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Storm Water Receiving Environment Monitoring Report for NPDES Permit No. WA-002465-1

Port of Seattle

June 1997

Vol. 1 Report

Exh. 426

AR 022300

PORT OF SEATTLE

STORM WATER RECEIVING ENVIRONMENT MONITORING REPORT

Prepared for

DEPARTMENT OF ECOLOGY
for NPDES Permit No. WA-002465-1

June 1997

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EXECUTIVE SUMMARY

INTRODUCTION

Ecology issued National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit No. WA-002465-1 to the Port of Seattle for the operation of Seattle-Tacoma International Airport on June 30, 1994. The NPDES Permit (hereafter referred to as the Permit) was modified on August 22, 1996.

The Port owns approximately 2,500 acres of land at Sea-Tac Airport. The Permit covers 705 acres that drain to Des Moines Creek through eight permitted outfalls, and 136 acres that drain to Miller Creek through four permitted outfalls. This study focuses on the NPDES-permitted discharges that flow to Des Moines and Miller creeks.

Special Condition S8 of the Permit requires a report evaluating the impact of storm water flow from the Airport to Miller and Des Moines creeks. The following topics are evaluated in this report:

INSTREAM TOXICITY

The instream Whole Effluent Toxicity (WET) for Miller and Des Moines creeks were determined by conducting bioassays of samples collected from storm events. Overall, there was little toxicity in any of the samples collected at outfall, upstream or downstream stations in Miller or Des Moines creeks. Little to no toxicity was observed even during deicing events. In addition, the toxicity observed was often only marginal.

SEDIMENTS

Evaluations of the impacts of storm water discharges on sediment quality in Miller Creek were inconclusive for two primary reasons. First, sediment samples collected upstream and downstream of the Little Lake Reba outlet were two distinctly different sediment types that are not comparable. Second, any effects on sediment quality from Sea-Tac Airport storm water would be masked by effects from SR 518, City of SeaTac street runoff, and other sources that discharge to Little Lake Reba. No Miller Creek sediment chemistry results, including samples collected downstream of Little Lake Reba, exceeded any established sediment quality standards or criteria.

The location of storm water outfalls prevented any Des Moines Creek sediment sample collection upstream of potential Sea-Tac Airport influence, so evaluations of downstream sediment quality centered on comparisons to other urban stream sediment quality data for the Puget Sound region. Concentrations of metals and total petroleum hydrocarbons (TPH) in Des Moines Creek sediment were within the ranges of concentrations typically found in the region. A follow-up study investigating the types and sources of TPH in storm water treatment facilities and waterbodies near the airport found that TPH concentrations were higher in Bow Lake, which does not receive any Airport storm water runoff, than in Little Lake Reba or the Northwest Ponds. Jet A fuel was not found in Little Lake Reba or Bow Lake, and only a small amount was found in the west pond of the Northwest Ponds. Sediment chemistry results for Des Moines Creek did not exceed any established sediment quality standards or criteria.

IDENTIFICATION OF OTHER SOURCES OF POLLUTANTS

Land uses within the drainage basin and other non-point pollutant sources in the vicinity of the Airport outfalls were identified. Estimated pollutant loading results from six storms were determined.

Over 62 percent of the Miller Creek basin is residential area, and over 80 percent of the Des Moines Creek basin is developed. The majority of the developments occurred prior to 1972, before King County required developments to install storm water detention and treatment facilities. Accordingly, there is a higher pollutant loading from most of the existing development than would be expected from new developments which would be required to treat storm water.

Several major roadways with high traffic volumes pass through the watersheds. Storm water from roads with these traffic volumes typically contain high concentrations of organic hydrocarbons, TSS and metals. Storm water sampling showed TPH/FOG introduced from SR 518 storm water.

Areas of the Airport that have a high potential to produce contaminated runoff drain to the IWS where the runoff is treated then discharged to Puget Sound. Since 1974, the storm drainage system area that drained into the Miller Creek basin decreased by about 14 acres (about 9 percent) due to the expansion of the IWS. The storm drainage system area that had drained into Des Moines Creek has decreased in area by approximately 98 acres due to the expansion of the area draining to the IWS.

Four outfalls contributing storm water to the Miller Creek Regional Detention Facility were sampled to estimate the relative loadings to the Miller Creek basin from Sea-Tac Airport; two outfalls to Des Moines Creek Basin were also monitored. Three storms were sampled in each basin. The storms are "snapshots in time" and, therefore, can only estimate relative contributions on a per-storm basis. Three parameters were used to estimate the pollutant loading: total suspended solids (TSS), total phosphorus, and total recoverable (TR) zinc. These three parameters were chosen because they were always present in urban storm water runoff at concentrations greater than their respective detection limits.

The loadings were estimated as a product of measured and estimated (modeled) flow and sample parameter concentration. The relative contribution of pollutant loads is small or moderate in comparison to the upstream outlet concentrations or at the Northwest Ponds or Little Lake Reba outlets.

METALS SPECIATION

Dissolved metal concentrations were monitored at storm water outfalls and at locations upstream/downstream of these discharges in Miller and Des Moines Creek. The Permit required monitoring of dissolved cadmium, copper, lead, nickel, silver, and zinc. Measured metals concentrations were compared with federal and state water quality criteria/standards.

Storm water metal concentrations were similar to those previously reported in the Annual Storm Water Monitoring Report (Port of Seattle 1996a). For Miller Creek, zinc exceeded the criterion upstream and downstream, but copper only downstream of the outfall. Copper is a common pollutant in waterbodies in the Seattle Metropolitan Area. For Des Moines Creek, copper and zinc were exceeded upstream and downstream of the outfall. However, dissolved zinc concentrations downstream of storm water discharges to Des Moines Creek only excluded the criterion 20 percent of the time. Cadmium, lead, nickel, and silver were below water quality criteria upstream and downstream of the outfalls at all times.

VEGETATION MANAGEMENT

On Port of Seattle property, riparian areas of Miller Creek are not subjected to significant vegetation management, and the creek is largely shaded by riparian vegetation. This shading protects water quality by reducing temperature increases due to solar heating. Temperatures of stormwater discharging to Miller Creek from Port property are generally at or below the temperature of receiving waters (Little Lake Reba), and thus storm water does not degrade this water quality parameter.

Portions of the Des Moines Creek riparian area is managed to facilitate golf course play, and in these areas, shading by woody vegetation is reduced. In unshaded reaches of the creek, temperatures do not appear to increase substantially, probably due to the discharge of cooler groundwater that compensates for any increased solar warming. Temperature of storm water discharges to the Des Moines Creek are generally less than those of the receiving water, and thus stormwater does not degrade this water quality parameter.

The influence of storm water on the ecological state or functioning of wetlands located in the Miller Creek Regional Detention Facility or adjacent to the Northwest Ponds cannot be determined because these areas have been subjected to a wide variety of disturbance and because baseline data in lacking. Because the timing, nature, and ecological significance of historical changes to the wetland are undocumented, the evaluation of present ecological conditions in the wetland cannot be used to differentiate or isolate potential stormwater impacts from other known disturbances.

STREAMBANK EROSION

Conditions of stream channel stability and streambank erosion in Miller and Des Moines creeks were described and analyzed. When watersheds are developed, the hydrologic conditions change and typically increase the magnitude of damaging erosive flows, and the frequency of such flows. Also, bridges, culverts, weirs, channel protection (i.e. rock or concrete), and other structures constructed in the channel will alter flow patterns and influence new erosion patterns.

Field observations in the vicinity of the Miller Creek Regional Detention Facility did not indicate any gross channel instability problems. The channel banks were found to be well-vegetated. Several structures were observed during the field reconnaissance, including fish passage structures and culverts. The lack of bank erosion or channel aggradation/degradation indicated that the channel in the vicinity of the Miller Creek Regional Detention Facility was reasonably well-adjusted to current hydrologic conditions. The Miller Creek Regional Detention Facility appeared to attenuate runoff from the Airport to Miller Creek.

A streambank and channel stability survey of Des Moines Creek was conducted to observe channel geometry, hydraulic structures, bed and bank materials, erosion and sedimentation patterns, bank erosion, mass wasting, vegetation, and surrounding development. The survey described channel and streambank characteristics and noted locations, types, and causes of erosion from the mouth to the northeast tributary (formerly known as Bow Lake Creek). Ratings of the streambank and bed stability ranged from excellent to poor.

All watershed development and channel modifications affect channel erosion and sediment transport; the system is too complex to assess the impact of specific development projects or channel modifications. Because watershed development and subsequent hydrologic changes are incremental, and large-scale erosive impacts are episodic, it is difficult to assess the direct impacts of specific watershed modifications. It is also difficult to determine system dynamics and assume that the area or volume of basin contribution to the stream flows is proportional to the impacts of the changes.

1. INTRODUCTION

This report is prepared pursuant to Special Condition S8 of the Port of Seattle's (the Port) National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit No. WA-002465-1 issued to the Port for the operation of Seattle-Tacoma International Airport (Sea-Tac Airport) on June 30, 1994.

The Port owns approximately 2,500 acres of land at Sea-Tac Airport. The NPDES Permit (the Permit) covers 705 acres that drain to Des Moines Creek through eight permitted outfalls, and 136 acres that drain to Miller Creek through four permitted outfalls. There are 247 acres, where aircraft fueling and servicing take place, that drain through the Industrial Waste System (IWS) and Industrial Waste Treatment Plant. After treatment at the IWS, the treated water is discharged directly to Puget Sound. This study is focused on NPDES permitted discharges that flow to Des Moines and Miller Creeks (Figure 1).

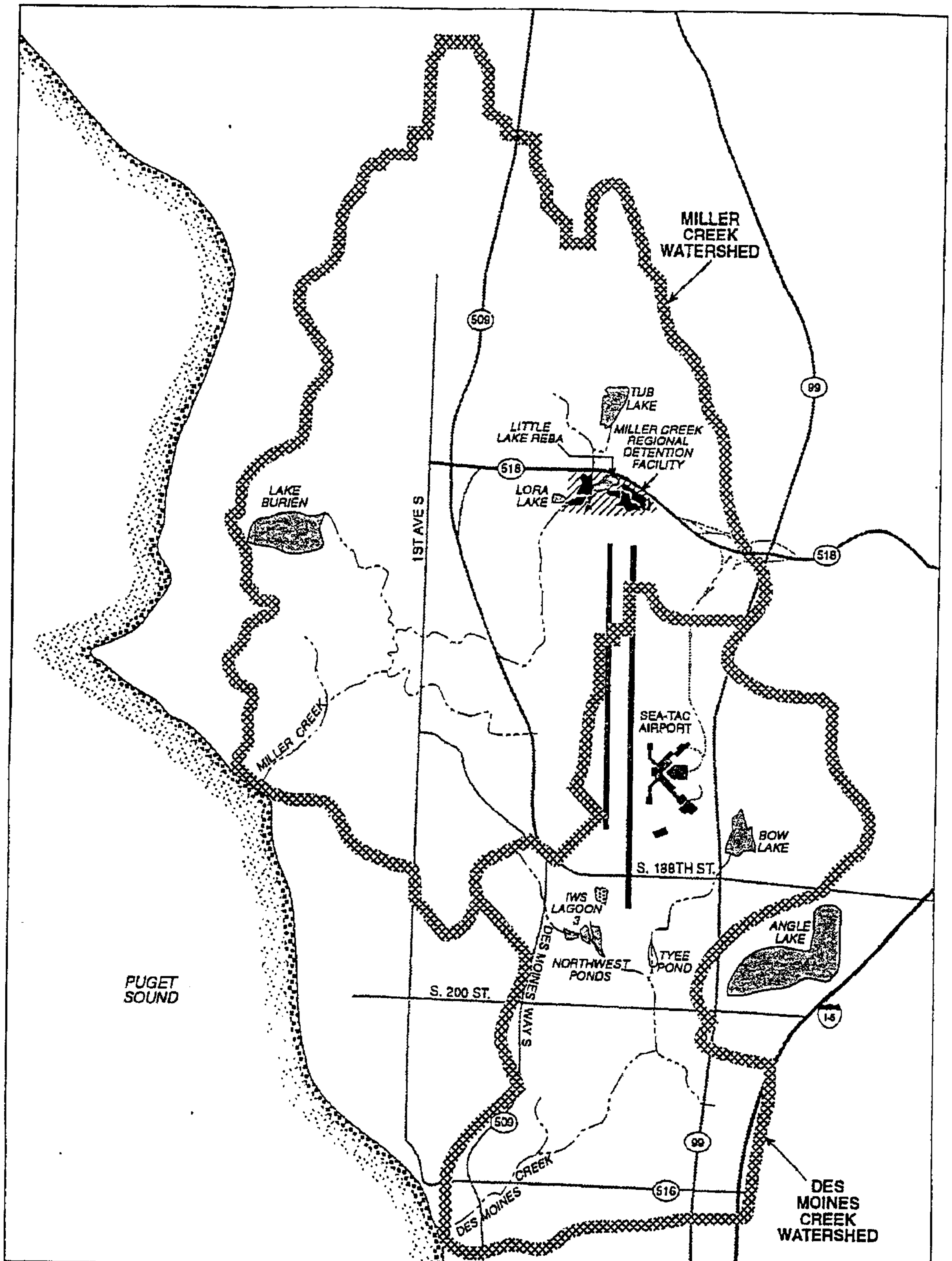
Under the permit, the Port monitors storm water at eight locations in Des Moines Creek and four locations in Miller Creek. For the purposes of this report, the outfalls to Miller and Des Moines creeks were monitored.

Prior to the expiration of the Permit, the Port is required to submit a report to Ecology, known as the Stream Effects Study, describing the results of monitoring to determine the impact of Airport storm water discharges to Miller and Des Moines creeks (see Figure 1). The purpose of this report is to meet that requirement. The report is organized to addresses the following topics, which are listed in Special Condition S8 of the permit:

- Instream toxicity
- Sediments
- Other sources of pollutants
- Metals speciation
- Vegetation management
- Streambank erosion

The report consists of this volume and a separate volume of technical reports that have been attached as appendices. The appendices include:

A. Microtox/Dissolved Metals Concentrations Raw Data for Miller Creek and Des Moines Creek.
B. Sediment Sample Data Packages
C. TPH Data Evaluation and Report (EcoChem 1996)
D. Pollutant Loading Results
E. Miller Creek Stream Effects Study for Sea-Tac Airport (WEST Consultants 1997a)
F. Des Moines Creek Stream Effects Study for Sea-Tac Airport (WEST Consultants 1997b)
G. Des Moines Creek Bank and Channel Stability Evaluation (Parametrix 1992)



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SCALE IN MILES

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- Lagoon 3
- Open Water (Lakes or Ponds)
- Palustrine Wetlands
- Watershed Boundary

Figure 1.
Miller Creek and Des Moines Creek Watersheds

The majority of data presented was collected specifically for this report. For more information on Airport storm water discharges, see the Annual Storm Water Monitoring Reports.

2. INSTREAM TOXICITY

2.1 INTRODUCTION

Under the Permit, the instream Whole Effluent Toxicity (WET) for Miller and Des Moines creeks must be determined by conducting bioassays. In addition to testing the required stations both upstream and downstream of storm water discharges, the outfall discharge itself was tested. The stations sampled are indicated in Figures 2 and 3. Instream bioassays were performed using Microtox following AZUR Environmental procedures (formerly Microbics Corporation 1992)—a method accepted by Ecology for screening level tests (Ecology 1995). From one to three replicate tests were conducted for each station sampled during a storm sampling event. This part of the study indicates if and to what degree the Port's storm water is toxic to a test organism. The test methods are first discussed (Section 2.2), followed by the test results for Miller Creek (Section 2.3) and then Des Moines Creek (Section 2.4). Appendix A contains the raw data.

Overall, there was little toxicity in any of the samples collected at outfall, upstream or downstream stations in Miller or Des Moines creeks. Little to no toxicity was observed even during deicing events. In addition, the toxicity observed was often only marginal, with EC50s of ≥ 91 percent sample.

2.2 METHODS

Microtox is a bioassay that uses luminescent bacteria commonly found in the sea as the test organism. It measures toxicity as the percent reduction of light production as a function of sample concentration. The measure of light reduction is recorded in units called gamma. Results are reported in concentrations of sample that cause 50 percent light reduction — the EC50, or effective concentration of the sample to reduce the light output by 50 percent in a specified time interval. Concentrations are reported in the raw data (Appendix A) as ppm or mg/kg, but they may also be reported as percent of sample, as in Tables 1 and 2.

Samples collected for bioassay followed the proper sample storage protocol. Samples were delivered to the King County Environmental Laboratory in Microtox-approved sample vials. Triplicate samples were generally collected at each station sampled. When the samples were received in the laboratory, the sample pH was tested to determine if it was in the expected range for surface waters. The laboratory then performed Microtox testing, including an ethanol control with each set of bioassays.

The Microtox testing, performed by the King County Environmental Laboratory, used three exposure regimes for each bioassay: 5, 15, and 30 minutes. Because Ecology generally requires the 15-minute exposure regime for rapid screening, this is the result reported herein. If the 15-minute interval test result was not toxic (toxicity is measured as reduced light emitted by the bioluminescent test bacteria) but either of the two other intervals tested was toxic, this fact was

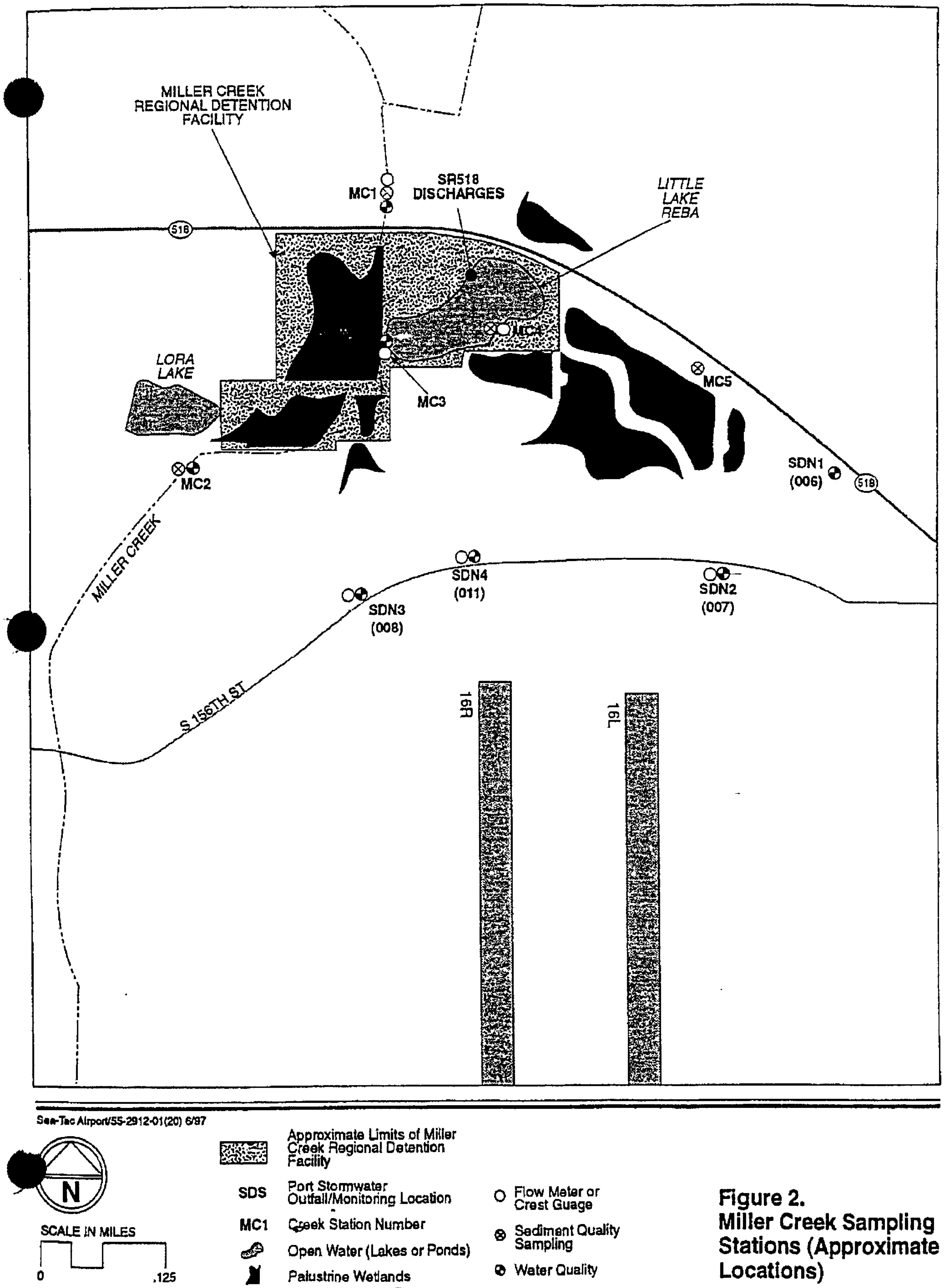
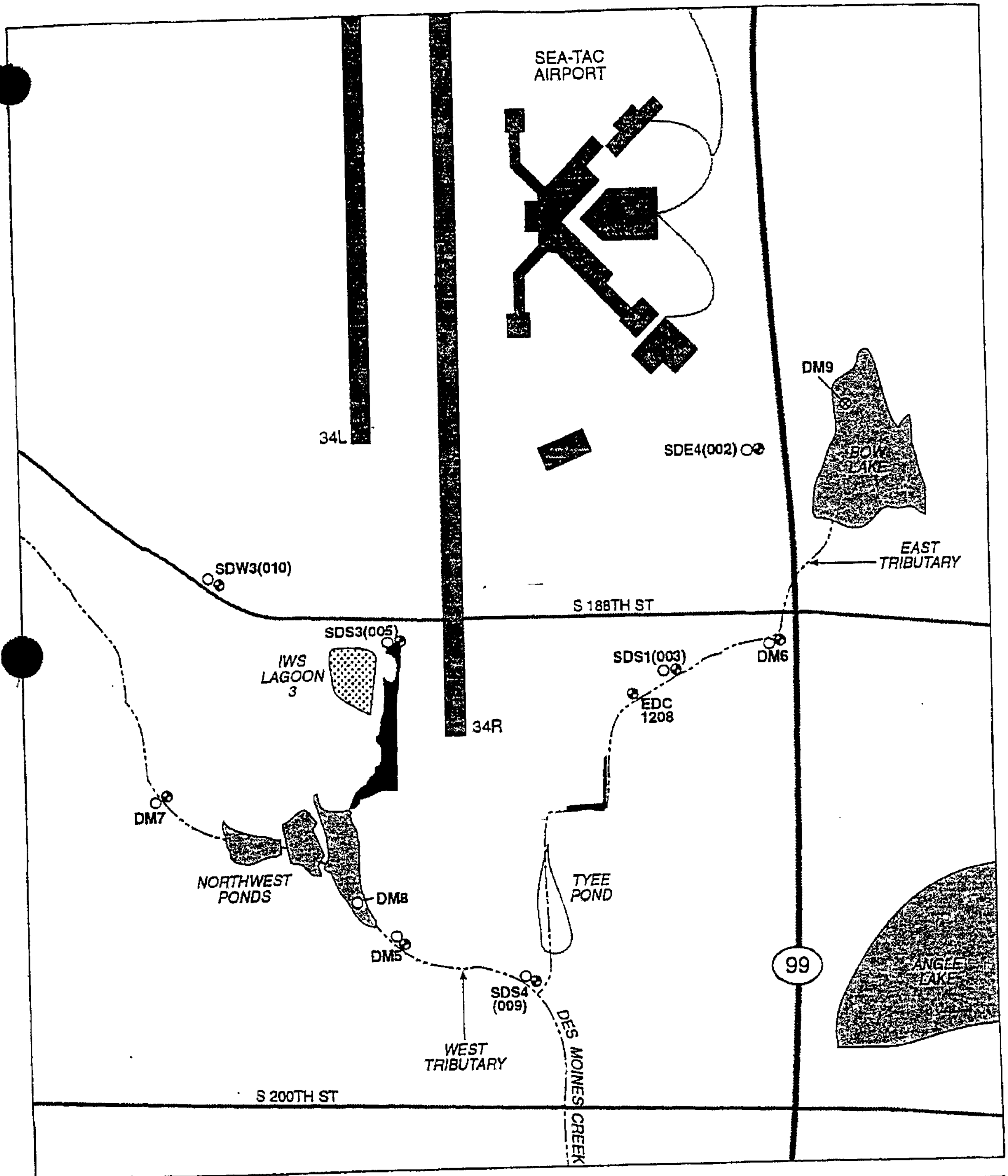


