190,000 sq. ft.

Not to Scale

SAMPLE SITE 4

DRAWN BY: cm CHECKED BY: PROJECT NO: 9653001F-5000 DATE: 9-22-98 FIGURE NO: 2-3

Woodward-Clyde

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runoff is discharged along Main Street and flows to Site 2. No trash dumpsters were noted in the drainage area. Runoff entering this catchbasin is confined to the runoff from the street, sidewalk, parking lot, and roofs from the businesses between and Hill and Ashland Streets. Overall, this site receives runoff that is primarily associated with light commercial activities. The drainage area is approximately 75,000 sq. ft.

Figure 2-2 shows Site 3. This site is located approximately ½ mile from Sites 1 and 2. Highland and Fourth Streets form "ridges" and water flows downhill to Site 3, which is an 8-foot wide catchbasin. The entire area, except for the school, is composed of single family residences and small apartment buildings. Parking is generally permitted along all of the streets shown. Catchbasins also exist on other cross streets (parallel to Ashland) and intercept stormwater. The overall runoff to site is from mixed residential land uses. The drainage area is approximately 250,000 sq. ft.

Figure 2-3 shows Site 4, which is also a mixed residential site. It is located approximately one-half mile from Site 3. Stormwater flows downhill from Highland Street to Site 4, which is a 4-foot wide catchbasin. No catchbasins exist along Hill Street except at Site 4. Stormwater from Lincoln Street and the south side of Hill Street are intercepted by other catchbasins. No runoff was observed entering this catchbasin from the nearby auto dealer or repair shop during the sampling. Hill Street is lined with single family residences and small apartment buildings. From a cursory observation, the land use draining to this site may appear to be mostly commercial, but in fact is virtually 100% mixed residential. The drainage area is approximately 190,000 sq. ft.

At the curb-face inlet opening of each catchbasin, grab samples of storm runoff were collected from the street surface using a polypropylene scoop, and then transferred to 1-L and 4-L amber glass bottles. The bottles were transported to the UCLA laboratory immediately after collection and were refrigerated until analyzed. The scoop was pressed against the pavement during sampling to capture suspended solids. For selected storms, multiple grab samples were collected.

A summary of the sampling dates, times, and sample types is presented in Table 2-1. The rainfall amounts are also shown in Table 2-1. The rain gauge at UCLA was the closest recording gauge to the field sites. The total amount of rainfall for each sampled storm event is reported, rather than the daily amount. The first sampled storm was also the first storm of the year, representing the first flush of the season. Additionally, when it was possible, the first sample for each event was taken during the first-flush period of the storm. This is noted in the "comments" column.

2.1.2 Conventional Water Quality Analyses

Table 2-2 lists the conventional water quality parameters that were analyzed for the stormwater runoff samples. Procedures described in *Standard Methods* (1992) were used except for oil and grease analyses. The dissolved oil and grease content of stormwater runoff was analyzed using a modified C18 solid-phase extraction method described in Lau and Stenstrom (1997). Oil and grease on, that may have been attached to, the suspended solids would not be measured by this method. Usually there is more oil and grease associated with the solids than in the dissolved phase in stormwater. Oil and grease measured by this method is the maximum that could be removed by oil sorbents. Oil and grease adsorbed to solids, which is not measured by this analysis, must be removed by sedimentation or filtration.

