STORMWATER MONITORING IN AN INDUSTRIAL CATCHMENT BASIN LOCATED IN BURNABY, BRITISH COLUMBIA

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March, 1985.

PREFACE

The Fraser River Water Quality Work Group (1979) estimated that 50% of the total volume of all discharges to the Fraser River estuary study area was from stormwater. Despite this, few comprehensive studies have been undertaken to investigate the impact of stormwater on the Fraser River estuary in the Vancouver area. Following review of reports by Franson (1973), Vernon (1974), and Hall (1976) and other pertinent literature, the Fraser River Estuary Study's Water Quality Work Group, in their Water Quality Summary Report (1979), proposed one year programs to characterize stormwater from typical industrial, commercial, and residential catchment basins to more accurately estimate stormwater contaminant loadings to the Fraser River. Some of this work, subsequently endorsed by the Pollution Control Board, was undertaken by the Aquatic Studies Branch (now Resource Quality Section of the Water Management Branch, Ministry of Environment) who, in 1981, monitored a South Vancouver residential drainage basin (Swain, 1983) and Waste Management, Region 2 (Ministry of Environment), who, in 1982-1983, studied an industrial stormwater discharge on Norland Avenue in Burnaby. This report presents the results of the Waste Management study.

SUMMARY

A stormwater monitoring study of an active light industrial drainage basin was conducted in 1982-83 by Waste Management, Region 2 (Ministry of Environment). This study follows a similar 1981 monitoring program of a South Vancouver residential drainage basin as part of a recommendation by the Fraser River Estuary Study Water Quality Group to gain more information on the impact of stormwater discharges to the Fraser River estuary.

Rainfall quantity and quality were monitored. 1 380 mm of precipitation, approximately 8% less than expected, fell during the study period. Although some strong and total acidity was detected, usually in association with peak traffic volume on the nearby freeway, the mean pH of the rainfall did not indicate acid rain. In comparison to other sources, contaminant loading from precipitation was negligible for the parameters examined.

Dustfall samples were collected approximately monthly. Significant amounts of sodium and chloride in these samples suggest the deposition of seawater picked up by storms moving in from the Pacific Ocean. Dustfall particulate material was mainly inorganic in nature and exhibited a seasonal trend with higher deposition in the dry portion of the year. Dustfall contributes significant amounts of lead and copper loading to the total loading from all sources.

Extrapolating the 37 900 m^3 of recorded stormwater flow from the 5.8 ha study area to the total estimated industrial area in the Fraser River Estuary Study area indicated 40% less volume than previously estimated possibly due to the very low dry weather stormwater discharge at the Norland Avenue site. An average runoff coefficient (R) of 0.31 was calculated which is considerably less than predicted for industrial areas (R=0.7) but may be due to the amount (40%) of unpaved area within the Norland Avenue drainage basin, type of building construction, or catchment area estimate.

Although concentrations of several parameters were higher in dry weather discharges their respective loadings are higher from wet weather discharges due to the larger wet weather stormwater discharge volume. Insoluble forms of several contaminants especially metals increased in association with suspended solids whose concentrations generally exhibited a positive correlation with flow. Dissolved metals, often higher in dry weather discharges, became diluted with increases in stormwater runoff. Hydrocarbons detected indicate diesel fuel and diesel oil contamination from the trucking activity which predominated in the study area. No pesticides but small PCB concentrations were detected in discharged sediments which also contained high heavy metal concentrations. Wet weather discharges were found to be non-toxic while some microtox and Daphnia toxicity was associated with the dry weather discharge.

Overall, stormwater loadings of most parameters originate from materials deposited directly into the drainage basin to be washed away by the runoff and not from precipitation or dustfall.

For several contaminants, especially metals, concentrations are higher than predicted for industrial stormwater. Many of these parameters exhibit a first flush effect resulting in large loadings during the initial period of the storm runoff. Subsequent discharges have caused localized transient impacts on the Fraser River.

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ACKNOWLEDGEMENTS

Thanks are due to the Ministry of Environment and Ministry of Health Laboratories for their analytical skills, the Greater Vancouver Regional District and the Atmospheric Environment Service (Environment Canada) for their weather information, the Water Management Branch (especially Mr. L. Swain and Mr. B. Holms) for their help in the study and reviewing the report, the Waste Management Branch's Environmental Quality Unit for computer services, the Municipality of Burnaby for assistance in constructing the sampling site, and Mrs. F. Aiken and Ms. M. Anderson for typing the report.

1.0 INTRODUCTION

Effluents discharged from point sources generally are well known and can be controlled. In comparison, non-point discharges from a diverse array of hard to identify sources such as urban and agricultural land use areas may be intermittent, of variable or unknown quality, and dispersed through a region making their control very difficult (Barton, 1978). Attempts to rectify some pollution problems by eliminating only point source discharges have failed due to continued contaminant input by runoff (AVCO Economic Systems Corporation - in Kluesener and Lee, 1974; Wakeham, 1977; Whipple and Hunter, 1977; Randall and Grizzard, 1983). The United States' Environmental Protection Agency has estimated that 50% of that Nation's water pollution originates from non-point sources (Barton, 1978).

Rainfall runoff is a major non-point discharge. This runoff contains high but variable levels of heavy metals (especially copper, lead, and zinc; Wilbur and Hunter, 1977), oxygen demanding substances, nutrients, hydrocarbons, pesticides, and bacteria but in terms of quantity the greatest problem is large suspended solids loads (Bradford, 1977; Mance and Harman, 1978; Melanen, 1978; Tucker and Mortimer, 1978; Hunter et al., 1979; Hoffman et al., 1982; Owe et al., 1982). Parameter concentrations found in field studies often vary in a complex fashion specific to the particular drainage basin but some generalizations can be made, as follows.

As an area becomes urbanized, contaminant loads increase but wide concentration ranges can exist for most parameters within a general land use category (i.e. residential, commercial, industrial, agricultural, green space; Randall and Grizzard, 1983). Runoff contaminant concentration variations may be related to increased animal density (dogs, cats, rodents, birds) increasing fecal coliform and nutrient levels (Robbins et al.,1972; Randall and Grizzard, 1983), greater human activity contributing more litter, construction activity (Bedient et al.,1980), and proximity to industrial and other air pollution discharges (e.g. highways) increasing contaminant levels in rainfall (Randall and Grizzard, 1983). Seasonal influences on runoff quality are also evident due to de-icing of roadways in winter (Weibel et al.,1964; Sartor et al.,1974), decomposition of vegetation especially leaves in the fall (Kluesener and Lee, 1974; Wilbur and Hunter, 1977), and increased burning of fossil fuels through the winter (Randall and Grizzard, 1983). Streets accumulate solids, heavy metals, and petroleum hydrocarbons at a rate governed by traffic volume and days without removal by wind, rain, or street cleaning equipment (Randall and Grizzard, 1983). In a drainage area the runoff rate is affected not only by the slope of the land but also the proportion of impervious area (roads, rooves, paved parking lots; Griffin et al., 1980). Rainfall may percolate gravelled parking lots but vehicle traffic through these areas can contribute large amounts of sediments to the paved areas.

Climatic variations also influence the quality and quantity of runoff. The amount of rainfall varies seasonally with the largest proportion occurring locally through the fall and early spring. Frequent light rainstorms wash out considerable amounts of contaminants but intense showers tend to mobilize larger particulates increasing solids loads (Tucker and Mortimer, 1978; Randall and Grizzard, 1983). The onset of a storm can result in an initial washout of materials producing a "first flush" effect and shock-loading of the receiving environment. The magnitude of contaminants in this first flush has been found to increase with the length of the dry period between storms but the relationship is not always clear (Kluesener and Lee,1974; Wilbur and Hunter, 1977; Helsel et al.,1979; Randall and Grizzard, 1983). Swain (1983) found that the length of the dry period in a residential catchment in Vancouver had very little effect on the runoff coefficient.

Overall, stormwater discharges can be detrimental to the receiving environment as they could cover fish feeding and spawning areas with sediment, depress oxygen concentrations by exerting an oxygen demand, eutrophy the receiving environment, and convey heavy metals and other potentially toxic chemicals such as pesticides and PCB's to the aquatic ecosystem.

2. STORMWATER MONITORING METHODOLOGY

2.1 Site Selection

Choosing the particular monitoring site was based on the following criteria:

a) The location should have a reasonably high rainfall to allow for a sufficient number of sampling opportunities.

b) The catchment basin must be primarily industrial in nature and sufficiently large so as to limit local peculiarities.

c) The storm sewer should have no cross-connections with sanitary sewers and infiltration must be minimal.

d) The storm sewer should have a flat slope as a major aim of the project is to quantify parameter loadings and the necessary flow measurements are more accurate under low stormwater velocities.

e) The monitoring station should have easy and safe access.

f) The area of the catchment basin should be well defined.

g) The stormwater runoff should eventually drain to the Fraser River in order to maintain relevance to the Fraser River Estuary Study.

2.2 Site Description

The 5.8 ha (area determined by planimetry by the Engineering Design Department of the Municipality of Burnaby) site selected is located in Burnaby on Norland Avenue at Cole Avenue just north of Highway 1 (Figures 1A, 1B). This area's average annual precipitation is approximately 1 500 mm per year most of which occurs from October through March (Greater Vancouver Regional District records). The geology is upland peat 8 m or more thick but this natural state is not immediately evident due to warehousing, roads, and asphalt or gravelled parking areas. During industrialization, the area was likely filled with woodwaste, gravel, or sand. Rain runoff from Norland Avenue and the bordering properties is collected into storm drains and flows from a 0.75 m diameter pipe at 2.17% slope into an 80 m long ditch draining into Still Creek. Still Creek is part of the Burnaby Lake - Brunette River system which drains into the Fraser River at New Westminster.

Classified as light industrial, most businesses within the study area are concerned with trucking (truck rental and maintenance, wholesale distributors). Approximately 40% of the catchment's surface area is green space or gravelled parking lots, 25% roadway and paved parking lots, and 35% rooftops. Activity within the drainage basin generally is greatest during weekday daytime business hours with additional influence from the nearby freeway especially at rush hours. Due to the valley location and prevailing winds, the site could also receive atmospheric fallout from Vancouver's downtown core.

Figure 1A

STORMWATER STUDY LOCATION

MUNICIPALITY OF BURNABY

SCALE-1:50000

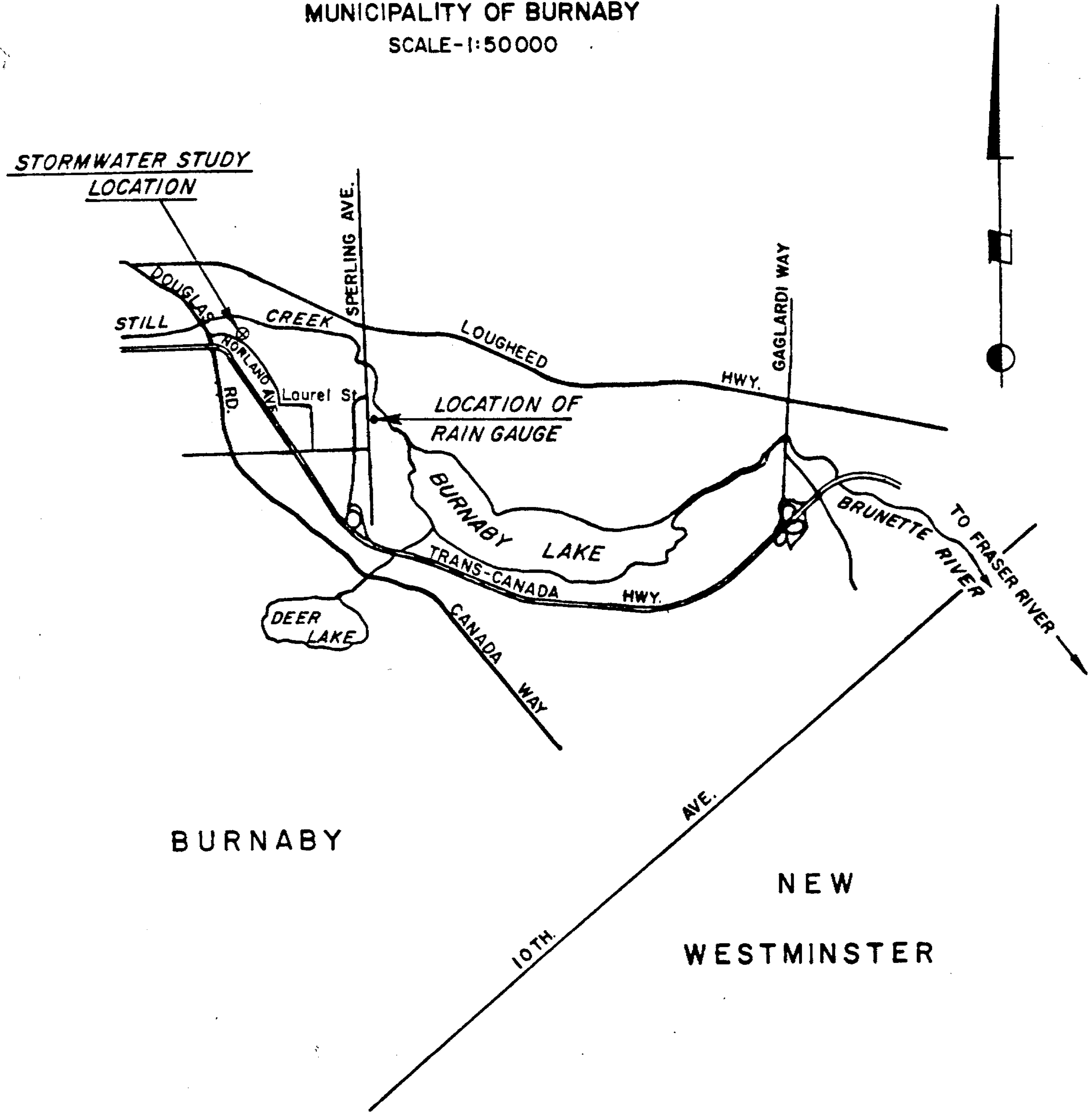
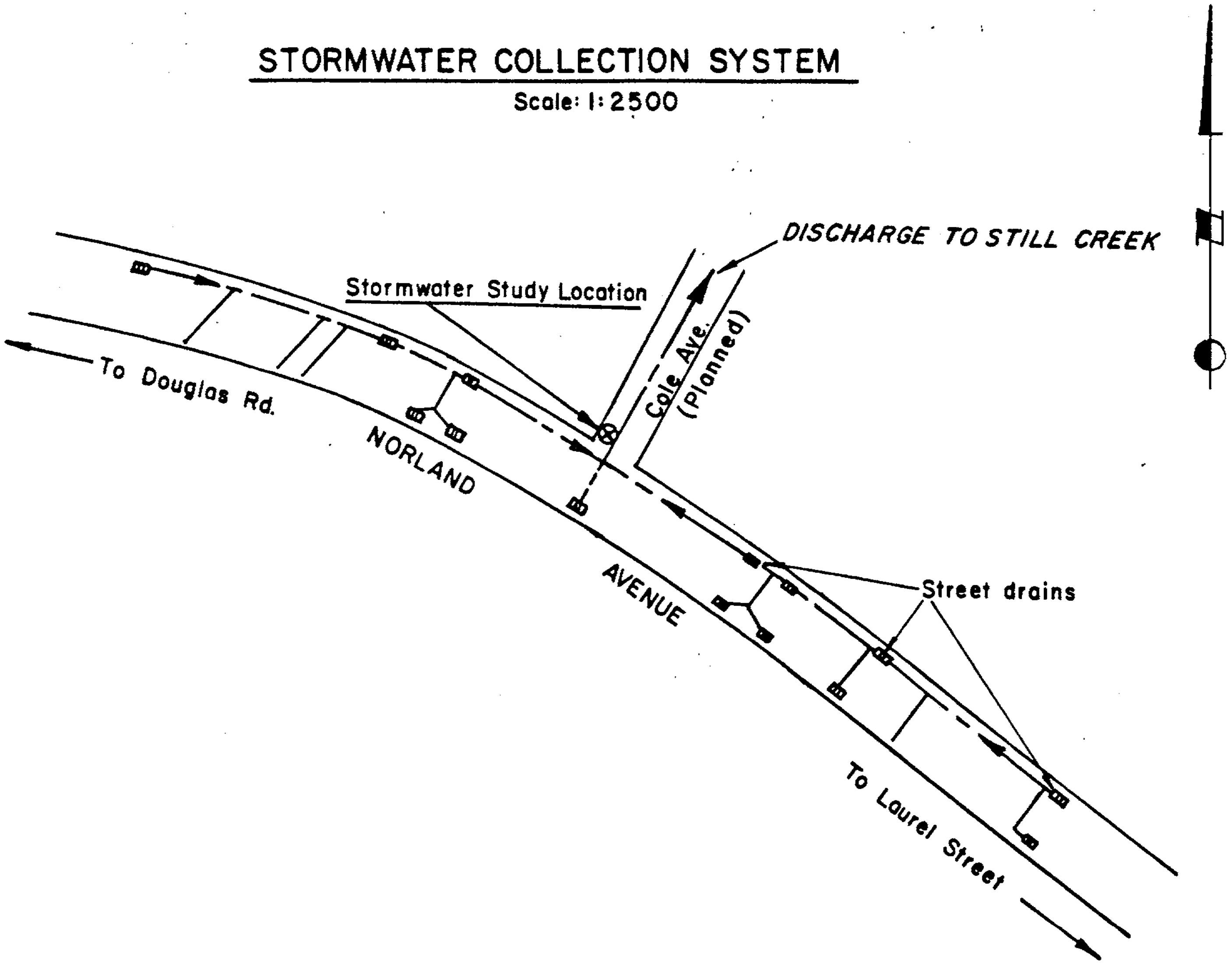


Figure 1B

STORMWATER COLLECTION SYSTEM

Scale: 1:2500



2.3 Monitoring Program

Prior to establishing the monitoring site the Municipality scoured the ditch to Still Creek facilitating faster runaway of the stormwater from the monitoring station. The outfall site was equipped with a storage shed and chainlink fence so that flow, rainfall quality, dustfall, and stormwater quality could be monitored. Rainfall quantity was monitored at a nearby Greater Vancouver Regional District rain gauge located at a pump station on Sperling Avenue (Figure 1A).

2.3.1 Flow Measurements

Flow was measured with a Parshall flume (0.92 m diameter, 0.3 m throat) secured onto the outfall pipe. The flume was initially levelled and subsequently cleaned and levelled as required, but at least monthly. The water level within the flume was measured with a Robert-Shaw capacitance liquid level sensor with its probe installed in a stilling well on the side of the flume. Output from the probe went to two strip chart recorders operating in parallel recording flow levels of 0-457 mm or 0-915 mm. Dry weather stormwater baseline flows were below the probe's detection limit necessitating flow estimates by recording the time to fill a known volume. Flow charts were reviewed and the raw data transposed by computer into discharge volumes by the Water Management Branch.

2.3.2 Stormwater Sampling

Composite stormwater samples for water chemistry analyses were collected from the discharge during both dry and wet weather periods. For wet weather sampling 4 L was manually collected from the discharge every 3.75 minutes and combined into a 15 minute composite. Such composite sampling was conducted continuously for up to 3 hrs.

In dry weather a 16 L composite was collected by combining essentially all the discharge over a time period determined by the small discharge volume. For dry weather sampling only four sets of samples were collected on each sampling occasion. As soon as possible after sampling, the samples were filtered and preserved as required. Discrete samples during dry and wet weather discharges were collected for coliform analysis directly from the flow for the appropriate sampling period.

All water chemistry and microtox and Daphnia bioassays were conducted by the Ministry of Environment's Laboratory in Vancouver following analytical procedures detailed in "A Laboratory Manual for the Chemical Analysis of Water, Wastewaters, Sediments, and Biological Materials" (Dept. of Environment, 1976). Bacteriological analyses were performed by the Ministry of Health's Vancouver Laboratory using techniques outlined in "Standard Methods for the Examination of Water and Wastewater"

(APHA-AWWA-WPCF, 15th Ed., 1980). Static bioassays using rainbow trout were done according to methods in "Provincial Guidelines and Laboratory Procedures for Measuring Acute Lethal Toxicity of Liquid Effluents" (Ministry of Environment, 1983) at the Federal Government's Environmental Protection Laboratory in North Vancouver.

2.3.3 Precipitation

The Ministry of Environment's Air Studies Branch could not locate a suitable site near the outfall for a rain gauge. Subsequently the Greater Vancouver Regional District granted use of data from their Sperling Avenue rain gauge located a short distance from the site.

Rainfall quality was determined by manually opening rainfall collectors at the outfall site and sampling the rainfall during storm events. Sample containers were replaced when full or when the rainfall ceased. Rainfall samples were submitted for analyses with the stormwater samples to the Environmental Laboratory.

2.3.4 Air Quality Sampling

Dustfall collectors for metals, mercury, or particulates were located at the outfall site. The collectors were replaced monthly or sooner if rainfall threatened to cause them to overflow.

RESULTS

3.1 **Precipitation**

Precipitation quality was measured at the outfall site while continous quantity measurements were made with a rain gauge on Sperling Avenue.

3.1.1 **Quantity**

The daily precipitation record (May, 1982 through May, 1983, Table 1) indicates the quantity and time of precipitation for the study area. The monthly totals are summarized in Table 2. Heavy rainfall occurred from October, 1982, through March, 1983, with November and February being the wettest months (215 and 237 mm, respectively). The driest months were May and June, 1982, and May, 1983, when 15, 20, and 37 mm of precipitation occurred, respectively. The 1 380 mm of precipitation which fell during the 13 month period is 1% greater than recorded at the Vancouver Airport for the comparable period. Historical data indicate that the rainfall was 17% heavier than usual. Isohyets plotted for the Greater Vancouver area (Ferguson and Hall, 1979) show that, on average, the Norland Avenue site receives 25% more rainfall than the airport. These differences may be due to the short time span of the stormwater study, equipment breakdowns resulting in discontinuous records, and different techniques in measuring rainfall.