Figure 2.
Miller Creek Sampling Stations (Approximate Locations)



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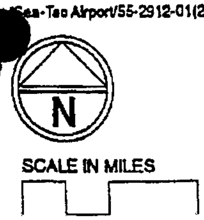

SDS Port Stormwater Outfall/Monitoring Location

DM1 Creek Station Number

Open Water (Lakes or Ponds)

○ Flow Meter or Crest Guage

⊗ Sediment Quality Sampling

Figure 3.
Des Moines Creek Basin Sampling Stations (Approximate Locations)

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footnoted. Non-toxic samples are indicated on the laboratory data sheets with the notation ">MR, 1E6,". This designation indicates the undiluted samples were not toxic at the Method Range of 1,000,000 mg/L (i.e., whole effluent). For ease in interpreting, non-toxic samples are indicated as >MR in Tables 1 and 2. Toxicity is indicated by values less than 1,000,000 mg/L or 100 percent sample. A toxic response does not indicate a specific toxicant(s).

2.3 BIOASSAYS IN MILLER CREEK

Miller Creek stations were sampled during three to seven storm events. No toxicity was observed for all but two stations and two sampling events (Table 1). Of the 78 samples collected, only five exhibited toxicity. Three of these samples were replicates collected at the same date (June 23, 1996) and location (SDN1). Four of the Miller Creek stations, including one outfall location (SDN2) and three downstream sites (MC2, MC3 and MC4), exhibited no toxicity during monitoring.

SDN1, a landside outfall[1], drains 14 acres of Air Cargo Road, SR 518 and the Food Service Facility and adjacent development. Two samples at SDN1 exhibited toxicity. This is not unexpected because the outfall sample is collected before dilution with the receiving water. What is more relevant, however, is that no toxicity was observed downstream of the outfall, once the storm water discharge had mixed with the receiving water. Importantly, on June 23, 1996 the upstream station exhibited toxicity, as did both outfalls SDN1 and SDN2. Because toxicity was observed upstream of the Airport's influence, it suggests that not all of the toxicity observed on this date may be explained by the Airport's storm water discharges. As mentioned above, SDN1 receives runoff from SR 518. Additionally, a cross-connection at Lufthansa was recently discovered and has been eliminated.

Toxicity was observed from two of the seven storm events sampled: June 23 and August 2. These samples were only moderately toxic — EC50s were ≥72 percent sample. The remaining storm water discharges did not exhibit any toxicity.

2.4 BIOASSAYS IN DES MOINES CREEK

Sampling at Des Moines Creek stations occurred during one to eight storm events. The results indicate no toxicity was observed for most stations and sampling events (Table 2). Of the 116 samples collected, only ten exhibited toxicity, and only marginally (e.g., EC50s generally ≥ 91 percent sample). Samples from one station, outfall station SDS3, which drains the majority of the airfield runways and taxiways, exhibited no toxicity during the entire course of monitoring. In early February 1996, samples from both SDS1 and SDS4 showed toxicity, but no toxicity was

[1] The storm water sampling locations for this element of the study fall into two general categories: "landside" (SDN1), and airfield (SDN2 and SDN3). Those that fall into the airfield category drain the Aircraft Movement Area (AMA), containing airport runways and taxiways. Outfall station SDN1 is associated with the landside activities of the airport, such as passenger vehicles areas and roadways.

Table 1. **Instream Microtox testing of storm water outfall and stream stations on Miller Creek.**

Station Type	Station ID	No. Sampling Events	Date Sampled (m/d/y)	No. Replicates Collected	EC50, % Sample[a]
Outfall	SDN1 (006)	5	12/10/95[d]	1	>MR[b]
			6/23/96	3	87, 76, 81
			8/2/96	1	72
			10/4/96	3	>MR
			10/21/96	3	>MR[c]
	SDN2 (007)	3	12/10/95[d]	1	>MR
			6/23/96	3	>MR
			10/4/96	3	>MR
	SDN3 (008)	3	12/10/95	1	>MR
			6/23/96	3	>MR
			10/4/96	3	>MR
Upstream	MC1	5	12/10/95[d]	1	>MR
			1/20/96[d]	3	>MR
			6/23/96	3	88, >MR, >MR
			10/4/96	3	>MR
			10/21/96	3	>MR
Downstream	MC2	7	12/10/95[d]	1	>MR
			1/20/96[d]	3	>MR
			6/23/96	3	>MR
			8/2/96	3	>MR
			10/4/96	3	>MR
			10/21/96	3	>MR
			12/30/96	2	>MR
	MC3	8	12/10/95[d]	1	>MR
			1/20/96[d]	1	>MR
			6/23/96	3	>MR
			8/2/96	3	>MR
			10/4/96	3	>MR
			10/21/96	3	>MR
			11/24/96	1	>MR
			12/30/96	2	>MR
	MC4	2	6/23/96	2	>MR
			10/4/96	3	>MR

[a] EC50 result for the replicate or replicates. If three replicate samples were tested and the results were the same for each replicate, the EC50 is listed once. If the replicates differed in toxicity, then the EC50s obtained for each replicate are provided.

[b] >MR = Greater than the Method Range of 1,000,000 mg/L. Results indicated by >MR are not toxic.

[c] The third replicate did not exhibit toxicity for the 15-minute exposure regime, but it did at the 5- and 30-minute regimes. However, neither of the other two replicates exhibited toxicity at any of the regimes.

[d] Sampling occurred during a deicing event.

observed at the downstream locations. (As the discharge mixes with the receiving water it is diluted and the toxicity eliminated.) These are the only instances of toxicity occurring when runoff was sampled during aircraft and/or runway deicing events.

Runoff was also sampled during similar deicing events in January and November 1996, and the samples were not toxic. Likewise, on one occasion, September 15, 1996, samples from downstream locations exhibited toxicity and yet samples from the Airport outfalls did not. On September 4, 1996, samples from upstream, one outfall location (SDE4) and two downstream locations exhibited toxicity. As indicated in the discussion about Miller Creek, in instances such as the latter one, it is apparent the toxicity observed cannot be explained only by the Airport storm water discharges, because upstream stations also exhibited toxicity. In addition, two of the sites exhibiting toxicity (SDE4 and SDS1) also receive non-Airport off-site storm water.

2.5 SUMMARY

Overall the Microtox results suggest only marginal and occasional toxicity. When toxicity was observed, samples rarely gave consistent results, either among replicates or over time. The laboratory reports provided 95 percent confidence bands around the effective sample concentrations that reduced light production 50 percent (EC50). These bands were very wide, meaning that the precision of the EC50 estimates is low. The upper limit in the confidence ranges was always in the non-toxic zone (EC50 >1,000,000 mg/L). The one case of somewhat consistent toxicity, outfall SDN1, is located in an area of high vehicle traffic and is affected by runoff from SR 518 and City of SeaTac streets (e.g., 24th Avenue South and South 154th Street). Detailed test results are presented in Table 1.

Overall, there was little toxicity in any of the samples collected at outfall, upstream or downstream stations in Miller or Des Moines creeks. In Miller Creek, only five of 78 samples exhibited toxicity, and on one of the two occasions on which toxicity occurred, the upstream sample was also toxic, suggesting that all of the toxicity cannot be explained by the Airport's storm water discharges. In addition, only moderate toxicity was observed, e.g., EC50s ≥ 72 percent sample.

In Des Moines Creek, only ten of 116 samples (8.6 percent) exhibited any toxicity, and generally only marginally (e.g., seven of the samples exhibiting toxicity had EC50s ≥91 percent, and replicate samples were non-toxic). As with Miller Creek, on one occasion, samples upstream of the Port's discharge, as well as the Port's discharge, exhibited toxicity, suggesting that the toxicity cannot entirely be explained by Airport activities. In addition, little or no toxicity was observed even during large deicing events, such as the one that occurred in November 1996.

Table 2. Instream Microtox testing of storm water outfall and stream stations on Des Moines Creek.

Station Type	Station ID	No. Sampling Events	Date Sampled	No. Samples Collected	EC50, % Sample[a]
Outfalls	SDE4 (002)	3	9/4/96	3	98, >MR[b], 97
			9/15/96	3	>MR[c]
			11/17/96	3	>MR
	SDS1 (003)	5	2/3/96[d]	3	74, >MR, >MR
			5/21/96	3	>MR
			9/4/96	3	>MR
			9/15/96	3	>MR
			11/17/96	3	>MR
	SDS4 (009)	1	2/3/96[d]	3	>MR, 77, 72
	SDS3 (005)	5	2/3/96[d]	3	>MR
			5/21/96	3	>MR
			9/4/96	3	>MR
			9/15/96	3	>MR
			11/17/96	3	>MR
Upstream	DM7	5	5/21/96	2	>MR
			9/4/96	3	>MR
			9/15/96	3	>MR
			11/17/96	3	>MR
			11/24/96	1	>MR
Downstream	DM6	6	1/20/96	3	>MR
			2/3/96	3	>MR
			5/21/96	3	>MR
			9/4/96	3	>MR
			9/15/96	3	>MR
			11/17/96	3	>MR
	DM5	3	9/4/96	3	>MR, 97, >MR
			9/15/96	3	>MR
			11/17/96	3	>MR
	DM3	9	1/20/96[d]	3	>MR[b]
			2/3/96[d]	3	>MR
			5/21/96	3	>MR[b]
			9/4/96	3	>MR, 99, 96
			9/15/96	3	96, >MR, >MR
			10/21/96	3	>MR
			11/17/96	3	>MR
			11/24/96	1	>MR
			12/30/96[d]	2	>MR

Table 2. Instream Microtox testing of storm water outfall and stream stations on Des Moines Creek (continued).

Station Type	Station ID	No. Sampling Events	Date Sampled	No. Samples Collected	EC50, % Sample[a]
	DM2	4	1/20/96[d]	3	>MR
			5/21/96	3	>MR
			9/15/96	3	>MR, 91, >MR
			12/30/96	2	>MR

[a] EC50 result for the replicate or replicates. If three replicate samples were tested and the results were the same for each replicate, the EC50 is listed once. If the replicates differed in toxicity, then the EC50s obtained for each replicate are provided.

[b] The 30-minute sample exhibited toxicity but the 5- and 15-minute samples did not.

[c] >MR = Greater than the Method Range of 1,000,000 mg/L. Samples indicated by >MR are not toxic.

[d] Sampling occurred during a deicing event.

3. SEDIMENTS

Part A.2 of Section S8 of the Permit requires that the Storm Water Receiving Environment Monitoring Plan address the impacts of storm water discharges on sediment quality in Miller and Des Moines creeks. This section summarizes data collected by the Port in compliance with this requirement.

3.1 MILLER CREEK

Limited historical data have been collected to characterize Miller Creek sediment quality (King County 1992). These data indicate that concentrations of common storm water contaminants in Miller Creek sediments upstream from the open water portion of Miller Creek Regional Detention Facility (a storm water detention facility built by the Port which has become known as Little Lake Reba or simply Lake Reba) are similar to sediment concentrations in Miller Creek downstream from the Little Lake Reba outlet to the mouth of Miller Creek (see Figure 2, Table 3). These concentrations are also generally in the range found in other urban stream sediments in the Puget Sound region (Beck 1992; Metro 1990; Metro 1994; Table 3).

Table 3. Ranges of historical sediment chemistry sample data (mg/kg-dry wt.) for Miller Creek and regional streams.

Site	Copper	Lead	Zinc	Total Petroleum Hydrocarbons	Total Phosphorus
Upstream from Little Lake Reba[b]	19-33	31-184	112-303	50-236	417-479
Downstream from Little Lake Reba	24-56	27-248	77-250	39-376	416-796
Regional streams	7-61	4-246	44-152	22-2,700	[a]

[a] not analyzed
[b]The open water portion of the Miller Creek Regional Detention Facility

3.1.1 Methods

To determine the impacts of storm water discharges on Miller Creek sediment quality, triplicate sediment samples were collected from Miller Creek upstream of Little Lake Reba (December 8, 1995), and downstream from Little Lake Reba (December 20, 1995). Samples designated MC1-1208-A through -C were collected approximately 100 yd upstream from the Little Lake Reba outlet (see Figure 2). Samples designated MC3-1208-A through -C were collected downstream from the outlet.

Sediment samples were collected using a $0.35m^2$ van Veen grab sampler and then placed into sample containers provided by Analytical Resources, Inc. Beyond keeping the samples on ice, no sample preservation or special handling requirements were employed because samples were delivered directly to the laboratory on the day of collection. Chain-of-custody records documented sample identifications, dates and times of collection, sample matrices, analyses required, and the signatures of individuals relinquishing and receiving the samples.

3.1.2 Results

The results of laboratory analyses, using analytical methods conforming to the *Guidelines Establishing Test Procedures for the Analysis of Pollutants* (40 CFR, Part 136), are summarized in Table 4. Copies of the laboratory data packages, including chain-of-custody records, are included in Appendix B. The data packages also included results for quality assurance samples (i.e., method blank analysis, blank spike analysis, replicate analysis, matrix spike/matrix spike duplicate analysis, laboratory control samples, and standard reference material analysis). In addition to the Miller Creek analytical results, Appendix B includes data packages for sediment samples collected within Little Lake Reba.

3.1.3 Discussion

Sample analyses indicated statistically higher concentrations of total aluminum, total copper, total lead, total zinc, total volatile solids, total kjeldahl nitrogen (TKN), total phosphate, sulfide, total organic carbon (TOC), total petroleum hydrocarbons (TPH), and percent fines in MC3 samples compared to MC1 samples; and MC3 samples showed lower percent total solids[2]. These results appear to contradict 1992 King County sampling program results that found similar concentrations of storm water contaminants in sediments collected upstream and downstream from Little Lake Reba.

The fact that TOC, percent fines, and total solids were statistically different between MC1 and MC3 raises doubt about both the representativeness and comparability of the two data sets. The percent fines at MC1 ranged from 0 to 2, and from 11 to 29 percent in MC3 samples. TOC ranged from 0.73 to 1.4 percent at MC1 and 6.4 to 7.6 percent at MC3. These order-of-magnitude differences document that the physical characteristics that influence chemical concentrations were very different between the two sampling stations. With its higher gradient and velocity, the upstream location is an environment where fine sediments are scoured and only coarse sediments (e.g., sand and gravel) are deposited. In contrast, the control structure at the downstream location creates a low-energy environment where fine sediments (e.g., silt and fine particulate organic material) accumulate.

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[2] Differences between triplicate analyses of downstream and upstream sediment concentrations were evaluated using analysis of variance (ANOVA) with alpha = 0.10.

Table 4. Miller Creek sediment quality data summary (mg/kg-dry weight).

Analyte	Method	Upstream from Lake Reba			Downstream from Lake Reba		
		MC1-1208-A	MC1-1208-B	MC1-1208-C	MC3-1208-A	MC3-1208-B	MC31208-C
Total aluminum	EPA 3050/6010	9,210	9,020	8,900	13,500	16,700	11,100
Total copper	EPA 3050/6011	17.4	8.4	9.9	22.3	47.8	19.7
Total lead	EPA 3050/6012	39	34	38	77	172	56
Total zinc	EPA 3050/6013	105	90.2	94.1	165	402	148
Soil pH (std. units)	EPA 150.1	6.1	6.5	6.2	6.6	6.7	6.6
Total solids (%)	EPA 160.3	78.5	75.3	67.1	53.2	34.8	58.6
Total volatile solids	EPA 160.4	34,000	12,000	22,000	73,000	140,000	49,000
Total Kjeldahl nitrogen	EPA 351.4	19	34	91	2,000	4,000	1,500
Total phosphate	EPA 365.2	370	260	360	410	720	490
Sulfide	EPA 376.2	<0.93 U	<0.94 U	1	540	2,300	270
Total organic carbon (%)	Plumb 1981	0.86	0.73	1.4	7.6	7	6.4
Total petroleum hydrocarbons	Mod. EPA 418.1 - IR	110	120	85	420	990	550
Percent fines (%)	PSEP #200 sieve	0	2	0	16	29	11

Because metals, nutrients, sulfide, and TPH are typically higher in sediments with high percent fines and TOC, it cannot be determined whether the differences between upstream and downstream concentrations are attributable to Little Lake Reba discharges or physical differences between sediment types. Extremely low TOC and percent fines are not representative of all sediment types found in Miller Creek upstream from Little Lake Reba, and high TOC and percent fines are not likely representative of all downstream sediment types. The chemistry results for MC1 and MC3 samples are not comparable due to their different physical characteristics.

Little Lake Reba receives storm water from multiple sources. Storm water entering Little Lake Reba includes one inlet originating at SR 518, overland flow from SR 518, and City of SeaTac urban runoff from the area north of SR 518, in addition to storm water outfalls from Sea-Tac Airport. Differences in Miller Creek sediment quality upstream and downstream from Little Lake Reba may therefore be attributable to several sources, including state highway runoff, City of SeaTac street runoff, airport runoff, and others. Other sources of storm water pollutants are addressed in Section 4 of this report.

The State of Washington has not developed freshwater sediment quality standards and no federal criteria have been established for freshwater sediments. Ecology is developing biologically based criteria for evaluating contamination in freshwater sediments; however, guidelines published by Ecology (e.g., those taken from Province of Ontario and Region V USEPA) are for reference only and are not currently endorsed or recommended by the agency (Batts and Cubbage 1995).

Comparisons to promulgated standards for marine sediments (WAC 173-204) indicate that all Miller Creek sediment sample concentrations were below standards for copper (390 mg/kg-dry wt.), lead (450 mg/kg-dry wt.), and zinc (410 mg/kg-dry wt.). No sediment quality standards are established for other parameters analyzed in Miller Creek sediments.

3.2 DES MOINES CREEK

To determine the impacts of the storm water discharges on Des Moines Creek sediment quality, triplicate sediment samples were collected from the east tributary of Des Moines Creek (samples EDC-1208-A through -C) in the Tyee Valley Golf Course on December 8, 1995 (see Figure 3). Replicate samples were also collected from the east tributary in the area of SDS-1 Outfall 003 on January 4, 1995 by the Port of Seattle (sample 1-003) and a citizen monitoring group (sample 003-S), as part of a stipulated agreement. Because storm water from the Airport enters the headwaters of Des Moines Creek, creek sediment samples could not be collected upstream from the potential influence of Airport storm water. Des Moines Creek sediment samples were collected using the same collection, handling, and analytical methods described above for Miller Creek sediments.

3.2.1 Results

The results of laboratory analyses, using analytical methods conforming to the *Guidelines Establishing Test Procedures for the Analysis of Pollutants* (40 CFR, Part 136), are summarized in Table 5. Copies of the laboratory data packages, including chain-of-custody records, are included in Appendix B. The data packages also include results for quality assurance samples (i.e., method blank analysis, blank spike analysis, replicate analysis, matrix spike/matrix spike duplicate analysis, laboratory control samples, and standard reference material analysis). Appendix B also includes data packages for triplicate sediment samples collected from the Northwest Ponds (samples NWE-A1 through -A3, NWE-B1 through -B3, NWM-C1 through -C3, NWW-D1 through -D3), the riparian corridor between Outfall 005 and Northwest Ponds (samples 005-1208-A through -C), and Bow Lake (UP-A through -C, and OUT-A through -C).