**Table 2-1
SUMMARY OF STORMWATER SAMPLING AND TESTING**

Storm Event No.	Date	Location	Time	Grab Sample No. ^a	Comments ^b
1	9/25/97	Site 1	12:45	1	Low flow (Rainfall = 0.28 in)
		Site 2	13:00	1	Low flow
		Site 3	13:15	1	Low flow (liquid phase metals)
		Site 4	13.30	1	Low flow (liquid phase metals)
2	11/10/97	Site 1	11:00	1	Very low flow (Rainfall = 0.67 in) (liquid phase metals)
		Site 2	11:00	1	Very low flow (liquid phase metals)
		Site 3	11:10	1	Low flow (liquid phase metals)
		Site 4	11:15	1	Moderate flow(liquid phase metals)
3	11/13/97	Site 1	08:40	1	Moderate flow (Rainfall = 0.48 in) (all metals)
			15:15	2	Low flow
		Site 2	08:45	1	Moderate flow
			15:15	2	Low flow (all metals)
		Site 3	09:00	1	Moderate flow
			15:30	2	Low flow (all metals)
		Site 4	09:15	1	Moderate flow (all metals)
			15:45	2	Low flow
4	11/26/97	Site 1	08:50	1	High flow (Rainfall = 0.72 in) (all metals)
		Site 2	08:55	1	High flow
		Site 3	09:00	1	High flow (all metals)
		Site 4	09:05	1	High flow(all metals)
5	11/30/97	Site 1	11:40	1	Moderate flow (Rainfall = 1.12 in) (particulate phase metals)
		Site 2	11:50	1	Moderate flow(all metals)
		Site 3	11:55	1	High flow(all metals)
		Site 4	12:00	1	High flow(all metals)
6	12/05/97	Site 1	12:10	1	First flush; moderate flow (Rainfall = 3.36)
			17:45	2	High flow
			03:00	3	High flow
	12/06/97	Site 2	12:15	1	First flush; moderate flow
			17:50	2	Peak flow
			03:05	3	Peak flow
	12/05/97	Site 3	12:20	1	First flush; high flow
			17:55	2	Peak flow
			03:10	3	Peak flow

Table 2-1 (Continued)
SUMMARY OF STORMWATER SAMPLING AND TESTING

Storm Event No.	Date	Site	Time	Grab Sample No. ^a	Comments ^b
6 (cont)	12/05/97	Site 4	12:25	1	First flush; high flow
			18:00	2	Peak flow
	12/06/97		03:15	3	Peak flow
7	12/18/97	Site 1	12:45	1	Peak flow (Rainfall =0.95 in)
			16:35	2	Low flow
		Site 2	12:50	1	Peak flow
			16:40	2	Low flow
		Site 3	12:55	1	Peak flow
			16:45	2	Low flow
		Site 4	13:00	1	Peak flow
			16:50	2	Low flow

^a All samples were tested individually except where noted.

^b Relative flow was based on visual observations. Rainfall data are from the UCLA gauge and are for the total storm.

Table 2-2
CONVENTIONAL WATER QUALITY ANALYSIS OF STORMWATER RUNOFF

Parameter	Method/Instrument	Holding Time and Preservation
Total suspended solids (TSS), mg/L	2540.D	7 days; refrigerated at 4°C
Volatile suspended solids (VSS), mg/L	2540.D	7 days; refrigerated at 4°C
pH	—	Analyzed immediately
Turbidity	2130.B; Hach Turbidimeter	48 hours; refrigerated at 4°C
Conductivity	2510.B; Fisherbrand™ Conductivity Meter	28 days; refrigerated at 4°C
Alkalinity, mg/L as CaCO ₃	2320.B	14 days; refrigerated at 4°C
Hardness, mg/L as CaCO ₃	2340.C	6 months; acidified with HNO ₃ to pH < 2
Chemical oxygen demand (COD), mg/L	5220.B	Analyzed as soon as possible
Dissolved organic carbon (DOC), mg/L	5310	7 days; acidified with H ₃ PO ₄ to pH < 2 and refrigerated at 4°C
Oil and Grease, mg/L	Lau and Stenstrom (1997)	28 days; acidified with HCl to pH < 2 and refrigerated at 4°C
Ammonia, mg/L as NH ₃ -N	4500-NH ₃ .F (Orion Model 9512)	Analyzed as soon as possible
Anions	Ion Chromatograph	48 hours; refrigerated at 4°C
Nitrite, mg/L as NO ₂ -N	4500 NO ₂ .B	28 days; acidified with H ₂ SO ₄ to pH < 2 and refrigerated at 4°C
Chloride, mg/L	4500 Cl.B	28 days; refrigerated at 4°C
Nitrate, mg/L as NO ₃ -N	Dionex Series 4000 Ion	28 days; acidified with H ₂ SO ₄ to pH < 2 and refrigerated at 4°C
Orthophosphate, mg/L as P	Chromatograph	48 hours; refrigerated at 4°C
Sulfate, mg/L	4500-SO ₄	28 days; refrigerated at 4°C

Anions (fluoride, nitrate, orthophosphate, and sulfate) were analyzed using a Dionex Series 4000 Ion Chromatograph. The ion chromatographic test apparatus included a gradient pump, a conductivity detector, and peak integrator. A 4 x 250 mm I.D. Dionex IonPac AS4 column was used. The eluent used was 1.7 mM sodium bicarbonate and 1.8 mM sodium carbonate solution, and was pumped isocratically through the column at a flow rate of 1.5 mL/min. The regenerant solution used was 0.025 N sulfuric acid. The eluted anions were detected at a suppressed mode at 13 μ S.