3.1.2 Quality

3.1.2.1 pH, Acidity

The mean pH of the rainwater (Table 3) at the Norland Avenue site is 5.63 indicating that the rainwater is not acidic (i.e. pH of pure rainwater at equilibrium with CO_2 at 25°C is pH 5.6). Samples collected at Revelstoke, Prince Rupert/Terrace, and especially the South Vancouver residential catchment all have lower pH (Table 4). However, the range of the pH values is much greater for the Vancouver study locations.

Although only 7 storms had more than one rainwater sample taken during the rain event, 5 of the 7 showed a pH decrease while one of the remaining storms showed a random but generally decreasing pH trend and the other had a very slight pH increase.

At Norland Avenue strong and total acidity measurements (Table 3) varied from less than detection up to 58 ueq/l and 122 ueq/l, respectively.

Corresponding acidity analyses for the South Vancouver residential catchment are higher. Values for Prince Rupert/Terrace are markedly similar but the range of values for the Norland Avenue site was much greater than for Prince Rupert/Terrace. Where multiple samples were taken during a storm it was found that positive strong acidity correlated with periods of increased vehicle activity (i.e. rush hour). Total acidity showed greater variability but generally parallelled strong acidity.

3.1.2.2 Ions

Levels of calcium, chloride, magnesium, potassium, phosphate, sodium, and sulphate measured at Norland Avenue are summarized in Table 3. Calcium concentrations were markedly higher while sulphate and magnesium were approximately the same as found at the Vancouver residential site (Table 4). Sodium, phosphate, and chloride levels were highest at the Vancouver residential site (Swain, 1983) but concentrations at both Vancouver sites were higher than the other British Columbia sites. Sodium, chloride, magnesium, and sulphate levels are likely picked up over the Pacific Ocean and are washed out relatively quickly once over the coast, thus accounting for higher concentrations of these parameters at the coastal stations.

For storms with multiple rainwater samples no consistent trend was apparent for these ions.

3.1.2.3 Heavy Metals

Iron, lead, zinc, copper, and cadmium were measured with digested (i.e. approximates total concentration) and undigested analytical procedures while aluminum values represent total concentrations (Table 3). All metals except cadmium were detected in the majority of Norland Avenue samples. In comparison to the Vancouver residential site (Table 4) only copper was present in higher concentrations at Norland Avenue. Lead was present in approximately the same concentrations as found at the Vancouver residential catchment.

3.1.2.4 Nitrogen

Ammonia, nitrate, and nitrite were detected in all Norland Avenue rainwater samples (Table 3). Levels of nitrate and nitrite were higher, but ammonia concentrations found were comparable to those in the Vancouver residential rainwater samples. The ammonia and nitrate concentrations far exceeded those of the Revelstoke and Prince Rupert/Terrace sampling locations.

3.1.3 Discussion

Precipitation at the Vancouver Airport during the study period was 17% higher than usual while at Norland Avenue it was 8% less than expected.

The mean pH found for rainwater indicates that overall it is not acidic but there is considerable pH variability, and a considerably greater range than for the Vancouver residential monitoring site. Although only 7 storms have multiple samples a trend to decreasing pH through a storm is apparent. A similar trend was noted at the Vancouver residential catchment.

Strong and total acidity were considerably higher at the Vancouver residential site. Generally, high strong and total acidity values found at the Norland Avenue site corresponded with periods of high local activity, especially rush hour on the freeway.

Ion concentrations for the Greater Vancouver sampling sites are equal to or greater than the other British Columbia sites. Parameters which relate to atmospheric washout of sea spray are higher at the Vancouver residential site as well as the other coastal stations.

Values of nitrate and nitrite but not ammonia are highest at the Norland Avenue site and may originate from vehicle or other local emissions.

Factors such as the number of data and varying means of sampling (i.e. sampling specific storm events versus continuously collected samples) may influence these findings. However, sampling techniques at the two Vancouver sites were consistent.

3.2 Dustfall

Dustfall was monitored at the Norland Avenue site with analyses for particulates, ions, and metals.

3.2.1 Ions

Soluble fluoride, sodium, and chloride were measured but only significant amounts of chloride were routinely detected (Table 5). The highest chloride and detectable sodium concentrations were found from October to March. In comparison to the Vancouver residential site (Swain, 1983), Norland Avenue sodium and chloride values are considerably less. Similar fluoride comparisons cannot be made due to different detection limits.

3.2.2 Heavy Metals

Analyses were conducted for total, soluble, and insoluble forms of arsenic, lead, copper, zinc, cadmium, and mercury. Analytical problems precluded obtaining an adequate number of mercury results (Table 5). Significant amounts of lead, copper, and zinc were found but little was detected for their soluble forms. No seasonal trend for variation in metal concentration is evident. Total copper, mercury, and zinc were lower while lead was higher at the Norland Avenue site in comparison to the Vancouver residential study (Swain,1983). Higher lead values at Norland Avenue are likely due to the close proximity of the monitoring site to heavier traffic volumes.

3.2.3 **Particulates**

Dustfall particulate material (particles larger than 20 micrometres in diameter which settle from the air by gravity) was measured in total, soluble, insoluble, soluble ash, and insoluble ash forms (Table 5). Most of the material was in the insoluble/ insoluble ash form indicating an inorganic nature. A seasonal variation in concentraiton of total, insoluble, and insoluble ash particulate forms is evident with low levels detected during the rainy portion of the year. The total particulate dustfall is well in excess of both the British Columbia Air Quality Objectives and Guidelines desirable (1.75 mg/dm^2/d) and interim (2.90 mg/dm^2/d) particulate levels. Total particulates at the Vancouver residential (Swain 1983), and Norland Avenue sites were approximately the same. However, soluble components were lower and insoluble higher at Norland

Avenue. This difference may be accounted for by the amount of fine material likely introduced to the road surface from unpaved parking areas, and subsequent suspension in the air by heavy vehicular traffic.

3.2.4 Discussion

Low levels of dissolved sodium and chloride were measured in dustfall. Elevated concentrations of both these ions occurred during the cool and rainy portion of the year suggesting their origin may be from rainstorms or road de-icing/vehicle spray. Significant amounts of lead, copper, and zinc were found but largely in the insoluble forms. No seasonal trend was noted for these metals. A seasonal cycle is evident for particulates. Through the rainy portion the year total, insoluble, and soluble ash (i.e. inorganic material) particulate forms are lower. This may result from continual particulate removal from the air by precipitation which may also wet road sufaces making them less dusty or wash the material from the roads entirely.

In general, concentrations of ions are higher while metals, except lead, are lower at the Norland Avenue versus Vancouver residential site. Total particulates are about the same.

3.3 Stormwater Runoff

Quantity and quality of the stormwater runoff was measured during the 12 month study period, May 1982 through May 1983, as described in Section 2.3.

3.3.1 Quantity

The maximum recorded daily flow of 1 683 m^3 occurred on February 19, 1983, while minimum flows occurred during dry periods when the flow was below detection (Table 6). Substantial wet weather discharges in excess of an average of 170 m^3 occurred from November through February. In all approximately 36 000 m^3 of wet weather stormwater runoff was discharged during the study period.

In fair weather periods the runoff was below the detection limit which necessitated estimating baseline flow when the dry weather stormwater samples were taken. The average dry weather flow was thereby estimated at 7.3 m^3/d (maximum 39 m^3/d, minimum 4.4 m^3/d) or 1 900 m^3/y.

The total combined flow of 37 900 m^3 represents a daily average of 104 m^3/d. Additional estimated discharge volumes for periods for which there was no chart record due to equipment failure are not included.

Runoff coefficients (R) were calculated (Table 7) for 20 of the storms sampled for which there is complete runoff, precipitation, and water chemistry data. The time interval used in the calculations was taken to be the period when the recorded flow exceeded the baseline flow. The coefficient's arithmetic mean of 0.31 (range 0.03 to 0.80, standard deviation 0.18) is substantially different from the value of 0.70 indicated by Ferguson and Hall (1979) for an industrial land use area and is more typical of a roads/residential (R=0.45) or an agricultural (R=0.2) land use area.

The discrepancy between the estimated and the calculated R-factors may be due to a number of factors which influence both the runoff volume and drainage area used to calculate the runoff coefficient. Buildings in the Norland Avenue catchment had slab above grade construction which would not require perimeter drainage with storm sewer connections. At least a third of these buildings had peaked rooves drained only to the ground surface, often gravel parking lots. Although the Burnaby Engineering Planning Department determined the drainage area it is likely difficult to accurately ascertain as the catchment is on a shallow slope down to Still Creek and the properties often do not have perimeter drains with storm sewer connections around their buildings.

3.3.2 Quality

The Norland Avenue stormwater discharge was sampled on 28 wet weather and 8 dry weather occasions as described in Section 2.3.2. Data summaries are provided for wet (Table 8) and dry (Table 9) weather discharge contaminant concentrations and their associated loadings (Table 10). Variation in parameter concentrations with flow during a storm which was sampled twice are also illustrated (Figure 2a to 2f). These parameter concentration variations were compared to parameter trends observed for all storms.

3.3.2.1 Bacteriological Data

Mean fecal coliform levels (Tables 8,9) for dry weather discharges (31475 MPN/100 ml) far exceed the level noted in wet weather discharges (2860 MPN/100 ml). The variation in level of fecal coliform is much greater in the dry weather discharge. Both total coliform levels and the proportion of fecal to total coliform are much lower in the wet weather discharge.

The coliform levels found by Swain (1983) for the Vancouver residential catchment site are considerably lower while the levels assumed by Ferguson and Hall (1979) for industrial and residential areas are much higher.

The fecal (Figure 2d) and total coliform levels were not observed to vary consistently with flow and an association with suspended solids, as found by Swain (1983), was not apparent.

3.3.2.2 Carbon

Both inorganic and organic carbon mean concentrations were lower during wet weather but carbon loading is approximately 8-fold higher in wet weather (Tables 8,9). For the rain event examined (Figure 2b) an initial positive correlation with flow was noted followed by a decline as the material presumably became flushed from the system. A close association with variation in suspended solids concentration was observed for this storm, however, examination of all storms sampled indicated that, unlike suspended solids, inorganic and organic carbon are not clearly associated with flow. Carbon concentrations found at the Norland Avenue site are 4 to 5-fold higher in dry weather and 2-fold higher in wet weather than at the Vancouver residential site (Swain, 1983).

3.3.2.3 Metals

Sixteen metals were assayed for (Tables 8,9), half of which for both dissolved (D) and total (T) forms. Arsenic, cadmium, chromium, molybdenum, and nickel were either not detected or found only in trace amounts. Substantial amounts of aluminum (T), calcium (D), iron (T), magnesium (T), potassium (D), and sodium (D) were found in both dry and wet weather discharges. Dissolved forms of several metals including aluminum, calcium, iron, lead, magnesium, manganese, potassium, and sodium are considerably higher in dry weather flows. Concentrations of total forms of aluminum and iron increased, while magnesium and manganese decreased, and copper, lead, and zinc remained essentially unchanged in wet versus dry weather flows. Loadings (Table 10) of all dissolved and total metals present in significant concentrations were considerably higher from the wet weather discharge due to the much larger discharge volume.

Most metal concentrations found at the Norland Avenue site are considerably higher than detected by Swain (1983) for the Vancouver residential catchment basin. Exceptions to this were total cadmium, copper, and mercury which were about the same at each site. Dissolved magnesium, copper, and iron, and total copper and mercury were present at both sites in approximately equal concentrations. Only dissolved lead was found in higher concentrations at the residential site

(Swain, 1983). Essentially no nickel or arsenic were detected at either site.

Examination of metal concentration changes within a particular storm (Figure 2e,f) indicated a close relationship between total lead, aluminum, manganese, and iron concentrations and non-filterable residue. Insoluble zinc concentrations follow the same trend but the effect is not as clear due to the influence of the dissolved portion of the total concentration. As more solids are mobilized later in the storm total metal concentrations are proportionately higher. Dissolved forms of zinc and aluminum follow quite different trends. Whereas dissolved zinc is quickly washed out near the beginning of the storm, dissolved aluminum exhibits a positive correlation with flow and was present in higher concentrations later in the storm.

Review of all storms indicated that total metal concentrations (aluminum, calcium, copper, iron, lead, magnesium, manganese, zinc) exhibit either a positive correlation with flow or vary without a clear trend. Dissolved metal concentrations (calcium, iron, magnesium, manganese, potassium, sodium, zinc) typically have a negative correlation with flow or vary with no obvious trend.

3.3.2.4 Nitrogen Forms

Forms of nitrogen measured were ammonia, nitrate/nitrite, nitrate, nitrite, organic, Kjeldahl, and total nitrogen (Tables 8,9). Only nitrate and nitrate/nitrite concentrations were higher in wet weather discharges although the loadings of all nitrogen forms are higher from the wet weather discharges (Table 10). Concentrations of wet weather nitrogen forms generally are higher at the Vancouver residential site (Swain, 1983) but in dry weather the only outstanding differences are ammonia (3-fold higher at Norland Avenue) and nitrate/nitrite (6-fold lower at Norland Avenue).

3.3.2.5 Phosphorus Forms

Dissolved orthophosphate, total dissolved phosphorus, and total phosphorus were measured and concentrations found to be considerably higher in the dry weather discharge (Table 8,9). Similar loadings for dry and wet weather discharges were found for orthophosphate and total dissolved phosphorus (Table 10). The only marked difference in loading was for total phosphorus which was 5-fold higher in wet weather.

Levels of total phosphorus measured within a storm (Figure 2a) followed the flow and were higher later in the storm suggesting an association with non-filterable residue (Figure 2b). A similar total phosphorus - flow association was noted in most storms while concentrations of orthophosphate and total dissolved phosphorus exhibited little relationship to flow.

Total phosphorus levels were higher at Norland Avenue than found by Swain (1983) for the Vancouver residential site.

3.3.2.6 **Oil and Grease**

Approximately the same mean oil and grease concentration was found in both dry and wet discharges while maximum concentrations were 40% higher in wet weather discharges (Tables 8,9). Loadings from oil and grease are 20-fold higher from the wet weather discharge (Table 10), probably as a result of traffic volume, fuel pump spillage, and hydrocarbon contributions from vehicle maintenance shops. The Norland Avenue oil and grease concentrations are substantially higher than those measured at the residential drainage area (Swain, 1983).

Variation within a storm (Figure 2a) indicated a positive correlation with flow and an increase in concentration later in the storm. The higher concentration may be due to increased mobilization as the storm progresses or increased activity in the drainage area due to the time of the day. A similar oil and grease flow association with flow was noted for most storms.

3.3.2.7 **Oxygen Demanding Substances**

Dry weather flows contained approximately 2.5-fold more BOD_5 and COD than wet weather flows but the wet weather loading is 6 to 8-fold greater due to the larger associated flow (Tables 8,9,10). BOD_5 and COD concentrations found at the industrial drainage site are considerably higher than at the Vancouver residential site (Swain, 1983) where only COD was detected and then only in wet weather discharges. Mean COD values at Norland Avenue were about twice those found at the Vancouver residential site (Swain, 1983).

BOD_5 variation within a specific storm (Figure 2d) indicated an initial concentration increase but the oxygen demanding substances were rapidly washed out as no BOD_5 was detected late in the storm. Very little association between flow and BOD_5 was noted over all the storms sampled.

COD exhibits a positive correlation with flow and was found at higher concentrations later in the storm (Figure 2d) suggesting that it may be associated with non-filterable residue. A positive association was observed between COD and flow over all storms.

3.3.2.8 pH, Alkalinity

Stormwater pH varied 6.9 to 10 in dry weather and 6.2 to 8.7 in wet weather but the mean pH for both dry and wet weather discharges was 7.4 (Table 8,9). At the Vancouver residential site the pH was significantly lower varying 6 to 7.7 (median 7.3) in dry and 5.6 to 7.5 (median 6.7) in wet weather discharges (Swain, 1983).

The alkalinity or buffering capacity of the stormwater was found to be 3-fold higher in the dry weather discharge. Alkalinities often could not be determined on wet weather unfiltered samples due to interfering substances generating unstable end points in the assay. Stormwater alkalinity measured at the residential site was considerably less in both the wet (mean of 15) and dry (mean of 34) weather discharges.

The mean pH of the rainfall at the Norland Avenue site was 5.6 therefore the alkaline nature of the drainage area acts to buffer the runoff to a greater extent than at the Vancouver residential site (Swain, 1983). Although some of the buffering capacity is lost in wet weather it is still greater than at the Vancouver residential site (Swain, 1983).

Review of all storms indicated that alkalinity most often exhibited a negative association with flow while pH showed no obvious association with fluctuations in flow within storms, remaining quite constant. Lower pH values were noted in samples taken late in a long storm runoff period.

3.3.2.9 **Solids**

Total residue, filterable residue, non-filterable residue, and fixed non-filterable residue were measured (Tables 8,9). Total residue was approximately the same in both dry and wet weather stormwater flows but filterable residue was 4-fold higher in dry weather flows while non-filterable residue was 7-fold higher in wet weather flows. The proportion of fixed non-filterable residue is 20% higher in wet versus dry weather flows indicating the amount of inorganic material being washed off the streets and discharged in wet weather flows is greater.

Concentrations of non-filterable residue and fixed non-filterable residue are much lower at the residential stormwater monitoring site

(Swain,1983) where concentrations show only a slight increase with rainy periods.

Solids account for most of the contaminant loadings from the industrial stormwater (Table 10). In wet weather mean concentrations of total residue, filterable residue, and non-filterable residue increased 17-fold, 5-fold, and 132-fold respectively. As the fixed non-filterable residue mean concentration increased 176-fold in wet weather the non-filterable solids increase in wet weather stormwater would appear to be mostly inorganic material such as sand. Despite the large difference in wet:dry weather discharge volumes, the respectively small increase in filterable residue is indicative of its greater proportion in dry weather flows.

The large quantity of solids discharged at the Norland Avenue industrial site is due to the large amount of unpaved parking area and the volume of vehicle trafffic, especially in the daytime, through these areas mobilizing the solids materials.

For the specific storm examined (Figure 2b) non-filterable residue has a positive correlation with flow and higher concentrations were noted later in the storm when there would be greater activity especially from vehicles within the drainage basin. Review of all the storms sampled indicated that total residue, non-filterable residue, and fixed non-filterable residue all exhibit a positive correlation with flow. Filterable residue has a negative association with flow.

3.3.2.10 **Chloride**

Although chloride loadings are 5-fold greater in wet weather, the dry weather dissolved chloride concentrations are 4-fold higher (Tables 8,9,10). The highest dry weather chloride concentrations were found in the late summer while peak wet weather concentrations were noted during the start of storms sampled in the winter. These higher winter concentrations may result from road de-icing but such buildups may be countered by high rainfall washing the chloride away. Within storm concentrations (Figure 2c) initially show a positive correlation with flow before falling to low levels either from washing out of the drainage area or a dilution of higher low flow concentrations. Review of all storms indicated that chloride has a negative association with flow.

3.3.2.11 Phenols

Low but approximately equal phenolic compound concentrations were detected in both dry and wet weather flows at the industrial site (Tables 8, 9). Considerably higher concentrations were noted in Vancouver residential stormwater (Swain, 1983). Unlike the industrial location, phenol concentrations at the residential site were reduced by rainfall runoff. A review of within storm variation indicated that phenols do not vary consistently with flow.

3.3.2.12 Silica

Dissolved silica concentrations were 6-fold higher in dry weather flows (Tables 8,9). Review of parameter trends for all storms showed that silica concentrations varied negatively with flow, dropping near the beginning of a storm then rising as flows abated indicating a dilution effect of background concentrations by the rainfall runoff.

3.3.2.13 Specific Conductivity

Conductivity ranged from 185 to 633 umhos/cm (mean 273) in dry weather discharges and from 53 to 286 umhos/cm (mean 122) in wet weather discharges (Tables 8,9). The higher dry weather values result from higher concentrations of dissolved species such as chloride, silica, calcium, potassium, and sodium. Comparison with mean values for the Vancouver residential site (Swain, 1983) indicates considerably higher conductivity levels in both dry and wet weather flows at the industrial site.

Within all the storms sampled conductivity was observed to have a negative correlation with flow.

3.3.2.14 **Sulphate, Sulphide**

No sulphide was detected in either wet or dry weather stormwater flows (Tables 8,9). Sulphate was present in considerably higher concentrations in dry weather flows (Tables 8,9). Variation in sulphate concentration over all storms indicated a negative association with flow.

3.3.2.15 **T.A.C. Colour**

Colour values for dry weather flows (range, 33 to 950; mean, 217) are considerably higher than for wet weather discharges (range, below detection to 150; mean, 37; Tables 8,9). Higher values within storms occurred either at the beginning or end indicative of a diluting influence by the rain runoff, therefore a negative association with flow. The high dry weather values likely result from humic substances from infiltrating groundwaters and the presence of metallic ions notably iron and manganese.

Colour was considerably higher at the Norland Avenue site than found for the Vancouver residential site (Swain, 1983).

3.3.2.16 Hydrocarbons

The hydrocarbon test provides a more specific analysis for petroleum hydrocarbons. Hydrocarbon levels in the dry weather discharge were below detection (Table 11). Concentrations in wet weather ranged from less than detectable up to 43 ppm and exhibited characteristics of either diesel oil or, more frequently, diesel fuel. Most of the hydrocarbons likely originated from a nearby truck rental maintenance facility and associated fuel pumps.

3.3.2.17 Toxicity Tests

The acute toxicity of wet and dry weather discharges was measured using microtox, Daphnia, and rainbow trout (static) bioassays (Tables 12, 13). Virtually no toxicity was detected in the wet weather discharge by any of the three tests. Some toxicity was detected in the dry weather discharge with the microtox and Daphnia but not the fish bioassays. Similar dry weather discharge toxicity was detected by Swain (1983) using Daphnia for a residential stormwater discharge, and by Anderson (1983) for several storm sewers from different land use drainage basins.