3.2.2 Discussion

Concentrations of metals and total petroleum hydrocarbons in Des Moines Creek sediment samples downstream from Sea-Tac Airport storm water discharges were within the range of concentrations commonly found in Puget Sound region urban stream sediments (Beck 1992; Metro 1990; Metro 1994; Table 6). These comparisons indicate that contributions of these pollutants from Airport storm water do not cause concentrations in downstream sediments to be elevated above the concentrations that may be expected from other urban runoff sources in the Des Moines Creek watershed. As explained above, background sediment quality data could not be collected upstream from Airport storm water outfalls on Des Moines Creek.

As previously stated, sediment quality standards have not been established for freshwater sediments. Comparisons to standards for marine sediments (WAC 173-204) indicate that all Des Moines Creek sample concentrations were below standards for copper (390 mg/kg-dry wt.), lead (450 mg/kg-dry wt.), and zinc (410 mg/kg-dry wt.). No sediment quality standards are established for other parameters analyzed in Des Moines Creek sediments.

3.3 OTHER SEDIMENT QUALITY DATA

In addition to the sediment quality data described above for Miller and Des Moines creeks, Appendix B includes analytical data packages for Sea-Tac Airport storm water sediment samples.

A follow-up study was undertaken to investigate the types and potential sources of total petroleum hydrocarbons found in storm water treatment facilities and water bodies in the vicinity of Sea-Tac Airport (EcoChem 1996, see Appendix C). Sediment samples were collected on May 24 and June 3, 1996 from the IWS Treatment Lagoon (Lagoon 3), Northwest Ponds, Little Lake Reba, and Bow Lake. These samples were analyzed for TPH and chromatographic results were compared to the patterns exhibited by certain known petroleum distillates (e.g., motor oil,

Table 5. Des Moines Creek sediment quality data summary (mg/kg-dry weight).

		East Tributary			SDS1 Outfall Area	
Analyte	Method	EDC-1208-A	EDC-1208-B	EDC-1208-C	1-003	003-S
Total aluminum	EPA 3050/6010	9,870	9,480	10,100	NA	NA
Total copper	EPA 3050/6011	25.6	23.4	20.7	23	19.6
Total lead	EPA 3050/6012	30	25	28	72	25
Total zinc	EPA 3050/6013	146	114	132	133	106
Soil pH (std. units)	EPA 150.1	6.3	6.1	6.2	NA	NA
Total solids (%)	EPA 160.3	82.6	85.7	73.9	NA	NA
Total volatile solids	EPA 160.4	12,000	9,600	<120 U	NA	NA
Total kjeldahl nitrogen	EPA 351.4	23	20	23	NA	NA
Total phosphate	EPA 365.2	290	330	340	NA	NA
Sulfide	EPA 376.2	<1.2 U	<0.86 U	<0.93 U	NA	NA
Total organic carbon (%)	Plumb 1981	1.4	0.61	0.76	NA	NA
Total petroleum hydrocarbons	Mod. EPA 418.1 - IR	210	200	380	390	570
Percent fines (%)	PSEP #200 sieve	2	1	2	NA	NA

NA = not analyzed

Table 6. Sediment quality data (mg/kg-dry wt.) for Des Moines Creek and regional streams.

Site	Copper	Lead	Zinc	Total Petroleum Hydrocarbons	Total Phosphorus
East Tributary	21-26	25-26	114-146	200-380	290-340
SDS1 Outfall Area	20-23	24-72	106-133	390-570	[a]
Regional streams	7-61	4-246	44-152	22-2,700	[a]

[a] not analyzed

Jet Fuel A, etc.) which could indicate the nature and possible origin of the TPH. EcoChem (1996) concluded that:

- Sediment TPH at the west pond stations in Northwest Ponds was predominantly motor oil, with limited Jet A fuel. Roadway storm water was identified as the most likely source of motor oil-range TPH.

- Sediment TPH at the east pond stations in Northwest Ponds was predominantly motor oil, with some mid-range TPH likely to be weathered diesel. Chromatograms did not indicate Jet A fuel.

- Sediment TPH from Little Lake Reba was predominantly motor oil, with minor components of gasoline-range and diesel-range hydrocarbons. There was no visible indication of jet fuel in the chromatograms.

- The highest sediment TPH concentrations were found in Bow Lake, which does not receive storm water from Sea-Tac Airport. The chromatograms indicated the same patterns seen in the east pond of the Northwest Ponds and Little Lake Reba sediments with TPH comprised of predominantly motor oil, some weathered diesel and a very minor component of gasoline-range hydrocarbons.

3.4 SUMMARY

The following findings summarize the impacts of storm water discharges on sediment quality in Miller and Des Moines creeks:

- Miller Creek sediment chemistry results for samples collected upstream and downstream from the open water portion of Miller Creek Regional Detention Facility (i.e., MCI and MC3) are not comparable due to their significantly different physical characteristics.

- Differences in Miller Creek sediment quality upstream and downstream from Little Lake Reba may be attributable to several sources, including state highway runoff, City of SeaTac street runoff, airport runoff, and others.

- Sediment chemistry results for Miller and Des Moines creeks did not exceed any established sediment quality standards or criteria.

- Concentrations of metals and total petroleum hydrocarbons in Des Moines Creek sediment samples downstream from Sea-Tac Airport storm water discharges were within the ranges of concentrations commonly found in Puget Sound urban stream sediments.

- Sediment TPH concentrations were higher in Bow Lake, which does not receive Sea-Tac Airport storm water, than in Little Lake Reba or Northwest Ponds.

- Jet fuel was identified as a minor component of sediment TPH only in the west pond of the Northwest Ponds, and was not found in the east pond of Northwest Ponds or in Little Lake Reba.

4. IDENTIFICATION OF OTHER SOURCES OF POLLUTANTS

4.1 INTRODUCTION

This section identifies storm water outfalls and other pollutant sources entering the creeks in the vicinity of Seattle-Tacoma International Airport that could be adversely affecting water quality in Miller Creek and Des Moines Creek. This section briefly describes each basin and their land uses, identifies other non-point pollutant sources in the vicinity of the Airport outfalls, and also presents estimated pollutant loading results from the six storms monitored, three for each basin.

4.2 MILLER CREEK BASIN

The Miller Creek drainage basin discharges into Puget Sound about 1.5 miles west of the intersection of 1st Avenue South and South 188th Street. This basin (see Figure 1) encompasses approximately 5,200 acres, including approximately 193 acres of Sea-Tac Airport runway, other non-industrial roadways and rooftops, airfield grass areas, and undeveloped property (HDR 1997).

Storm water from Sea-Tac Airport is detained and treated in the Miller Creek Regional Detention Facility. The Port constructed Little Lake Reba in 1973; and King County constructed the Miller Creek Regional Detention Facility in 1992. In addition to storm water runoff from the airfield, the detention facility also receives storm water from approximately 25 acres of SR 518, 150 acres of undeveloped Port property, food service facilities, as well as some upstream residential areas.

4.2.1 Miller Creek Land Uses and Other Sources of Pollution

Information on historical land uses within the Miller Creek basin indicate that the watershed consists of the airport, other commercial property, housing, and open space (Table 7).

Table 7. Miller Creek watershed land uses.

Classification	Area (acres)	1995 Land Use (percent of total basin)
Commercial-Airport	193	4
Commercial (Non Airport)	728	14
Multifamily Housing	260	5
Residential	2,964	57
Open Space	1,040	20

Source: Montgomery Water Group 1996

4.2.1.1 Development and Urbanization

Over 62 percent of the Miller Creek basin is residential area. The majority of the developments occurred prior to 1972, before King County required individual developments to install storm water detention and treatment facilities. Accordingly, it is likely that there is a higher pollutant loading from most of the existing Miller Creek basin developments than would be expected from new developments which would be required to treat storm water. There are also homes using septic tanks within the basin which could contribute bacteria, fecal coliform, and nutrients.

4.2.1.2 Landfill

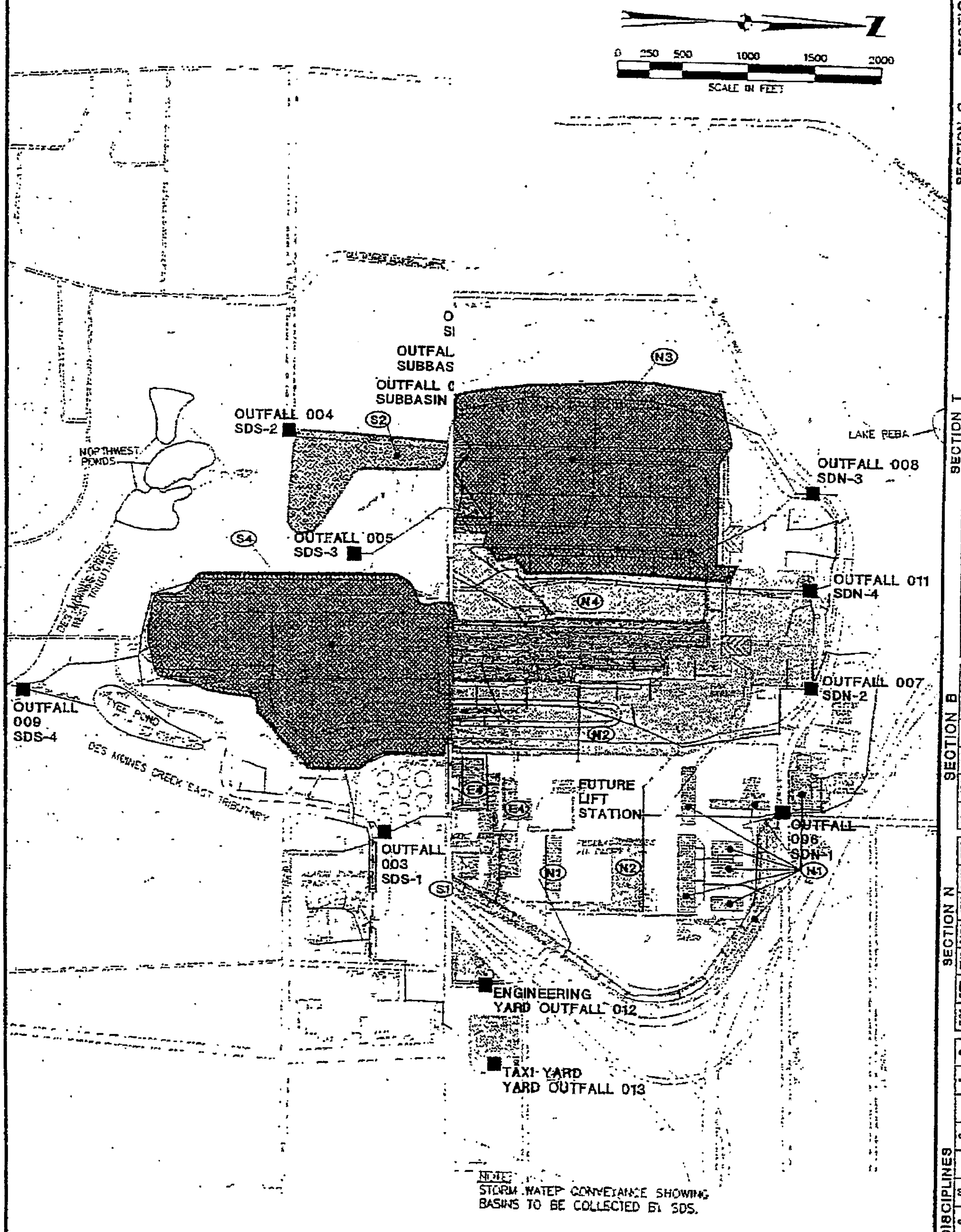
One abandoned landfill has been identified near the intersection of South 140th and 18th Avenue South, immediately north of Tub Lake. This landfill may contribute pollutants to Miller Creek. The site was used to dispose used oil between 1936 and 1942 (King County 1985). The study states "only liquid waste was deposited and . . . at least 98 percent of that was oil waste." The study also states that "oil problems remain . . . oil bubbles up in Tub lake and when there is a high water table in the area an oil sheen can sometimes be seen on the water adjacent to Tub lake." This potential source of pollution contributes contaminants upstream of the storm water inflow from Sea-Tac Airport.

4.2.1.3 Freeway

Two freeways pass through the watershed. Traffic volumes on SR 518 and SR 509 are currently about 50,000 and 57,000 vehicle per day (Port of Seattle 1996b). Storm water from roads with these traffic volumes typically contain high concentrations of organic hydrocarbons, TSS and metals. Portions of SR 518 discharge above the SDN1 storm water outfall and directly into Miller Creek Regional Detention Facility. A recent dye study confirmed that SDN1 receives storm water from SR 518. Storm water sampling showed TPH/FOG introduced from SR 518 storm water (Port of Seattle 1997).

4.2.1.4 Sea-Tac Airport

The northern portion of the Sea-Tac runways drain into the Miller Creek basin (Figure 4). There are no passenger terminals, aircraft fueling, or aircraft repair sites that drain into this basin. The estimated area of Sea-Tac Airport property in the Miller Creek basin is approximately 193 acres, which is approximately 4 percent of the Miller Creek Basin. Since 1974, the storm drainage system area that drained into the Miller Creek basin decreased by about 14 acres (about 9 percent) due to the expansion of the IWS (HDR 1997). Areas of the Airport that have a high potential to produce contaminated runoff drain to the IWS where the runoff is treated then discharged to Puget Sound.



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...ORM WATER CONVEYANCE SYSTEM

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DRAWN BY	C. OFFERM...
SCALE	AS NOTE...
DATE	DECEMBER...

WORK ORDER NO. C-3258
CONSULTANT'S NO. 94066

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4.2.2 Estimated Storm Event Pollutant Loading

4.2.2.1 Methods

As shown in Figure 4, there are four outfalls that contribute run-off to the Miller Creek basin. These four outfalls are located in the northern section of Sea-Tac Airport and drain northerly to the Miller Creek Regional Detention Facility. The outfalls contributing storm water to the facility that were sampled included the following:

- Subbasin SDN1 (006)
- Subbasin SDN2 (007)
- Subbasin SDN3 (008)

Subbasin SDN4 (011) was not sampled as the characteristics of SDN3 were considered to be representative of SDN4. Therefore, concentrations and flows were estimated using concentrations and abstraction coefficients from SDN3. To estimate the relative loadings to the Miller Creek basin from Sea-Tac Airport three storms were monitored and sampled. These three storms occurred on December 10, 1995; June 23, 1996; and October 4, 1996. The sampled storms are "snapshots in time" and are only intended to estimate relative contributions on a per-storm basis. The characteristics of each of the storms are presented in Table 8.

Table 8. Characteristics of storms sampled for loading analysis for Miller Creek basin.

Storms	December 10, 1995	June 23, 1996	October 4, 1996
Total Rainfall	1.70 inches	0.45 inch	0.45 inch
Antecedent Rainfall (72 hours)	0 inch	0 inch	0.08 inch
Rainfall Duration	49 hours	12 hours	10 hours
Sampling Period	14 hours	23 hours	12 hours
Storm Runoff Duration in Stream	ND[1]	48 hours	58 hours
Storm Runoff Duration from Sea-Tac Outfalls	ND[1]	8-13 hours	10-18 hours
Period used to estimate loading	31 hours	48 hours	58 hours

ND = Not determined

[1]The December 10 storm was a series of small rain fall events separated by periods of no rain.

Three parameters were used to estimate the pollutant loading: total suspended solids (TSS), total phosphorus, and total recoverable (TR) zinc. These three parameters were chosen because they were always present in urban storm water runoff at concentrations greater than their respective detection limits. The concentrations represent storm event-mean concentrations.

The loadings were estimated as a product of measured and estimated (modeled) flow and sample parameter concentration. The actual parameter concentrations, flow data, and loading estimates each storm are summarized in Appendix D. The concentrations represent estimated mean storm concentrations.

4.2.2.2 Results

The sampling stations near the Miller Creek Regional Detention Facility and along Miller Creek (see Figure 2) were:

- Upstream from the Miller Creek Regional Detention Facility (MC1)
- Downstream from the Miller Creek Regional Detention Facility (MC2)
- Three Port Outfalls, (SDN1 through SDN3)

The loading results from upstream and downstream of the Miller Creek Regional Detention Facility are presented in Table 9. Estimated concentrations and flow were assigned to SR 518 and other pollutant sources. The storm water runoff parameters (abstraction coefficients) for SR 518 were estimated to be similar to SND1. The area north of SR 518, was assumed to have the same abstraction coefficients as the larger upper watershed, MC1, and the pollutant concentrations were assumed to be the same as SDN3.

Table 9. Storm event pollutant loading estimates for upstream and downstream of the Miller Creek Regional Detention Facility (lbs).

	Upstream of Miller Creek Regional Detention Facility (MC1)			Downstream of Miller Creek Regional Detention Facility (MC2)		
Constituent	12/10/95	6/23/96	10/4/96	12/10/95	6/23/96	10/4/96
TSS	1,559	132	911	1,173	153	384
Total Phosphorus	9.91	1.25	4.14	10.04	0.49	4.08
TR Zinc	5.14	0.33	2.54	6.39	0.14	0.63

There are three main contributors of storm water to the Miller Creek Regional Detention Facility:

- SR 518
- Four Port outfalls
- Runoff from City of SeaTac and Burien north of SR 518

Flows from SR 518 (about 20 acres) enter the Miller Creek Regional Detention Facility from the northeast inlet and overland flow and via SDN1. The area north of SR 518 includes about 113 acres which enters Miller Creek Regional Detention Facility through the north inlet. The sampling results are presented below in Table 10.

Table 10. Storm event pollutant loading estimate for the Miller Creek Regional Detention Facility (lbs).

	SR 518[a]			Total of 4 Port Outfalls			North of SR 518		
Constituent	12/10/95	6/23/96	10/4/96	12/10/95	6/23/96	10/4/96	12/10/95	6/23/96	10/4/96
TSS	28	153	64	97	101	60	200	42	78
Total Phosphorus	0.13	0.49	0.32	0.44	1.11	0.57	0.86	0.37	0.74
TR Zinc	0.43	0.14	0.45	0.62	0.73	0.40	0.71	0.25	0.30

[a] estimated loads

The flow and loads for SR 518 and the area north of SR 518 were estimated. It was assumed that the abstract coefficients and pollutant concentrations were the same as SDN1 since the area draining SDN1 consists of roads. The area north of SR 518 was assumed to have the same abstraction coefficients as MC1 (upper water shed), and the same concentrations as SDN3.

Both total phosphorus and TSS loadings increased between upstream and downstream sampling points in two out of the three storms monitored. TR Zinc loading decreased from the upstream and downstream sampling points in two out of the three storms. Therefore, the limited data presented is inconclusive since there were no consistent trends of water quality enhancement or degradation downstream of the Miller Creek Regional Detention Facility.

4.3 DES MOINES CREEK BASIN

The Des Moines Creek Basin totals 5.8 square miles (3,712 acres) which drains into Puget Sound. The basin includes 1.1 square miles (705 acres) draining Sea-Tac Airport. The remainder of the basin is highly urbanized; a total of 80 percent of the basin is developed (Herrera 1996).

As shown in Figure 4, the majority of Sea-Tac Airport storm water drains to Des Moines Creek. Sea-Tac Airport comprises approximately 27 percent of the Des Moines Creek Basin area. As mentioned previously, 247 acres of storm water runoff form impervious areas is diverted to the IWS, then discharged into Puget Sound. Eight of these subbasins drain to Des Moines Creek as shown in Figure 4. Existing land use in the basin is listed in Table 11.

4.3.1 Potential Sources of Other Pollution

4.3.1.1 Development and Urbanization

The primary pollution source is urbanization of the watershed over the last few decades. The majority of this development occurred prior to the enactment of regulations by King County and now recently by SeaTac, and Des Moines, that require individual developments to install storm water detention and treatment facilities. Some storm water pollutants enter the creek from street runoff and other sources in the vicinity of the Sea-Tac Airport outfalls. The contribution from

Table 11. Des Moines Creek watershed land uses.

Classification	Area (acres)	Land Use 1995 (percent of total basin)
Commercial-Airport	1,002	27
Commercial	854	23
Multifamily Housing	186	5
Residential	891	24
Open Space	780	21

Source: Montgomery Water Group 1996.

street storm water are potentially sources of metals from tire wear, brake linings, galvanized flashing and other exterior metal products. Other common urban runoff pollutants are petroleum hydrocarbons from motor vehicles and equipment use, organic chemicals from decomposition of plastics, phosphorus from lawn fertilizer, coliform bacteria from wildlife, pet wastes, and failing septic tanks. In addition to vehicle pollutants, sediment originating from street dust and litter accumulation on impervious surfaces, localized soil erosion produce significant sediment loads causing high TSS concentrations are found in the creek, and elevated fecal coliform concentrations are found due to failing septic systems (King County 1997).

4.3.1.2 Golf Course

The Tyee Valley Golf Course is located south of Sea-Tac Airport. The east and west tributaries at Des Moines Creek receive overland flow from the golf course, which has landscape practices that utilize fertilizer. The golf course follows the King County best management practices manual, which minimizes water pollution.

4.3.1.3 Other Storm Water Runoff Sources

Some Port outfalls receive storm water from other sources. South 188th Street contributes storm water runoff and pollutants to outfalls SDS1 and SDS2. SR 99 contributes run-off and pollutants to SDE4 (Port of Seattle 1996a). Also, storm water runoff from the commercial area along SR 99 discharges to the east branch, which then flows through Tyee Valley Golf Course.

4.3.1.4 Sea-Tac Airport

Since 1974, the storm drainage system area that drains to Des Moines Creek has decreased in area by approximately 98 acres due to the expansion of the area draining to the IWS (HDR 1997). Areas of the Airport that have a high potential to produce contaminated runoff drain into the IWS treatment system.