2.1.3 Sample Filtration for Metals and Organic Analysis

All samples collected for organic analysis were stored at 4°C until filtered. Samples were filtered as soon as possible to minimize any alteration or redistribution of contaminants between the dissolved and aqueous phases. Whole water samples were filtered through 142 mm diameter, 0.7 μ m pure glass (no binder) TCLP filters (MSI, Inc.). These filters are manufactured specifically to be extremely low in metal contaminants. In addition, they produce the lowest background concentration of organic impurities when used with subsequent supercritical fluid extraction (SCFE). Justification for the use of these filters, and the filter preparation and cleaning procedure are described in Capangapangan *et al.* (1996). The filters used for organic analyses were pre-cleaned by baking at 175° to 200°C overnight, then cooled to room temperature in a desiccator. The filters were then weighed to the nearest 0.1 mg, and placed in order into a glass Petri dish for storage. The filters for metals analyses were used directly from the box.

A stainless steel, Teflon-lined Millipore 142 mm diameter Hazardous Waste Filtration System with an integral 1.5-liter reservoir was used for filtration. The system was pressurized up to 100 psi by zero grade nitrogen. Between 2 and 4 liters of whole water sample were passed through each filter depending upon the suspended solids load. Samples were filtered in one-liter increments until the filter became clogged. A new filter was then used, and filtration resumed until each sample was consumed.

After each sample run was completed, the filtration apparatus was disassembled, and the filter was carefully removed, folded in half, then in quarter to enclose the solids, and placed into a pre-cleaned 125- or 250-ml glass jar with a Teflon-lined closure. The samples for metals analysis were stored at 4°C until digested. Filter blanks were prepared by filtering equal volumes of Milli-Q water through filters, and were then treated as actual samples in all subsequent procedures.

2.1.4 Sample Pretreatment

The acid digestion procedures used for filtered samples and suspended solids of wet-weather samples were based on EPA Methods 3120B and 3150B, respectively. Digested samples were then analyzed for trace metals using an inductively coupled plasma atomic emission (ICP-AE).

2.2 RESULTS AND DISCUSSION

2.2.1 Conventional Water Quality Analyses

Table 2-3 presents the water quality data for each storm water runoff sample (by storm event). Large differences in pollutant concentrations were noted among sites and among samples at a given site. Table 2-4 shows the average and standard deviations of water quality data by site. Site 1, which has the greatest vehicular activity, had the greatest concentrations of organic containing pollutants (e.g., COD, SPE oil and grease, and DOC). This finding is consistent with previous work by the authors for similar land uses. Exhaust emissions and crankcase drippings have been associated with higher concentrations of oil and grease in stormwater.

The magnitude of the parameters shown in Table 2-3 in some instances is comparable with other types of wastewaters. The COD values are generally greater than values commonly observed for treated sanitary wastewaters. The suspended solids level associated with Site 1 is greater than allowable for secondary treated wastewater. Other parameters such as conductivity, chlorides, nitrite, hardness and alkalinity are either not considered pollutants in wastewater or are much less than associated with most wastewaters.

In making comparisons to wastewaters and assessing the potential impacts of stormwater on the environment, additional considerations are important. For example, the composition of the oil and grease from Site 1 is probably quite different than from Sites 3 and 4. Site 1 would most likely contain anthropogenic (synthetic) materials such as refined and cracked petroleum products. Sites 3 and 4 probably contain more biogenic material. Although not always true, the anthropogenic material is usually more harmful to the environment than the biogenic material. Other parameters also vary by land use. For example, the suspended solids in the samples from Sites 3 and 4, which are mixed residential sites, were composed of more leaf and plant debris than the solids at Site 1, which is a vehicular activity site.

To facilitate the evaluation of suspended solids removal during the laboratory phase of testing of retrofits, additional sampling was performed after January 1, 1998, to evaluate the types and size fractions of solids in stormwater. Site 1 was selected because it had the greatest concentration of TSS and the composition of the solids represented constituents which are more desirable to remove than the more biogenic material at Sites 3 and 4. Screens (sieves) were used to filter samples before TSS and volatile suspended solids (VSS) analysis. The TSS and VSS were captured on 100 (0.150 mm), 200 (0.075 mm) and 325 mesh (0.045 mm) ASTM standard screens. Table 2-5 presents the results.