3.3.3 **Sediment**

Three sediment samples were collected from that accumulated in the flume following major storms (Table 14). The particle size range was quite consistent between samples with most material being larger than 0.149 mm, the size of medium to coarse sand ("<u>Methods of Aquatic Data Collection In British Columbia: A Catalogue</u>", Ministry of Environment Manual 7, W. Shera, ed., 1984). Concentrations of cadmium, copper, iron, lead, and zinc were 5 to 10-fold higher than reported for Fraser River sediments at New Westminster (Stancil, 1980). In comparison to sediments collected at the Vancouver residential site (Swain, 1983), the industrial site's sediments are higher in aluminum, copper, lead, and mercury but not zinc or cadmium. PCB's were found on two occasions but no pesticides were detected in the Norland Avenue sediments.

3.3.4 **Discussion**

In all some 36 000 m^3 of wet weather and 1 900 m^3 of dry weather stormwater runoff was discharged during the year of study. Extrapolating this volume to the total estimated flow from industrial drainage areas entering the Fraser River indicates the runoff quantity would only be 60% of that estimated by Ferguson and Hall (1979). This may be due to the low Norland Avenue dry weather discharge rate.

A runoff coefficient of 0.31 was calculated from data for 20 storms sampled. This value differs markedly from the 0.70 coefficient stated by Ferguson and Hall (1979) as being typical of industrial areas. The low value found for Norland Avenue may be due to a significant proportion of the drainage area not being paved.

Many parameters including inorganic and organic carbon, total aluminum, potassium, sodium, ammonia, BOD_5, COD, orthophosphate, and filterable residue are higher in the dry weather discharge. However, the loadings of essentially all parameters are higher from the wet weather discharge due to the larger discharge volume.

Typically the dry weather discharge had higher concentrations of soluble species which became diluted with rain runoff. Concentrations of insoluble forms, especially metals, tended to increase during wet weather periods in association with suspended solids which generally exhibited a positive correlation with flow.

Hydrocarbons found in the wet weather discharges were characterized as diesel oil and diesel fuel as may be expected due to the predominance of trucking in the drainage basin.

Microtox and Daphnia toxicity was associated with some dry but not wet weather discharges.

Generally parameter concentrations except for silica were higher in the stormwater runoff than recently measured in the Fraser River (Lawson et al., 1983).

PCB's were detected in sediments collected from the flume following periods of high runoff. No pesticides were detected in the sediments but heavy metal concentrations were considerably higher than for Fraser River sediments.

Stormwater quality was observed to be affected by activities such as vehicle washing, truck traffic, and fuel pump spillage within the drainage basin. The amount of such activity depended in part on both the time of the day and the day of the week.

4.0 DISCUSSION

4.1 Parameter Concentrations In Stormwater Compared with Municipal Sewage Treatment Plant Effluent

A comparison of the Norland Avenue industrial stormwater concentrations compared to those from Ferguson and Hall (1979) showed BOD_5, total copper, fecal coliform, and total nitrogen concentrations to be similar, total iron, total manganese, total lead, total zinc, and total phosphorus concentrations to be underestimated, and total nickel and total coliform to be overestimated (Table 15). Concentrations of many parameters are higher at the Vancouver industrial site compared to the residential monitoring site. In comparison to municipal sewage treatment plants some of the Norland Avenue industrial stormwater contaminant concentrations are higher; notably suspended solids, total aluminum, total lead, and total zinc (except for Lulu STP) during wet weather.

4.2 Parameter Loadings in Stormwater Compared with Municipal Sewage Treatment Plant Effluent and the Fraser River

Extrapolation of loadings to all industrial areas entering the Fraser River showed that when compared to the Ferguson and Hall (1979) predicted loadings, Ferguson and Hall's predictions were considerably higher for BOD_5, total copper, total nickel, total nitrogen, and total phosphorus and lower for total iron, total manganese, total lead, and total zinc (Table 16).

Comparing daily loadings from stormwater (extrapolated data) to the three sewage treatment plants indicated higher loadings of BOD_5, COD, chromium, total phosphorus, and Kjeldahl nitrogen from the individual treatment plants. Industrial stormwater loadings contribute comparatively large quantities of total lead, total zinc, total aluminum, and suspended solids.

The extrapolated industrial stormwater loading represents only 0.065% of the suspended solids, 0.37% of the total copper, 0.84% of the total zinc, 0.15% of the Kjeldahl nitrogen, 0.001% of the total nitrogen, and 0.15% of the total phosphorus loading in the Fraser River (November 1981 to November 1982 Fraser River data; Lawson et al.,1983). The comparatively small stormwater loading is due to the considerably larger Fraser River discharge volume but, as found by Lawson et al.,(1983) stormwater can significantly impact the Fraser River as the maximum stormwater discharge often occurs when the Fraser River flow is minimal. As large numbers of stormwater discharges occur along the North Arm, which carries only 15% of the Fraser River's flow, regional impacts may occur.

Larger stormwater loadings may be expected during the first phase of a rain event with an inital flushing of contaminants from the drainage basin. Examination of several parameters sampled at Norland Avenue during the first hour of seven storms (Table 17) and extrapolating these data to include all industrial areas within the Fraser River Estuary Study Area indicated that the industrial stormwater loadings exceeded those from municipal sewage treatment plants for all parameters examined except total phosphorus and Kjeldahl nitrogen.

When a peaking factor of 3:1 is assumed, a value common for design of outfall pipes from combined sewer systems, loads from sewage treatment plants are then higher for BOD_5, COD, chromium, iron, phosphorus, and Kjeldahl nitrogen. It therefore appears that, at all times, stormwater from industrial catchments contributes more suspended solids, lead, aluminum, and zinc than from the 3 primary sewage treatment plants.

4.3 Sources of Loadings

Stormwater contaminants may be contributed from dustfall, rainfall, or runoff passing over the ground surface. By calculating loadings from precipitation and dustfall and comparing precipitation and dustfall ratios for several parameters, the relative contribution from each loading source can be assessed (Table 18). Dry deposition is the major contributor for all parameters although precipitation accounts for significant amounts of sodium and chloride. At the Vancouver residential monitoring site (Swain, 1983) chloride and sodium loading also resulted mainly from dry deposition but metals were mostly from precipitation.

In addition to the precipitation and dustfall sources stormwater contaminant loading may result from runoff mobilizing materials deposited within the drainage basin. Dry deposition cannisters may not detect all contributing contaminants as the cannisters are two metres above the ground and were sited only in one location. Materials may be discharged at a distance from the cannisters at a height so low as to make their collection unlikely. Comparing loadings from precipitation and dustfall (Table 19) to the residual picked up from materials deposited directly into the drainage basin indicates that 85 to 95% of sodium, chloride, copper, and zinc loadings originate from sources other than precipitation or dustfall. The only significant loadings from precipitation or dustfall are for lead (77%) and copper (14%) in dustfall. The lead likely originates from vehicle emissions. The great association of loadings with sources other than precipitation and dry deposition is likely due to the trucking activity (truck washing, fuel pump spillage, tire wear, parking lot runoff, transport of dirt and hydrocarbon into the drainage basin by vehicles, solids movement from unpaved to drained paved areas by vehicle traffic).

4.4 First Flush Effects

The magnitude and frequency of the initial or first flush of a contaminant from the drainage basin during a rainstorm was determined using the method proposed by

Griffin as reported in Helsel et al.(1979) and used by Swain (1983). The method relates incremental contaminant loading over a specified time interval to the total contaminant loading for the storm, and the incremental flow over the same time interval to the total flow for the storm. These relationships are expressed as a ratio of loading to flow for the same time interval. A flush of contaminant occurs when the ratio is greater than 1. The larger the ratio, the greater the flush.

Six storms were adequately sampled to permit determination of parameter first flush effects (Table 20). All nine parameters examined showed some initial flushing but only oil and grease, total organic carbon, biochemical oxygen demand, chemical oxygen demand, and total nitrogen consistently (at least 5 of 6 storms) showed first flush effects. The flushing effect lasted up to 1.5 hours.

The first flush magnitude may in part be determined by the number of antecedent dry days but the importance of this factor is not consistent or clear (Bedient et al., 1980). For example at the Norland Avenue site the amount of vehicle activity was observed to have a major influence on the runoff's load of suspended solids (and associated parameters) irrespective of the amount of current rainfall or previous dry days. Swain (1983) did not find a positive correlation between first flush and the number of antecedent dry days when this was statistically tested using data for their Vancouver residential stormwater study.

5.0 CONCLUSIONS

5.1 Rainfall

1 380 mm of precipitation fell at the monitoring location, approximately 13% less than expected. The mean pH of the rainfall was 5.63 indicating it is not acidic as this is the pH of rainwater in equilibrium with CO_2. Strong and total acidity was detected in association with rush hour traffic. In comparison to other sources, precipitation contributed very little contaminant loading for the parameters examined.

5.2 Dustfall

Dustfall chloride and sodium concentrations were detected through the most frequent storm period, from October to March, suggesting atmospheric washout of ocean spray picked up as the storms moved in from the Pacific. Significant amounts of lead, copper, and zinc were detected in their insoluble forms but no seasonal variations were noted. Dustfall particulates were mostly of an inorganic nature and exhibit a seasonal trend with low levels being detected during the rainy portion of the year. Dustfall loading is greater than that from precipitation for all of the contaminants examined, contributing to the total loading 77% of the lead and 14% of the copper. The lead loading likely originates from vehicle emissions (Laxen and Harrison, 1977).

5.3 **Stormwater Runoff**

37 900 m^3 of stormwater was discharged at the Norland Avenue monitoring site over the year's study period, 40% less than estimated by Ferguson and Hall (1979). Similarly a runoff coefficient of 0.31 calculated for the Norland Avenue site is considerably less than the 0.70 expected for an industrial drainage basin (Ferguson and Hall,1979).

Concentrations of several parameters including inorganic and organic carbon, total aluminum, potassium, sodium, ammonia, BOD_5, COD, orthophosphate, and filterable residue are higher in the dry weather discharge but contaminant loadings are higher in the wet weather discharge due to the larger discharge volume. Typically the dry weather discharge had higher concentrations of soluble forms which became diluted with rain runoff. Concentrations of insoluble forms especially metals tended to increase through periods of runoff in association with suspended solids which generally exhibited a positive correlation with flow. Generally the industrial stormwater metal concentrations detected are higher than estimated by Ferguson and Hall (1979) and higher than found by Swain (1983) for a Vancouver residential stormwater site. Only silica was found in the industrial stormwater at lower concentrations than observed for the Fraser River (Lawson _et al_., 1983). Loadings predicted by Ferguson and Hall (1979) were significantly higher for BOD_5, total copper, total nickel, total nitrogen, and total phosphorus and lower for total iron, total manganese, total lead, and total zinc.

Hydrocarbon analyses detected the presence of diesel oil and diesel fuel likely originating from truck maintenance facilities and fuel pumps. No toxicity was associated with the rain runoff but some toxicity to microtox and Daphnia was associated with the dry weather discharge. Some industrial stormwater toxicity using the Daphnia assay has been detected by Anderson (1982) but he could not correlate specific variables to the observed toxicity. Sediment analyses showed the presence of PCB's but not pesticides. The sediment particle size range indicates medium to coarse sand which has less tendency than silt/clay to bind metals. Despite this the sediment metal concentrations found are considerably higher than in Fraser River sediments collected at New Westminster.

Stormwater can potentially create localized transient concentration increases in the Fraser River. First flush effects, whereby high concentrations occur early in the storm, were observed for several parameters. Consequent loadings for the initial portion of a storm are also often high. A worst case, as observed on one occasion for the Still Creek-Brunette River system, was an extreme runoff period coupled with a high tide on the Fraser River which backed up the discharge until the tide ebbed. Although the impact on Fraser River water quality of such discharges has been observed during low river flows (Lawson _et_ _al_., 1983) the contribution of parameters to the total loading is quite small (i.e. less than 1%).

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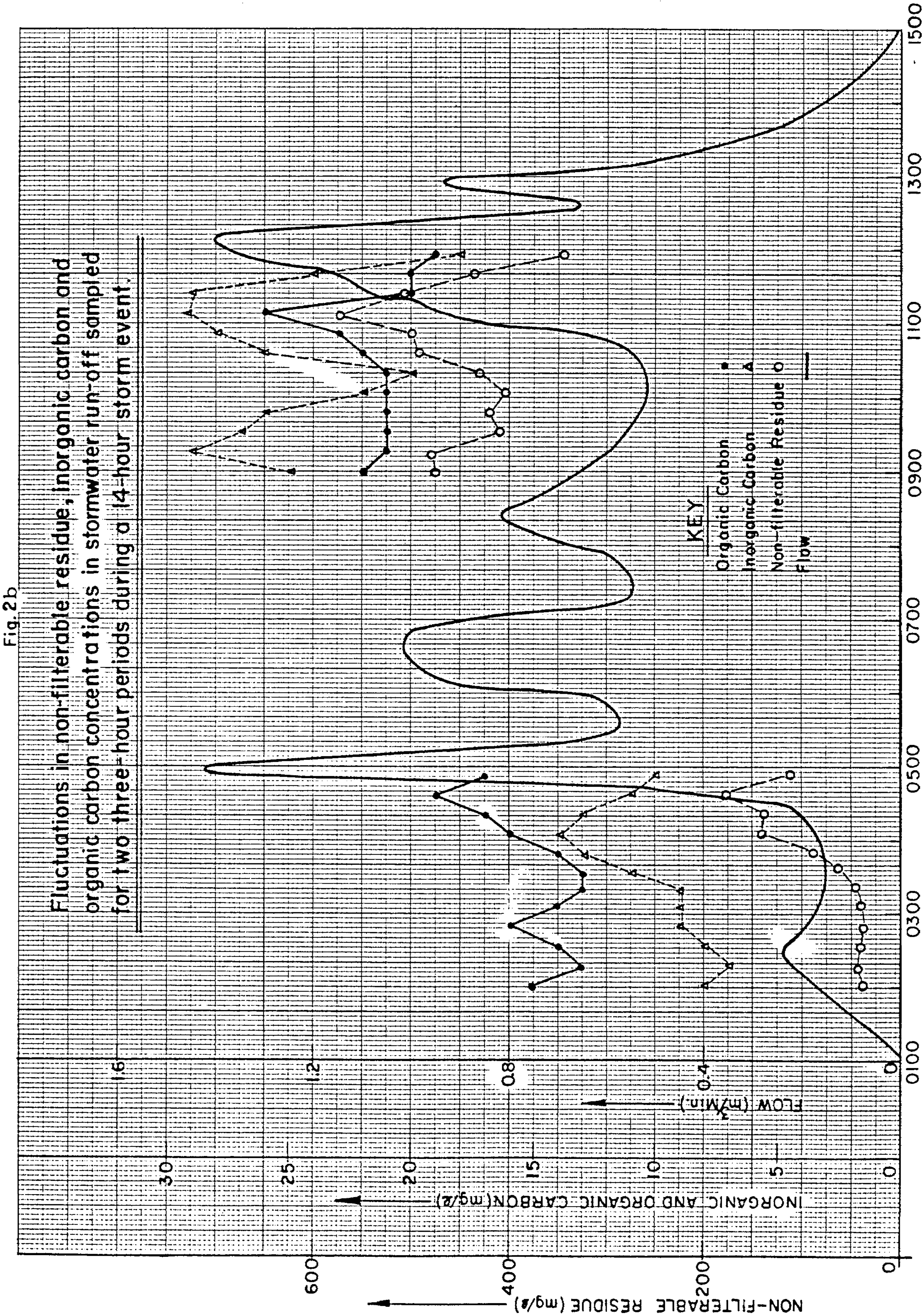
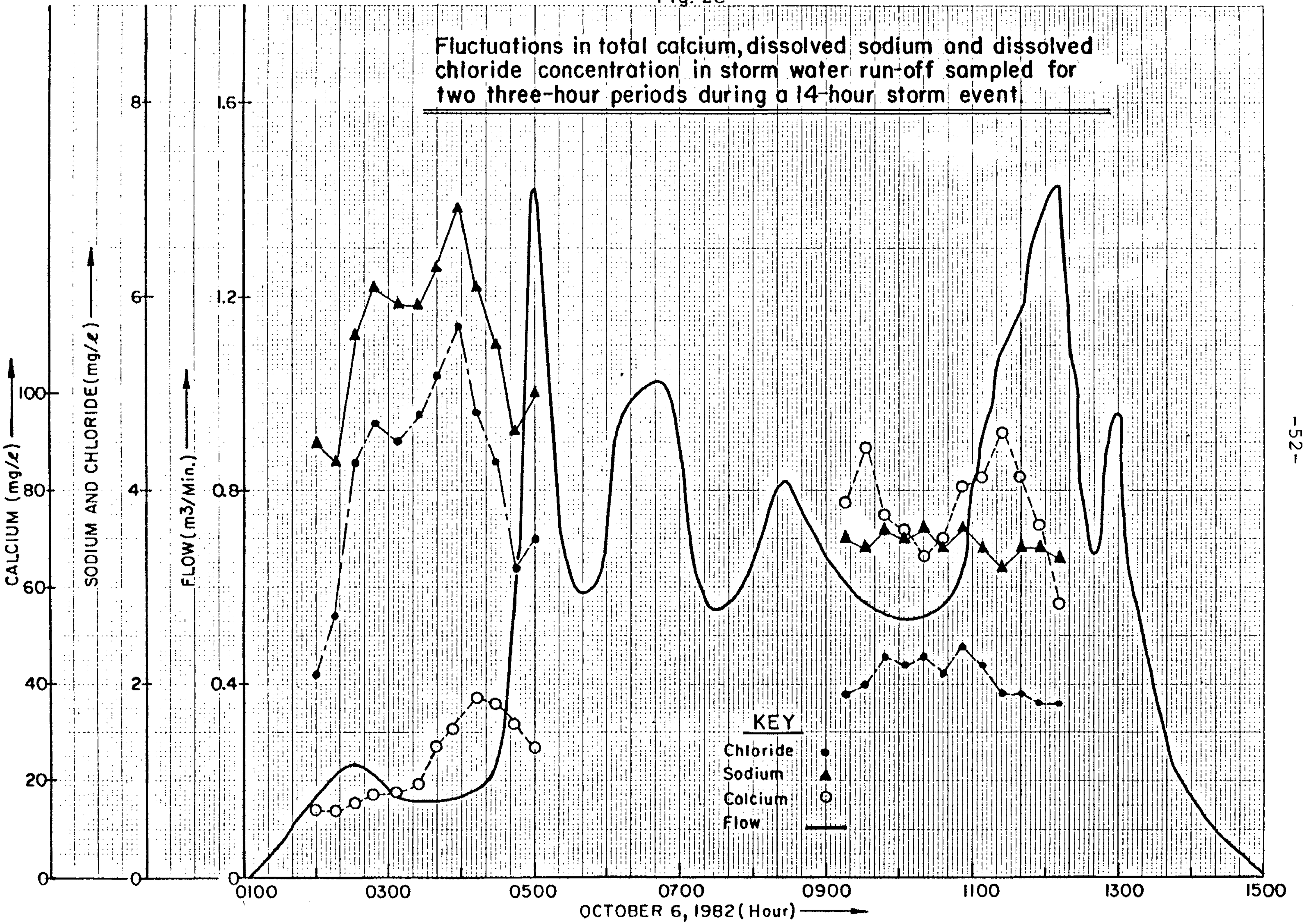


Fig. 2b

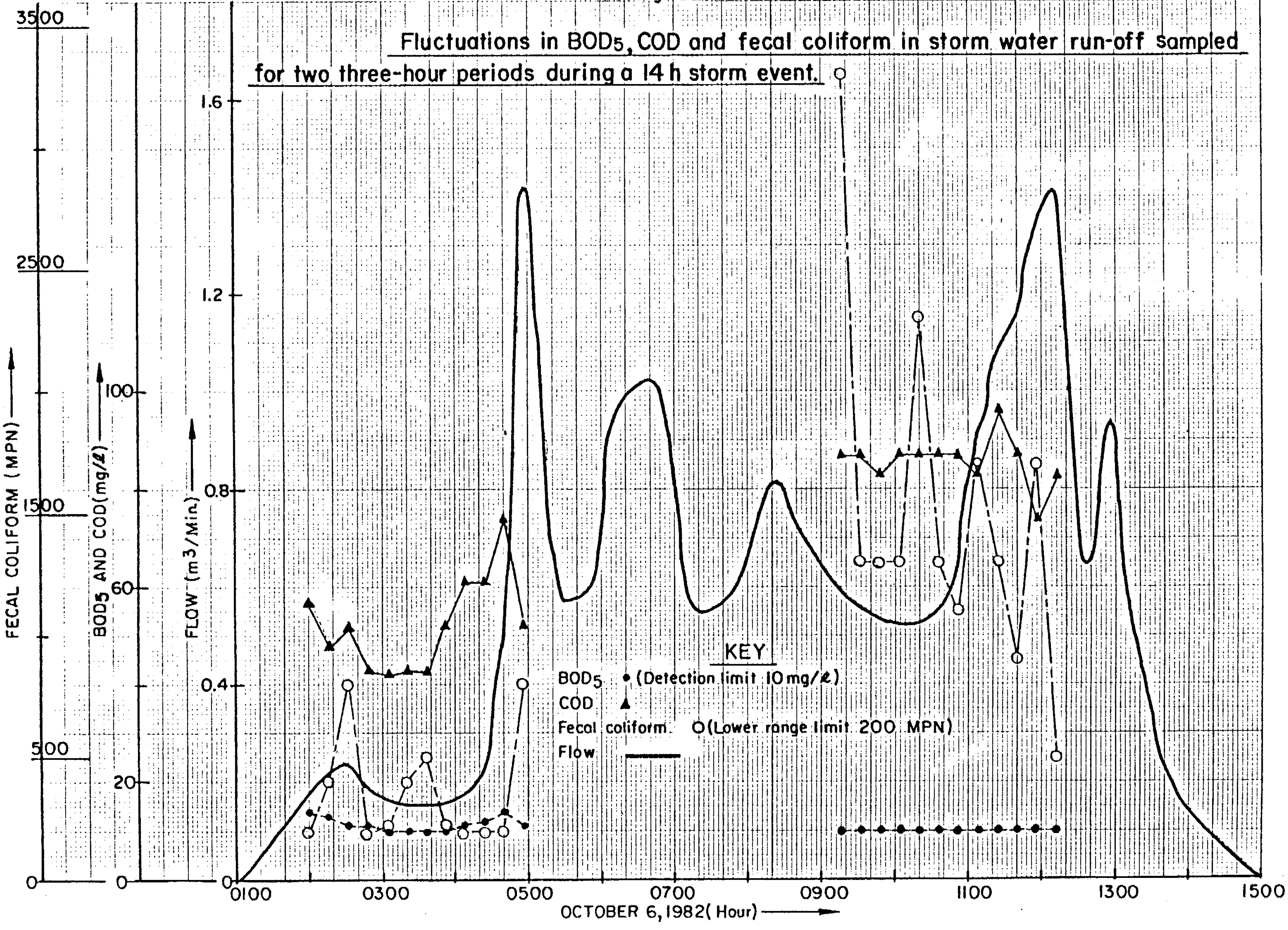
Fluctuations in non-filterable residue, inorganic carbon and organic carbon concentrations in stormwater run-off sampled for two three-hour periods during a 14-hour storm event.