There are currently 8 permitted outfalls from Sea-Tac Airport that drain south into Des Moines Creek: SDS1 through SDS4, SDE4, SDW3, and SDW3B & D. Two outfalls, SDE4 and SDS1, drain to the east tributary, upstream from Tyee detention pond. Storm water outfalls SDS2, SDS3, SDW3, B & D discharge to the Northwest ponds, then into the west tributary of Des Moines Creek. SDS4 discharges directly to the creek immediately upstream of the tributary confluence. The remaining outfalls drain directly into the west tributary. Only two of the outfalls drain directly into Des Moines Creek; SDS1 directly drains to the east tributary and SDS4 to the west tributary.

Subbasins SDS3, SDN2, SDN3, SDS4, and SDW3 have a relatively small amount of runoff from outside the Port's SWPPP boundary. In contrast, non-Port off-site storm water influences subbasins SDE4, SDS1, SDS2, and SDN1 in the following manner:

- The total area draining to SDE4 (outfall 002) contains a relatively small area (in proportion to the total SDE4 subbasin area) of commercial property and public roadway along the International Boulevard corridor within the City of SeaTac's jurisdiction.

- In addition to the SDS1 subbasin, the total area draining to the sampling point of outfall 003 contains about two acres of public road (South 188th Street). This is about 5 percent of the SDS1 drainage area. Roadway runoff could upwardly bias monitoring results for metals and petroleum hydrocarbons.

- In addition to the SDS2 subbasin, the area draining to outfall 004 includes off-site drainage from commercial property along 16th Avenue South as well as 16th Avenue South itself (about 4 acres and portions of South 188th Street). This inclusion of off-site parking and roadway storm water cannot be avoided. The first point of accumulated run-off from the total SDS2 subbasin lies downstream of the off-site storm water inputs from South 188th Street the gravel parking areas along 16th Avenue South. Because the majority of SDS2 is vegetated, storm water from the Port's area drains more slowly than the adjacent roadway's runoff. As a consequence, the offsite runoff may upwardly bias the Port's sample results for total suspended solids (TSS), turbidity, and petroleum products.

- Subbasin SDN1 (Outfall 006) receives runoff from SR 518 and nearby grassed areas. Total Port property in SDN1 is about 14 acres. Inclusion of the offsite runoff from SR 518 elevates certain pollutant concentrations detected at this location.

4.3.2 <u>Estimated Storm Event Pollutant Loading</u>

4.3.2.1 Methods

To estimate the relative loading to Des Moines Creek Basin from Sea-Tac Airport, three storms were monitored and sampled. These storms occurred on May 22, 1996; September 14, 1996; and

November 16, 1996. The storms are "snapshots in time" and therefore, can only estimate relative contributions on a per-storm basis. The characteristics of each storm are presented in Table 12.

Table 12. Characteristics of storms sampled for loading analysis for Des Moines Creek basin.

Date	May 21, 1996	September 14, 1996	November 16, 1996
Total Rainfall	0.25 inch	0.47 inch	0.36 inch
Antecedent rainfall (72 hours)	0.03 inch	0.21 inch	0.50 inch
Rainfall Duration	6 hours	12 hours	34 hours
Sampling Period	9 hours	9 hours	18 hours
Storm runoff duration in Stream	24 hours	24 ours	30 hours
Storm runoff duration from Sea-Tac outfalls	8-24 hours	14-21 hours	22-29 hours
Period used to estimate loadings	24 hours	24 hours	24 hours

As in the Miller Creek basin sampling, TSS, total phosphorus and TR zinc were analyzed for each storm at various sampling locations (see Figures 3 and 5).

Loadings were estimated as the product of measured or estimated (modeled) flow and sample parameter concentration. The actual parameter concentrations, flow data, and loading estimate for each storm are summarized in Appendix E. The concentrations represent estimated mean storm concentrations.

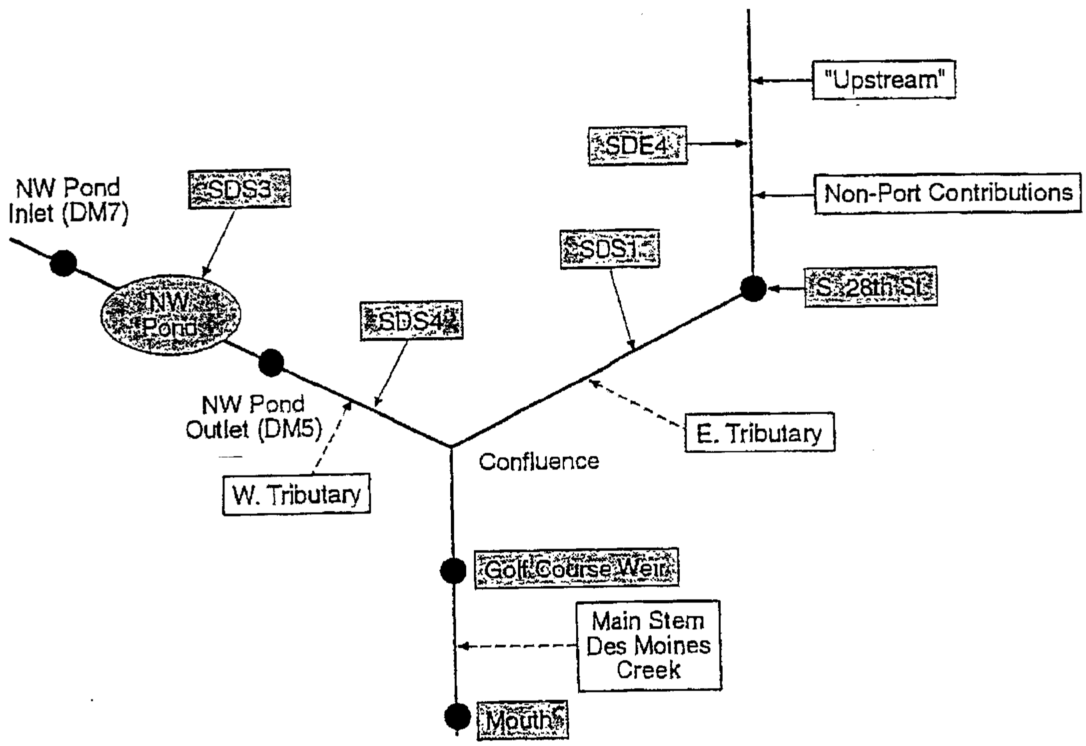
4.3.2.2 Results

<u>West Tributary</u>

The west tributary of Des Moines Creek collects groundwater and storm water from the Airport and industrial, commercial, and residential areas. Port outfalls discharge into the lower portion of the Northwest Ponds (see Figure 3). Loading results for each storm event for the Northwest Ponds are presented in Table 13.

Table 13. Storm event pollutant loading estimates for Northwest Ponds inlet and outlet (lbs).

	Northwest Pond Inlet (DM 7)			Northwest Pond Outlet (DM5)		
Constituent	5/22/96	9/14/96	11/16/96	5/22/96	9/14/96	11/16/96
TSS	31	88	90	23	6	29
Total Phosphorus	0.25	0.58	0.76	0.50	0.19	1.74
TR Zinc	0.13	0.36	0.50	0.05	0.01	0.05



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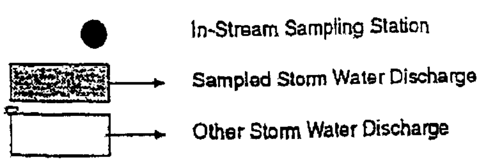

Figure 5.
Des Moines Creek Schematic for Loading Estimates

There are five outfalls from the Port that discharge into these ponds, SDS2 and SDS3, SDW3, SDW3B, and SDW3D. Other pollutant sources from the commercial park north of ponds and residential storm drains which could be contributing loading to the Northwest ponds were not measured. Water quality generally improved between the inlet and outlet of the Northwest Ponds with the exception of phosphorus, which is a common pollutant released from ponds or wetland treatment systems (see Table 13). SDS3 has a substantially larger subbasin than that others, and was the only outfall sampled. The loadings from outfall SDS3 for each of the storms are summarized in Table 14.

Table 14. Storm event pollutant loading estimates for SDS3 (lbs).

Constituent	5/22/96	9/14/96	11/16/96
TSS	10	38	101
Total Phosphorus	0.21	0.57	0.61
TR Zinc	0.14	0.27	0.33

SDS4 discharges into the west tributary downstream from the Northwest Ponds. The loading estimates for each of the three storms analyzed are presented in Table 15.

Table 15. Storm event pollutant loading estimates for SDS4 (lbs).

Constituent	5/22/96	9/14/96	11/16/96
TSS	3	6	13
Total Phosphorus	0.05	0.10	0.08
TR Zinc	0.02	0.05	0.04

The relative contribution from SDS4 is very small in comparison to the outlet concentrations of Northwest Ponds. There were no concentrations measured downstream from SDS4, therefore overall contributions to the west tributary could not be estimated.

East Tributary

The east tributary flows from Bow Lake, under South 28th Street, and through Tyee Pond (see Figures 3 and 5). There were three sampling locations on the east tributary:

- South 28th Street
- SDE4
- SDS1

The estimated constituent loadings for the east tributary upstream from Port storm water outfalls are summarized in Table 16. The upstream concentrations were estimated by subtracting the loading from SDE4 from the loading measured at South 28th Street.

Table 16. Storm event pollutant loading estimates for east tributary upstream* of the Sea-Tac Airport outfalls (lbs).

Constituent	5/22/96	9/14/96	11/16/96
TSS	68	287	134
Total Phosphorus	0.43	1.82	1.28
TR Zinc	0.01[1]	0.8	0.81

*Upstream concentrations were estimated by subtracting loading from South 28th Street from SDE4
[1]Value estimate

There were two storm drains monitored that discharge into the east tributary (SDE4 and SDS1) (Figure 3). The estimated loadings from the two Port outfalls monitored are summarized by storm in Table 17.

Table 17. Storm event pollutant loading estimates from the Sea-Tac Airport outfalls (lbs).

	SDE4			SDS1		
Constituent	5/22/96	9/14/96	11/16/96	5/22/96	9/14/96	11/16/96
TSS	24	74	140	2	2	1
Total Phosphorus	0.18	0.45	0.60	0.02	0.03	0.02
TR Zinc	0.64	0.69	0.56	0.02	0.05	0.03

There were no sampling stations downstream from the Airport discharge points and upstream from the east tributary confluence with the west tributary. Therefore, overall loading for the east tributary could not be estimated.

There were two sampling points downstream from the confluence of east and west tributaries; the golf course weir and the mouth of the creek. The estimated loadings are presented in Table 18.

Table 18. Storm event pollutant loading estimates for golf course weir and mouth of Des Moines Creek (lbs).

	Golf Course Weir (DM3)			Mouth		
Constituent	5/22/96	9/14/96	11/16/96	5/22/96	9/14/96	11/16/96
TSS	335	697	506	856	3,764	3,925
Total Phosphorus	2.30	3.41	4.67	3.66	12.19	7.26
TR Zinc	1.05	1.62	2.04	0.70	2.01	2.96

The relative contribution of loading from SDE4 and SDS1 is very small compared to the total loading in the creek. Also shown in Table 18, constituent loadings increased from the golf course weir to the mouth of the Des Moines Creek indicating additional pollutant sources downstream from the Port property.

5. METALS SPECIATION

5.1 METALS CONCENTRATIONS

The Permit requires an assessment of dissolved forms of cadmium, copper, lead, nickel, silver, and zinc in storm water discharged to Miller and Des Moines creeks. In ambient waters downstream and upstream of the storm water discharges to Miller Creek, dissolved cadmium and silver[3] are not detectable; thus, they were not included in this study. In Des Moines Creek samples, dissolved cadmium was occasionally present, and therefore it was included in the study for that stream. Dissolved lead was not frequently detected downstream of the outfalls; however, because it was occasionally detected, it was included in the study along with copper, nickel, and zinc.

Concentrations of total recoverable copper in ambient waters downstream of the storm water discharges generally exceeded both the EPA and State acute criteria, while concentrations of total recoverable cadmium, lead, and zinc did not. Copper is a common pollutant in waterbodies in the Seattle Metropolitan area. Monitoring by Metro found exceedances of the acute copper criterion in many of the sites samples, including rivers (e.g. Green River) and creeks (e.g., Coal Creek, Kelsey Creek) (Metro 1989).

5.2 METHODS

For this study, storm water samples were collected on the following dates:

Miller Creek	Des Moines Creek
December 10, 1995	May 17, 1996
June 23, 1996	May 21-22, 1996
August 2, 1996	September 3, 1996
October 4, 1996	September 14, 1996
October 21, 1996[4]	October 21, 1996
December 10, 1996	November 17, 1996

In general, triplicate samples were collected at each outfall, upstream and downstream station. Most of the samples were analyzed for all of the metals covered in the study. The sample set size for each analyte is indicated in the tables in Section 5.3 and by date in the raw data in Appendix A.

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3 The Port requested relief from the requirement for analyzing silver in a letter to Ecology (Lisa Zinner) dated 9 August 1996. Ecology responded affirmatively on 14 August 1996 in a letter to Michael Feldman of the Port (Ecology 1996).

4 A double storm was sampled on October 21, 1996.

Samples were collected using equipment appropriate for metals sampling, such as teflon tubing. Equipment was washed between sampling events. Twenty-four bottle ISCO 3700 compositors were used, with all metals parts in the sampling system removed and replaced with plastic or equivalent. Sample compositing was done manually with flow rate proportional samples based on hydrograph data.

Samples were delivered to the analytical laboratory with chain-of-custody forms indicating the analyses to be performed. Total recoverable and dissolved metals were analyzed using Inductively Coupled Plasma Mass Spectrometer (ICP-MS). The Method Detection Limit (MDL) achieved was 0.5 μg/L[5], and the Reporting Detection Limit Achieved was 0.2 μg/L.

Included with each sample batch were method blanks, matrix spikes, and duplicate spikes. The data were qualified as necessary — see Appendix A for details on the qualifiers applied.

The data are summarized to show the range, median, mean and 95th percentile values obtained by station type (e.g., outfall, upstream or downstream locations) and creek. The results are then compared to (1) those reported in the Annual Storm Water Monitoring Report (Port of Seattle 1996a), (2) the comparator values, and (3) the State[6] and EPA water quality criteria. To calculate the mean, nondetectable concentrations were replaced with one-half the detection limit.

The majority of the discussion of the results focuses on dissolved versus total recoverable metals concentrations because this is the bioavailable fraction, thus, that which is potentially toxic to biota.

5.3 RESULTS

The total recoverable and dissolved metals concentrations in the discharge and samples collected at both upstream and downstream stations are summarized in Tables 19 and 20. Total recoverable copper, lead and zinc concentrations in the storm water discharge measured during this study were similar to those reported in the Annual Storm Water Monitoring Report (Port of Seattle 1996a), although the detection limits achieved in this study were much lower. Metals concentrations were generally above the comparative median values of 10.4, 26.3 and 161.4 μg/L, respectively, which is consistent with findings discussed in the Annual Storm Water Monitoring Report (Port of Seattle 1996a).

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5 In a few instances a detection limit of 0.2 μg/L was achieved for cadmium and lead.

6 The comparison to State standards is strictly of total recoverable metals.

Table 19. **Range of total recoverable and dissolved metals concentrations (µg/L) for Miller Creek.**

Metal	Upstream[a]	Outfall[b]	Downstream[c]	Criteria[d]/(Standards[e])
Total Recoverable				
Copper	4.7-14.8	4.2-82.9	0.72-44	4.4 (5.3)
Lead	5.2-34.7	<0.5-21.6	<0.5-106	12.6 (16)
Nickel	2.1-5.4	0.81-6.2	1.0-20.2	409 (483)
Zinc	37-69	15-525	2.3-295	33.7 (40)
Dissolved				
Copper	3.1-11.5	2.8-74.8	<0.5-7.8	4.2
Lead	<0.5-1.1	<0.5-1.9	<0.5-0.96	12.6
Nickel	1.4-4.5	<0.5-5.2	1.1-4.2	408
Zinc	19.1-46.5	10.8-494	0.83-26	32.9
Hardness, mg/L $CaCO_3$	23-58	9-84	30-170	--

[a] The upstream station is MC1.

[b] Outfall stations include stations SDN1, SDN2, and SDN3.

[c] Downstream stations include MC2, MC3 and MC4.

[d] Acute criteria are calculated at 23 mg/L $CaCO_3$ for Miller Creek and 35.6 mg/L $CaCO_3$ for Des Moines Creek, which is the 10th percentile for these receiving waters, calculated on hardness measured during this study. The dissolved criteria are based on EPA's (EPA 1996) translator factors to convert from total recoverable to dissolved.

[e] Ecology criteria are for class AA receiving waters, see WAC 173-201A.

Table 21 presents comparator values. As in the Annual Storm Water Monitoring Report (Port of Seattle 1996a), the "best" comparison was selected as the more conservative of either of the two City of Bellevue studies, because they were comprehensive, local studies. **However, caution must be exercised in comparing storm water quality data because the Washington State water quality standards for certain metals apply to the receiving waters, not to the discharge at end of pipe.**

Maximum concentrations of dissolved metals measured in Miller Creek only exceeded EPA's and the State's acute criteria for aquatic life for copper and zinc. Copper and zinc criteria were exceeded in samples from both upstream of the storm water discharges and in the storm water discharge itself, but only copper was exceeded downstream of the outfall. Likewise, in Des Moines Creek, only copper and zinc concentrations exceeded the criteria. Copper and zinc were exceeded in samples from both upstream and downstream of the discharge, as well as in the storm water discharge itself. However, dissolved zinc concentrations downstream of storm water discharges in Des Moines Creek only exceeded the criterion about 20 percent of the time. None of the other dissolved metals exceeded the criteria except cadmium, which exceeded the criterion in only two instances. Dissolved nickel concentrations, even at their highest (5.3 µg/L), were

Table 22. Summary of dissolved metals concentrations in Miller Creek, µg/L.

	Copper	Lead	Nickel	Zinc
Dissolved metals concentrations in the upstream receiving water				
Detection limit	0.5	0.5	0.5	0.5
Number analyzed	9	9	9	9
Non detects	0	1	0	0
% nondetect	0%	11%	0%	0%
Median	3.66	0.29	1.44	11.90
Mean (using ½ DL)[a]	6.69	0.85	2.49	31.47
95th percentile	13.87	1.43	5.31	54.78
Acute criteria	4.26	12.64	408.23	32.95
Dissolved metals concentrations in all outfall stations combined				
Detection limit	0.5	0.5	0.5	0.5
Number analyzed	30	30	30	30
Non detects	0	17	4	0
% nondetect	0%	57%	13%	0%
Median	20.68	0.57	1.37	146.13
Mean (using ½ DL)[a]	17.29	0.67	1.72	113.59
95th percentile	53.01	1.64	4.08	365.98
Acute criteria	4.26	12.64	408.23	32.95
Dissolved metals concentrations in the downstream receiving water, all stations combined				
Detection limit	0.5	0.5	0.5	0.5
Number analyzed	34	32	32	34
Non detects	1	19	0	0
% nondetect	3%	59%	0%	0%
Median	1.87	0.30	0.82	6.30
Mean (using ½ DL)[a]	3.70	0.49	1.94	13.96
95th percentile	6.91	1.01	3.35	24.77
Acute criteria	4.26	12.64	408.23	32.95

[a] One-half the detection limit was used in calculating the mean when the laboratory indicated the measured concentration was less than the detection limit.

At Des Moines Creek, dissolved copper concentrations were highest in samples from the storm water outfalls, particularly SDS3 (45.5 µg/L) and SDE4 (34 µg/L). These outfalls collect storm water from a basin with a high level of vehicular traffic. The highest measured concentration at SDS1 was 27 µg/L dissolved copper. Downstream dissolved copper concentrations were all <15.2 µg/L. Median dissolved copper concentrations were above the criterion at the upstream site.

Table 23. Summary of dissolved metals concentrations in Des Moines Creek, μg/L.

	Cd	Cu	Pb	Ni	Zn
Dissolved metals concentrations in the upstream receiving water					
Detection limit	0.2	0.5	0.5	0.5	0.5
Number analyzed	6	12	6	6	12
Non detects	5	0	0	0	0
% nondetect	83%	0%	0%	0%	0%
Median	0.10	5.19	0.57	1.40	14.01
Mean (using ½ DL)[a]	0.12	4.95	0.57	1.41	15.28
95th percentile	0.23	10.31	0.64	2.43	39.80
Acute criteria	0.83	4.64	14.01	441.03	35.60
Dissolved metals concentrations in all outfall stations combined					
Detection limit	0.2	0.5	0.5	0.5	0.5
Number analyzed	30	40	30	30	40
Non detects	3	0	9	0	0
% nondetect	10%	0%	30%	0%	0%
Median	0.44	25.95	0.65	1.70	73.25
Mean (using ½ DL)[a]	0.47	23.76	0.99	2.24	67.33
95th percentile	0.87	41.06	2.53	4.30	143.63
Acute criteria	0.83	4.64	14.01	441.03	35.60
Dissolved metals concentrations in the downstream receiving water, all stations combined					
Detection limit	0.2	0.5	0.5	0.5	0.5
Number analyzed	48	56	49	49	55
Non detects	40	0	17	0	0
% nondetect	83%	0%	35%	0%	0%
Median	0.10	6.66	0.58	1.90	18.80
Mean (using ½ DL)[a]	0.12	6.95	0.62	1.85	24.94
95th percentile	0.22	12.12	1.28	2.69	60.01
Acute criteria	0.83	4.64	14.01	441.03	35.60

[a] One-half the detection limit was used in calculating the mean when the laboratory indicated the measured concentration was less than the detection limit.