Table 2-5 shows the average size of the material that entered the Site 1 catchbasin. For example, on the average 9.8 mg/L of TSS that is greater than 325 mesh enters the Site 1 catchbasin. This compares to the entire TSS of 62 mg/L (Table 2-5). This suggests that an insert that could remove all suspended solids greater than 325 mesh or 0.045 mm (45 microns) might remove only one-sixth, or 16% of the entire TSS. Later work performed in this study quantified the efficiency for removing various size solids, as described in Section 4.

SECTION TWO

Characterization of Local Urban Runoff

Table 2-3
WATER QUALITY RESULTS OF WET WEATHER RUNOFF FROM SEPTEMBER THROUGH DECEMBER 1997

Storm Event No.	2												3			
	1				2				3							
	September 25, 1997				November 10, 1997				November 13, 1997							
Date	12:45	13:00	13:20	13:35	11:00	11:00	11:10	11:15	8:45	13:00	13:20	13:35	11:00	11:00	11:10	11:15
Time	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
TSS (mg/L)	61.4	32.1	111	78	277	31.5	47.6	77.2	10.7	28	12.2	16.9	13.6	40.4	11.0	9.6
VSS (mg/L)	43.9	27.5	67.9	52	240	23.4	29.1	33.8	9.23	17.4	9.06	8.93	9.9	16.3	8.5	5
Turbidity (NTU)	74.5	22	29.4	35.5	19.2	31.3	19.1	30.9	23.5	26.6	14.2	17	9.8	3.9	6.3	7.2
Conductivity (mmho/cm)	314	519	374	453	728	387	502	460	137	116	257	157	94.6	88.9	233	144
pH	7.1	7.45	7.6	7.7	6.45	6.6	6.9	6.9	6.85	7.1	7.15	7	6.7	6.8	7.1	6.95
Alkalinity (mg/L as CaCO ₃)	36	47	62	53	54	44	58	60	30	28	36	36	18	20	32	28
Hardness (mg/L as CaCO ₃)	72	108	98	148	152	72	104	120	28	28	52	48	32	28	44	40
COD (mg/L)	354	387	387	323	512	69.8	186	395	144	91.7	128	114	53.5	65.1	74.4	74.4
SPE Oil and Grease (mg/L)	24.8	17.2	13.0	15.0	33.2	16.1	17.9	29.2	6.8	5.7	4.6	4.8	2.1	2.6	2.6	3.3
Ammonia (mg/L as NH ₃ -N)	1.88	2.30	1.89	2.30	3.16	2.15	4.64	2.61	1.78	1.21	2.61	1	1.47	0.68	3.16	1
Chloride (mg/L)	46.1	91.6	47.6	58.6	136	66.0	67.0	64.0	16.0	18.0	51.0	23	20.5	17.5	43	25
DOC (mg/L)	81.2	151	85.8	84.5	185	77.4	90.7	93.8	29.2	21.3	31.4	31.6	14.8	15.1	25	26
Nitrite (mg/L as NO ₂ -N)	0.277	0.249	0.373	0.332	0.332	0.396	1.451	0.46	0.428	0.396	0.588	0.473	0.236	0.205	0.396	0.256