Fig. 2c



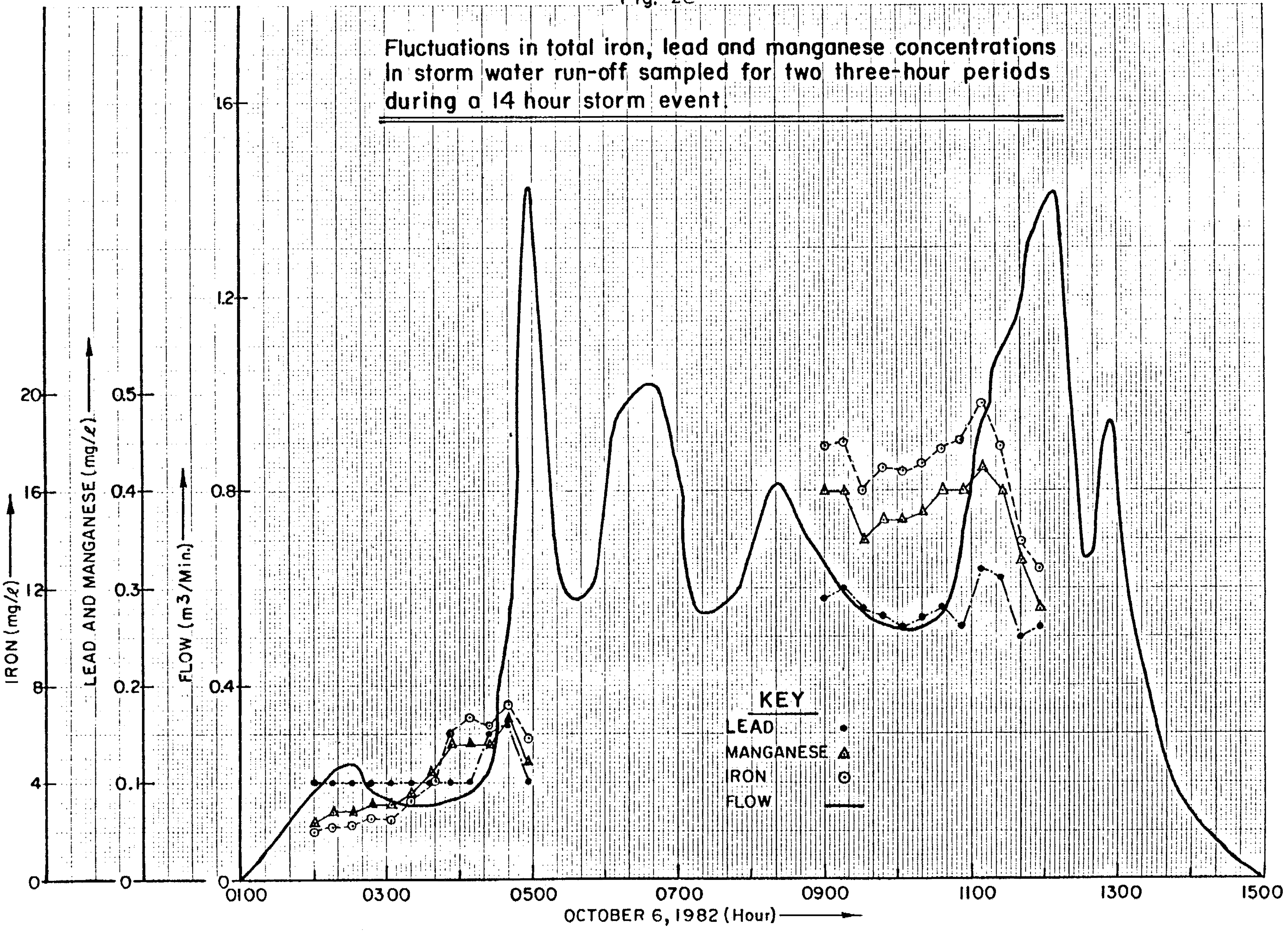
Fluctuations in total calcium, dissolved sodium and dissolved chloride concentration in storm water run-off sampled for two three-hour periods during a 14-hour storm event

Fig. 2d



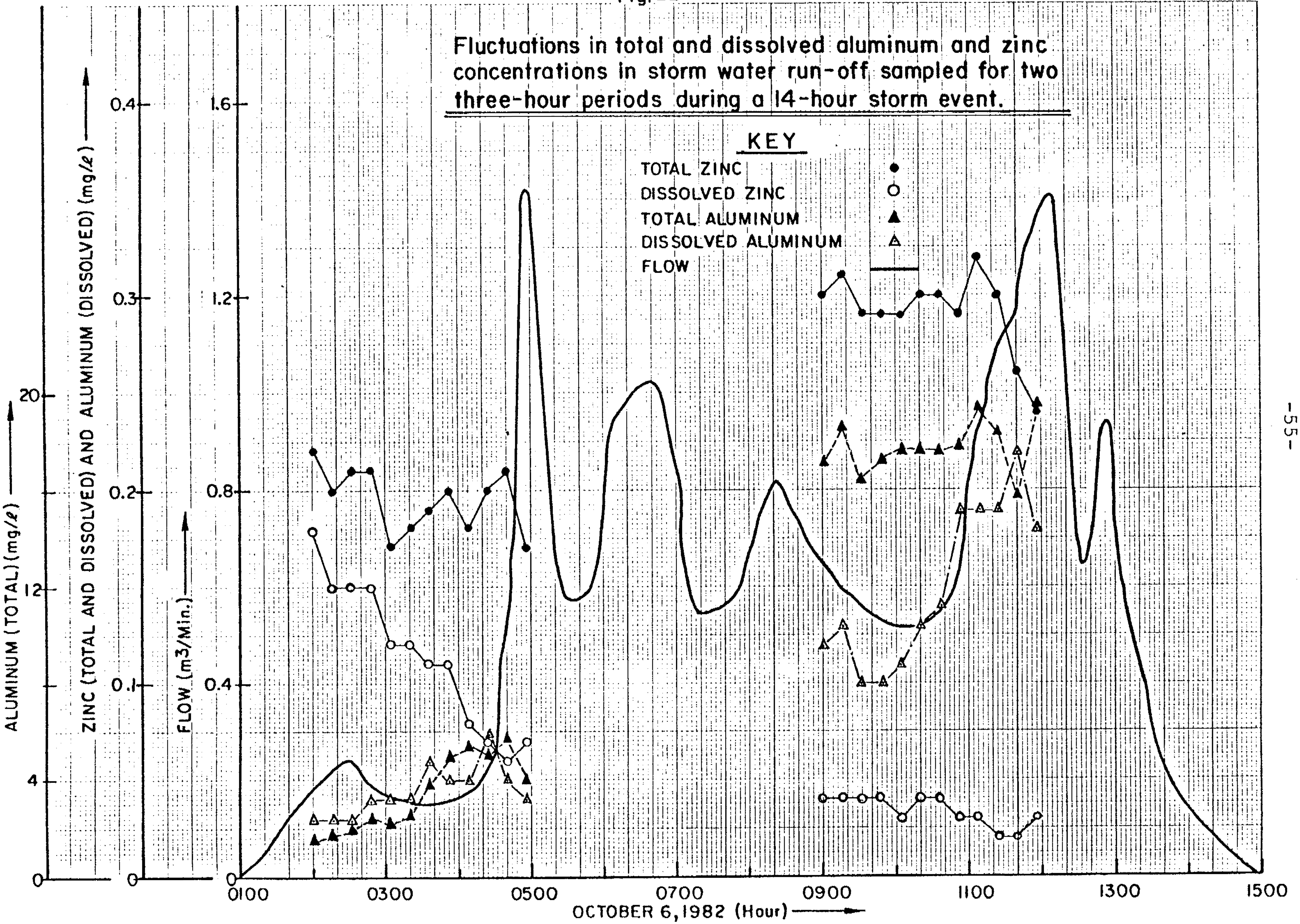
Fluctuations in BOD5, COD and fecal coliform in storm water run-off sampled for two three-hour periods during a 14 h storm event.

Fig. 2e



Fluctuations in total iron, lead and manganese concentrations In storm water run-off sampled for two three-hour periods during a 14 hour storm event.

Fig. 2f



Fluctuations in total and dissolved aluminum and zinc concentrations in storm water run-off sampled for two three-hour periods during a 14-hour storm event.

TABLE 1 Daily Rainfall Record, May 1982 to May 1983

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT
STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: MAY 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																							HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX NET mm FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	10m	30m	45m	60m	2h	
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17	.06	.03	.06	.01			.01		.01																6	.18								
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28																																		
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30																																		
31																																		
TOTAL FOR MONTH																									33	.59								
TOTAL FOR YEAR TO END OF																																		

NOTE: WHERE A 'STORM TOTAL' IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (....) FOR A DURATION OF HOURS (H) THUS 1.75/7H

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES

A/B × C = INTENSITY IN/HOUR

RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT
STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: JUNE 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																							HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX NET mm FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	10m	30m	45m	60m	2h	
1																																		
2						.05	.02	.01	.03	.01															5	.12								
3																																		
4																																		
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26				.01	.02	.01		.02	.05	.04	.04	.05	.07	.03	.09	.01	.04	.01							14	.50		[illegible]	[illegible]	[illegible]	[illegible]			SHORT PERIOD INTENSITY [illegible]
27											.01														1	.01								
28																																		
29																																		
30						.01																			1	.01								
31																																		
TOTAL FOR MONTH																									26	.80								
TOTAL FOR YEAR TO END OF																																		

NOTE: WHERE A 'STORM TOTAL' IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (....) FOR A DURATION OF HOURS (H) THUS 1.75/7H

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES

A/B × C = INTENSITY IN/HOUR

RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

TABLE 1 Daily Rainfall Record, May 1982 to May 1983 (Continued)

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT
STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: JULY 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT in/hr FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																																		
2		.04	.04	.04	.06	.01		.01	.02											.01					8	.23								
3		.01	.04	.28	.16	.18	.09	.09	.05	.04	.06	.03	.04	.13	.04	.05	.07	.02	.01		.02	.04	.02	.02	22	1.33		.72 0310	.56 0320	.44 0326	.36 0341	.28 0356	.21 0400	
4	.06	.03	.01									End of Tape													3	.10								
5								.01	.01			← [illegible]													3	.03								
6																																		
7																																		
8																																		
9																																		
10																																		
11																																		
12																																		
13												.01				.02	.06	.05		.01					5	.15								
14									.07												.04		.04	.06	4	.21								PEN NOT STEPPING PROPERLY
15	.07	.12	.06	.08	.05	.02	.01		.01	.01		.01		.02	.02	.02				.01					14	.51								
16																																		
17																																		
18																																		
19																																		
20	.01	.01	.01	.01		.01		.01						.01											7	.07								
21																.02	.03								2	.05								
22					.01																				1	.01								
23																																		
24																																		
25																																		
26																																		BETWEEN JULY 26 1125 HRS AND
27																																		AUG. 9 1127 HRS. PEN NOT
28																																		STEPPING PROPERLY
29																																		
30																																		
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (....) FOR A DURATION OF HOURS, (X) THUS 1.75/3hrs

TOTAL FOR MONTH 69 2.69
TOTAL FOR YEAR TO END OF

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT
STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: AUGUST 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT in/hr FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																				.01			.01	.01		.03								BETWEEN JULY 26 1125 HRS. AND
2	.01							.01																		.02								AUG. 9 1127 HRS. PEN NOT
3																																		STEPPING PROPERLY
4																																		
5																																		
6																																		
7																																		
8																																		
9																.01	.01	.03	.01							.06								
10												.02	.01	.02	.01											.06								
11																																		
12															.03	.06	.10	.04	.06	.08	.05	.06	.02	.03		.53								
13	.03																				.02					.05								
14				.03	.01																					.04								
15																																		
16																																		
17																																		
18																																		
19																																		
20																																		
21																																		
22																																		
23																																		
24																																		
25																																		
26																																		
27																																		
28																																		
29																																		
30	.12	.12	.27	.42		.03	.11	.01												.01	.01	.03	.01			1.34		2.40 0255	2.80 0306	1.44 0316	1.07 0327	.82 [illegible]	.46 [illegible]	
31		.01																								.01								

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (....) FOR A DURATION OF HOURS, (X) THUS 1.75/3hrs

TOTAL FOR MONTH 2.14
TOTAL FOR YEAR TO END OF

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

TABLE 1 Daily Rainfall Record, May 1982 to May 1983 (Continued)

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: SEPTEMBER 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT IN/HR FOR PERIODS OF 5m to 2HRS						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																																		
2																																		
3																.04	.07	.20	.09			.01	.19	.49*	7	1.09		1.16 / (2340)	.81 / (2348)	.64 / (2353)	.56 / (0002)	.44 / (2400)	.35 / (0005)	* INTENSITY INCLUDED PART OF FIRST
4	.08	.03			.01		.01	.19	.14	.01	.01														8	.48		.36 / [illegible]	.32 / [illegible]	.26 / [illegible]	.24 / [illegible]	.20 / [illegible]	.17 / [illegible]	HOUR ON SEPT 4
5																																		
6																				.01					1	.01								
7	.01						.01					.01													3	.01								
8																					.04	.04	.01		3	.09								
9	.07	.15	.02																						3	.24		.36 / (0200)	.24 / (0205)	.20 / (0205)	.16 / (0210)	.12 / [illegible]	.11 / [illegible]	
10	.03	.09	.07	.12	.13	.12	.06	.04	.02	.01															10	.69								
11																																		
12																																		
13																																		
14																																		
15																																		
16																																		
17																																		
18																																		
19																																		
20																.01									1	.01								
21																																		
22																																		
23																																		
24										.01	.01	.03	.01	.01				.02				.02			7	.11								
25			.03			.01																			2	.04								
26																																		
27																																		
28														.08		.07									2	.15		.40 / (1342)	.28 / (1355)					SHORT PERIOD INTENSITY 15 MIN. SHOWN
29																																		
30																																		
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS [.....] FOR A DURATION OF HOURS (H) THUS 2.78/5H

TOTAL FOR MONTH 47 | 2.92
TOTAL FOR YEAR TO END OF

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: OCTOBER 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT IN/HR FOR PERIODS OF 5m to 2HRS						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																	.01		.06	.01	.01				4	.09								
2	.01		.09	.18	.22	.02	.02																		6	.54		.48 / (0405)	.36 / (0410)	.38 / (0410)	.27 / (0410)	.26 / (0440)	.22 / (0445)	
3											End of Tape																							
4												←																						
5																							.02		1	.02								
6	.02	.05	.03	.06	.07	.11	.11	.09	.08	.07	.10	.12	.08	.01						.01					15	1.01								
7	.01	.03								.01	.02														4	.07								
8										.01															1	.01								
9																																		
10																																		
11																																		
12										.01															1	.01								
13																																		
14																																		
15																																		
16								.01	.02	.03	.07	.13	.20	.06	.08							.01	.19	.01	11	.56		.72 / (1253)	.44 / (1300)	.28 / (1304)	.26 / (1300)	.21 / (1310)	.14 / (1333)	
17	.01				.01																				2	.01								
18					.01																				1	.01								
19																																		
20																		.01	.02	.01	.01	.01	.01		6	.07								
21	.02	.01								.02	.03	.03	.04				.02		.06	.09	.07	.08	.06	.03	13	.68								
22	.01	.03			.05	.01	.01	.03	.03			.01		.02								.01			10	.21								
23																					.01	.03	.02	.01	4	.07								
24					.01		.01	.04	.04	.09	.03	.03	.07	.06	.01	.06	.03								12	.44								
25													.02	.05	.01							.06	.06	.03	6	.22								
26	.05									.01	.01	.04	.10	.06	.01					.01					7	.29								
27								.01	.01		.01	.01	.02	.03	.05	.04	.09	.05	.05	.04	.03	.09	.09	.09	16	.69								
28	.07	.03	.09	.04	.01	.01	.01	.01	.01	.02	.02	.01													12	.35								
29																																		
30																							.01	.01	2	.02								
31	.02*		.01	.01	.07	.01		.01	.07	.10	.03	.01			.03	.01									12	.38								* PACIFIC STANDARD TIME

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS [.....] FOR A DURATION OF HOURS (H) THUS 2.78/5H

TOTAL FOR MONTH 146 | 5.63
TOTAL FOR YEAR TO END OF

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

TABLE 1 Daily Rainfall Record, May 1982 to May 1983 (Continued)

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC STANDARD

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: NOVEMBER 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT IN/HR FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																																		
2																																		
3																																		
4				.01	.01		.01	.01	.05	.16	.08	.20	.04	.10	.01		.01					.08	.02	.01	18	.88		.34 / 1125	.32 / 1125	.26 / 1130	.24 / 1144	.19 / 1200	.16 / 1140	
5												.03			.01	.03	.05	.06	.06	.07	.05	.13	.07		10	.56								
6	.04	.07																			.01	.01			4	.13								
7	.03	.02										.03							.01	.01		.01		.01	7	.12								
8																																		
9																																		
10																																		
11																																		
12									.02	.03	.09	.08	.01												5	.23								
13																																		
14																																		
15												.03	.04	.06	.04	.05	.06	.03	.07	.09	.06	.10	.09	.10	13	.81								
16	.07	.09	.11	.10	.04	.01	.01	.04	.06	.09	.07	.08	.09	.11	.08	.12	.06	.08	.02	.01			.01		21	1.35								
17	.02	.01		.01	.02	.05	.02	.01	.01	.02						.01									10	.16								
18																			.01	.04	.03	.01	.03	.02	6	.14								
19			.02	.01	.01			.05	.03	.05	.02														7	.19								
20											.04	.01			.02	.02									4	.09								
21																																		
22																																		
23																																		
24																																		
25																																		
26			.01	.02	.03	.04	.04	.04	.02	.04	.01				.04	.01	.01	.02	.03	.05	.05	.01	.01	.02	19	.50								
27	.01	.01	.01	.03	.01	.02	.07	.08	.02	.01	.05	.08	.03			.12	.14	.11	.03	.06	.06	.05	.07	.02	22	1.04		.24 / 1545	.24 / 1552	.22 / 1607	.21 / 1622	.20 / 1237	.16 / 1737	
28	.03	.02	.04	.04		.01		.01	.02	.07	.08	.10	.15	.22	.13	.13		.03	.02		.07	.01		.01	19	1.16		.24 / 1320	.24 / 1330	.24 / 1344	.23 / 1400	.23 / 1401	.19 / 1406	
29	.02	.05	.07	.06	.04		.01	.02		.01										.01	.05	.07	.01	.01	13	.43								
30		.03	.03	.01	.01	.04	.02	.06	.13	.06	.02								.02	.01	.06	.09	.05	.01	16	.66								
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS {....} FOR A DURATION OF HOURS, (H) THUS 1.70/3hs

TOTAL FOR MONTH 191 8.45
TOTAL FOR YEAR TO END OF

A: FALL IN INCHES
B: NUMBER OF MINS
C: 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC STANDARD

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: DECEMBER 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT IN/HR FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1	.01	.02	.03	.05	.01	.01			.01	.01							.01	.07	.01						11	.24								
2								.02	.04	.07	.06	.03	.02	.02		.01		.01	.03	.07	.15	.11	.13	.16	15	.93		.24 / [illegible]	.20 / 2237	.18 / 2121	.16 / 2347	.15 / 2347	.14 / [illegible]	
3	.15	.13	.13	.20	.22	.31	.14	.06	.04	.02	.01	.01													12	1.52		.36 / 0415	.34 / 0447	.34 / [illegible]	.33 / 0917	.33 / 0932	.32 / [illegible]	
4										.01															1	.01								
5																																		
6																																		
7																																		
8																																		
9																																		
10																																		
11																					.02	.06	.06	.03	4	.16								
12	.02	.05	.03	.05	.04	.08	.10	.11	.07	.07	.02	.01	.01		.02	.01								.01	16	.70								
13																.05	.08	.08	.01						4	.22								
14	.01	.03	.01									.01	.01	.04	.01	.01	.01	.02	.04	.03	.09			.01	14	.33								
15		.01				.04	.02			.03	.02	.02						.03	.07	.04	.04	.04	.06	.21	13	.60		.64 / 1320	[illegible] / 2130	.36 / 1330	.32 / 2334	.23 / 2341	.16 / 2300	
16				.03	.03																	.03	.10	.01	5	.20								
17							.01		.02	.07	.02			.01	.02	.03						.05		.03	9	.26								
18	.01	.02	.01		.02	.02	.01				.01	.03	.02	.08				.01	.01					.01	13	.26								
19	.03																								1	.03								
20													.01	.01	.01	.02	.01	.01	.01						7	.08								
21			.01	.02	.05	.07															.01	.02	.01	.05	8	.24								
22	.05	.14	.21																						3	.40		.43 / 0153	.36 / 0204	.36 / 0219	.34 / 0236	.33 / 0244	.32 / [illegible]	
23																																		
24					.01																				1	.01								
25								.01	.01	.05	.04	.05	.03	.04	.06	.03	.02	.03	.02						12	.39								
26																																		
27																																		
28																																		
29																																		
30																																		
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS { } FOR A DURATION OF HOURS (H) THUS 1.70/3hs

TOTAL FOR MONTH 149 6.58
TOTAL FOR YEAR TO END OF

A: FALL IN INCHES
B: NUMBER OF MINS
C: 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT

TABLE 1 Daily Rainfall Record, May 1982 to May 1983 (Continued)

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC STANDARD

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: JANUARY 1983

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT IN/HR FOR PERIODS OF 5m TO 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																																		PEN NOT STEPPING
2																																		
3																																		
4											End of Time →|							.01		.01	.03	.03	.04	.07	6	.19								FROM JAN 4 1100 HRS TO JAN 31 2400 HRS
5	.09	.07	.06	.06	.09	.05	.02	.03																	8	.50								PEN NOT STEPPING PROPERLY. HOURLY
6												.04	.02		End of Time →|					.01	.01			4	.08								RAINFALL MAY BE OUT BY A MAXIMUM
7						.05	.06	.03	.13	.11	.10	.02	.16	.04	.03	.06	.12	.12	.04	.06	.03	.02	.02	.01	19	1.16								OF ±0.03 IN
8	.02				.01						.02														3	.05								
9			.01	.01				.01	.09	.15	.12	.10	.02	.01		.05	.15	.06	.07	.10	.10	.10	.10	.06	18	1.36		.84 / 0923	.30 / 1134	.20 / 1041	.17 / 0956	.13 / 1000	.12 / 1100	
10	.06	.05	.05	.10	.07	.08	.06	.04			.01									.01					10	.50								
11																.02	.02	.04	.02	.01	.01	.03	.05	.02	9	.22								
12	.01	.03	.03	.02	.01																				5	.10								
13																																		
14																																		
15																																		
16																								.02	1	.02								
17	.03	.01			.01	.02	.01	.02	.01	.01											.01	.01	.01	.01	12	.18								
18	.02	.01			.01	.01	.01	.01		.02	.01	.04	.03	.01										.02	12	.20								
19	.01	.01			.03	.09	.09	.04	.01	.01	.01	.03	.01	.01	.01		.01						.06		15	.43								
20					.01																				1	.01								
21					.01																				1	.01								
22																																		
23	.01	.01	.01	.01	.01		.01		.01		.03	.01			.01		.01								11	.13								
24		.01	.03			.02	.08	.12								.07	.02	.06		.01					9	.42								
25																.03	.04	.03	.01			.01	.01	.05	7	.18								
26	.03	.01										.05	.06	.05	.02		.01								7	.21								
27		.02					.01																		2	.03								
28																																		
29																							.03	.04	2	.07								
30			.04	.03	.04	.07	.09	.07	.05	.02															8	.43								
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (.....) FOR A DURATION OF HOURS (H) THUS ↑ H/hr

	HOURS OF RAIN	DAILY TOTAL
TOTAL FOR MONTH	170	6.50
TOTAL FOR YEAR TO END OF		

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES

A/B × C = INTENSITY IN/HOUR

RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC STANDARD

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: LAT: LONG:
MONTH OF: FEBRUARY 1983

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT IN/HR FOR PERIODS OF 5m TO 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																																		
2																																		
3																																		
4																																		
5																																		
6								.03	.07	.01				.06			.03	.04	.04	.01			.01		9	.29								
7												End of Time →|																						
8																	.02	.02	.05	.02	.01				5	.12								FROM FEB 8 1400 HRS TO FEB 10 2400 HRS
9	.02	.02		.03	.04	.07	.04	.01	.05	.11	.13	.11	.09	.02										.01	14	.71								PEN NOT STEPPING PROPERLY. HOURLY
10	.01							.01		.01		.01						.06	.05	.04	.04	.02	.05	.13	11	.50								RAINFALL MAY BE OUT BY A MAXIMUM
11	.11	.10	.10	.07	.04	.10	.10	.05	.03	.06		.02	.01				.01	.01	.01	.02	.01	.02	.06	.08	20	1.01		.84 / [illegible]	.20 / [illegible]	.18 / [illegible]	.17 / [illegible]	.13 / [illegible]	.11 / [illegible]	OF ±0.03 IN
12	.03	.04	.09	.12	.06	.05	.12	.07	.14	.05	.11	.10	.02		.02	.06	.01	.06		.01		.03	.02	.05	21	1.13		.84 / [illegible]	.20 / [illegible]	.16 / [illegible]	.12 / [illegible]	.10 / [illegible]	.11 / [illegible]	
13							.01			.06	.10														3	.10								
14			.01					.01				.01	.01	.04	.05	.08	.09	.06		.01	.03		.06		9	.46								
15		.01																.01	.05	.07	.09	.08	.06	.04	8	.43								
16						.01	.03					.04							.01		.01	.03	.05	.06	8	.24								
17	.07	.10	.06	.04	.02	.05	.10	.07	.06	.03		.01	.01	.01	.03	.02	.01	.02	.02		.01	.14			20	.88		.36 / [illegible]	.28 / [illegible]	.22 / [illegible]	.21 / [illegible]	.16 / [illegible]	.07 / [illegible]	
18																																		
19			.01							.01	.04	.10	.13	.14	.13	.10	.11	.15	.12	.11	.10	.14	.10	.04	16	1.53		.44 / [illegible]	.40 / [illegible]	.16 / [illegible]	.15 / [illegible]	.14 / [illegible]	.13 / [illegible]	
20	.04	.05	.06	.05	.08	.12	.10	.09	.01																9	.60								
21																				.06	.05	.01	.02	.05	5	.19								
22	.05	.02	.01		.01	.01	.01	.08			.01										.03	.04	.05	.03	12	.39								
23			.01	.04	.04	.06	.03	.02	.04		.02			.01					.02					.02	11	.31								
24	.02	.02	.01	.01	.01	.01	.01	.02		.01									.01						10	.13								
25																						.05	.06	.04	3	.15								
26			.01							.01										.02	.07	.02	.01		6	.14								
27							.01																		1	.01								
28																																		
29																																		
30																																		
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS ( ) FOR A DURATION OF HOURS (H) THUS ↑ H/hr

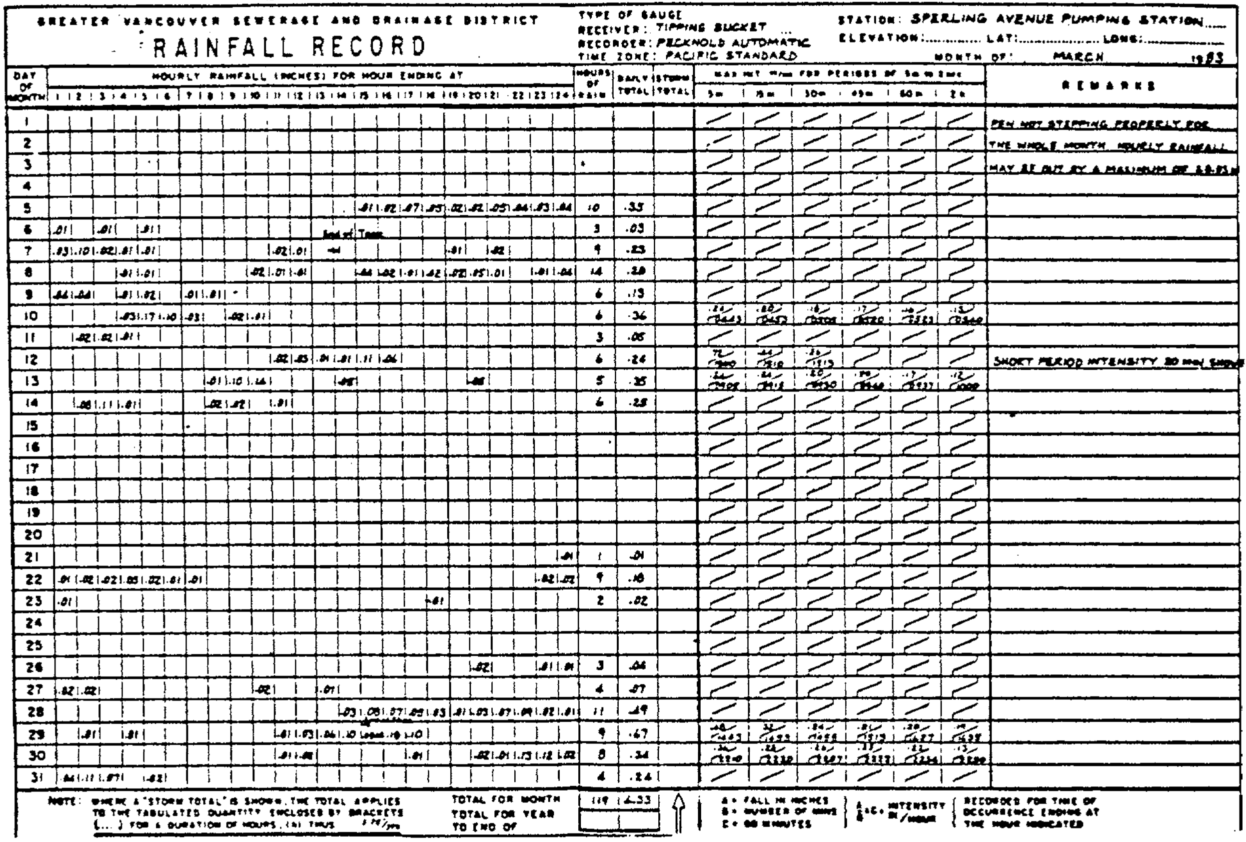
	HOURS OF RAIN	DAILY TOTAL
TOTAL FOR MONTH	201	9.32
TOTAL FOR YEAR TO END OF		

A = FALL IN INCHES
B = NUMBER OF MINS

A/B × C = INTENSITY IN/HOUR

RECORDED FOR TIME OF OCCURRENCE ENDING AT

TABLE 1 Daily Rainfall Record, May 1982 to May 1983 (Continued)



GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC STANDARD

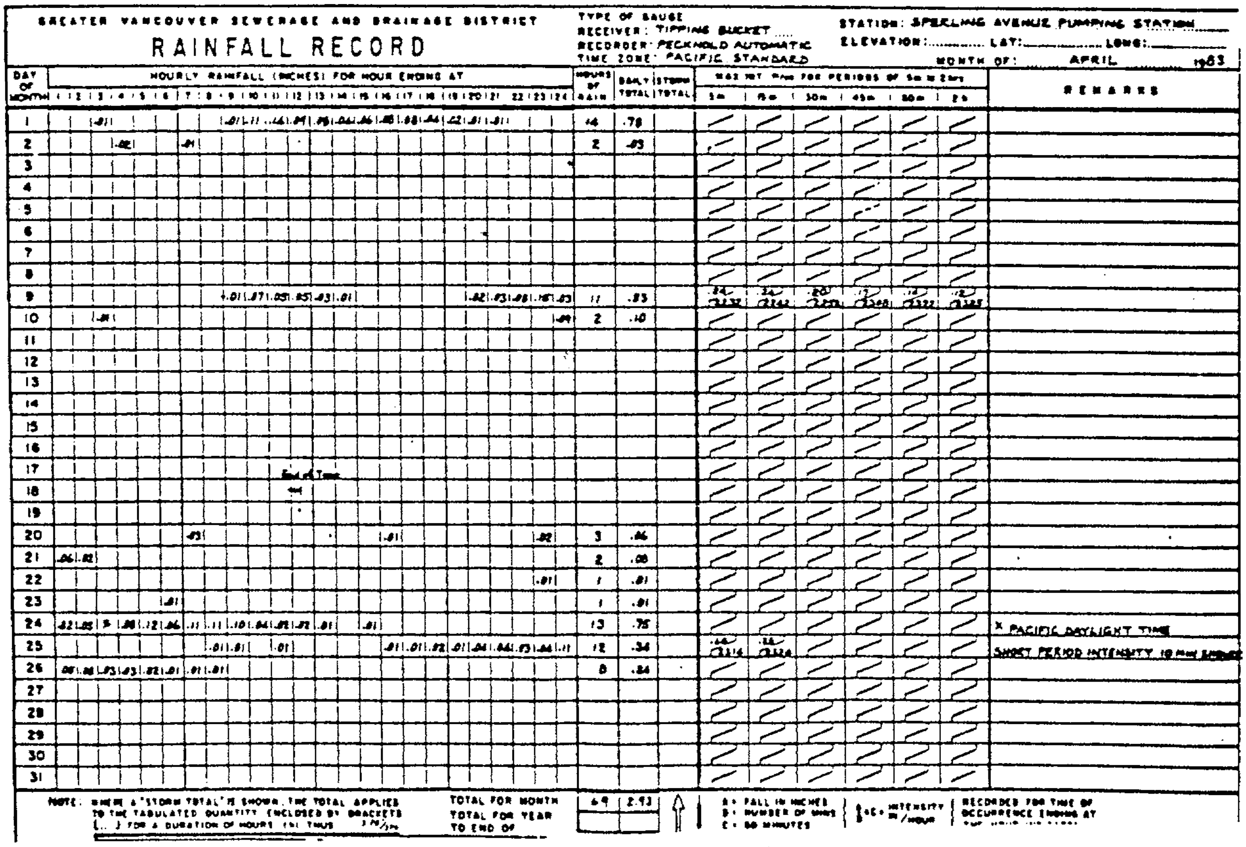
STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: .... LAT: .... LONG: ....
MONTH OF: MARCH 1983

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT in/hr FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1																																		PEN NOT STEPPING PROPERLY FOR
2																																		THE WHOLE MONTH. HOURLY RAINFALL
3																																		MAY BE OUT BY A MAXIMUM OF ±0.03 in
4																																		
5															.01	.02	.07	.05	.02	.02	.05	.04	.03	.04	10	.35								
6	.01		.01		.01								End of Tape												3	.03								
7	.03	.10	.02	.01	.01					.02	.01		←						.01		.02				9	.23								
8				.01	.01					.02	.01	.01			.04	.02	.01	.02	.02	.05	.01		.01	.04	14	.28								
9	.04	.04		.01	.02		.01	.01																	6	.13								
10				.03	.17	.10	.03		.02	.01															6	.36		.24/0443	.20/0452	.18/0508	.17/0520	.16/0551	.13/0540	
11		.02	.02	.01																					3	.05								
12											.02	.03	.01	.01	.11	.06									6	.24		.72/1500	.44/1510	.26/1515				SHORT PERIOD INTENSITY 20 min SHOWN
13								.01	.10	.14				.05						.05					5	.35		.24/0908	.24/0915	.20/0930	.19/0940	.17/0937	.12/1000	
14		.08	.11	.01				.02	.02		.01														6	.25								
15																																		
16																																		
17																																		
18																																		
19																																		
20																																		
21																								.01	1	.01								
22	.01	.02	.02	.05	.02	.01	.01																.02	.02	9	.18								
23	.01																	.01							2	.02								
24																																		
25																																		
26																				.02			.01	.01	3	.04								
27	.02	.02								.02			.01												4	.07								
28														.03	.08	.07	.05	.03	.01	.03	.07	.09	.02	.01	11	.49								
29		.01		.01							.01	.03	.06	.10	[illegible]	.19	.10								9	.67		.48/1443	.32/1453	.24/1458	.21/1515	.20/1527	.19/1535	
30											.01	.02					.01			.02	.01	.13	.12	.02	8	.34		.34/2210	.24/2212	.26/2207	.22/2222	.22/2234	.13/2300	
31	.04	.11	.07		.02																				4	.24								

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (...) FOR A DURATION OF HOURS, (N) THUS ?/hrs

TOTAL FOR MONTH: 119 | 4.33
TOTAL FOR YEAR TO END OF:

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED



GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC STANDARD

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: .... LAT: .... LONG: ....
MONTH OF: APRIL 1983

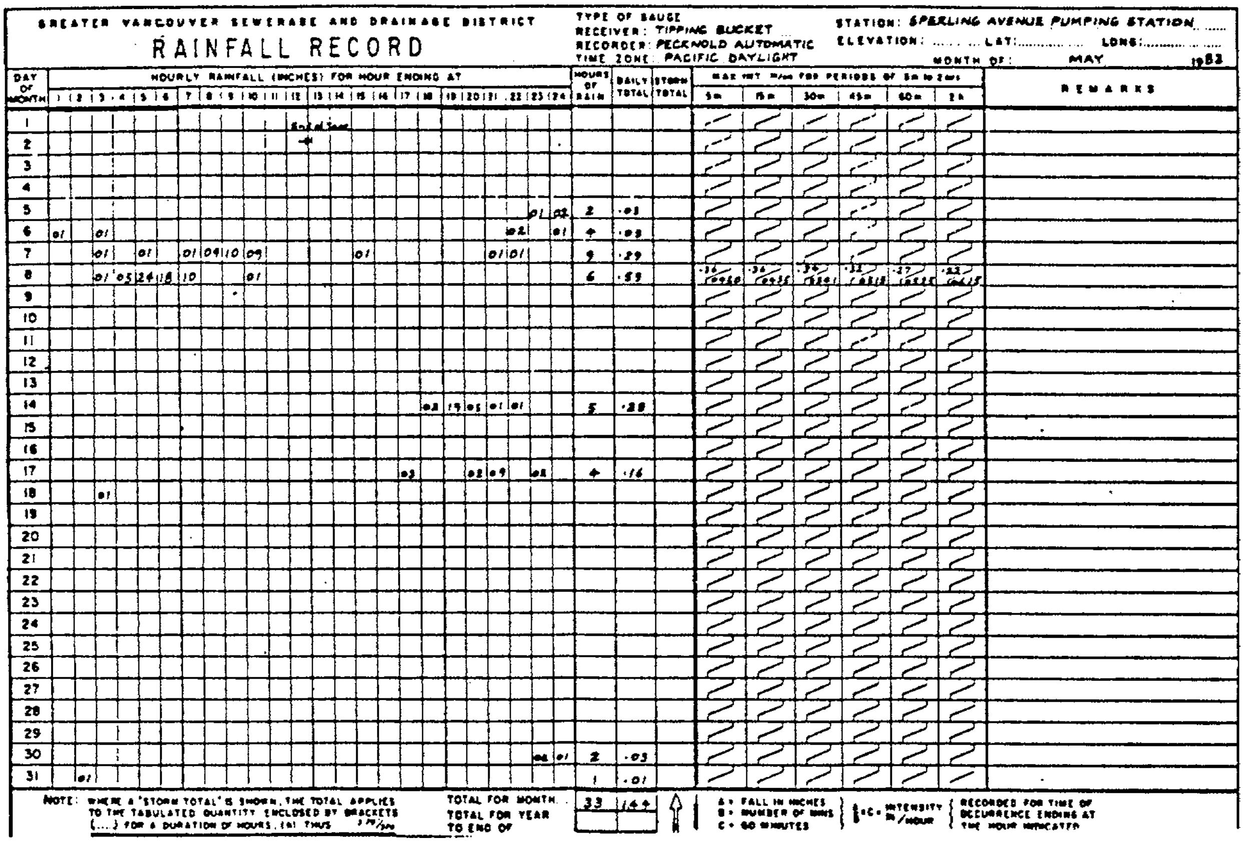
DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT in/hr FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1			.01						.01	.11	.14	.09	.05	.04	.06	.05	.08	.04	.02	.01	.01				14	.78								
2				.02			.01																		2	.03								
3																																		
4																																		
5																																		
6																																		
7																																		
8																																		
9									.01	.07	.05	.05	.03	.01						.02	.03	.08	.15	.03	11	.53		.24/2132	.24/2142	.20/2203	.17/2300	.14/2322	.12/2325	
10			.01																					.09	2	.10								
11																																		
12																																		
13																																		
14																																		
15																																		
16																																		
17											End of Tape																							
18											←																							
19																																		
20							.03									.01							.02		3	.06								
21	.06	.02																							2	.08								
22																							.01		1	.01								
23						.01																			1	.01								
24	.02	.05	*	.08	.12	.06	.11	.11	.10	.04	.05	.05	.01		.01										13	.75								* PACIFIC DAYLIGHT TIME
25								.01	.01		.01					.01	.01	.02	.01	.04	.04	.03	.04	.11	12	.34		.44/2314	.36/2324					SHORT PERIOD INTENSITY 10 min SHOWN
26	.07	.06	.03	.03	.02	.01	.01	.01																	8	.24								
27																																		
28																																		
29																																		
30																																		
31																																		

NOTE: WHERE A "STORM TOTAL" IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (...) FOR A DURATION OF HOURS, (N) THUS ?/hrs

TOTAL FOR MONTH: 69 | 2.93
TOTAL FOR YEAR TO END OF:

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES
A/B × C = INTENSITY IN/HOUR
RECORDED FOR TIME OF OCCURRENCE ENDING AT

TABLE 1 Daily Rainfall Record, May 1982 to May 1983



GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

RAINFALL RECORD

TYPE OF GAUGE
RECEIVER: TIPPING BUCKET
RECORDER: PECKNOLD AUTOMATIC
TIME ZONE: PACIFIC DAYLIGHT

STATION: SPERLING AVENUE PUMPING STATION
ELEVATION: .... LAT: .... LONG: ....
MONTH OF: MAY 1982

DAY OF MONTH	HOURLY RAINFALL (INCHES) FOR HOUR ENDING AT																								HOURS OF RAIN	DAILY TOTAL	STORM TOTAL	MAX INT. in/hr FOR PERIODS OF 5m to 2hrs						REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				5m	15m	30m	45m	60m	2h	
1												End of Tape																						
2												→																						
3																																		
4																																		
5																							01	02	2	.03								
6	01		01																			02		01	4	.05								
7			01		01		01	04	10	09					01						01	01			9	.29								
8			01	05	24	18	10			01															6	.59		.36 0950	.36 0935	.34 [illegible]	.32 0815	.27 [illegible]	.23 0615	
9																																		
10																																		
11																																		
12																																		
13																																		
14																		02	19	05	01	01			5	.28								
15																																		
16																																		
17																	03			02	09		02		4	.16								
18			01																															
19																																		
20																																		
21																																		
22																																		
23																																		
24																																		
25																																		
26																																		
27																																		
28																																		
29																																		
30																							02	01	2	.03								
31		01																							1	.01								

NOTE: WHERE A 'STORM TOTAL' IS SHOWN, THE TOTAL APPLIES TO THE TABULATED QUANTITY ENCLOSED BY BRACKETS (....) FOR A DURATION OF HOURS, (a) THUS