5.3.3 Lead

At all Miller Creek stations, dissolved lead concentrations were low. The maximum concentration observed (1.9 μg/L) was in discharges from SDN1. Upstream and downstream dissolved lead concentrations did not exceed 1.1 μg/L. No concentrations exceeded the criterion (12.64 μg/L). The same was true for Des Moines Creek. Dissolved lead concentrations were highest in discharge from the outfalls (maximum of 3.2 μg/L)—not approaching the criterion of 14.01 μg/L.

5.3.4 Nickel

Because dissolved nickel concentrations were similar regardless of the station sampled (e.g., upstream, downstream, or at the outfall), the value of monitoring nickel is questionable. Generally, dissolved nickel concentrations measured less than 1.8 μg/L at all of the Miller and Des Moines creek stations. During the June 23, 1996 sampling event, elevated nickel concentrations were observed, but these concentrations still fell well below the acute criterion for protection of aquatic life. Concentrations never exceeded 5.3 μg/L at either creek—far below the criteria (> 400 μg/L).

5.3.5 Zinc

The highest dissolved zinc concentrations were found in Miller Creek samples collected from SDN1 (maximum concentration of 494 μg/L). The upstream station and SDN2 had similar maximum dissolved concentrations of 46 and 45 μg/L, respectively. The upstream location did not exceed 46.5 μg/L dissolved zinc, and the maximum downstream concentration (26 μg/L) was below the criterion of 32.9 μg/L.

The median zinc concentration (18.8 μg/L) downstream of the storm water discharges was below the acute criterion (35.6 μg/L[8]); however the 95th percentile concentration was above the criterion. Des Moines Creek outfalls SDE4 and SDS1 had the highest dissolved zinc concentrations measuring ~175 and 109 μg/L, respectively. Concentrations at the remaining upstream, downstream, and outfall locations were less than 85 μg/L.

[8] Note, the criteria for hardness dependent metals are slightly different for the two creeks.

6. VEGETATION MANAGEMENT

The Permit requires that the relationship between stream bank vegetation, TSS, and temperature effects be described along those reaches of Miller and Des Moines creeks located near Sea-Tac Airport. This section discusses streambank (riparian) vegetation, vegetation management, and creek temperature. The evaluation is limited to those portions of Miller and Des Moines creeks on Port property and in the vicinity of storm water outfalls.

Riparian vegetation along Miller and Des Moines creeks in the vicinity of storm water discharges were assessed to describe the species composition of dominant riparian plants, the general vegetation structure of riparian plant communities, and the approximate stream cover (shade) provided by these communities. The results of these evaluations are described in Section 6.1 below. The potential effect of storm water discharge and vegetation management on stream temperature regimes is discussed in Section 6.2. The relationship between vegetation management and TSS is discussed in Section 7, Streambank Erosion.

The results of these evaluations show that a lack of vegetation management on Miller Creek results in high shading of the creek which is protective of stream temperatures. Vegetation management along Des Moines Creek prevents 100 percent shading in some areas. However, temperature monitoring showed that stream temperatures decline across the least shaded stream segment and that lack of shade does not appear to adversely impact stream temperature in downstream reaches. For nearly all sampling periods, storm water temperatures measured in storm water outfalls were found to be generally cooler than the temperatures of receiving waters, indicating storm water discharge temperatures are not detrimental to Miller or Des Moines creeks.

6.1 EXISTING RIPARIAN VEGETATION AND VEGETATION MANAGEMENT

Riparian vegetation rooted on or near streambanks provides shade and soil stabilization to Miller and Des Moines creeks. Any management practices that remove riparian vegetation may increase water temperatures by increasing the solar radiation to the stream. Stream temperature increases are of particular concern to habitat supporting cold-water fish species, particularly during summer months when warm air temperatures, low baseflows, and high solar radiation can produce higher-than-optimal stream temperatures. Removal of bank vegetation may also increase streambank erosion, reducing removal of sediment and pollutants from overland flow. Sediment derived from bank erosion can degrade water quality (by increasing TSS and turbidity) and stream habitat (due to sediment deposition in gravel or feeding areas), and stress or kill aquatic biota.

6.1.1 Miller Creek

Miller Creek crosses Port of Seattle property between SR 518 and Lora Lake (see Figure 1). In this area, the creek is largely bordered by wetlands, and lies within the Miller Creek Regional Detention Facility (built in 1992 by King County). The outlet control structure for this facility is located near the western edge of Port property; during larger storm events, these wetlands are inundated for periods of 24 to 36 hours. An open-water portion of the Miller Creek Regional Detention Facility, also referred to as Little Lake Reba, was constructed by the Port in 1973. Storm water from four storm water outfalls (SDN1, SDN2, SDN3, and SDN4) is routed through wetlands adjacent to Little Lake Reba before it enters the Miller Creek Regional Detention Facility.

In general, the Miller Creek riparian area on Port property is vegetated with emergent, forest, and shrub wetland plant species that provide nearly complete shade and canopy coverage to the creek. The Port's vegetation management policy in this area is to allow native plant communities to develop. If these communities attract wildlife to unacceptable levels for airport safety, vegetation management may be required to reduce wildlife attraction.

Between the point where Miller Creek emerges from the culvert beneath SR 518 and enters a culvert beneath an emergency access road to the south (about 800 linear ft), the riparian area is dominated by Pacific and Sitka willow trees. Where tree and shrub cover is less dense, the riparian area contains reed canary grass, tall manna grass, and nightshade. Vegetation cover over the stream approaches 100 percent. This area appears to have been largely undisturbed since construction of Little Lake Reba in 1973.

Between the emergency access road and the control structure for the Miller Creek Regional Detention Facility (approximately 700 linear ft), Miller Creek is bordered by trees and emergent vegetation. Trees in this area include red alder and black cottonwood, with shrub understory vegetation consisting of salmonberry and red elderberry. Where forest cover is lacking, emergent vegetation—including cattail and reed canary grass—covers the stream channel. Plant communities in this area are not disturbed by ongoing vegetation management. Construction of the Miller Creek Regional Detention Facility by King County in 1992 disturbed a small area of stream channel and wetland, but these areas were restored.

Little Lake Reba is a shallow open-water body, bordered by shrub and forested wetland. Shrub communities bordering the open-water area contain Sitka willow and hardhack. Portions of the wetland bordering the facility also contain red alder and big-leaf maple trees. No significant ongoing vegetation management occurs in this area, and it appears to have been largely undisturbed since the facility was constructed.

The additional forested wetland areas that lie east of Little Lake Reba are dominated by black cottonwood and Pacific willow trees. These wetlands are not subject to significant vegetation management, and appear to have been largely undisturbed since construction of Little Lake Reba in 1973.

6.1.2 Des Moines Creek

Des Moines Creek crosses the Tyee Golf Course (Port property) at the south end of Sea-Tac Airport (see Figure 1). In this area, Des Moines Creek includes a west tributary, which originates three shallow, open-water ponds (Northwest Ponds) and an east tributary, which originates at Bow Lake. The west tributary of Des Moines Creek receives storm water from outfalls SDS2, SDS3, SDS4, SDW3B, and SDW3D. The east tributary of Des Moines Creek receives storm water from outfalls SDS1 and SDE4. The riparian vegetation adjacent to these reaches of Des Moines Creek contains a variety of trees, shrubs, and herbaceous plants; much of this vegetation is managed to accommodate Tyee Valley Golf Course operations.

On the west tributary, from the outlet of the Northwest Ponds downstream to the approximate location of outfall SDS4 (approximately 900 ft), the riparian areas of Des Moines Creek are dominated by emergent wetland plant species. Common species include common cattail, nightshade, purple loosestrife, reed canary grass, and soft rush. Vegetation management includes periodic mowing to within about 10 to 15 ft of the creek channel and removal of most woody vegetation along the channel. Throughout the area, the ground surface is nearly 100 percent vegetated, while vegetation shading over the water surface ranges from about 25 to 75 percent.

From SDS4 downstream to South 200th Street, riparian vegetation is a combination of forested upland and herbaceous plant communities. Forested communities border about 700 ft of the stream banks in this area and consist of red alder, black cottonwood, and sitka willow. While ice and snow during December 1996 damaged some trees, this vegetation still provides 25 to 100 percent shade to the stream. Non-wetland herbaceous communities border about 300 ft of stream bank in this area. They are dominated by reed canary grass and cultivated lawn grasses that provide little shade to the creek. The non-forested portions of the streambank are managed to prevent tree or shrub vegetation from interfering with golfing.

The Northwest Ponds are unvegetated open-water areas bordered by forested and shrub wetlands. Forested areas adjacent to the ponds are dominated by red alder and black cottonwood. In shrub-dominated areas Sitka willow, Pacific willow, and red-osier dogwood are predominate. Near the perimeter of the ponds, limited emergent vegetation, consisting of bentgrass, smartweed, cattail, or purple loosestrife is present. About 800 ft along the east bank of the pond is mowed as part of the golf course.

Riparian areas along the east tributary of Des Moines Creek begin where the creek daylights near a parking area. Throughout the parking area, the creek is densely to moderately shaded by a vegetation buffer consisting of blackberry, red alder, and black cottonwood. Downstream (south) of the parking area, the creek flows through the Tyee Valley Golf Course and Tyee pond. Golf course vegetation management results in little to no shading in a small reach of the creek. About 200 ft of culvert (the outlet of Tyee Pond) provide 100 percent shade to the creek. Within the pond itself, densely planted willow, alder, and black cottonwood provide nearly complete shading of the creek channel and form a buffer about 50 ft in width. The buffer is not subject to routine vegetation management but could be managed to reduce wildlife attractants. The non-buffer portions of the pond are routinely mowed.

6.2 TEMPERATURE EFFECTS

In natural streams, temperature is recognized as a critical indicator of health for aquatic life. In the Pacific Northwest, the primary biological concern related to stream temperature is its effect on salmonid fisheries, such as those that occur in the lower reaches of Miller and Des Moines creeks downstream of Port property. The water temperature tolerance ranges for fish include optimal and lethal levels that vary by species and life history stage (Reiser and Bjornn 1979). In addition to these tolerance ranges and their effects on fish, water temperatures affect other ecosystem organisms and processes that can also indirectly effect fish populations. For example, water temperatures influence microbial, algae, and invertebrate communities that form the energy base for fish communities (Beschta et al. 1987). Changes in the quantity or quality of these communities can potentially impact fish populations by changing available food.

For small streams in western Washington, a dense forest canopy typically shades nearly all of the water surface from the solar radiation that heats the streams. Removing this canopy can significantly affect stream temperatures by increasing the solar radiation reaching the stream. In developed areas, storm water runoff may be another factor influencing stream temperatures. The degree to which this occurs depends on the flow-weighted temperature differences between storm water discharges and the receiving water.

For Miller and Des Moines creeks, the permanently saturated wetlands and visible seep areas near the perimeter of these wetlands suggests groundwater discharge is present in the vicinity of constructed ponds. This groundwater inflow may be an important cooling mechanism for these streams.

6.2.1 Miller Creek

Temperature monitoring of Miller Creek, Little Lake Reba, and associated storm water outfalls was conducted to determine if storm water or vegetation management affects stream temperatures. The monitoring results are summarized in Table 24.

As discussed in Section 6.1, Miller Creek has a high percentage of the shaded stream surface. The effect of vegetation management along Miller Creek is to provide nearly total shade to the creek, thus minimizing solar heating of the creek water.

Table 24. Summary of mean water temperatures (°C) at Miller Creek, Little Lake Reba, and adjacent storm water outfalls[1].

Station	Period: Fall 11/29/95 -12/19/95	Summer 6/16/96- 6/28/96	Fall 10/30/96- 12/11/96	Winter 1/1/97- 1/10/97	Winter 1/28/97- 2/21/97
Miller Creek upstream (MC1)	7.3	13.9	7.1	6.0	6.4
Miller Creek upstream (MC2)	7.1	16.2	6.9	6.2	6.4
Little Lake Reba Outlet (MC3)	6.9	20.4	ND	6.7	6.7
Storm water (SDN1)	ND	12.6	ND	ND	ND
Storm water (SDN2)	ND	13.9	ND	ND	ND
Storm water (SDN3)	7.9	12.7	ND	8.6	8.5

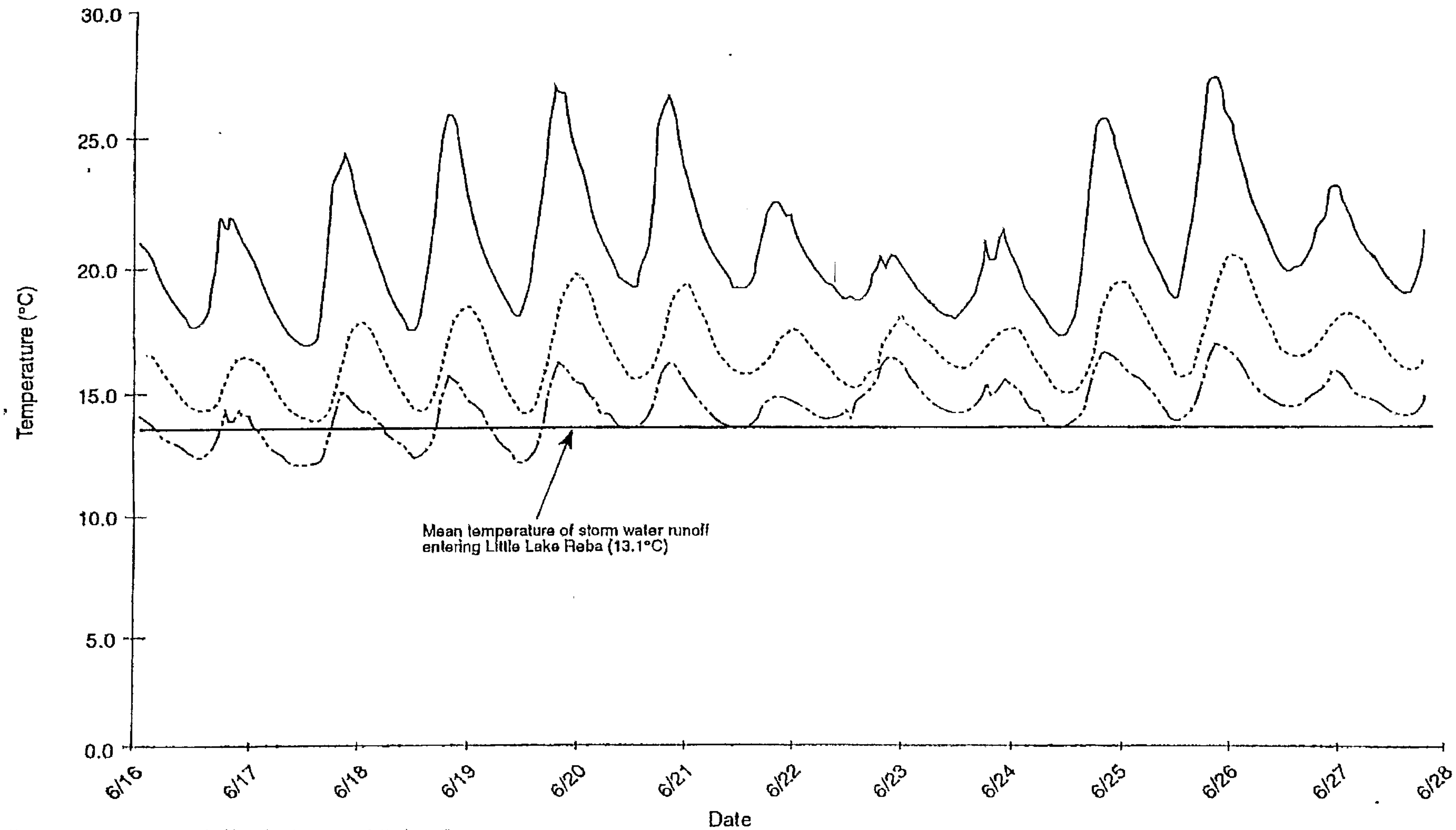
[1]Data for stream stations represent means of hourly measurements for the entire period. Data for storm water outfalls represent means of hourly measurements for days with greater than 0.05 inches of precipitation.
ND = No temperature measurements during this period

During the summer monitoring period (June 16 to 28, 1996), the temperature of Miller Creek increased an average of 2.3° C as it flowed through Port property (see Table 24). The temperature increases occurring during this period are related to the discharge of relatively warmer baseflow from Little Lake Reba to Miller Creek rather than the discharge of storm water to Miller Creek. This fact is demonstrated by Figure 6, which shows that temperature increases in the creek were not limited to periods when runoff contributions came from the airport.

Little Lake Reba is unshaded and subject to significant solar heating, such that diurnal temperature variations of as much as 10° C occur on clear days during the early summer (when solar heating is greatest) (see Figure 6). As the warm water from Little Lake Reba discharges to Miller Creek, the Miller Creek temperature increases.

During summer months, the influence of storm water discharges on water temperature in Little Lake Reba appears to be beneficial (i.e. it reduces water temperatures in the facility) because storm water discharges are cooler than warmer water in Little Lake Reba. In summer, storm water discharge can average up to 6°C below the temperature of water in Little Lake Reba.

During winter, the average temperatures of (1) Miller Creek as it enters Port property, (2) Little Lake Reba, and (3) Miller Creek, as it exits Port property, are within 1° C of one another (see Table 24). The average winter temperature of storm water entering Little Lake Reba is within about 2° C of the water in the facility. On a storm-by-storm basis, the temperature differences



Note: Temperatures recorded hourly; dates are plotted starting at 12:00 a.m.

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Miller Creek Upstream
Miller Creek Downstream
Little Lake Reba - Outlet

Figure 6.
Temperature of Miller Creek in the Vicinity of Little Lake Reba June 16 through 28, 1996

between storm water discharge and Little Lake Reba may vary more due to differences between air temperatures during the storm event and antecedent air temperatures.

6.2.2 Des Moines Creek

Temperature monitoring of Des Moines Creek, Northwest Ponds, Bow Lake, and associated Port storm water outfalls was conducted to determine if storm water or vegetation management affects stream temperatures. The monitoring results are summarized in Table 25.

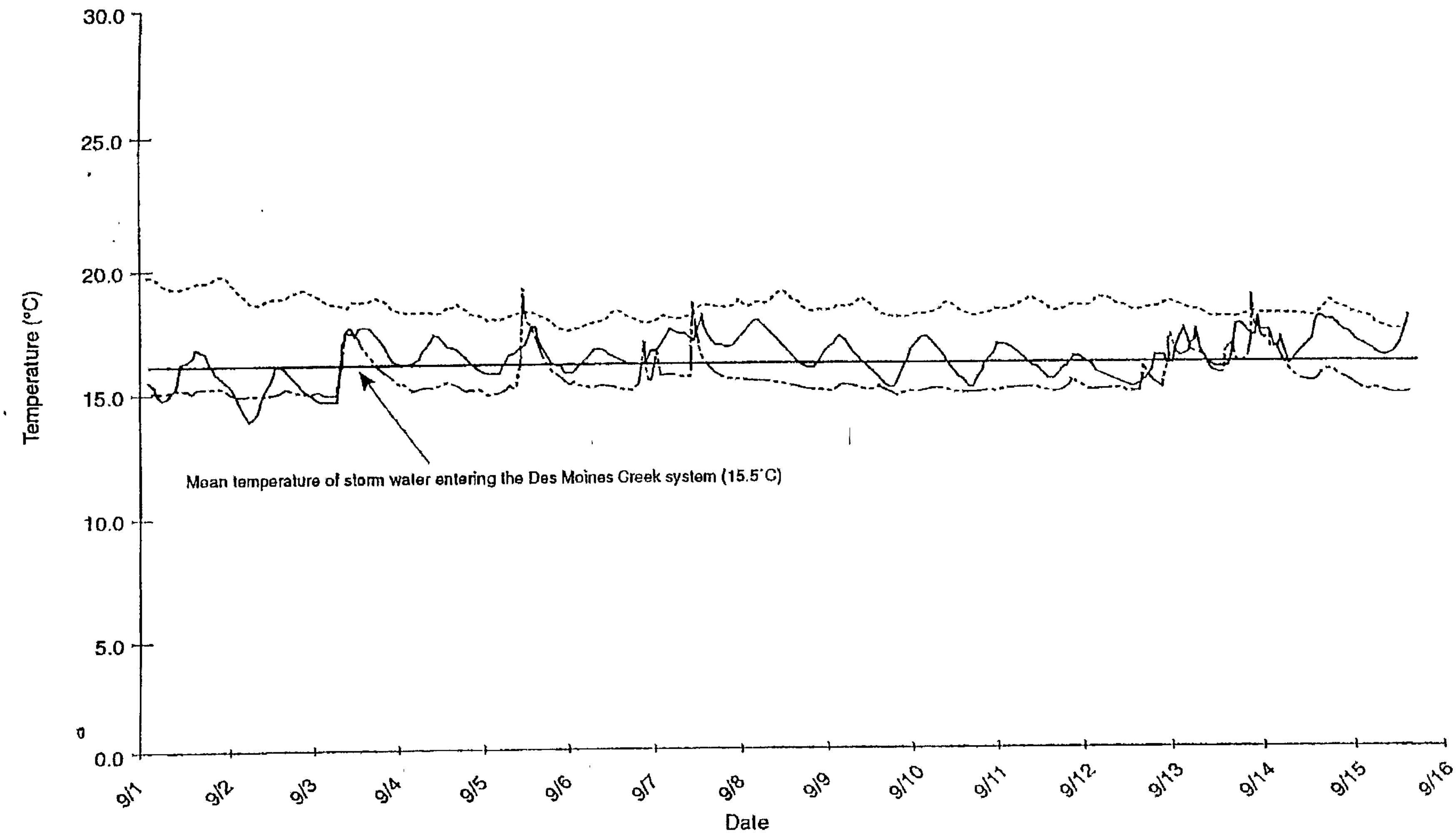
Table 25. Summary of mean water temperatures (°C) in Des Moines Creek, Northwest Ponds, and adjacent storm water outfalls[1].