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SECTION TWO

Characterization of Local Urban Runoff

**Table 2-3 (Continued)
WATER QUALITY RESULTS OF WET WEATHER RUNOFF FROM SEPTEMBER THROUGH DECEMBER 1997**

Storm Event No.	5												6					
	4						5						6					
	November 26, 1997						November 30, 1997						December 5, 1997					
Date	08:50	08:55	09:00	09:05	11:40	11:50	11:55	12:00	12:10	12:15	12:20	12:25	17:45	17:50	17:55	18:00		
Time	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4		
Site	39.1	96.5	33.8	10.9	22.1	22.7	21.5	23.5	128	118	99.7	139	33.2	33.2	27.0	10.4		
TSS (mg/L)	20.6	39.8	16.1	9.22	15.6	14.8	16.9	16.3	63.8	55.2	46.3	58.1	16.4	21.6	9.00	4.85		
VSS (mg/L)	5.9	13.5	14.5	8.8	5.9	10.9	8.5	12.8	74.8	33.3	24.3	13.1	8.2	9.2	5.6	4.7		
Turbidity (NTU)	105	97.5	147	144	30	102	195	112	392	437	273	207	58.4	57.6	51.3	47.4		
Conductivity (mmho/cm)	6.6	6.95	7.2	6.95	6.7	6.95	7.25	7.3	5.5	6.6	6.25	6.4	6.1	6.65	6.2	6.4		
pH	14	17	22	24	10	18	28	28	26	40	40	30	12	14	11	12		
Alkalinity (mg/L as CaCO ₃)	32	30	30	38	16	28	45	19	106	110	76	70	18	22	14	16		
Hardness (mg/L as CaCO ₃)	50.5	40	46.3	37.9	46.2	37.4	57.1	48.4	682	366	220	195	28.6	28.6	26.5	32.7		
COD (mg/L)	1.8	1.6	7.3	2.2	0.73	1.4	2.9	1.9	13.3	11.7	9.0	7.2	2.1	2.3	0.73	1.2		
SPE Oil and Grease (mg/L)	0.96	0.41	0.57	0.52	0.41	0.48	1.9	0.50	3.78	3.443	2.574	1.487	1.396	1.145	0.902	0.633		
Ammonia (mg/L as NH ₃ -N)	23	21	21.5	23.5	5.5	15.5	21.5	10	64.0	72.0	40.0	30	8	8	6.75	5.5		
Chloride (mg/L)	12.8	9.01	13.4	18.6	4.63	10	19.1	13.7	141	98.5	50.4	41.1	6.93	7.03	5.63	6.53		
DOC (mg/L)	0.045	0.026	0.048	0.037	0.027	0.067	0.144	0.102	0.426	0.387	0.506	0.182	0.072	0.06	0.048	0.048		
Nitrite (mg/L as NO ₂ -N)																		

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Table 2-3 (Continued)
WATER QUALITY RESULTS OF WET WEATHER RUNOFF FROM SEPTEMBER THROUGH DECEMBER 1997

Storm Event No.	6				7							
	December 6, 1997				December 18, 1997							
	03:00	03:05	03:10	03:15	12:45	12:50	12:55	13:00	16:35	16:40	16:45	16:50
Date	1	2	3	4	1	2	3	4	1	2	3	4
Time	6.7	3.5	5.7	3.7	52.9	24.2	29.6	32.1	37.7	31.8	16.9	20.5
Site	4.2	2.07	2.7	1.34	31.4	13.0	15.4	14.8	32.3	22.1	9.9	15.1
TSS (mg/L)	2.9	3.4	3.2	3.4	7.4	4.8	7.5	4.2	34.8	26.8	12	17.9
VSS (mg/L)	21.9	31	47.7	45	22.1	28.8	30	27.5	48.1	113	91.2	79.6
Turbidity (NTU)	6.15	6.15	6.65	6.5	6.5	6.65	6.75	6.6	6.7	6.9	7.1	7.1
Conductivity (mmho/cm)	8	9	12	12	10	9	10	10	15	28	26	26
pH	7	14	16	18	11	12	13	14	17	34	28	35
Alkalinity (mg/L as CaCO ₃)	18.4	18.4	14.3	10.2	95.6	55.6	55.6	64.4	68.9	82.2	44.4	62.2
Hardness (mg/L as CaCO ₃)	2.0	2.1	1.2	1.5	1.8	1.1	0.55	0.52	2.0	3.7	3.8	4.1
COD (mg/L)	0.523	0.344	0.585	0.347	0.413	0.225	0.238	0.234	0.386	0.256	0.793	0.236
SPE Oil and Grease (mg/L)	4	4.25	6.25	5	6	4.5	4.5	4.5	5.5	11	7.5	7
Ammonia (mg/L as NH ₃ -N)	3.93	3.02	4.72	3.95	6.33	3.93	3.65	5.26	11.6	15.1	11	14
Chloride (mg/L)	0.009	0.019	0.024	0.029	0.026	0.026	0.024	0.02	0.093	0.1	0.136	0.109
DOC (mg/L)												
Nitrite (mg/L as NO ₂ -N)												