TOTAL FOR MONTH	33	1.44
TOTAL FOR YEAR TO END OF		

A = FALL IN INCHES
B = NUMBER OF MINS
C = 60 MINUTES

A/B × C = INTENSITY IN/HOUR

RECORDED FOR TIME OF OCCURRENCE ENDING AT THE HOUR INDICATED

TABLE 2

MONTHLY PRECIPITATION (PPT) RECORD
FOR THE VANCOUVER INTERNATIONAL AIRPORT AND
SPERLING AVENUE RAIN GAUGE

	Vancouver Airport			Sperling Ave.
Date	Total Monthly PPT (mm)	Normal Monthly PPT (mm)	Percent Actual Over or Under (-) Normal	Total Monthly PPT (mm)
May 1982	22.6	51.6	-43.8	15.0
June 1982	29.2	45.2	-64.6	20.3
July 1982	67.0	32.0	209.4	68.3
August 1982	37.2	41.1	90.5	54.4
September 1982	44.2	67.1	65.9	74.2
October 1982	118.0	114.0	103.5	143.5
November 1982	174.9	150.1	116.5	214.6
December 1982	149.7	182.4	82.1	167.1
January 1983	172.3	153.8	112.0	165.1
February 1983	234.2	114.7	204.2	236.7
March 1983	149.2	101.0	147.7	110.0
April 1983	127.7	59.6	214.3	74.4
May 1983	37.9	51.6	73.4	36.6
Total for Year	1,364.1	1,164.2	117.2	1,380.2

TABLE 3

SUMMARY OF RAINFALL WATER QUALITY DATA*

	Number of Values				
	Total	Above MDC	Max	Min	Mean
pH (rel. unit)	35	35	7.92	4.23	5.63
Acidity: strong tot. (UEQ/L)	35	8	58	L15	17.2
Acidity: total (UEQ/L)	35	33	122	L15	37.3
Sulphate - tot (mg/L)	34	34	7.6	1.2	2.49
Ammonia - (mg/L)	35	35	0.57	0.033	0.20
Nitrate - (mg/L)	35	35	4.61	0.22	1.28
Nitrite - (mg/L)	34	34	0.227	0.016	0.0434
Phosphate - tot (mg/L)	35	23	0.328	L0.009	0.025
Sodium - tot (mg/L)	35	35	1.4	0.1	0.45
Chloride - tot (mg/L)	35	22	1.9	L0.05	0.74
Potassium - tot (mg/L)	35	14	0.2	L0.1	0.11
Magnesium - tot (mg/L)	33	31	0.24	L0.02	0.092
Calcium - tot (mg/L)	33	33	8.16	0.1	1.29
Iron - tot (mg/L)	33	31	0.56	L0.01	0.085
Lead-Undigested (mg/L)	28	28	0.085	0.004	0.0205
Lead-Digested (mg/L)	22	22	0.05	0.004	0.0183
Zinc-Undigested (mg/L)	28	23	0.035	L0.005	0.0097
Zinc-Digested (mg/L)	22	19	0.03	L0.005	0.012
Aluminum - tot (mg/L)	30	24	0.64	L0.02	0.091
Copper-Undigested (mg/L)	28	25	0.011	L0.001	0.0027
Copper-Digested (mg/L)	21	21	0.006	0.001	0.0027
Cadmium-Undigested (mg/L)	28	8	0.0016	L0.0005	0.0008
Cadmium-Digested (mg/L)	22	7	0.0022	L0.0005	0.0009

*MDC - minimum detection limit
L - less than

tot - total
digested - approximates total

TABLE 4

PRECIPITATION QUALITY AT OTHER LOCATIONS WITHIN BRITISH COLUMBIA^{a,b,c}

Parameter	Revelstoke Sept. 79-Dec. 80		Prince Rupert/Terrace Sept. 80-Nov. 81		South Vancouver Dec. 80-Dec. 81	
	Range	Mean	Range	Mean	Range	Mean
Acidity-strong	-	-	15-21	15*	15-110	23
-total	-	-	24-55	39.6	18-180	68
Aluminum	-	-	0.02- 0.02	0.02*	-	-
Ammonia	ND-0.57	0.03*	0.007-0.11	0.022*	0.007-3.75	0.221
Cadmium	-	-	-	-	0.0005-0.0059	0.0012
Calcium	0.15-1.2	0.52	0.02-0.07	0.03*	0.02-1.66	0.53
Chloride	ND-1.5	0.22*	0.5-0.5	0.5*	0.5-10	1.4
Copper	-	-	-	-	0.001-0.140	0.016
Fluoride	-	-	0.04- 0.04	0.04*	-	-
Lead	-	-	-	-	0.001-0.3	0.029
Magnesium	0.02-0.12	0.05	0.02-0.04	0.02*	0.02-0.61	0.1
Nitrate	0.04-1.77	0.46	0.09-1.11	0.42	0.09-5.23	0.99
Nitrite	-	-	-	-	0.016-0.112	0.028
pH	4.7-6.0	5.5*	4.7-5.63	5.03*	3.95-6.84	4.86*
Phosphate	-	-	0.009-0.015	0.009*	0.009-1.21	0.044
Potassium	0.06-0.29	0.14	0.009-0.1	0.1*	0.1-5.6	0.5
Sodium	ND-0.8	0.1*	0.1-0.5	0.2*	0.1-5.6	0.81
Specific Conductivity	4.1-26.8	8.8	-	-	-	-
Sulphate	0.4-3.7	0.94	0.5-1.9	0.96	0.7-7.2	2.79
Zinc	-	-	-	-	0.005-0.23	0.057

a - Values marked with an asterisk represent medians

b - All values are in mg/L except for pH (arbitrary units) and acidity (UEQ/L)

c - Revelstoke Samples were collected at monthly intervals while the Prince Rupert/Terrace and South Vancouver samples were collected during specific rain events (Swain, 1983).

* median values

TABLE 5

SUMMARY OF DUSTFALL DATA*

Parameter	Number of Values		Maximum	Minimum	Mean
	Total	Above M.D.C.			
Particulate (mg/dm^2/d)					
-total	17	17	8.2663	1.5295	4.9154
-soluble	17	17	1.9498	0.49037	1.2156
-insoluble	17	17	7.3672	1.0391	3.7039
-soluble ash	17	17	1.2376	0.32691	0.6710
-insoluble ash	17	17	6.6784	0.58378	3.1277
Ions (mg/dm^2/d)					
Fluoride-soluble	15	3	0.0023	L0.0023	0.0023
Sodium -soluble	15	6	0.0934	L0.0234	0.0319
Chloride-soluble	15	10	0.1868	L0.0234	0.0490
Metals (mg/dm^2/d)					
Arsenic -total	14	3	0.0002	L0.00002	0.00004
-soluble	15	1	0.0002	L0.00002	0.00004
-insoluble	14	2	0.00004	L0.00002	0.00003
Lead -total	14	14	0.0036	0.00105	0.00314
-soluble	15	2	0.00035	L0.00012	0.00013
-insoluble	14	14	0.0036	0.00817	0.00310
Copper -total	14	14	0.00257	0.00023	0.00083
-soluble	15	3	0.00035	L0.00012	0.00015
-insoluble	14	14	0.00257	0.00023	0.000767
Zinc -total	14	14	0.0029	0.0011	0.0019
-soluble	15	4	0.0020	L0.0001	0.00032
-insoluble	14	14	0.0029	0.00023	0.0016
Cadmium -total	14	1	0.000234	L0.00012	0.00013
-soluble	15	1	0.000234	L0.000117	0.000125
-insoluble	14	0	L0.000117	L0.000117	0.000117
Mercury -total	2	2	0.000009	0.000008	0.000009
-soluble	18	5	0.000007	L0.000002	0.000003
-insoluble	17	5	0.000005	L0.000002	0.000002

*M.D.C. - minimum detection limit

L. - less than

TABLE 6

TOTAL DAILY STORMWATER FLOWS (m^3/DAY)

Day of Month	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	
1		0	0	0	0	19.1	0	143.6	0.1	0	N.D.	526.1	0	
2		8.8	23.3	26.1	0	216.8	0	684.0	512.8	0	N.D.	21.9	0	
3		0	960.3	0	610.6	1.6	284.8	917.2	343.6	0	N.D.	0	0	
4		0	209.1	0	559.0	0	339.0	11.7	287.0	0	0.8	0	0	
5		22.8	6.2	N.D.*	0	0	303.8**	0	352.5	0	57.6	0	0	
6		0	0		0	685.1	19.1	0	278.2	92.9	17.0	0	0.9	
7		0	0		0	11.1	3.5	0	1568.3	0	77.3	0	72.2	
8		0	0		11.4	0	0	0	225.9	69.1	426.6	0	240.0	
9		0	0		88.9	0	0	0	1274.3	165.2	229.1	181.4	0	
10		0	0		0	0	0	0	935.6	297.3	277.6	14.4	0	
11		0	0		295.1	0	0	45.1	216.3	1160.4	4.1	3.0	0	
12		0	0	↓	0	0	58.2	763.7	198.6	141.2	N.D.	0	0	
13		0	49.6	1.9	0	0	0	143.3	55.4	424.0	N.D.	0	0	
14		0	96.4	3.4	0	0	0	258.5	20.7	293.6	N.D.	0	39.6	
15	Recorder	0	272.1	0	0	0	343.1	517.7	0	325.6	N.D.	0	0	
16	Operational	0	0	0	0	287.3	1154.1	243.6	0	232.0	0	0	0	
17	820519	0	0	0	0	14.5	126.7	161.3	47.5	1213.2	0	0	14.2	
18		0	0	0	0	0	50	187.7	81.7	64.6	0	0	0	
19	0	0	0	0	0	0	94	26.2	354.5	1683.7	0	0	0	
20	0	0	0	0	0	0	17.8	48.1	0.8	1043.3	0	1.8	end of record	
21	0	0	6.2	0	0	187.5	1.6	150.7	0	19.3	0	10.5		
22	0	0	0	0	0	66.5	4.2	641.6	0	N.D.	34.3	0		
23	0	0	0	0	0	11.6	6.0	0	11.3	N.D.	11.7	0		
24	0	0	0	0	0.6	191.2	3.5	0	182.2	N.D.	0	327.7		
25	0	0	0	0	0.7	75.9	0	345.2	45.5	N.D.	0	132.8		
26	0	167	0	0	0	147.1	128.9	0	91.0	N.D.	0.9	132.2		
27	0	0	0	0	0	343.8	534.6	0	1.2	N.D.	10.7	0		
28	0	0	0	0	30.9	292.6	1079.1	0	0	N.D.	212.3	0		
29	0	0	0	0	0	0	338.2	0	2.1		506.1	0		
30	0	0	0	387.0	0	2.4	400.3	0	238.4		215.9	0		
31	0		0	0		117.3		0	0		438.8			
Monthly Total	0.0	198.6	1623.2	418.4	1597.2	2671.4	5290.5	5289.2	7325.5	7225.4	2520.8	1351.8	366.9	35878 m^3 total for year
Daily Average	0.0	6.62	52.4	18.2	51.5	86.2	176.4	170.6	236.3	258.1	81.3	45.1	19.3	

* N.D. = no data, equipment failure

** partial daily flow

TABLE 7

RUNOFF COEFFICIENTS FOR STORM EVENTS SAMPLED*

Period of Precipitation	Period of Runoff	Approx Storm Duration (h)	Total Precip (mm)	Total Runoff (m^3)	R
82/07/13 1500-1800	82/07/13 1550-1910	4.5	3.6	47.5	0.23
82/08/30 0000-0400	82/08/30 0030-0445	4.0	28.7	57.9	0.03
82/09/08 2000-2300	82/09/08-09 2015-0015	4.0	2.3	11.4	0.08
82/09/28 1500-1600	82/09/28 1430-1530	1.0	1.8	27.9	0.27
82/10/06 0000-1400	82/10/06 0110-1500	14.0	25.4	685.1	0.47
82/10/21 0900-1300	82/10/21 1000-1340	4.0	3.0	17.0	0.10
82/10/24 0600-1700	82/10/24 0700-2150	15.0	10.9	187.9	0.30
82/10/25-26 2100-0100	82/10/25-26 2115-0755	10.5	4.8	109.3	0.39
82/10/31 0700-1600	82/10/31 0800-1700	9.0	6.6	142.3	0.37
82/11/03-04 2100-0300	82/11/03-04 2005-0435	8.5	20.3	538.0	0.46
82/11/15-17 1100-1000	82/11/15-18 1150-0900	70.0	58.7	1624.9	0.31
82/11/26- 82/12/01 1400-1900	82/11/26- 82/12/02 1330-0455	136.5	89.4	2559.3	0.49
83/01/17 2000-0200	83/01/17-18 2120-0340	6.0	1.8	7.2	0.07
83/01/24 0500-0800	83/01/24 0610-1020	4.0	5.5	107.3	0.34
83/01/25 1500-1900	83/01/25 1550-2150	6.0	2.8	32.6	0.20
83/01/26 1100-1700	83/01/26 0750-2130	13.5	4.3	64.0	0.26
83/01/30 0200-1000	83/01/30 0300-1540	12.5	10.9	232.9	0.37
83/02/08-09 1600-1400	83/02/08-09 1650-1900	26.0	20.8	240.8	0.20
83/02/10-13 1700-1100	83/02/10-13 1710-1900	74.0	70.9	3289.9	0.80
83/02/14-15 1100-0200	83/02/14-15 1110-0510	18.0	11.4	299.5	0.45
				Arithmetic Mean	0.31
				Standard Deviation	0.18

* 1. Calculated only for those storm events with complete runoff and precipitation data (i.e. no equipment problems).

2. Calculation $R = \frac{\text{total runoff } (m^3)}{\text{total precipitation } (m) \times \text{catchment basin area}}$

TABLE 8

DATA SUMMARY OF WET WEATHER STORMWATER WATER QUALITY*

Parameter	No. of Values	Maximum	Minimum	Mean	Ratio Max:Min
Alkalinity: total $CaCO_3$	103	87	18.9	38.2	4.6:1
Bacteriological:					
Fecal Coliform	297	54,000	L200	2860	270:1
Total Coliform	297	G240,000	L200	24800	1200:1
Carbon:					
Inorganic	318	59	6	17.7	9.8:1
Organic	318	118	4	24	29.5:1
Chloride	270	17.4	1.4	4.7	12.4:1
Colour (TAC)	318	150	L1	36.8	-
Metals:					
Aluminum (D)	316	0.51	L0.02	0.15	25.5:1
Aluminum (T)	317	35.2	L0.02	8.72	1760:1
Arsenic (T)	316	L0.25	L0.25	-	-
Cadmium (T)	317	0.03	L0.01	0.01	3:1
Calcium (D)	316	46.8	0.14	17.3	334:1
Calcium (T)	317	313	6.81	51.9	6.03:1
Chromium (T)	317	0.09	L0.01	0.02	9:1
Copper (D)	316	0.05	L0.01	0.01	5:1
Copper (T)	317	0.4	L0.01	0.04	40:1
Iron (D)	316	2	L0.01	0.24	200:1
Iron (T)	317	45	0.05	9.08	900:1
Lead (D)	316	L0.1	L0.1	-	-
Lead (T)	317	0.93	L0.1	0.22	9.3:1
Magnesium (D)	316	3.22	0.02	0.69	16:1
Magnesium (T)	317	13.5	0.45	3.46	30:1
Manganese (D)	316	0.38	L0.01	0.05	38:1
Manganese (T)	317	0.88	0.04	0.22	22:1
Mercury (T)	317	0.00019	L0.00005	0.00007	3.8:1
Molybdenum (D)	316	0.02	L0.01	0.01	2:1
Molybdenum (T)	317	0.1	L0.01	0.03	10 :1
Nickel (T)	316	L0.05	L0.05	-	-
Potassium (D)	318	3.1	0.5	1.15	6.2:1
Sodium (D)	318	13.4	1.9	5.16	7.1:1
Zinc (D)	316	0.27	L0.01	0.08	27 :1
Zinc (T)	317	0.97	0.06	0.24	16.2:1
Nitrogen:					
Ammonia	318	0.935	L0.005	0.092	187:1
Nitrate/Nitrite	318	2.24	0.03	0.36	74.7:1
Nitrate	306	1.89	0.02	0.29	94.5:1
Nitrite	306	0.086	L0.005	0.025	17.2:1
Organic	12	2	1	1.3	2:1
Kjeldahl	318	4	0.14	1.0	28.6:1
Total-N	318	5	0.35	1.31	14.3:1
Oil and Grease	317	35.7	L1	7.8	35.7:1
Oxygen Demand:					
BOD_5	318	159	L10	14	15.9:1
COD	318	359	L10	77.6	35.9:1
pH	318	8.7	6.2	7.4	-
Phenol	318	0.039	L0.002	0.009	19.5:1
Phosphorus:					
Orthophosphate	306	0.249	0.011	0.063	22.6:1
Total (D)	318	0.316	0.026	0.091	12.2:1
Total	318	1.47	0.086	0.418	17.1:1
Silica	293	9.7	0.9	2.7	10.8:1
Solids:					
Residue Total 105°	318	1640	61	326	26.9:1
Residue Filterable 105°	318	214	42	84.7	5.1:1
Residue Non-Filterable 105°	318	1520	6	241.6	253:1
Residue Fixed Non-Filterable 550°	318	1370	4	206.9	342.5:1
Specific Conductivity	318	286	53	121.6	5.4:1
Sulphate	318	26.3	2.6	6.7	10.1:1
Sulphide	195	L0.5	L0.5	-	-

* 1. D=dissolved, T=total, L=less than
2. All values in mg/L except: Specific Conductivity=umho/cm; pH=relative units; Colour=TAC (colour units); mercury=ug/L; fecal and total coliform=MPN/100 ml

TABLE 9

DATA SUMMARY OF DRY WEATHER STORMWATER WATER QUALITY PARAMETERS*

Parameter	No. of Values	Maximum	Minimum	Mean	Ratio Max:Min
Alkalinity:total $CaCO_3$	28	218	61.1	142.4	3.6:1
Bacteriological:					
Fecal Coliform	31	G 240000	L 20	31475	12000:1
Total Coliform	31	G 240000	80	63366	3000:1
Carbon:					
Inorganic	32	66	20	41.3	3.3:1
Organic	32	275	23	58.9	12.0:1
Chloride	19	34.6	9.2	17.6	3.8:1
Colour (TAC)	32	950	33	213	
Metals:					
Aluminum (D)	32	1.46	0.05	0.27	29.2:1
Aluminum (T)	32	10.1	0.16	1.29	63.1:1
Arsenic (T)	32	L 0.25	L 0.25		
Cadmium (T)	32	0.02	L 0.01	0.01	2:1
Calcium (D)	32	73	21.2	42.6	3.4:1
Calcium (T)	32	73	23.9	44.7	3.1:1
Chromium (T)	32	0.05	L 0.01	0.013	5:1
Copper (D)	32	0.1	L 0.01	0.033	10:1
Copper (T)	32	0.21	L 0.01	0.048	21:1
Iron (D)	32	7.82	1.41	3.59	5.5:1
Iron (T)	32	11.8	1.85	5.65	6.4:1
Lead (D)	32	0.4	L 0.1	0.12	4:1
Lead (T)	32	0.62	L 0.1	0.15	6.2:1
Magnesium (D)	32	7.68	1.95	4.55	3.9:1
Magnesium (T)	32	8.3	2.47	5.18	3.4:1
Manganese (D)	32	1.12	0.2	0.56	5.6:1
Manganese (T)	32	1.16	0.23	0.62	5.04:1
Mercury	32	0.00015	L 0.00005	0.00006	2.5:1
Molybdenum (D)	32	L 0.01	L 0.01		
Molybdenum (T)	32	0.01	L 0.01	0.01	
Nickel (T)	32	L 0.05	L 0.05		
Potassium (D)	32	166	1.7	15.0	97.6:1
Sodium (D)	32	77	10.5	25.7	7.3:1
Zinc (D)	32	0.25	0.02	0.078	12.5:1
Zinc (T)	32	0.39	0.03	0.095	13:1
Nitrogen:					
Ammonia	32	2.24	L 0.005	0.601	448:1
Nitrate/Nitrite	32	0.47	L 0.02	0.17	23.5:1
Nitrate	28	0.24	L 0.02	0.11	12:1
Nitrite	28	0.157	0.005	0.032	31.4:1
Organic	4	3	1	1.8	3:1
Kjeldahl	32	6	0.7	2.14	8.6:1
Total - N	32	6	0.84	2.24	7.1:1
Oil and Grease	32	26.1	L 1	7.2	26:1
Oxygen Demand:					
BOD_5	32	256	L10	39.2	25.6:1
COD	32	834	63	176.3	13.2:1
pH	32	10	6.9	7.4	
Phenol	32	0.02	L 0.002	0.010	10:1
Phosphorus:					
Orthophosphate	28	15.9	0.034	1.231	467.6:1
Total (D)	32	16	0.064	1.137	250:1
Total	32	22.5	0.10	1.56	225:1
Silica	20	42.8	12.5	18.0	3.4:1
Solids:					
Residue Total 105°	32	854	167	351	5.1:1
Residue (F) 105°	32	690	160	316.9	4.3:1
Residue (Non-F) 105°	32	264	5	34.3	52.8:1
Residue Fixed(NonF)550°	32	215	2	22.0	107.5:1
Specific Conductivity	32	633	185	372.5	3.4:1
Sulphate	32	97.5	4.7	20.2	20.7:1
Sulphide	23	L0.5	L0.5		

* (1) D=dissolved, T=total, L=less than

(2) All values in mg/L except: specific conductivity - umho/cm
pH - relative units
colour - TAC (colour units)
mercury - ug/L
fecal and total coliform - MPN/100 ml