	Period			
	Winter	Fall	Fall	Spring
Station	12/28/95-1/21/96	9/1/96-9/16/96	9/27/96-10/26/96	5/11/96-5/26/96
Northwest Pond Inlet	ND	14.9	12.8	12.2
Northwest Pond Outlet	6.3	17.8	13.0	15.3
Golf Course Weir	6.7	15.8	12.6	14.4
Bow Lake Outlet	ND	19.3	16.6	ND
South 28th Street	5.8	ND	ND	16.1
Storm water (SDS1)	ND	15.5	18.2	12.4
Storm water (SDS3)	6.4	15.4	13.1	12.4
Storm water (SDS4)	ND	ND	13.3	ND

[1]Data for stream stations represent means of hourly measurements for the entire period. Data for storm water outfalls represent means of hourly measurements for days with greater than 0.05 inches of precipitation.
ND = No temperature measurements during this period

Vegetation management adjacent to Des Moines Creek on the Tyee Valley Golf Course prevents development of shrub or forested vegetation on over 1,200 ft of the channel. Stream temperatures declined between the Northwest Pond outlet and the golf course weir (where stream shading is lowest) for all monitoring periods (Figure 7 and Table 25). The golf course weir monitoring station is below the confluence of the east and west tributaries so the data at this station integrate temperatures of water from the two tributaries.

Similar stream temperature patterns are found in the east tributary of Des Moines Creek (Figure 8). This tributary flows from Bow Lake through storm drains and a moderately shaded stream



Note: Temperatures recorded hourly; dates are plotted starting at 12:00 a.m.

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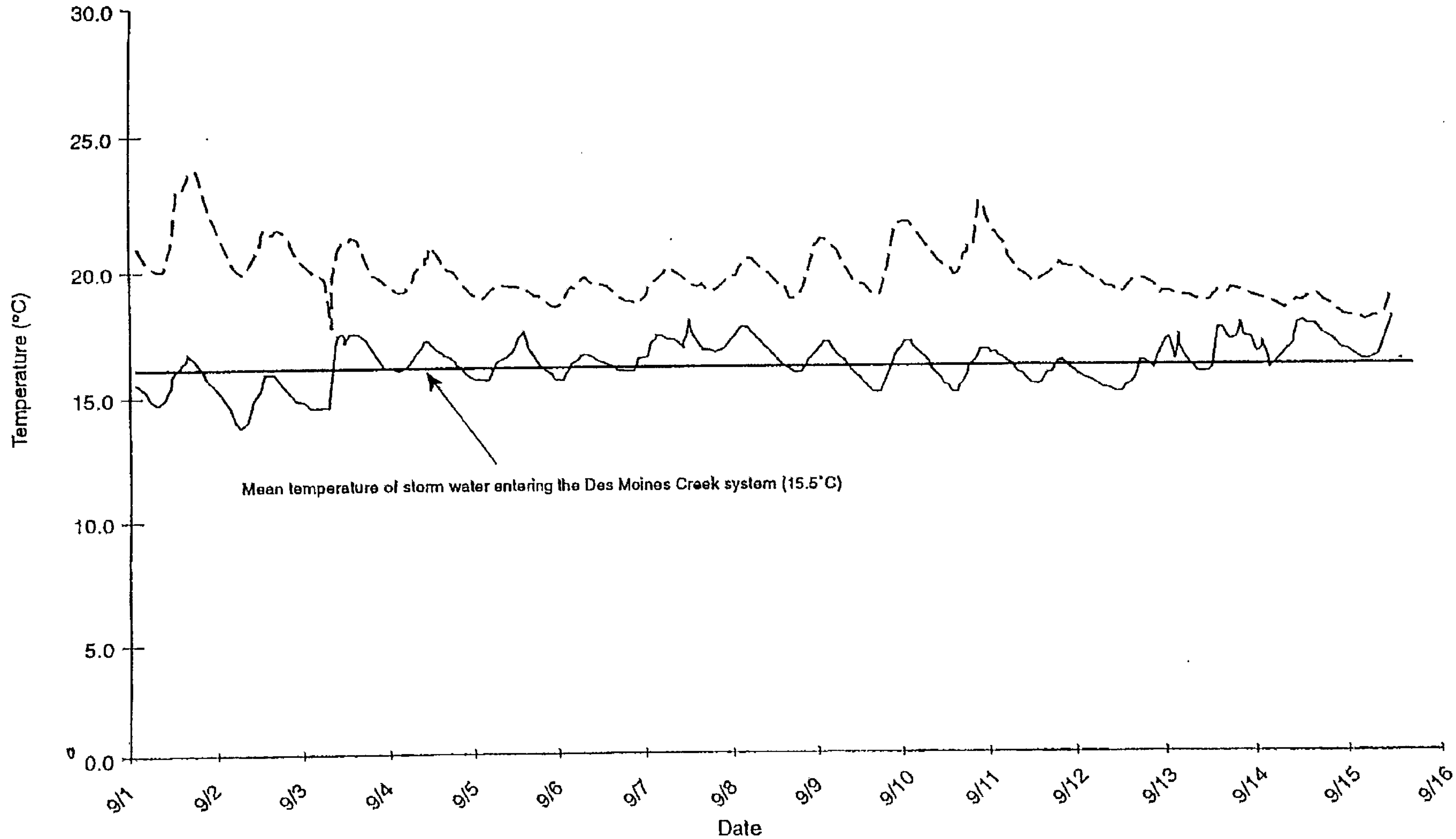
— — — Northwest Pond Inlet
-------- Northwest Pond Outlet
——— Golf Course Weir

Figure 7.
Des Moines Creek Water Temperatures, September 1 through September 16, 1996



Note: Temperatures recorded hourly; dates are plotted starting at 12:00 a.m.

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- - - · Bow Lake

——— Golf Course Weir

Figure 8.
Des Moines Creek and Bow Lake Water Temperature September 1 through September 16, 1996

corridor and joins with the west tributary in the Tyee Valley Golf Course. Along the east tributary, stream temperatures decline several degrees from the outlet of Bow Lake to the golf course weir. This decline is likely due to the influx of relatively cool groundwater to the creek, sufficient to negate accumulation of heat from moderately shaded stream sections. (Visible groundwater influx to the creek can be seen as seeps near the base of the bluff north of the Tyee Valley Golf Course clubhouse.)

As with storm water outfalls to Miller Creek, storm water entering Des Moines Creek is generally cooler than the temperature of the receiving water (see Table 25). An exception occurred during the September to October 1996 monitoring period when discharges from SDS1 averaged 18.2° C, while receiving water (east tributary) temperatures would be expected to be between 12.6° C (golf course weir) and 16.6° C (Bow Lake).

6.3 WETLANDS ASSESSMENT

The wetland evaluations are limited to wetlands associated with Northwest Ponds (Wetland 28, located north of the ponds) and wetlands associated with Little Lake Reba (Wetlands 7 and 8, located east of the facility), and include characterization of water level variations, plant species diversity, and amphibian surveys, as described in Section 6.3.2. Based on this data and other observations, general evaluations of wetland functions provided by the wetlands were made (Section 6.3.3). The influence of storm water discharge in defining the ecological state of these wetlands cannot be determined due to the complex pattern of other anthropogenic disturbances the wetlands have experienced (Section 6.3.4).

6.3.1 <u>Methods</u>

6.3.1.1 Vegetation

Vegetation sampling procedures for this study followed, in part, the Washington State Department of Transportation (WSDOT) Guide for Wetland Mitigation Project Monitoring (Horner and Raedeke 1989). Vegetation was sampled to determine percent cover of each species and overall abundance. Cover was assessed in each wetland by installation of multiple permanent linear transects and with sampling plots adjacent to each transect. Transects were sampled at Little Lake Reba and surrounding wetland complexes, and the Northwest Ponds and Wetland 28.

Transects (100 meters in length) were established in each wetland to monitor coverage of shrubs and emergent vegetation. Transect locations were selected to represent different vegetation and habitat types and were randomly placed within a habitat type. Along each transect, shrub data was collected using line-intercept sampling methods and herbaceous data was collected using quadrat sampling methods.

The line-intercept method from WSDOT Guide for Wetland Mitigation Project Monitoring (Horner and Raedeke 1989) was used for all shrubs and trees. This method allows for the assessment of canopy cover. The intercept length (the length of transect intersecting vegetation) for each species of shrub along each transect was measured.

The quadrat sampling method (Daubenmire 1959), was used for all herbaceous plants. To collect this data, quadrats were defined by marking 4-ft-square areas on alternative sides along the transect at 5-ft intervals. Percent cover of each herbaceous species was visually estimated within each quadrat and recorded; included in the estimates of coverage was bare ground.

Vegetation data was collected in October 1995 and June 1996 at each wetland. A summer and fall sampling schedule was selected to provide data on changes, if any, in dominance which may occur within each community type by season.

6.3.1.2 Amphibians

The amphibian sampling protocols for terrestrial and aquatic species were based on the procedures used by Dr. Klaus Richter (Puget Sound Wetlands and Storm Water Research Program 1996). The purpose of the monitoring was to determine the presence or absence of species and to obtain a general idea of populations. Sampling was conducted in Little Lake Reba and in the Northwest Ponds and Wetland 27.

The amphibian survey included the following:

- Silent species of salamanders and non-courting frogs and toads were observed during the warmer part of the day by lifting up decaying logs, boards, woody debris, and rocks within the wetland buffer. Frogs and toads were observed by walking along the waters edge in late afternoon and listening for them to jump.

- Courting and breeding species (vocalizing) species were observed during the late afternoon by walking around the wetland and listening for their calls.

- Funnel trapping (Richter 1995) of adults and larvae in aquatic environments along the perimeters of Little Lake Reba and the Northwest Ponds were conducted.

Sampling for amphibians involved dividing each wetland into four quadrats: southeast, southwest, northeast, and northwest. Aquatic funnel traps were set in quadrats where emergent or floating aquatic vegetation was present and water was less than 3 ft deep (Table 26). Species were recorded according to the quadrat in which they were captured. Where appropriate vegetation was not present, traps were not set.

Funnel traps were baited with five to ten salmon eggs and then one to two traps were attached vertically to one wooden dowel. Traps were set in the morning and then removed and checked for presence of amphibians 24 hours later. Larvae were identified to species, and then were released.

Table 26. Number of aquatic traps set in each quadrat.

Location	Quadrat			
	Southeast	Southwest	Northeast	Northwest
Northwest East Pond	1	2	1	1
Northwest Middle Pond	1	0	1	1
Northwest Pond	0	1	1	1
Wetland 28	0	0	0	0
Little Lake Reba	1	0	1	1
Wetland 7	0	0	0	0
Wetland 8	0	0	0	0

Amphibian field sampling was conducted May 2, 3, 5, and 9, 1995, and June 5, 6, 9, and 10, 1996. Data analysis consisted of counting and identifying all observed species and averaging counts over the 2-year period.

6.3.1.3 Water Level Fluctuations

Hydrologic data for Little Lake Reba was collected by King County staff. Resource Planning Associates collected the data for the Northwest Ponds from 1992 through 1997. Surveyed staff and crest guages were placed by Resource Planning Associates within accessible portions of the Northwest Ponds. Measurements were conducted on a monthly basis however, no measurements were taken in April or June 1996. At Little Lake Reba, King County did not take measurements during January, March, October, November, and December of 1992; and January, February, March, October, November, and December of 1993. From October 1994 to June 1995, monthly measurements of Little Lake Reba were taken. For each scheduled site measurement, the water level on the staff gage and the level of the "cork dust" on the crest gage was recorded to the nearest 0.01 ft.

6.3.2 <u>Findings</u>

6.3.2.1 Miller Creek

Vegetation

Little Lake Reba is a shallow, steep-sided waterbody. Primarily native species grow along its perimeter. The bottom is comprised of a silt layer approximately 12 inches deep. A small emergent community of common cattail is located on the east side of the lake. The majority of the lake lacks emergent and floating aquatic vegetation.

The dominant trees for Little Lake Reba in order of descending abundance, consisted of red alter (*Alnus rubra*) and big leaf maple (*Acer macrophyllum*). The dominant scrub-shrub vegetation for Little Lake Reba consisted in order of descending abundance: Sitka willow (*Salix sitchensis*), hardhack (*Spiraea douglassii*), and red elderberry (*Sambucus racemosa*).

The dominant herbaceous vegetation for Little Lake Reba in order of descending abundance, consisted of common cattail, reed canary grass (*Phalaris arundinacea*), Canada thistle (*Cirsium arvense*), stinging nettle (*Urtica dioica*) and buttercup (*Ranunculus repens*).

Wetland 7 is a palustrine forested wetland approximately 5 acres in area and is dominated by red alder, black cottonwood (*Populus balsamifera*), and Pacific willow (*Salix lucida* var. *lasiandra*). It is located immediately east of Little Lake Reba. Understory vegetation includes salmonberry (*Rubus spectabilis*), Himalayan blackberry (*Rubus procerus=R. discolor*), bentgrass (*Agrostis* spp.), and reed mannagrass (*Glyceria grandis*). A culvert inlet is located on the east side of the wetland. Water exits the wetland and drains to Little Lake Reba via a culvert in the northwest portion of the wetland.

The dominant trees for Wetland 7 in order of decreasing abundance, consisted of red alder and black cottonwood. The dominant scrub-shrub vegetation, in order of descending abundance, consisted of Pacific willow, salmonberry, and Sitka willow.

The dominant herbaceous vegetation for Wetland 7 in order of decreasing abundance, consisted of fall mannagrass (*Glyceria elata*), reed canary grass, bluegrass (*Poa* spp.) bentgrass and buttercup.

Wetland 8 is located immediately south east of Little Lake Reba and is an approximately 4.5-acre palustrine forested wetland. The wetland is dominated by red alder, Sitka willow, and Pacific willow in the canopy. Understory vegetation consists of salmonberry, and Himalayan blackberry, false lily of the valley (*Maianthemum dilatatum*), water-cress (*Rorippa nasturtium-aquaticum*), and European bittersweet (*Solanum dulcamara*). Water exits the wetland via a culvert in the northwest corner of the wetland where it eventually drains to Little Lake Reba.

The dominant trees for Wetland 8 in order of decreasing abundance, consisted of red alder, black cottonwood, and Western red cedar (*Thuja plicata*). The dominant scrub-shrub vegetation, in order of descending abundance, consisted of salmonberry, Sitka willow, and Himalayan blackberry.

The dominant herbaceous vegetation for Wetland 8, in order of decreasing abundance, consisted of false lily of the valley, giant horsetail (*Equisetum telmatiea*), European bittersweet and water-cress.

Amphibians

No native amphibians were observed while walking the perimeter of the water edge, the surrounding wetland (including Wetland 7 and 8) or buffer as a result of lifting up decaying logs, boards, and woody debris. Bull frogs were observed in the southeast, northwest, and northeast quadrats of Little Lake Reba.

One long-toed salamander (*Abystoma macrodactylum*) larvae, a native species, was captured in the southeast quadrat using the aquatic funnel trapping method. No other native or non-native species were captured.

Water Level Fluctuations

Little Lake Reba base water level (Figure 9) is relatively stable with a maximum variation of 0.75 ft. The crests occurred primarily between November and March, with a maximum crest of approximately 3.5 ft above the staff gage base flow reading. The water level fluctuations for Little Lake Reba are presented in Figure 7, with a maximum water fluctuation of over 4 ft. The mean annual water level fluctuation is 1.52 ft. Data on the duration of crests is not available, however, in most storm water management facilities, water levels return to base conditions within about 24 hours.

6.3.2.2 Northwest Ponds Watershed

The Northwest Ponds consist of three hydrologically connected open water areas. Low berms vegetated by willow (*Salix* spp.) define the individual ponds. The ponds are predominantly ringed with willows and occasionally black cottonwood along the water edge. Patches of emergent communities were found growing at or near the water edge. Douglas' spirea occurs occasionally in areas. The east pond, located in the golf course, has mowed grass to the water edge along the east side. A palustrine forested wetland is present along the west side of the middle pond, the largest of the three ponds.

The dominant trees for the Northwest Ponds in order of decreasing abundance, consisted of black cotton and red alder. The dominant scrub-shrub vegetation, in order of descending abundance, consisted of hardhack, Sitka and Pacific willow and red-osier dogwood (*Cornus sericea* spp. *sericea* = *C. stolonifera*).

The dominant herbaceous vegetation for the Northwest Ponds, in order of decreasing abundance, consisted of bentgrass, common cattail, smartweed (*Polygonum hydropiper*), foxtail (*Alopecurus* spp.), purple loosestrife (*Lythrum salicaria*), buttercup, and small fruit bulrush (*Scirpus microcarpus*).

Wetland 28 is north of and hydrologically connected to the Northwest Ponds. The wetland is a palustrine scrub-shrub with patches of palustrine emergent communities and is periodically

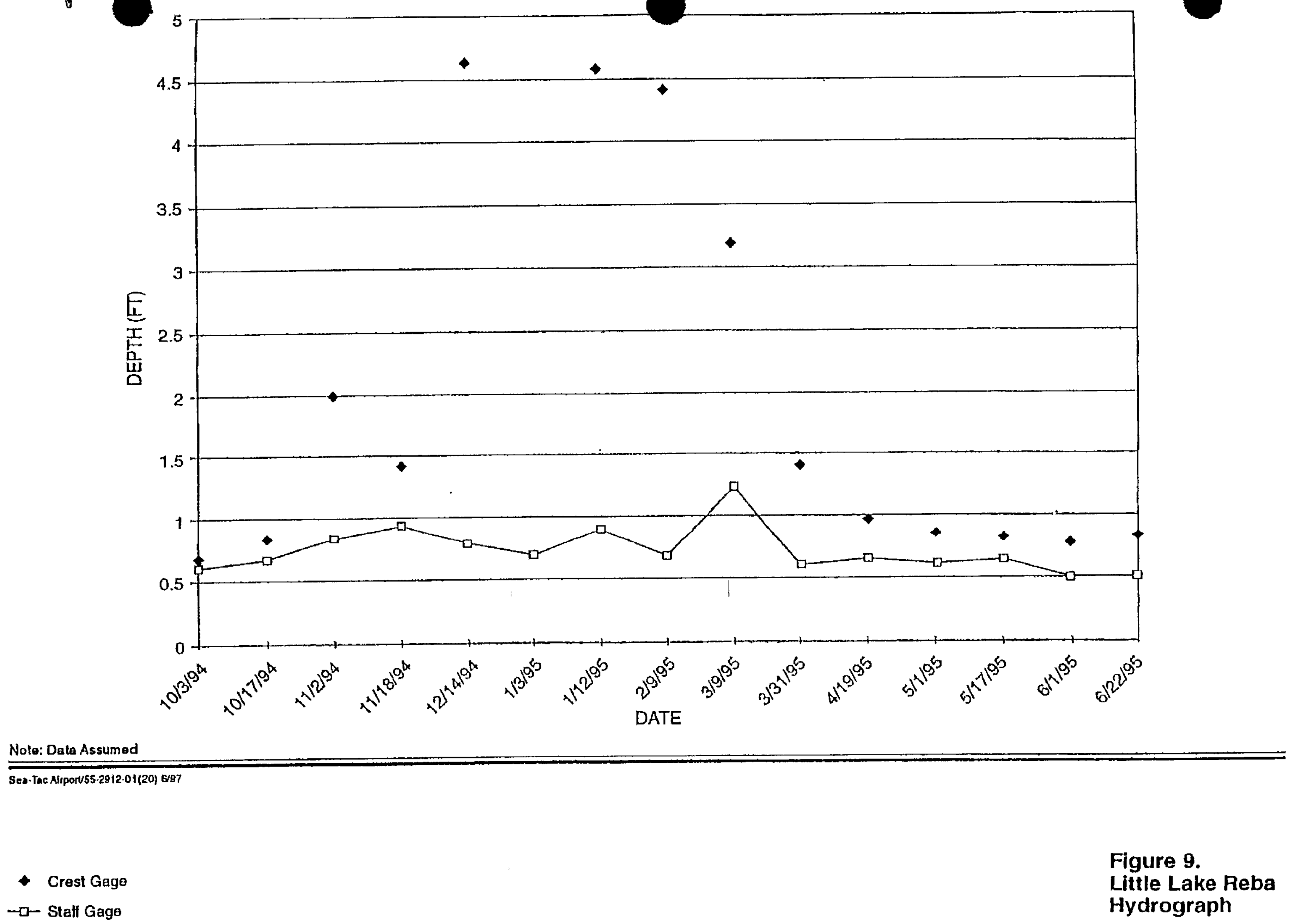


Figure 9.
Little Lake Reba
Hydrograph

inundated approximately 6 inches deep in areas. Dominant shrub species consisted of Sitka and Pacific willow, red elderberry, stinging nettle, mannagrass (*Glyceria* spp.), lady fern (*Athyrium filix-femina*), Himalayan blackberry, and common cattail.

The dominant tree species for Wetland 28 was red alder. The dominant scrub-shrub vegetation for Wetland 28, in order of descending abundance, consisted of Sitka willow, willow species, Pacific willow, and Himalayan blackberry. The dominant herbaceous vegetation for Wetland 28, in order of decreasing abundance, consisted of common cattail, sawbeck sedge (*Carex stipata*), willowherb (*Epilobium ciliatum*), and mosses.

Amphibians

Bull frogs (*Rana catesbeiana*), an introduced species to the region, were observed in all three ponds. Table 27 summarizes the quadrat in which the bull frogs were observed or captured and the total number of bull frogs observed or captured in each of the ponds. Three bullfrogs were observed in Wetland 28.

Table 27. Northwest ponds – summary of bull frogs observed or captured.