**Table 2-4
WATER QUALITY PARAMETER MEANS AND
STANDARD DEVIATIONS OF ALL DATA BY SITE**

Water Quality Parameter	Site 1		Site 2		Site 3		Site 4	
	Vehicular Activity		Light Commercial		Mixed Residential		Mixed Residential	
	Mean	Standard Dev	Mean	Standard Dev	Mean	Standard Dev	Mean	Standard Dev
TSS (mg/L)	62.0	78.9	42.0	34.0	37.8	35.5	38.3	42.2
VSS (mg/L)	44.3	67.2	23.0	14.2	21.0	19.7	19.9	19.4
Turbidity (NTU)	24.3	26.6	16.9	11.4	13.1	8.3	14.1	10.7
Conductivity (mmho/cm)	178	220	180	177	200	148	171	152
pH	6.5	0.4	6.8	0.3	6.9	0.4	6.9	0.4
Alkalinity (mg/L as CaCO ₃)	21.2	14.2	24.9	13.6	30.6	17.6	29.0	16.0
Hardness (mg/L as CaCO ₃)	44.6	46.3	44.2	35.6	47.3	32.5	51.5	44.5
COD (mg/L)	187	227	113	132	113	112	123	127
SPE Oil and Grease (mg/L)	8.2	11.0	5.9	6.1	5.8	5.6	6.4	8.6
Ammonia (mg/L as NH ₃ -N)	1.5	1.1	1.2	1.1	1.8	1.4	1.0	0.8
Chloride (mg/L)	30.4	39.9	30.1	31.2	28.8	21.9	23.3	21.0
Nitrate (mg/L as NO ₂ -N)	0.18	0.16	0.18	0.16	0.34	0.42	0.19	0.17
DOC (mg/L)	45.2	63.0	37.4	49.3	31.0	31.5	30.8	31.1

**Table 2-5
SIEVE ANALYSIS OF SUSPENDED SOLIDS FROM SITE 1**

Sampling Date	Rainfall (in.)	TSS (mg/L)					VSS (mg/L)			
		Particle Diameter					Mesh Size			
		>150µm	150-74µm	75-45µm	<45µm	Total	>100	100/200	200/325	>325
1/4/98	0.42	6.41	3	2.87	12.3	24.58	3.88	0.76	1.01	5.7
1/19/98	0.25	3.71	2.47	2.16	8.3	16.64	2.02	1.08	0.58	3.7
2/14/98	2.53	5.26	1.92	1.62	8.8	17.6	1.73	0.55	0.64	2.9
AVERAGE		5.13	2.46	2.22	9.8	19.61	2.54	0.80	0.74	4.1

2.2.2 Metals Analysis

Table 2-6 shows the average and standard deviations of the metals concentration data. Figure A-1 (Appendix A) shows the average, total metals concentration by site. The soluble metal concentration is reported and noted in the table headings. Concentration data for particulate-

phase metals (i.e., metals adsorbed to particles) can be reported in two ways. The first is a total liquid concentration (units of mg/L); this is calculated as the total mass of metals recovered, divided by the total volume of water filtered. The second method is a solid-phase concentration, which is reported as the mass of recovered metals divided by the TSS mass. Table 2-6 shows the soluble and particle-phase concentrations. The total concentrations (i.e., the sum of the two concentrations based upon liquid volume) are reported along with the percent that are adsorbed to particles. The tables in Appendix A show all the metals results by storm and site. Metals concentrations as mg of metal per unit particle mass (mg/Kg) are also reported in this table. For some samples, the column is blank. This results because the TSS was too low to quantify even though the ICP can detect metals desorbed from the particles' surfaces. The ICP is much more sensitive than the balance used to weight the filtrate. In some cases, very soluble metals were found in the particulate phase (e.g., sodium). This probably results because of precipitated metals, as opposed to adsorption to the surface of particulates.

Table 2-6 also shows the percent of the total metals that are adsorbed to particles (TTS). This calculation was performed by averaging all soluble phase and particle phase concentrations measured during the study, then determining the percentage. Alternate methods for calculation are also possible, such as restricting the averaging samples from each storm. All data are present in Appendix A, which can be used for alternate calculation procedures, if desired. The blanks in Table 2-6 indicate that samples were not collected, or that too few data were collected to obtain standard deviation. When the concentration was below detection limits, the value was indicated as "<DL" or less than the detection limit.

2.3 CONCLUSIONS

The goal of the sampling program was to characterize the pollutants in stormwater runoff entering catchbasins in the study area and the potential for inserts to remove them. This section describes the average concentrations of key constituents such as TSS and oil and grease, that are found in the runoff entering four catchbasins in the study area.