TABLE 10

CONSTITUENT LOADINGS DURING DRY AND WET STORMWATER RUNOFF PERIODS*

Parameter	Dry Weather Loading (Kg/yr)	Wet Weather Loading (Kg/yr)
Carbon:		
Inorganic	78	633
Organic	112	858
Chloride	33	168
Metals:		
Aluminum (D)	0.5	5.4
Aluminum (T)	2.5	312
Cadmium (T)	0.02	0.4
Calcium (D)	81	619
Calcium (T)	85	1856
Chromium (T)	0.02	0.7
Copper (D)	0.06	0.4
Copper (T)	0.09	1.4
Iron (D)	6.8	8.6
Iron (T)	11	325
Lead (D)	0.02	below detection limit
Lead (T)	0.29	7.9
Magnesium (D)	8.6	24.7
Magnesium (T)	9.8	127
Manganese (D)	1.1	1.8
Manganese (T)	1.2	7.9
Mercury (T)	0.0001	0.003
Molybdenum (D)	below detection limit	0.4
Molybdenum (T)	0.02	1.1
Potassium (D)	29	41
Sodium (D)	49	185
Zinc (D)	0.15	2.9
Zinc (T)	0.18	8.9
Nitrogen:		
Ammonia	1.1	3.3
Nitrate/Nitrite	0.32	13
Nitrate	0.21	10
Nitrite	0.06	0.9
Organic-N	3.4	46
Kjeldahl-N	4.1	36
Total-N	4.3	47
Oil and Grease	13.7	279
Oxygen Demand:		
BOD5	74	501
COD	335	2775
Phenol	0.02	0.3
Phosphorus:		
Orthophosphate	2.3	2.3
Total (D) Phosphorus	2.2	3.3
Total Phosphorus	3.0	15
Silica	34	97
Solids:		
Residue Total 105°	667	11658
Residue Filterable 105°	602	3029
Residue Non-Filt 105	65	8640
Residue Fixed Non-Filt 550°	42	7399
Sulphate	38	240

* D = dissolved, T = total

TABLE 11

DRY AND WET WEATHER STORMWATER DISCHARGE HYDROCARBONS

Wet Weather Discharge:

Date:Time	Concentration (ppm)	Comment
November 3, 1982		
2038-2053	1	diesel oil
2053-2108	1	diesel oil
2108-2123	6	diesel oil
2123-2138	11	diesel oil
2138-2153	19	diesel oil
2153-2208	6	diesel oil
2208-2223	43	diesel oil
2223-2238	5	diesel oil
2238-2253	2	diesel oil
2253-2308	1	diesel oil
2308-2323	2	diesel oil
2323-2338	6	diesel oil
November 16, 1982		
1515-1530	1	
1530-1545	1	
1545-1600	1	
1600-1615	1	
1615-1630	1	
1630-1645	1	
1645-1700	1	
1700-1715	1	
1715-1730	1	
1730-1745	1	
November 28, 1982		
1013-1028	1	
1028-1043	1	
1043-1058	1	
1058-1113	1	
1113-1128	1	
1128-1143	1	
1143-1158	1	
1158-1213	1	
1213-1228	1	
1228-1243	1	
1243-1258	1	
1258-1313	1	
November 29, 1982		
1948-2003	1	
2003-2018	1	
2018-2033	1	
2033-2048	1	diesel fuel
2048-2103	1	diesel fuel
2103-2118	1	fiesel fuel
2118-2133	1	diesel fuel
2133-2148	1	diesel fuel
2148-2203	1	diesel fuel
2203-2218	trace	diesel fuel
2218-2233	1	
2233-2248	1	

TABLE 11 (Cont'd)

DRY AND WET WEATHER STORMWATER DISCHARGE HYDROCARBONS

Wet Weather Discharge:

Date:Time	Concentration (ppm)	Comment
January 11, 1983		
1730-1745	1	diesel fuel
1745-1800	1	diesel fuel
1800-1815	1	diesel fuel
1815-1830	1	diesel fuel
1830-1845	1	diesel fuel
1845-1900	1	diesel fuel
January 25, 1983		
1728-1743	19	diesel fuel
1743-1758	23	diesel fuel
1758-1813	12	diesel fuel
1813-1828	20	diesel fuel
1828-1843	18	diesel fuel
1843-1858	12	diesel fuel
1858-1913	16	diesel fuel
1913-1928	37	diesel fuel
1928-1943	24	diesel fuel
February 9, 1983		
0915-0930	1	diesel fuel
0930-0945	0.4	diesel fuel
0945-1000	0.4	diesel fuel
1000-1015	0.6	diesel fuel
1015-1030	0.9	diesel fuel
1030-1045	7.2	diesel fuel
1045-1100	0.7	diesel fuel
1100-1115	0.8	diesel fuel
1115-1130	0.2	diesel fuel
1130-1145	0.2	diesel fuel
1145-1200	0.2	diesel fuel
1200-1215	0.2	diesel fuel

Dry Weather Discharge:

November 24, 1983		
0830	1	
0845	1	
0910	1	
0925	1	
May 24, 1983		
0916-0922	0.02	
1010-1017	0.02	

TABLE 12

WET WEATHER STORMWATER BIOASSAY DATA SUMMARY

Date	Time	Microtox	Daphnia	Fish (Rainbow/Trout)
Oct.28,1982	1120-1130	Non-toxic	Non-toxic	Non-toxic *
Nov.15,1982	1640-1655	↓	↓	-
Nov.15,1982	1710-1725	↓	↓	-
Nov.15,1982	1740-1755	↓	↓	-
Nov.15,1982	1810-1825	↓	↓	-
Nov.15,1982	1840-1855	↓	↓	-
Nov.15,1982	1910-1925	↓	↓	-
Nov.15,1982	1940-1955	↓	↓	-
Nov.15,1982	2010-2025	↓	↓	-
Jan.25,1983	1728-1743	↓	48hr.LC_{50} 90-100%	-
Jan.25,1983	1743-1758	↓	Non-Toxic	-
Jan.25,1983	1758-1813	↓	↓	-
Jan.25,1983	1813-1828	↓	↓	-
Jan.25,1983	1828-1843	↓	↓	-
Jan.25,1983	1843-1858	↓	↓	-
Jan.25,1983	1858-1913	↓	↓	-
Jan.25,1983	1913-1928	↓	↓	-
Jan.25,1983	1928-1943	↓	↓	-
Feb. 9,1983	0915-0930	↓	↓	-
Feb. 9,1983	0930-0945	↓	↓	-
Feb. 9,1983	0945-1000	↓	↓	-
Feb. 9,1983	1000-1015	↓	↓	-
Feb. 9,1983	1015-1030	↓	↓	-
Feb. 9,1983	1030-1045	↓	↓	-
Feb. 9,1983	1045-1100	↓	↓	-
Feb. 9,1983	1100-1115	↓	↓	-
Feb. 9,1983	1115-1130	↓	↓	-
Feb. 9,1983	1130-1145	↓	↓	-
Feb. 9,1983	1145-1200	↓	↓	-
Feb. 9,1983	1200-1215	↓	↓	-

*96hr.LC_{50} > 100%

TABLE 13

DRY WEATHER DISCHARGE TOXICITY TESTS

DATE : TIME	MICROTOX	DAPHNIA	RAINBOW TROUT (96 HR LC_{50})
July 8,1982 : 0905	50 Sec 82%(v/v)	Non-toxic	--
July 8,1982 : 0935	Non-toxic	20% mort.in 100% eff.	--
July 8,1982 : 0944	50 Sec 75%(v/v)	48 hr.LC_{50}- 53% eff.	--
July 8,1982 : 1026	50 Sec 61%(v/v)	48 hr.LC_{50}- 26% eff.	--
Sept.23,1982	50 Sec 90%(v/v)	48 hr.LC_{50}- 70-80% eff.	Non-toxic
Oct. 19,1982	Non-toxic	Non-toxic	Non-toxic
Nov.24,1982 : 0830	Non-toxic	Non-toxic	--
Nov.24,1982 : 0845	Non-toxic	Non-toxic	--
Nov.24,1982 : 0915	Non-toxic	Non-toxic	--
Nov.24,1982 : 0930	Non-toxic	Non-toxic	--
Feb. 3,1983 : 1034	Non-toxic	Non-toxic	--
Feb. 3,1983 : 1045	Non-toxic	Non-toxic	--
Feb. 3,1983 : 1101	50 Sec 21%(v/v)	Non-toxic	--
Feb. 3,1983 : 1115	Non-toxic	Non-toxic	--
May 24,1983 : 0916	Non-toxic	Non-toxic	--
May 24,1983 : 0933	Non-toxic	Non-toxic	--
May 24,1983 : 0952	Non-toxic	Non-toxic	--
May 24,1983 : 1010	Non-toxic	Non-toxic	--

TABLE 14

SUMMARY OF ANALYSES OF SEDIMENT ACCUMULATED IN THE FLUME*

PARAMETER	Sept.2/82	Feb.16/83	June 21/83
Particle Size % (16 mesh,1.19mm)	9.3	16.5	8.3
Particle Size % (30 mesh,0.59mm)	39.5	34.8	36.6
Particle Size % (50 mesh,0.297mm)	37.5	28.9	36.3
Particle Size % (100 mesh,0.149mm)	11.5	10.3	15.3
Particle Size % (140 mesh,0.105mm)	2.1	3.8	3.2
Particle Size % (200 mesh, 0.074 mm)	L0.1	2.7	0.2
Particle Size % (270 mesh,0.057mm)	L0.1	2.0	L0.1
Particle Size % (400 mesh,0.037mm)	L0.1	1.0	L0.1
Particle Size % (less than 0.037mm)	L0.1	0.0	L0.1
Carbon:Organic (mg/g, dry)	4	8	8
Carbon:Inorganic (mg/g, dry)	8	10	11
Carbon:Total (mg/g, dry)	12	18	19
Sulphur:Total (mg/g, dry)	0.5	0.3	0.5
Phosphorus:Total (ug/g, dry)	357	392	420
Calcium (mg/g, dry)	15.3	23.8	20
Magnesium (mg/g, dry)	3.02	2.78	3.40
Mercury (ug/g, dry)	0.06	0.3	0.10
Arsenic (ug/g, dry)	L25	L25	L25
Boron (ug/g, dry)	L1	L1	L1
Cadmium (ug/g, dry)	L1	1	1
Chromium (ug/g, dry)	25	22	29
Copper (ug/g, dry)	48	32	128
Iron (mg/g, dry)	12.1	11.8	12
Lead (ug/g, dry)	300	149	271
Manganese (ug/g, dry)	196	195	211
Molybdenum (ug/g dry)	8	9	5
Nickel (ug/g, dry)	14	12	16
Zinc (ug/g, dry)	96	101	109
Aluminum (mg/g, dry)	6.59	7.4	10.1
Cobalt (ug/g, dry)	L10	L10	L10
Barium (ug/g, dry)	56	87	115
Vanadium (ug/g, dry)	20	21	19
Selenium (ug/g, dry)	L10	10	L10
Titanium (ug/g, dry)	378	383	335
Tin (ug/g, dry)	L5	7	8
Beryllium (ug/g, dry)	L1	L1	L1
Thallium (ug/g, dry)	L20	33	L20
Strontium (ug/g, dry)	31	53	51
Tellurium (ug/g, dry)	L20	27	L20
Aroclor 1242 (ug/g)	L0.02	L0.02	L0.02
Aroclor 1254 (ug/g)	L0.02	L0.02	L0.07
Aroclor 1260 (ug/g)	0.04	L0.02	L0.02
Organo-Chlorine (pesticide) Scan	not detectable	not detectable	not detectable
Nitrogen-Kjeldahl (mg/g, dry)	0.18	0.38	0.26

*L = less than

TABLE 15

COMPARISON OF MEAN CONCENTRATIONS OF SELECTED PARAMETERS IN STORMWATER RUNOFF AND MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT*

	Norland Avenue Industrial Site		Ferguson & Hall (1979)	Swain (1983) South Vancouver Residential Site		Cain and Swain (1980)		
	Wet Weather	Dry Weather	Industrial Runoff	Wet Weather	Dry Weather	Iona STP (1979)	Annacis STP (1979)	Lulu STP (1979)
Suspended Solids	241	34	-	20	14	54	74	71
BOD$_5$	14	39	29	<10	<10	94	157	178
COD	78	176	-	33.2	38	164	321	165
Aluminum (total)	8.7	1.3	-	0.43	0.39	0.9	1.0	0.7
Chromium (total)	0.02	0.01	-	<0.01	-	-	0.07	0.21
Copper (total)	0.04	0.048	0.049	0.037	0.04	-	-	-
Iron (dissolved)	0.24	3.6	-	0.022	-	0.34	0.74	0.94
Iron (total)	9.08	5.65	0.259	0.918	-	-	-	-
Manganese (total)	0.22	0.62	0.048	0.04	0.07	-	-	-
Nickel (total)	N.D.	N.D.	0.005	N.D.	-	-	-	-
Lead (total)	0.22	0.15	0.060	0.071	0.02	0.04	0.03	0.15
Zinc (total)	0.24	0.10	0.068	0.12	0.086	0.12	0.16	0.41
Kjeldahl Nitrogen	1.1	2.1	-	1.1	1.3	19	24	34
Total Nitrogen	1.3	2.2	2.0	1.6	2.4	-	-	-
Total Phosphorus	0.42	1.6	0.006	0.089	0.067	3	4.4	6.1
Fecal Coliform	2900	31000	11000	2400^{+}	700^{+}	-	-	-
Total Coliform	25000	63000	100,000	9200^{+}	9200^{+}	-	-	-

* Concentrations are in mg/L except for coliform data which are in MPN/100 mL

Norland Avenue stormwater runoff parameter concentrations are from Tables 8 and 9

N.D. = not detected

\+ median value

TABLE 16

COMPARISON OF DAILY LOADINGS (Kg/d) FOR SELECTED MUNICIPAL SEWAGE TREATMENT PLANTS AND INDUSTRIAL STORMWATER RUNOFF *

	Extrapolation to all Lower Mainland Industrial Areas	Ferguson & Hall (1979) Industrial Runoff Estimate	Iona STP (1979)	Annacis STP (1979)	Lulu STP (1979)
SUSPENDED SOLIDS	23,515	-	24,000	14,200	1800
BOD	1,553	4,160	41,700	30,100	4500
COD	8,401	-	73,000	61,600	7400
ALUMINUM (total)	850	-	400	192	32.8
CHROMIUM (total)	1.9	-	-	13.4	5.3
COPPER (total)	4.03	7.05	-	-	-
IRON (dissolved)	42	-	150	140	24
IRON (total)	908	37.9	-	-	-
MANGANESE (total)	24.6	6.92	-	-	-
NICKEL (total)	N.D.	0.71	-	-	-
LEAD (total)	22	8.7	18	5.8	3.8
ZINC (total)	25	9.7	53	31	10.3
KJELDAHL NITROGEN	108	-	8,450	4,600	860
TOTAL NITROGEN	139	223	-	-	-
TOTAL PHOSPHORUS	49	87	355	845	154

* - Municipal treatment plant data are from Cain and Swain (1980)

- Extrapolated industrial loadings calculated with the Ferguson and Hall (1979) estimate of 5720 ha of industrial land-use area within the Fraser River Estuary Study area.

TABLE 17

FIRST HOUR LOADINGS (kg/h) OF SELECTED PARAMETERS*

DATE:	SUSPENDED SOLIDS	BOD_5	COD	ALUMINUM (T)	CHROMIUM (T)	IRON (D)	LEAD (T)	ZINC (T)	PHOSPHORUS (T)	KJELDAHL NITROGEN
82/08/30	1.3	-	1.6	0.05	-	0.007	-	0.36	0.004	0.03
82/09/08	0.4	0.08	0.57	0.01	-	0.006	0.0008	0.0006	0.001	0.009
82/09/28	16.	0.93	5.8	0.5	0.001	0.005	0.002	0.02	0.03	0.07
82/10/21	1.7	0.13	0.85	0.06	0.0001	0.0001	0.002	0.002	0.004	0.01
82/10/25	5.4	0.31	2.1	0.20	0.0005	0.006	0.005	0.005	0.01	0.03
82/11/03	3.8	0.26	1.7	0.15	0.0002	0.0002	0.004	0.004	0.007	0.02
82/11/29	31.	6.7	17.	1.4	0.002	0.03	0.02	0.02	0.05	0.10
Arithmetic Mean	8.5	1.4	4.2	0.3	0.0008	0.008	0.006	0.06	0.02	0.04
Extrapolation to all Industrial Areas within the Fraser River Estuary Study Area	8381	1380	4141	296	0.8	7.9	5.9	59	19.7	39
Municipal STP 1/24th average load	556	1060	1972	8.7	0.4	4.4	0.4	1.3	32	193
Peaking Factor of 3	1668	3180	5916	26.1	1.2	13.2	1.2	3.9	96	579

*- Loadings extrapolated to the total Fraser River Estuary Study estimated industrial area of 5720 ha. (Ferguson and Hall,1979)

- Municipal sewage treatement plant data from Cain and Swain (1980) using 1979 data for Iona and Annacis and Lulu.

TABLE 18

RELATIONSHIP OF LOADINGS FROM PRECIPITATION AND DRY DEPOSITION AT THE STORMWATER SITE*

	PRECIPITATION		DRY DEPOSITION	RATIO
PARAMETER	CONCENTRATION (mg/L, Table 3)	LOADING (mg/dm^2/d)	LOADING (mg/dm^2/d)	PRECIPITATION / DRY DEPOSITION
Sodium	0.45	0.017	0.0319	0.533
Chloride	0.74	0.028	0.049	0.571
Lead	0.0183	0.0007	0.00314	0.223
Copper	0.0027	0.0001	0.00083	0.120
Zinc	0.012	0.0005	0.0019	0.263

*calculated on the basis of 1380 mm of rainfall (Table 2) over 5.8 ha during 12 months.

TABLE 19

STORMWATER LOADINGS AND THEIR ORIGIN*

PARAMETER	TOTAL LOADING WET WEATHER (TABLE 10) (Kg/d)	LOADING (Kg/d) PRECIPITATION	LOADING in DUSTFALL (Kg/d)	LOADING BALANCE in RUNOFF (Kg/d)
Sodium	0.507	0.003	0.018	0.486
Chloride	0.462	0.005	0.028	0.429
Lead	0.022	0.0012	0.017	0.0038
Copper	0.004	0.00002	0.0005	0.003
Zinc	0.024	0.00008	0.001	0.023

*Precipitation loading is calculated on the basis of 1380 mm of rainfall (Table 2) over 5.8 ha during 12 months, using the mean runoff coefficient of 0.31 (Table 7) and mean parameter concentrations in rainfall (Table 3).

$$\text{eg. precipitation loading} = \frac{\text{total rainfall x area x runoff coefficient}}{\text{365 days}}$$

dustfall loading is determined from precipitation loading using the ratio calculated in Table 18 and compensating for the runoff coefficient.

$$\text{eg. dustfall loading} = \frac{\text{precipitation loading}}{\text{runoff coefficient x ratio}}$$

TABLE 20

DETERMINATION OF FIRST FLUSH EFFECTS FOR SELECTED RAIN EVENTS*

Loading (Kg)

	Flow (m^3)		Oil & Grease			Res. N.F. 105			Total Organic Carbon		
Date:time	Incremental	I/T	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/09/08											
2015-2030	2.1	0.202	0.016	0.235	1.16:1	0.271	0.315	1.56:1	0.103	0.314	1.55:1
2030-2045	1.8	0.173	0.009	0.132	1:1	0.148	0.172	1:1	0.059	0.180	1.04:1
2045-2100	0.3	0.029	0.001	0.015	1:1	0.013	0.015	1:1	0.008	0.024	1:1
2100-2115	0.3	0.029	0.002	0.029	1:1	0.012	0.014	1:1	0.008	0.024	1:1
2115-2130	2.7	0.260	0.020	0.294	1.13:1	0.219	0.254	1:1	0.078	0.238	1:1
2130-2145	2.6	0.250	0.018	0.265	1.06:1	0.177	0.206	1:1	0.060	0.183	1:1
2145-2200	0.5	0.048	0.002	0.029	1:1	0.018	0.021	1:1	0.010	0.030	1:1
2200-2215	0.1	0.010	0.0003	0.004	1:1	0.003	0.003	1:1	0.002	0.006	1:1
2215-2230	0	0	-	-	-	-	-	-	-	-	-
2230-2245	0	0	-	-	-	-	-	-	-	-	-
2245-2300	0	0	-	-	-	-	-	-	-	-	-
TOTAL	10.4		0.068			0.861			0.328		
82/09/27											
1449-1504	18.8	0.681	0.540	0.732	1.36:1	14.2	0.709	1.04:1	1.316	0.72	1.06:1
1504-1519	6.7	0.243	0.165	0.224	1.37:1	4.97	0.248	1.02:1	0.409	0.224	1:1
1519-1534	2.0	0.072	0.032	0.043	1.34:1	0.826	0.041	1:1	0.098	0.054	1:1
1534-1549	0.1	0.004	0.001	0.001	1:1	0.032	0.002	1:1	0.005	0.003	1:1
1549-1604	0.0	-	-	-	-	-	-	-	-	-	-
1604-1619	0.0	-	-	-	-	-	-	-	-	-	-
1619-1634	0.0	-	-	-	-	-	-	-	-	-	-
1634-1649	0.0	-	-	-	-	-	-	-	-	-	-
1649-1704	0.0	-	-	-	-	-	-	-	-	-	-
1704-1719	0.0	-	-	-	-	-	-	-	-	-	-
1719-1734	0.0	-	-	-	-	-	-	-	-	-	-
1734-1749	0.0	-	-	-	-	-	-	-	-	-	-
TOTAL	27.6		0.738			20.028			1.828		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS FOR SELECTED RAIN EVENTS*

Loading (Kg)