Pond	Quadrat				Total No. of Individuals Observed
	Southeast	Southwest	Northeast	Northwest	
East	0	BF (4)	-	-	4
Middle	0	BF(3)	BF(2)	BF(1)	6
West	0	0	BF(1)	BF(3)	4

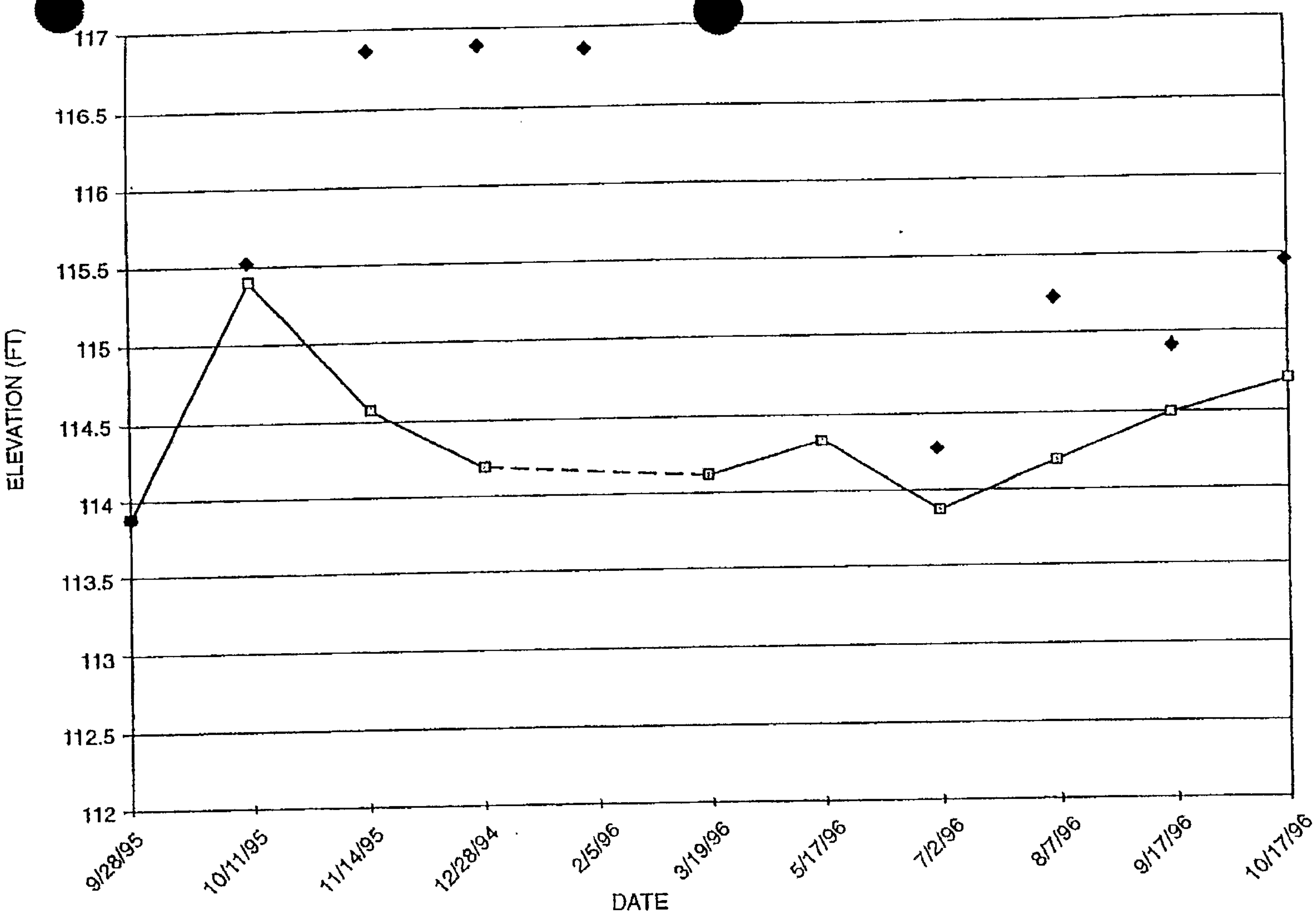
No native or non-native amphibian larvae were observed or captured as a result of using the aquatic funnel trapping method.

Hydrology

Figure 10 presents the wetland hydrograph for the Northwest Ponds. The base level is the controlled outlet level and the maximum crest was 2.68 ft. The annual average water level fluctuation is approximately 1 ft. Though no data are available for duration of crests, it was observed that water levels dropped relatively rapidly from crests after storm events.

6.3.3 Discussion

Any effects caused by storm water discharges—from either Sea-Tac Airport or other developed land—on the ecological conditions or functioning of Miller or Des Moines creeks, cannot be determined because adequate baseline data are lacking. In addition to potential storm water



Datum Assumed

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Figure 10.
Northwest Ponds Hydrograph

Confidential: Attorney-Client Work Product

◆ Crest Gage
-□- Staff Gage

impacts, these systems have been subjected to a variety of other influences during the past several decades (Table 28, Figures 11, 12, and 13). Significant ecological disturbance to the creek systems, prior to airport development, included timber harvest, agricultural uses, channel dredging and straightening, wetland drainage, wetland filling, pond excavation, peat mining, and sedimentation from construction runoff.

Since the timing, nature, and significance of these changes to the stream systems are unknown, the evaluation of present conditions cannot differentiate or isolate the potential impact of storm water to wetland or stream functions. For example, while the wetlands may have a low diversity of native amphibians compared to other urban wetlands in Puget Sound (Puget Sound Wetlands and Storm Water Management Research Program 1996) the reason for this low diversity could be attributable to the relatively recent development of amphibian breeding habitat (resulting from the construction of the Northwest Ponds and Little Lake Reba from farmland) and lack of migration corridors (due to surrounding urban development), rather than hydrologic or water quality impacts from storm water. Likewise, low plant diversity is likely to be the result of clearing and farming practices prior to airport development, rather than from hydrologic impacts associated with storm water.

Habitat conditions for wildlife in and adjacent to Little Lake Reba and the Northwest Pond systems are significantly more diverse than was the condition in the early 1960s when open-water habitat was lacking, tree and shrub habitat very limited, and the area was subjected to ongoing agricultural disturbance. During the same period (1960 to present), when habitat conditions (in terms of vegetation structure) were improving, hydrologic and water quality conditions were changing as a result of runoff from increasing urbanization and decreasing agricultural impacts. Without baseline data, the relative effects of these co-occurring disturbances cannot be determined.

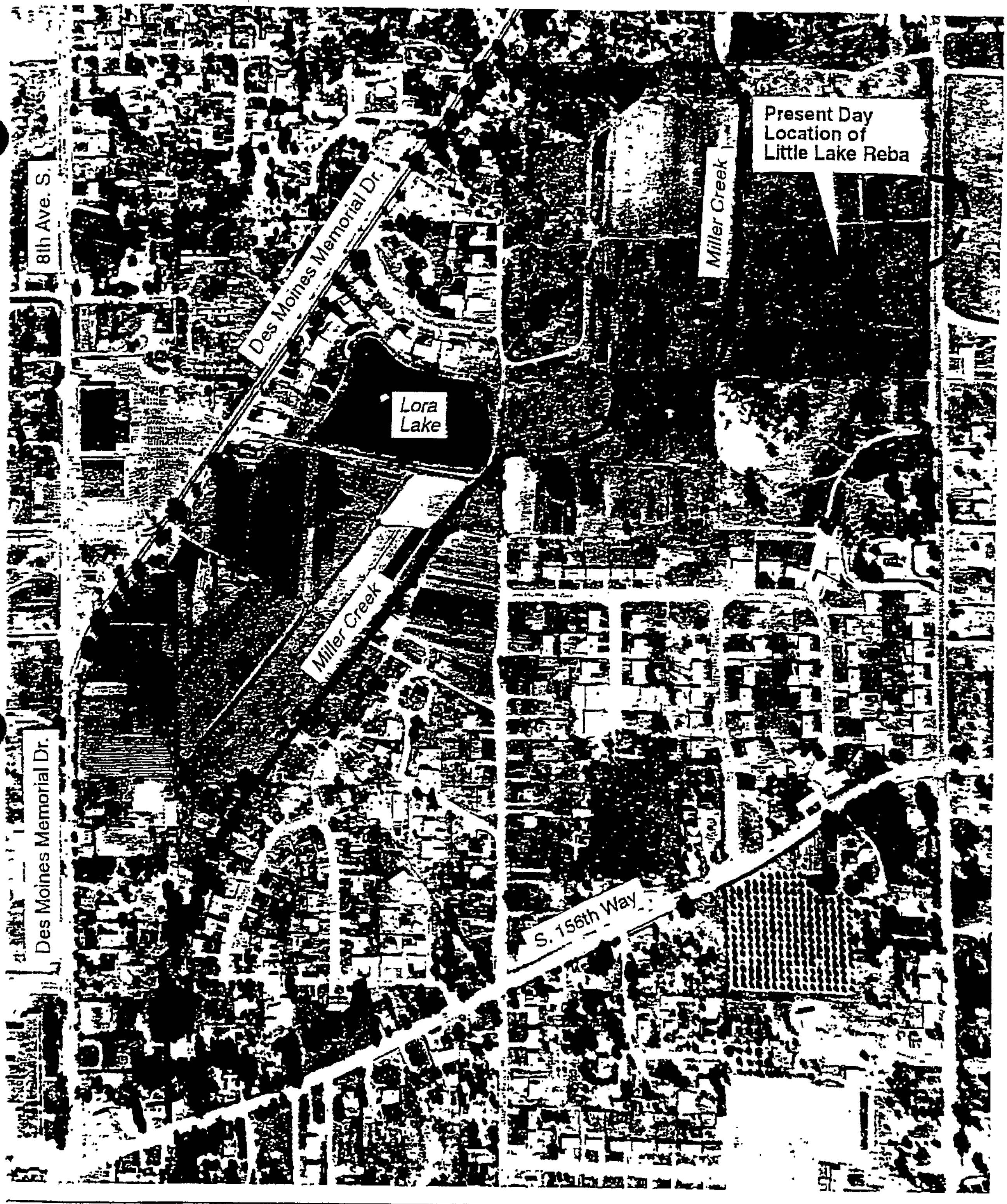

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Figure 11.
Aerial Photograph of Miller Creek and Miller Creek Regional Detention Facility Area on August 7,1961

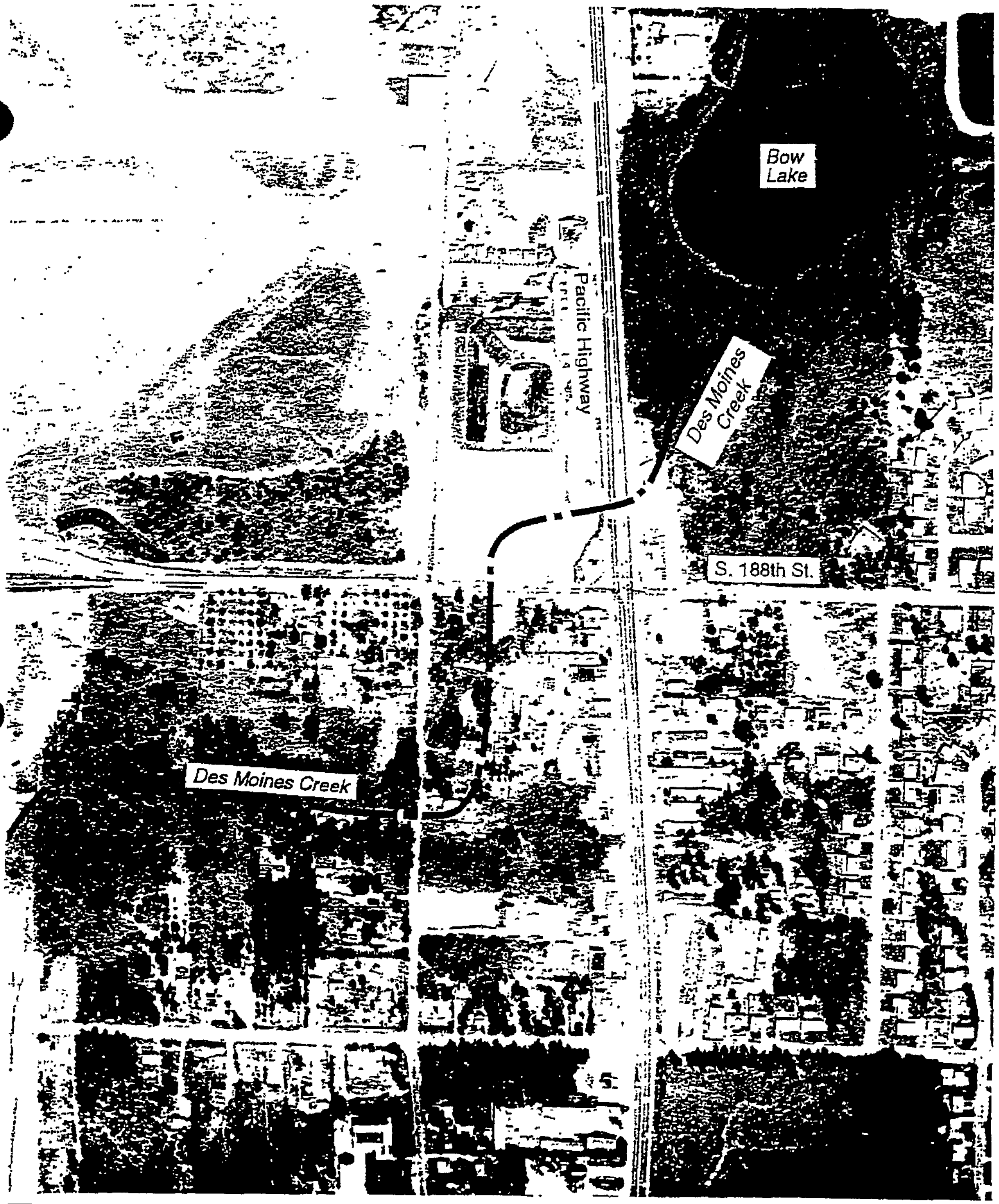

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Figure 12.
Aerial Photograph of Des Moines Creek (East Tributary) and Bow Lake Area on August 7, 1961

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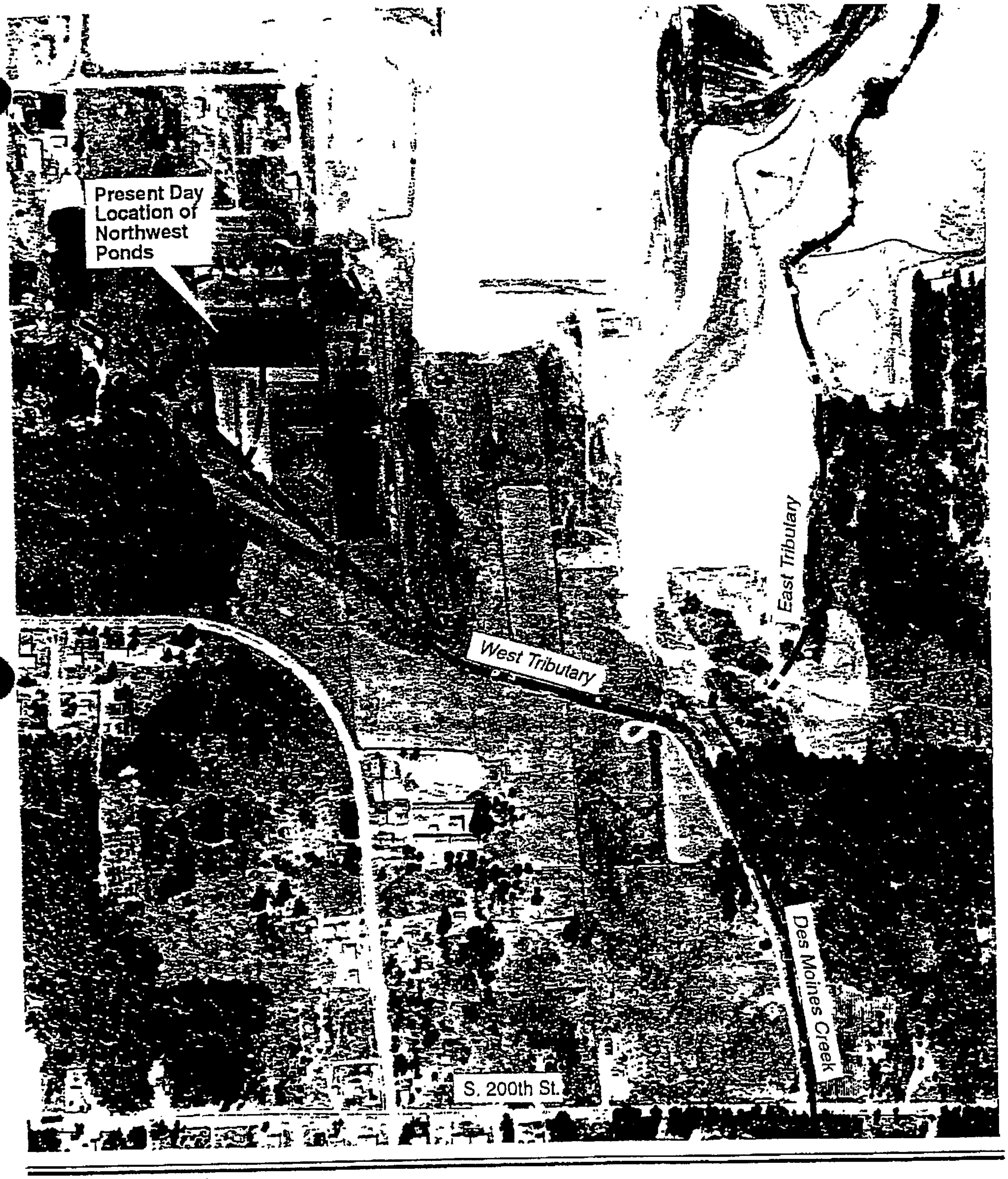

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Figure 13.
Aerial Photograph of Des Moines Creek and Northwest Ponds Area on August 7, 1961

Table 28. Summary of land use changes that modified Miller Creek, Little Lake Reba, Des Moines Creek, or Northwest Ponds[1].

Year	Location	Condition
1960	Miller Creek	Miller Creek is channelized between farmed fields. Much of the area between existing SR 518 and 154th Street South is either farmland or developed for single family houses.
		Little tree or shrub vegetation shading Miller Creek
		The tributary to Miller Creek (flowing through the future site of Little Lake Reba) is also channelized and lacks woody riparian vegetation over much of its length.
	Des Moines Creek-East Tributary	The east tributary appears to occur in a natural channel between SR 99 and the location of the current Alaska Airlines parking area. Much of this area is farmed.
		The channel is being relocated in the area of the existing Alaska Airlines parking.
	Des Moines Creek-West Tributary and Mainstem	The creek channels flow through farmland, are linear, and generally lack buffer vegetation.
		The area of the existing Northwest Ponds is farmed wetland, with several drainage ditches connecting to the Des Moines Creek channel.
		Some runway fill may have been placed in the wetland.
1965	Miller Creek	Little change in overall condition since 1961, except that vegetation patterns indicate that much of the farmland has been abandoned.
	Des Moines Creek-East Tributary	Portions of channel are being relocated south of South 188th Street.
		Reconstruction of the creek channel between Runway 34R and the bluff to the east has been completed.
	Des Moines Creek-West Tributary and Mainstem	Farming between the airport and South 188th Street appears to have ceased, and the Tyee Valley Golf Course appears to be under construction.
		A small pond has been excavated in and adjacent to the creek channel. This pond corresponds to the shape of the existing Northwest Pond outlet vicinity.
1970	Miller Creek	SR 518 is under construction, resulting in filling of farmed wetland and culverting of Miller Creek.
		Several acres of farmed wetland east of Lora Lake are filled.
		Runway construction is ongoing, with some wetland fill north of South 154th Street.
		Tree and shrub vegetation beginning to develop along Miller Creek riparian corridor.
	Des Moines Creek-East Tributary	Tyee Valley Golf Course is visible along this channel between the runway and bluff to the east. There is little woody vegetation shading the creek.

Table 28. Summary of land use changes that modified Miller Creek, the Reba Detention Facility, Des Moines Creek, or Northwest Ponds (continued)[1].

Year	Location	Condition
	Des Moines Creek-West Tributary and Mainstem	Northwest Ponds constructed in its present configuration.
		The Northwest Pond margins lack shrub or tree vegetation.
		Des Moines Creek channels generally lack woody vegetation.
		Considerable fill of farmed wetlands northeast of the ponds has occurred.
1973	Miller Creek	Little Lake Reba constructed adjacent to Miller Creek.
1989	Des Moines Creek – East Tributary	Tyee Pond constructed as an inline detention facility.
1992	Miller Creek	Miller Creek Regional Detention Facility constructed.

1 Land-use changes determined from aerial photographs available at the University of Washington Library.

7. STREAMBANK EROSION

To describe and analyze conditions of stream channel stability and streambank erosion in Miller and Des Moines creeks, this section references three primary documents and reports text from them. These documents are *Miller Creek Stream Effects Study for Sea-Tac Airport* (WEST Consultants 1997a), *Des Moines Creek Stream Effects Study for Sea-Tac Airport* (WEST Consultants 1997b), and *Des Moines Creek Bank and Channel Stability Evaluation* (Parametrix 1992). These reports are Appendix E, F, and G, respectively. Des Moines and Miller Creeks are discussed separately.

Streambank erosion occurs when the energy of flowing water exceeds the resistance of geological or constructed substrate to remain in place. Flowing water uses its energy to move sediment in the channel or erode new material from the stream channel. The amount, flow rate, and frequency of flowing water that has the energy to move or erode sediments depends upon the hydrologic conditions in the stream's watershed. When watersheds are developed, the hydrologic conditions change and typically increase the magnitude of damaging erosive flows, and the frequency of such flows. Also, bridges, culverts, weirs, channel protection (i.e. rock or concrete), and other structures constructed in the channel will alter flow patterns and influence new erosion patterns. Channel downcutting further destabilizes streams banks, causing bank failures and mass wasting (commonly know as landslides, slumps, slope failures, etc). Each of the aforementioned erosive agents adds sediment that is carried by the stream until there is no longer sufficient energy to transport the increased load. Sediment is then dropped by the stream, filling the channel and changing flow patterns.