The results lead to the following conclusions:

1. Water quality from the vehicular land use site was generally poorer (i.e., had higher pollutant concentrations) than water quality from the residential land use sites. This is consistent with previous studies that evaluated runoff from various land uses.
2. The average soluble and free oil and grease concentrations ranged from 5 to 8 mg/L for the four sites. These concentrations do not include the oil adsorbed to the surface of suspended solids. In previous studies, the soluble and free oil and grease have been found to average only 10 to 30% of the total oil and grease. Free oil and grease is the form of oil and grease that is most easily removed by devices of interest in this study, such as separators or sorbers. It is important for the reader to understand that many of the sorbers (i.e., adsorption media, absorption media, and various devices that employ such media) that are promoted commercially advertise their effectiveness using tests based on oil and grease concentrations

**Table 2-6
AVERAGE AND TOTAL METALS CONCENTRATION**

Metal	Site 1						Site 2					
	Soluble Phase		Particulate Phase		Total	% Particulate	Soluble Phase		Particulate Phase		Total	% Particulate
	Avg	SD	Avg	SD			Avg	SD	Avg	SD		
Aluminum	89.04	86.73	2145.61	2300.82	2234.65	96.02	99.08	61.05	1042.04	1141.13	91.32	
Antimony	10.00	0.00	2.80	2.46	12.80	21.88	10.00	0.00	0.55	10.55	5.19	
Arsenic	2.97	1.12	2.00	0.87	4.97	40.26	1.57	1.42	1.50	3.07	48.86	
Barium	294.84	483.95	1.00	0.43	294.84	0.00	178.88	158.03	0.75	178.88	0.00	
Beryllium	1.00	0.00	1187.02	409.00	2.00	50.00	1.00	0.00	1272.95	1.75	42.86	
Boron	193.90	314.94	0.87	3.31	1380.92	85.96	134.14	111.79	0.29	1407.10	90.47	
Cadmium	0.78	0.87	2.12	2.90	2.90	73.07	1.23	1.45	0.02	1.51	18.84	
Calcium	12.52	15.08	3540.00	2391.12	3552.52	99.65	8.48	7.25	570.00	578.48	98.53	
Chromium	2.10	1.25	7.81	8.26	9.91	78.77	1.29	0.49	2.12	3.41	62.21	
Cobalt	3.07	3.60	0.91	1.55	3.98	22.87	1.36	1.18	0.02	1.38	1.09	
Copper	47.69	42.15	54.82	88.12	102.50	53.48	39.67	39.33	2.48	42.14	5.87	
Iron	536.92	856.49	21.17	32.62	558.08	3.79	154.79	121.56	1.53	156.32	0.98	
Lanthanum	5.00	0.00	0.86	0.98	5.86	14.60	5.00	0.00	0.34	5.34	6.32	
Lead	3.24	2.99	41.67	68.62	44.90	92.79	2.65	1.19	1.31	3.96	33.11	
Magnesium	5.19	5.61	735.00	1044.43	740.19	99.30	2.66	2.64	68.25	70.91	96.25	
Manganese	123.14	159.15	47.88	77.49	171.02	28.00	55.80	75.97	2.56	58.35	4.38	
Molybdenum	1.53	0.63	2.81	2.71	4.34	64.78	1.03	0.07	1.04	2.08	50.24	
Nickel	12.60	14.19	62.45	103.49	75.05	83.21	9.32	8.41	14.36	23.68	60.63	
Phosphorous	1308.80	1227.87	181.53	286.34	1490.33	12.18	467.38	322.70	9.87	477.25	2.07	
Potassium	8.66	8.74	1310.00	832.25	1318.66	99.34	4.10	2.74	941.25	945.35	99.57	
Selenium	10.00	0.00	2.20	2.11	12.20	18.03	10.00	0.00	0.89	10.89	8.13	
Silicon	1.10	0.33	2430.00	745.94	1.10	0.00	0.94	0.30	2692.50	0.94	0.00	
Sodium	34.66	39.10	2.38	1.81	2464.66	98.59	19.66	18.80	1.24	2712.16	99.28	
Tin	4.05	3.34	1.00	0.43	2.38	100.00	3.48	3.01	0.75	4.23	17.73	
Vanadium	783.31	963.50	1817.53	1261.60	2600.83	69.88	761.12	866.67	1300.47	2061.59	63.08	
Zinc												