	BOD$_5$			COD			Nitrogen-Total		
Date:time	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/09/08									
2015-2030	0.042	0.298	1.48:1	0.313	0.301	1.49:1	6.3	0.258	1.28:1
2030-2045	0.027	0.191	1.10:1	0.191	0.184	1.06:1	5.4	0.222	1.28:1
2045-2100	0.004	0.028	1:1	0.026	0.025	1:1	0.765	0.031	1.07:1
2100-2115	0.004	0.028	1:1	0.025	0.025	1:1	0.645	0.026	1:1
2115-2130	0.035	0.248	1:1	0.240	0.230	1:1	5.724	0.235	1:1
2130-2145	0.029	0.206	1:1	0.200	0.192	1:1	4.602	0.189	1:1
2145-2200	-	-	-	0.039	0.038	1:1	0.79	0.032	1:1
2200-2215	-	-	-	0.006	0.006	1:1	0.147	0.006	1:1
2215-2230	-	-	-	-	-	-	-	-	-
2230-2245	-	-	-	-	-	-	-	-	-
2245-2300	-	-	-	-	-	-	-	-	-
TOTAL	0.141			1.04			24.373		
82/09/27									
1449-1504	0.94	0.78	1.15:1	5.38	0.74	1.09:1	0.075	0.693	1.01:1
1504-1519	0.201	0.17	1:1	1.59	0.22	1:1	0.027	0.249	1.02:1
1519-1534	0.056	0.05	1:1	0.33	0.05	1:1	0.006	0.055	1:1
1534-1549	0.003	0.003	1:1	0.01	0.001	1:1	0.0003	0.00003	1:1
1549-1604	-	-	-	-	-	-	-	-	-
1604-1619	-	-	-	-	-	-	-	-	-
1619-1634	-	-	-	-	-	-	-	-	-
1634-1649	-	-	-	-	-	-	-	-	-
1649-1704	-	-	-	-	-	-	-	-	-
1704-1719	-	-	-	-	-	-	-	-	-
1719-1734	-	-	-	-	-	-	-	-	-
1734-1749	-	-	-	-	-	-	-	-	-
TOTAL	1.2			7.31			0.1083		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS FOR SELECTED RAIN EVENTS*

Loading (Kg)

	Phosphorus-Total			Iron (T)			Aluminum (T)		
Date:time	Incre-mental	I/T	Ratio	Incre-mental	I/T	Ratio	Incre-mental	I/T	Ratio
82/09/08									
2015-2030	0.00	0.185	1:1	0.015	0.333	1.6:1	0.007	0.28	1.39:1
2030-2045	0.0005	0.185	1.07:1	0.009	0.200	1.2:1	0.006	0.24	1.39:1
2045-2100	0.00001	0.004	1:1	0.0007	0.016	1:1	0.0005	0.02	1:1
2100-2115	0.00001	0.004	1:1	0.006	0.133	1:1	0.004	0.16	1:1
2115-2130	0.0009	0.333	1.28:1	0.012	0.267	1.07:1	0.006	0.24	1:1
2130-2145	0.0007	0.259	1.04:1	0.002	0.044	1:1	0.001	0.04	1:1
2145-2200	0.0001	0.037	1:1	0.0003	0.007	1:1	0.00009	0.004	1:1
2200-2215	0.00002	0.007	1:1	-	-	-	-	-	-
2215-2230	-	-	-	-	-	-	-	-	-
2230-2245	-	-	-	-	-	-	-	-	-
2245-2300	-	-	-	-	-	-	-	-	-
TOTAL	10.4			0.045			0.025		
82/09/27									
1449-1504	0.028	0.778	1.14:1	0.538	0.712	1.05:1	0.380	0.669	1:1
1504-1519	0.006	0.167	1:1	0.185	0.245	1.01:1	0.155	0.273	1.12:1
1519-1534	0.002	0.056	1:1	0.032	0.042	1:1	0.032	0.056	1:1
1534-1549	0.00008	0.0022	1:1	0.001	0.001	1:1	0.001	0.002	1:1
1549-1604	-	-	-	-	-	-	-	-	-
1604-1619	-	-	-	-	-	-	-	-	-
1619-1634	-	-	-	-	-	-	-	-	-
1634-1649	-	-	-	-	-	-	-	-	-
1649-1704	-	-	-	-	-	-	-	-	-
1704-1719	-	-	-	-	-	-	-	-	-
1719-1734	-	-	-	-	-	-	-	-	-
1734-1749	-	-	-	-	-	-	-	-	-
TOTAL	0.036			0.756			0.568		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS

FOR SELECTED RAIN EVENTS*

Loading (Kg)

	Flow (m^3)		Oil & Grease			Res. N.F. 105			Total Organic Carbon		
Date:time	Incremental	I/T	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/10/21											
1015-1030	0	0	-	-	-	-	-	-	-	-	-
1030-1045	0.1	0.006	0.003	0.01	1.83:1	0.030	0.004	1:1	0.006	0.007	1.17:1
1045-1100	1.2	0.073	0.039	0.144	1.97:1	0.490	0.060	1:1	0.084	0.097	1.33:1
1100-1115	1.5	0.091	0.043	0.159	1.75:1	0.807	0.099	1.09:1	0.111	0.128	1.41:1
1115-1130	1.3	0.079	0.024	0.088	1.11:1	0.530	0.065	1:1	0.069	0.08	1.01:1
1130-1145	2.4	0.146	0.043	0.159	0.09:1	0.910	0.112	1:1	0.113	0.131	1:1
1145-1200	1.6	0.098	0.034	0.125	1.28:1	0.744	0.092	1:1	0.070	0.081	1:1
1200-1215	0.5	0.030	0.011	0.041	1.37:1	0.233	0.029	1:1	0.022	0.025	1:1
1215-1230	2.0	0.061	0.041	0.151	2.48:1	0.944	0.116	1.90:1	0.086	0.099	1.63:1
1230-1245	4.7	0.287	0.027	0.100	1:1	2.760	0.340	1.18:1	0.249	0.288	1.003:1
1245-1300	0.9	0.055	0.006	0.022	1:1	0.546	0.067	1.22:1	0.041	0.047	1:1
1300-1315	0.2	0.012	0.0002	0.0007	1:1	0.120	0.015	1:1	0.008	0.009	1:1
TOTAL	16.4		0.2712			8.114			0.865		
82/10/25											
2100-2115	0.0	-	-	-	-	-	-	-	-	-	-
2115-2130	0.2	0.004	0.002	0.003	1:1	0.026	0.002	1:1	0.007	0.004	1:1
2130-2145	1.3	0.024	0.022	0.028	1.17:1	0.502	0.032	1.33:1	0.068	0.039	1.63:1
2145-2200	4.7	0.088	0.077	0.099	1.13:1	2.01	0.129	1.47:1	0.235	0.135	1.53:1
2200-2215	9.3	0.174	0.20	0.257	1.48:1	4.28	0.274	1.57:1	0.465	0.266	1.53:1
2215-2230	7.1	0.133	0.107	0.138	1.04:1	2.84	0.182	1.37:1	0.227	0.130	1:1
2230-2245	4.0	0.075	0.085	0.109	1.45:1	2.54	0.163	2.17:1	0.128	0.073	1:1
2245-2300	5.6	0.105	0.086	0.111	1.06:1	3.29	0.200	2.01:1	0.168	0.096	1:1
2300-2315	8.4	0.158	0.077	0.099	1:1	0.057	0.004	1:1	0.210	0.120	1:1
2315-2330	6.1	0.114	0.045	0.058	1:1	0.033	0.002	1:1	0.116	0.066	1:1
2330-2345	3.4	0.064	0.038	0.049	1:1	0.018	0.001	1:1	0.065	0.037	1:1
2345-0000	3.2	0.060	0.038	0.049	1:1	0.014	0.0009	1:1	0.058	0.033	1:1
TOTAL	53.3		0.777			15.61			1.747		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS

FOR SELECTED RAIN EVENTS*

Loading (Kg)

	BOD$_5$			COD			Nitrogen-Total		
Date:time	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/10/21									
1015-1030	-	-	-	-	-	-	-	-	-
1030-1045	0.004	0.011	1.83:1	0.020	0.007	1.17:1	0.0003	0.007	1.17
1045-1100	0.040	0.114	1.56:1	0.271	0.096	1.32:1	0.0036	0.087	1.19
1100-1115	0.039	0.111	1.22:1	0.345	0.122	1.34:1	0.0045	0.109	1.20
1115-1130	0.030	0.085	1.08:1	0.225	0.080	1.01:1	0.0039	0.094	1.19
1130-1145	0.048	0.137	1:1	0.382	0.136	1:1	0.0048	0.116	1:1
1145-1200	0.032	0.091	1:1	0.254	0.09	1:1	0.0032	0.077	1:1
1200-1215	0.01	0.028	1:1	0.080	0.028	1:1	0.0015	0.036	1:1
1215-1230	0.038	0.108	1.77:1	0.300	0.106	1.74:1	0.008	0.193	1:1
1230-1245	0.089	0.254	1:1	0.790	0.28	1:1	0.0094	0.227	1:1
1245-1300	0.017	0.048	1:1	0.123	0.04	1:1	0.0018	0.043	1:1
1300-1315	0.004	0.011	1:1	0.028	0.010	1:1	0.0004	0.0097	1:1
TOTAL	0.351			2.818			0.0414		
82/10/25									
2100-2115	-	-	-	-	-	-	-	-	-
2115-2130	0.003	0.005	1.25:1	0.020	0.004	1:1	0.0003	0.005	1.25:1
2130-2145	0.029	0.048	2:1	0.194	0.036	1.5:1	0.003	0.046	1.92:1
2145-2200	0.099	0.163	1.85:1	0.743	0.139	1.56:1	0.009	0.138	1.57:1
2200-2215	0.205	0.338	1.94:1	1.302	0.243	1.40:1	0.019	0.291	1.67:1
2215-2230	0.085	0.140	1.05:1	0.781	0.146	1.10:1	0.011	0.168	1.26:1
2230-2245	0.04	0.066	1:1	0.404	0.075	1:1	0.006	0.092	1.23:1
2245-2300	0.062	0.102	1:1	0.515	0.096	1:1	0.008	0.123	1:1
2300-2315	0.084	0.138	1:1	0.630	0.117	1:1	0.009	0.138	1:1
2315-2330	-	-	-	0.372	0.069	1:1	-	-	-
2330-2345	-	-	-	0.207	0.039	1:1	-	-	-
2345-0000	-	-	-	0.195	0.036	1:1	-	-	-
TOTAL	0.607			5.363			0.0356		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS

FOR SELECTED RAIN EVENTS*

Loading (Kg)

	Phosphorus-Total			Iron (T)			Aluminum (T)		
Date:time	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/10/21									
1015-1030	-	-	-	-	-	-	-	-	1:1
1030-1045	0.089	0.006	1:1	0.001	0.004	1:1	0.001	0.004	1:1
1045-1100	1.21	0.081	1.11:1	0.015	0.062	1:1	0.016	0.060	1:1
1100-1115	1.65	0.110	1.21:1	0.025	0.104	1.14:1	0.025	0.094	1.03:1
1115-1130	1.12	0.075	1:1	0.079	0.079	1:1	0.020	0.075	1:1
1130-1145	1.99	0.133	1:1	0.033	0.137	1:1	0.034	0.127	1:1
1145-1200	1.36	0.091	1:1	0.025	.104	1.06:1	0.026	0.097	1:1
1200-1215	0.44	0.029	1:1	0.008	0.033	1.1:1	0.0006	0.002	1:1
1215-1230	1.75	0.117	1.92:1	0.032	0.133	2.18:1	0.036	0.135	2.21:1
1230-1245	4.30	0.287	1:1	0.082	0.340	1.18:1	0.086	0.322	1.12:1
1245-1300	0.86	0.057	1.04:1	0.001	0.004	1:1	0.018	0.067	1.22:1
1300-1315	0.19	0.013	1.08:1	0.0002	0.00008	1:1	0.004	0.015	1.25:1
TOTAL	14.96			0.241			0.267		
82/10/25									
2100-2115	-	-	-	-	-	-	-	-	-
2115-2130	0.00007	0.0020	1:1	0.0013	0.0017	1:1	0.0011	0.0013	1:1
2130-2145	0.001	0.028	1.17:1	0.0192	0.0306	1.36:1	0.0185	0.0221	1:1
2145-2200	0.003	0.084	1:1	0.0752	0.0959	1.09:1	0.0733	0.0876	1:1
2200-2215	0.0066	0.185	1.06:1	0.1469	0.1873	1.08:1	0.1525	0.1823	1.05:1
2215-2230	0.0046	0.129	1:1	0.1022	0.1303	1:1	0.1051	0.1256	1:1
2230-2245	0.0035	0.098	1.31:1	0.0784	0.0999	1.33:1	0.088	0.1052	1.40:1
2245-2300	0.0050	0.140	1.33:1	0.1075	0.1370	1.30:1	0.1210	0.1446	1.38:1
2300-2315	0.0050	0.140	1:1	0.1075	0.1370	1:1	0.1159	0.1385	1:1
2315-2330	0.0033	0.092	1:1	0.0708	0.090	1:1	0.0769	0.0919	1:1
2330-2345	0.0019	0.053	1:1	0.0408	0.0520	1:1	0.0428	0.0512	1:1
2345-0000	0.0017	0.048	1:1	0.0346	0.0441	1:1	0.0416	0.050	1:1
TOTAL	0.0356			0.7844			0.8367		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS

FOR SELECTED RAIN EVENTS*

Loading (Kg)

	Flow (m^3)		Oil & Grease			Res. N.F. 105			Total Organic Carbon		
Date:time	Incremental	I/T	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/11/03											
2038-2053	3.6	0.019	0.045	0.015	1:1	1.08	0.009	1:1	0.166	0.022	1.16:1
2053-2108	6.4	0.034	0.08	0.027	1:1	2.02	0.018	1:1	0.25	0.034	1:1
2108-2123	10.6	0.056	0.123	0.042	1:1	3.26	0.029	1:1	0.392	0.053	1:1
2123-2138	16.0	0.085	0.232	0.0709	1:1	6.75	0.059	1:1	0.592	0.080	1:1
2138-2153	25.5	0.136	0.365	0.1242	1:1	19.48	0.170	1.25:1	1.02	0.138	1.01:1
2153-2208	27.0	0.144	0.397	0.1351	1:1	17.22	0.151	1.05:1	1.08	0.146	1.01:1
2208-2223	31.1	0.166	0.868	0.2953	1.78:1	33.59	0.294	1.77:1	1.71	0.231	1.39:1
2223-2238	23.4	0.125	0.232	0.0789	1:1	9.92	0.087	1:1	0.608	0.082	1:1
2238-2253	9.8	0.052	0.067	0.0228	1:1	2.54	0.022	1:1	0.235	0.032	1:1
2253-2308	7.0	0.037	0.030	0.01	1:1	1.15	0.010	1:1	0.147	0.02	1:1
2308-2323	16.6	0.088	0.095	0.032	1:1	2.22	0.019	1:1	0.349	0.047	1:1
2323-2338	40.9	0.218	0.405	0.1378	1:1	15.05	0.132	1:1	0.859	0.116	1:1
TOTAL	187.9		2.939			114.28			7.408		
82/11/29											
1948-2003	0.7	0.011	0.00005	0.00007	1:1	0.265	0.008	1:1	0.033	0.011	1:1
2003-2018	1.2	0.018	0.0126	0.018	1:1	0.51	0.016	1:1	0.142	0.048	1:1
2018-2033	2.5	0.038	0.035	0.050	1.32:1	1.19	0.036	1:1	0.27	0.091	2.39:1
2033-2048	5.3	0.081	0.107	0.152	1.88:1	3.88	0.118	1.46:1	0.50	0.169	2.09:1
2048-2103	7.1	0.109	0.118	0.168	1.54:1	4.20	0.128	1.17:1	0.52	0.175	1.61:1
2103-2118	8.2	0.126	0.163	0.232	1.84:1	11.07	0.338	2.68:1	0.46	0.155	1.23:1
2118-2133	8.1	0.124	0.071	0.101	1:1	3.43	0.105	1:1	0.24	0.081	1:1
2133-2148	7.7	0.118	0.049	0.070	1:1	2.53	0.077	1:1	0.25	0.084	1:1
2148-2203	8.5	0.131	0.056	0.080	1:1	1.98	0.060	1:1	0.18	0.061	1:1
2203-2218	5.6	0.086	0.035	0.050	1:1	1.47	0.045	1:1	0.13	0.04	1:1
2218-2233	5.8	0.089	0.044	0.063	1:1	1.58	0.048	1:1	0.151	0.051	1:1
2233-2248	4.4	0.068	0.013	0.018	1:1	0.691	0.021	1:1	0.09	0.03	1:1
TOTAL	65.1		0.704			32.80			2.97		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS FOR SELECTED RAIN EVENTS*

Loading (Kg)

	BOD$_5$			COD			Nitrogen-Total		
Date:time	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/11/03									
2038-2053	0.072	0.018	1:1	0.522	0.023	1.21:1	0.011	0.030	1.58:1
2053-2108	0.141	0.036	1.06:1	0.845	0.038	1.12:1	0.013	0.036	1.06:1
2108-2123	0.286	0.073	1.30:1	1.346	0.061	1.09:1	0.021	0.058	1.04:1
2123-2138	0.448	0.114	1.34:1	2.032	0.091	1.07:1	0.028	0.077	1:1
2138-2153	0.714	0.181	1.33:1	4.029	0.181	1.33:1	0.077	0.212	1.56:1
2153-2208	0.648	0.165	1.15:1	3.429	0.154	1.07:1	0.046	0.127	1:1
2208-2223	1.057	0.269	1.62:1	6.401	0.288	1.73:1	0.062	0.171	1.03:1
2223-2238	0.328	0.083	1:1	1.849	0.083	1:1	0.025	0.069	1:1
2238-2253	0.098	0.025	1:1	0.598	0.027	1:1	0.010	0.028	1:1
2253-2308	-	-	-	0.371	0.017	1:1	0.007	0.019	1:1
2308-2323	-	-	-	0.797	0.036	1:1	0.014	0.039	1:1
2323-2338	0.142	0.036	1:1	0.023	0.001	1:1	0.049	0.135	1:1
TOTAL	3.934			22.24			0.363		
82/11/29									
1948-2003	0.031	0.014	1.27:1	0.104	0.011	1:1	0.001	0.014	1.27:1
2003-2018	0.191	0.089	4.94:1	0.431	0.044	2.4:1	0.003	0.041	2.28:1
2018-2033	0.338	0.157	4.13:1	0.808	0.082	2.16:1	0.008	0.108	2.84:1
2033-2048	0.551	0.256	3.16:1	1.62	0.165	2.04:1	0.011	0.149	1.84:1
2048-2103	0.419	0.195	1.79:1	1.63	0.166	1.53:1	0.013	0.176	1.61:1
2103-2118	0.312	0.145	1.15:1	1.88	0.191	1.52:1	0.016	0.216	1.71:1
2118-2133	0.186	0.086	1:1	1.02	0.104	1:1	0.012	0.162	1.31:1
2133-2148	0.123	0.057	1:1	0.693	0.070	1:1	0.009	0.122	1.03:1
2148-2203	-	-	-	0.612	0.062	1:1	0.008	0.108	1:1
2203-2218	-	-	-	0.375	0.038	1:1	0.006	0.081	1:1
2218-2233	-	-	-	0.418	0.042	1:1	0.006	0.081	1:1
2233-2248	-	-	-	0.246	0.025	1:1	0.004	0.054	1:1
TOTAL	2.15			9.837			0.074		

TABLE 20 (Cont'd)

DETERMINATION OF FIRST FLUSH EFFECTS FOR SELECTED RAIN EVENTS*

Loading (Kg)

	Phosphorus-Total			Iron (T)			Aluminum (T)		
Date:time	Incremental	I/T	Ratio	Incremental	I/T	Ratio	Incremental	I/T	Ratio
82/11/03									
2038-2053	0.002	0.015	1:1	0.047	0.015	1:1	0.043	0.013	1:1
2053-2108	0.004	0.031	1:1	0.084	0.026	1:1	0.077	0.023	1:1
2108-2123	0.005	0.038	1:1	0.127	0.040	1:1	0.123	0.037	1:1
2123-2138	0.010	0.077	1:1	0.232	0.073	1:1	0.218	0.065	1:1
2138-2153	0.022	0.169	1.24:1	0.592	0.186	1.37:1	0.561	0.168	1.24:1
2153-2208	0.020	0.154	1.07:1	0.54	0.170	1.18:1	0.454	0.136	1:1
2208-2223	0.028	0.215	1.30:1	0.715	0.224	1.35:1	0.522	0.157	1:1
2223-2238	0.012	0.092	1:1	0.339	0.106	1:1	0.524	0.157	1.256:1
2238-2253	0.004	0.031	1:1	0.103	0.032	1:1	0.141	0.042	1:1
2253-2308	0.002	0.015	1:1	0.049	0.015	1:1	0.064	0.019	1:1
2308-2323	0.004	0.031	1:1	0.091	0.029	1:1	0.123	0.037	1:1
2323-2338	0.131	0.131	1:1	0.266	0.084	1:1	0.483	0.145	1:1
TOTAL	0.13			3.185			3.33		
82/11/29									
1948-2003	0.0004	0.009	1:1	0.010	0.009	1:1	0.011	0.009	1:1
2003-2018	0.0009	0.021	1.17:1	0.020	0.018	1:1	0.023	0.018	1:1
2018-2033	0.0020	0.046	1.21:1	0.053	0.048	1.26:1	0.061	0.048	1.26:1
2033-2048	0.005	0.114	1.41:1	0.143	0.129	1.58:1	0.164	0.130	1.6:1
2048-2103	0.006	0.137	1.26:1	0.163	0.147	1.35:1	0.185	0.147	1.35:1
2103-2118	0.010	0.228	1.81:1	0.242	0.218	1.73:1	0.267	0.212	1.68:1
2118-2133	0.005	0.114	1:1	0.130	0.117	1:1	0.154	0.122	1:1
2133-2148	0.004	0.091	1:1	0.100	0.010	1:1	0.116	0.092	1:1
2148-2203	0.004	0.091	1:1	0.085	0.076	1:1	0.094	0.075	1:1
2203-2218	0.002	0.046	1:1	0.062	0.056	1:1	0.073	0.058	1:1
2218-2233	0.003	0.068	1:1	0.064	0.058	1:1	0.068	0.053	1:1
2233-2248	0.001	0.023	1:1	0.04	0.036	1:1	0.044	0.035	1:1
TOTAL	0.043			1.112			1.26		

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*- T = Total
- Flush occurs when Ratio> 1
- Ratio = $\frac{\text{I/T (Loading)}}{\text{I/T (Flow)}}$
- Rain event loading data from Table 10
- I/T refers to incremental divided by total (either total flow or total loading for the particular storm)