* all concentrations are in ug/L

SD: Standard deviation

Table 2-6 (Continued)
AVERAGE AND TOTAL METALS CONCENTRATION

Metal	Site 3						Site 4					
	Soluble Phase		Particulate Phase		Total	% Particulate	Soluble Phase		Particulate Phase		Total	% Particulate
	Avg	SD	Avg	SD			Avg	SD	Avg	SD		
Aluminum	123.69	57.57	1211.21	621.03	1334.90	90.73	165.03	74.03	513.05	65.45	678.07	75.66
Antimony	10.00	0.00	1.49	1.75	11.49	12.97	10.00	0.00	1.03	0.15	11.03	9.30
Arsenic	3.31	1.38	2.00	0.87	5.31	37.68	2.33	1.42	1.50	0.00	3.83	39.16
Barium	353.74	398.72			353.74	0.00	251.29	210.11			251.29	0.00
Beryllium	1.00	0.00	1.00	0.43	2.00	50.00	1.00	0.00	0.75	0.00	1.75	42.86
Boron	375.08	342.86	1645.21	657.96	2020.29	81.43	242.34	244.13	710.19	180.73	952.53	74.56
Cadmium	0.52	0.20	0.29	0.20	0.81	35.92	1.15	1.48	0.35	0.20	1.50	23.31
Calcium	15.66	8.81	1030.00	617.98	1045.66	98.50	19.56	14.67	915.00	833.55	934.56	97.91
Chromium	1.59	0.46	6.40	7.10	7.98	80.11	2.47	0.84	4.37	1.47	6.84	63.84
Cobalt	1.58	1.29	0.02	0.01	1.60	1.25	4.87	3.70	0.02	0.00	4.89	0.31
Copper	47.38	33.84	4.19	2.74	51.57	8.12	35.20	20.91	4.46	3.81	39.66	11.24
Iron	243.01	186.92	3.54	3.18	246.54	1.43	197.91	86.30	2.95	0.81	200.86	1.47
Lanthanum	5.00	0.00	0.34	0.16	5.34	6.28	5.00	0.00	0.22	0.10	5.22	4.21
Lead	3.88	2.64	3.33	2.97	7.20	46.17	9.14	3.63	1.92	0.85	11.05	17.32
Magnesium	5.49	3.27	99.00	49.93	104.49	94.74	4.74	3.70	78.00	17.30	82.74	94.27
Manganese	74.18	80.93	4.68	3.46	78.86	5.93	220.03	374.83	8.02	6.84	228.05	3.52
Molybdenum	1.15	0.36	1.99	1.91	3.13	63.35	1.00	0.00	1.89	0.51	2.89	65.40
Nickel	16.76	12.35	21.21	32.67	37.96	55.86	11.55	9.78	27.72	39.97	39.27	70.59
Phosphorous	1571.96	956.26	17.78	11.97	1589.74	1.12	897.69	566.16	16.45	3.89	914.14	1.80
Potassium	12.64	7.93	1170.50	464.83	1183.14	98.93	6.45	3.05	678.00	193.57	684.45	99.06
Selenium	10.00	0.00	1.54	1.19	11.54	13.31	10.00	0.00	1.23	0.41	11.23	10.91
Silicon	1.89	1.00			1.89	0.00	2.59	1.17			2.59	0.00
Sodium	28.53	14.67	3425.00	1232.04	3453.53	99.17	24.45	19.41	1495.00	606.40	1519.45	98.39
Tin			1.61	0.89	1.61	100.00			1.23	0.23	1.23	100.00
Vanadium	5.62	3.99	1.00	0.43	6.62	15.11	4.66	2.46	0.75	0.00	5.41	13.87
Zinc	625.58	426.62	1751.65	680.26	2377.22	73.68	391.83	237.64	928.71	176.27	1320.54	70.33

* all concentrations are in ug/L

SD: Standard deviation

in the thousands (0.1%) or ten thousands (1%) mg/L. It should be clear that results using these very high concentrations are not applicable to average stormwater runoff from the land uses evaluated in this study. To evaluate sorbers for use in the study area, the sorber media and/or devices should be tested at concentrations in the 10 to 35 mg/L range. Although this range is higher than that typically observed in urban runoff from residential areas, concentrations of oil in runoff from commercial and industrial areas may be higher.

3. The storms evaluated early in this study (and earlier in the wet-weather season) were found to have higher concentrations of organic materials (i.e., COD, TOC and oil and grease) than did the later storms. This suggests a potential seasonal first flush effect.
4. Suspended solids from the highest source land use were typically smaller than 325 mesh (0.045 mm or 45 microns). The concentrations of suspended solids that were retained on screens averaged 9 mg/L. The concentrations of suspended solids collected in the earlier testing program that were retained on a 1 micron filter averaged 62 mg/L.

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