Natural stream channels are dynamic systems with many variables that influence the rate and magnitude of channel erosion and aggradation. Changing watershed hydrology has an impact on the stream's ability to erode and transport sediments. Because watershed development and subsequent hydrologic changes are incremental, and large-scale erosive impacts are episodic, it is difficult to assess the direct impacts of specific watershed modifications. Also, the impact of in-stream structures is easy to observe yet difficult to quantify. Watershed development has had an adverse impact on Des Moines Creek and, to a lesser extent, Miller Creek. The direct contribution of storm water runoff from Sea-Tac Airport to the erosion of the banks of Miller and Des Moines creeks is difficult if not impossible to quantify.

The following sections discuss qualitative geomorphic assessments that were reported in documents listed above. The assessments reviewed field reconnaissance observations, described stream hydrology, characterized channel geometry, investigated bed materials and sediments, and analyzed channel hydraulics. General conclusions about the current stability and expected future response of the stream channel are also presented.

7.1 MILLER CREEK

Miller Creek, a perennial watercourse that drains to Puget Sound, has headwaters originating at Arbor, Burien, and Tub Lakes (see Figure 1). Sea-Tac Airport contributes drainage to the creek through the Miller Creek Regional Detention Facility. Walker Creek, a tributary to Miller Creek, begins in the wetlands west of the airport. The Miller Creek watershed encompasses an area of about 8.1 square miles (5,200 acres). The Airport covers about 0.4 square mile (5 percent) of the Miller Creek watershed. Approximately 136 acres (or 2.6 percent of the Miller Creek watershed) of Airport property drains through four NPDES-permitted outfalls into Miller Creek. Elevations in the watershed range from sea level, at the mouth, to over 400 ft along the basin's boundary.

Miller Creek's watershed includes portions of Normandy Park and Burien in southwest King County, Washington. The basin is substantially developed with primarily residential and commercial properties. Commercial development is primarily located along the major roads in the area and along the eastern basin boundary (Sea-Tac Airport).

The Miller Creek watershed, located on a plateau between Puget Sound and the Duwamish Valley, is underlain by a thick deposit of glacial till (King County 1987). Surface topography on the plateau consists of north-south oriented hills and swales. Silt and sand deposits, the result of deglaciation periods, are found in various topographically low areas on the plateau. Several lakes, bogs, wetlands, and depressions also occur in the watershed. This includes two closed subbasins within the watershed referred to as the Hermes and SW 42nd Street depressions.

Miller Creek flows off the plateau, through a ravine, toward the southwest. Materials along the sides of the ravine are of glacial origin, primarily non-cohesive, erodible, sandy till. Underlying these units is a glacio-lacustrine clay. The clay is significantly more erosion resistant than the non-cohesive materials on the walls of the ravine. Bank erosion and landsliding occur along this ravine, which terminates in an alluvial valley that begins downstream of 1st Avenue South.

Urbanization is believed to have increased flood peaks and volumes along Miller Creek (King County 1987). Increases in mass wasting, bank erosion, bed scour, sedimentation, degradation of fish habitat and water quality, and flooding along the stream has been attributed to increased runoff. Storm water runoff detention is the primary mitigation action recommended by some previous studies.

7.1.1 Qualitative Geomorphic Assessment

A field reconnaissance of the Miller Creek watershed was conducted in April 1996 to observe the physical characteristics of the watershed and the stream channel. Channel geometry, hydraulic structures, bed and bank materials, erosion and sedimentation patterns, bank erosion, mass wasting, vegetation, and surrounding development were observed. The field reconnaissance focused on the area surrounding the Miller Creek Regional Detention Facility and the tributary channel extending from the Airport to the lake. Private ownership restricted access to most of Miller Creek.

Field observations in the vicinity of the Miller Creek Regional Detention Facility did not indicate any gross channel instability problems. The channel banks were found to be well-vegetated. Channel bed materials varied from sand to gravel. The Miller Creek Regional Detention Facility appeared to attenuate runoff from the Airport to Miller Creek.

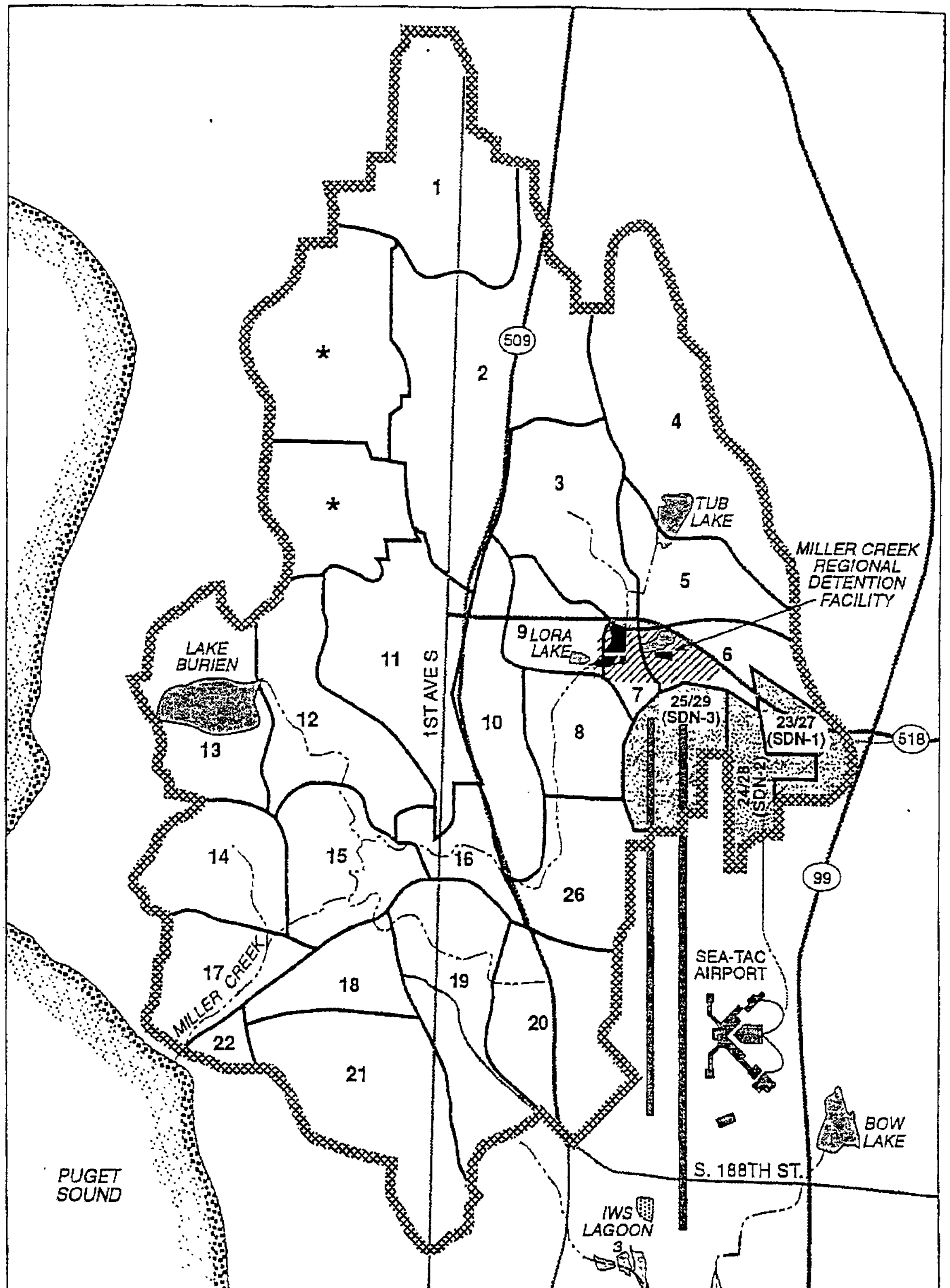
Several structures were observed during the field reconnaissance, including fish passage structures and culverts. No instability problems were noted at either location. The structures were not found to be perched or in danger of being flanked by the watercourse. The lack of bank erosion or channel aggradation/degradation indicated that the channel in the vicinity of the Miller Creek Regional Detention Facility was reasonably well-adjusted to current hydrologic conditions.

7.1.2 Hydrology

Miller Creek hydrology was evaluated during a previous study (Montgomery Water Group 1996) and a hydrologic model of the watershed was developed using the Environmental Protection Agency (EPA) Hydrologic Simulation Program – FORTRAN (HSPF) computer program. The general schematic, showing the delineation of subbasins and channels within the Miller Creek watershed used in the HSPF model, is shown in Figure 14. As the figure shows, the area of Sea-Tac Airport contributing to Miller Creek represents a very small percentage (less than 5 percent) of the total basin.

Miller Creek's total drainage area is about 5,200 acres. Storm water discharges from the northern portion of the Airport drain through three storm drain outfalls (SDN1, SDN2, and a combined SDN3 and SDN4 in the model) to Tributary 0375, which in turn drains to the Miller Creek Regional Detention Facility and finally to Miller Creek.

The Miller Creek drainage area upstream of the Miller Creek Regional Detention Facility confluence is about 1,600 acres or 30 percent of the total basin area. A previous hydrology study (Montgomery Water Group 1996) defined impervious area for the Airport and other subbasins of the Miller Creek. The Airport represents about 14 percent of the impervious area associated with the upper watershed. The portion of Sea-Tac Airport with aircraft-related activity that drains to the Miller Creek Regional Detention Facility is about 117 acres or 7 percent of the upper Miller Creek watershed. The Airport contributes less than 5 percent of the total impervious area in the basin. Of the 5 percent impervious area modeled, only 2 percent is from aircraft-related activities.



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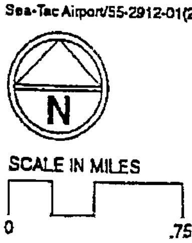

Airport Drainage Areas in Miller Creek Basin

* Closed Depression (not modeled)

Open Water (Lakes or Ponds)

Palustrine Wetlands

Watershed Boundary

Subbasin Boundary

Figure 14.
Miller Creek Watershed Subbasins

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The relative amount of drainage area and the impervious surface represented by the Airport is very small, compared to both the upper watershed and the total basin (Table 29). In addition, the HSPF model does not account for the impervious area that drains to the IWS and on to Puget Sound, which further reduces airport storm water effects on stream bank erosion. Thus, the percent increase in flow along Miller Creek that could be attributed to the Airport is assumed to be very small. Since the storm water flow increase is small, any relative change in channel slope, sediment discharge, or streambank erosion due to Airport drainage is also assumed to be very small.

Table 29. Airport contribution to storm flows[1].

	Airport Area of Watershed (%)		Flow Volume (%)		Percent of Peak
Creek Location	Total	Impervious[2]	Annual	January 6, 1990	January 6, 1990
Miller Creek Regional Detention Facility outlet	7.0	14	8.3	13	13
Creek mouth	2.4	<5	2.8	3.4	3.6

1 Contribution from airfield itself, that is, the area draining to SDN1 through SDN4.
2 Based on acreages used in HSPF model.

Because discharges from the Airport are mitigated by the Miller Creek Regional Detention Facility, the Airport storm water discharge effects on hydraulics, sediment transport, and stream stability along Miller Creek should be minimal.

7.1.3 Miller Creek Summary of Impacts

All watershed development and channel modifications affect channel erosion and sediment transport; the system is too complex to assess the impact of specific development projects or channel modifications. It is difficult to determine the point at which the natural channel processes of erosion and sediment transport are modified sufficiently to adversely affect the system. Also, it is difficult to quantify whether watershed hydrology has a more dramatic impact than channel modifications. Finally, it is not possible with the available analysis to reasonably estimate the quantity of sediment erosion and deposition that is attributable to natural processes or increased by development impacts. Therefore, it is an oversimplification of system dynamics to assume that the area or volume of basin contribution to the stream flows is proportional to the impacts of the changes.

Sea-Tac Airport comprises 2 percent of the watershed area and less than 5 percent of the impervious area in the Miller Creek drainage basin. The Miller Creek Regional Detention Facility mitigates most of the stream erosion hydrologic impacts normally associated with development. It is unlikely that Sea-Tac Airport contributes significantly to Miller Creek erosion or sediment transport impacts.

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7.2 DES MOINES CREEK

Des Moines Creek, a dynamic fluvial system formed in erodible sediments, has been evolving and adjusting its channel for thousands of years. Urban development (i.e., roads, houses, and commercial and industrial areas), including Sea-Tac Airport (approximately 24 percent of the Des Moines Creek watershed), has undoubtedly altered runoff patterns within the creek's drainage basin and along the channel. In addition to watershed development, the construction of a variety of structures (e.g., bridges, buildings, roads, pipelines, culverts) on and adjacent to the creek has had a substantial effect on stream hydraulics.

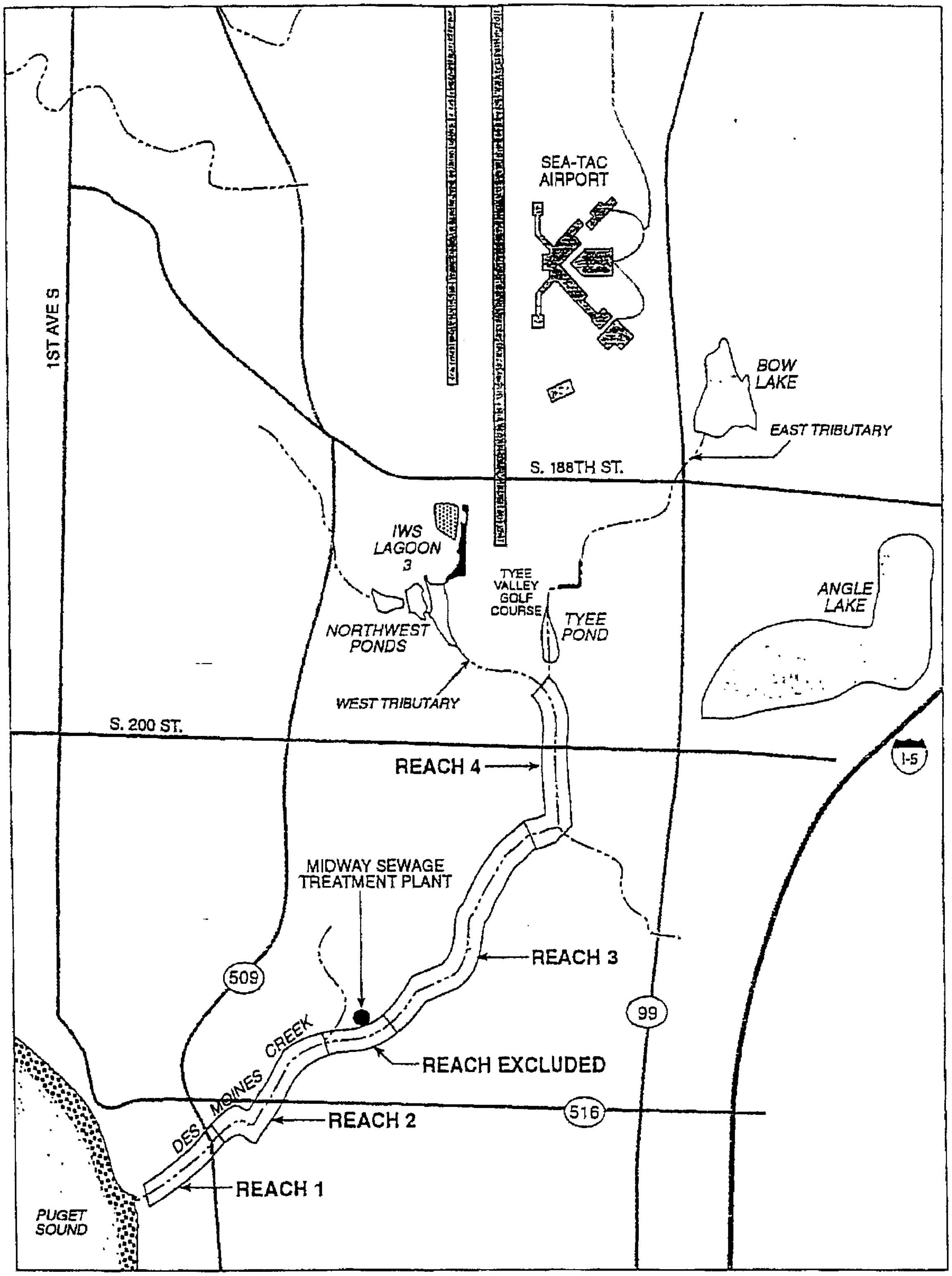
The Des Moines Creek watershed (Figures 1 and 15) comprises about 3,712 acres in south King County, including portions of the cities of Des Moines, Normandy Park, and SeaTac. Land areas in the basin are substantially developed. Land use is primarily urban and suburban residential. Commercial development, consisting primarily of small businesses, is located south of Des Moines Beach Park, near the Puget Sound shore. Open space in the basin includes Des Moines Beach Park and the Tyee Valley Golf Course, which is at the south end of the Airport and is owned by the Port of Seattle. The Airport's NPDES-permitted drainage area covers 705 acres that drain to Des Moines Creek through eight outfalls. The NPDES drainage area is less than 20 percent of the watershed.

The Des Moines Creek watershed is located on the Des Moines-West Seattle drift plain (King County 1987), a long plateau between Puget Sound and the Duwamish Valley. The plateau is a thick deposit of unconsolidated sediments. Surface topography consists of north-south oriented hills and swales. Des Moines Creek flows from the plateau through a steep-sided ravine toward the southwest. Materials along the sides of the ravine are of glacial origin, primarily non-cohesive, highly erodible, sandy till. Underlying these units is a glacio-lacustrine clay. The clay is significantly more erosion resistant than the non-cohesive materials on the walls of the ravine. The ravine terminates in a small alluvial valley at the mouth of the stream.

7.2.1 Qualitative Geomorphic Assessment

A streambank and channel stability survey was conducted by Parametrix in 1992 (Appendix G). Channel geometry, hydraulic structures, bed and bank materials, erosion and sedimentation patterns, bank erosion, mass wasting, vegetation, and surrounding development were observed. The survey described channel and streambank characteristics and noted locations, types, and causes of erosion from the mouth to the northeast tributary (formerly known as Bow Lake Creek). The survey compared conditions to creek stability surveys conducted by King County (1987) and Herrera Environmental Consultants (1989).

Subsequently, several reconnaissance trips to the Des Moines Creek watershed were made as part of a geomorphic assessment in the physical characteristics of the watershed and stream channel. A field reconnaissance was held on August 7, 1996. Site visitors observed and assessed channel geometry, hydraulic structures, bed and bank materials, erosion and



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Open Water (Lakes or Ponds)
Palustrine Wetlands

Figure 15.
Des Moines Creek
Reach Locations

sedimentation patterns, bank erosion, mass wasting, vegetation, and surrounding development. The field reconnaissance extended from the confluence of the east and west tributaries in Tyee Valley Golf Course to the mouth of Des Moines Creek.

An elevation survey was conducted on December 19 and 23, 1996. Representative cross sections of the stream were surveyed at various locations along the channel by on January 8, 1997. The stream survey was undertaken to collect quantitative information on the slope of the stream channel and representative cross sections along each reach of the watercourse.

Based on hydraulic and sediment transport characteristics, Des Moines Creek was divided into five distinct reaches for this study (Figure 15). The four reaches used for the assessment are discussed below.

7.2.1.1 Reach 1 – Des Moines Creek mouth to outlet of culvert at Marine View Drive

In this area the channel is located within an alluvial valley; the creek flows through a relatively broad floodplain surrounded by hills that rise in an upstream direction. At its mouth, the stream is tidally influenced, with the tidal influence estimated to extend upstream for approximately one-third the length of the reach. At the upstream end of the reach, Des Moines Creek flows through a 245-ft-long, 6.2- by 4.0-ft concrete box culvert.

The low gradient of the reach and the tidal influence cause sediment deposition, primarily sand and fine gravel, along much of its length. The channel in this area has a generally flat bed and relatively low banks. Average channel top width for the reach is estimated to be about 19 ft and average bank heights are approximately 3 ft.

Along the lower half of the reach, the extent of riparian vegetation was limited because developed areas closely border the channel. Vegetation was relatively more dense along the upstream half of the reach, consisting of a variety of trees, vines, shrubs, and grasses. In general, the banks along Reach 1 appeared relatively stable. These observations were supported by good to excellent streambank and bed stability index ratings along the reach (Parametrix 1992).

In the lower half of the reach, several buildings and small bridges were constructed directly over the stream. Sediment deposition, low bank heights, hydraulic constrictions caused by the bridges and buildings, and tidal effects promote overbank flooding along the reach.

7.2.1.2 Reach 2 – Inlet of box culvert at Marine View Drive to below Midway Sewage Treatment Plant

Similar to Reach 1, the channel in Reach 2 meanders through a relatively broad floodplain that is surrounded by hill slopes. The downstream end of the reach is hydraulically controlled by the capacity of the box culvert. Extensive sediment deposits were noted along the channel upstream of the box culvert.

A typical channel width in the reach is about 26 ft. Bank heights along the channel are irregular, but maximum heights are on the order of 4 to 5 ft. Vegetation along the channel banks and overbank areas is relatively dense, consisting of a variety of trees, shrubs, vines, and grass. Fallen trees and woody debris are common along the reach.

Landslides and slumps were observed in several locations, but primarily along the steep hill slopes immediately upstream of the Marine View Drive box culvert. They appear to be associated with concentrated runoff from adjacent development and roadways surrounding the stream. In several locations, concentrated runoff from parking lots and roads was observed above mass wasting sites.

Sediment deposits along the reach range from sand to large gravel-sized material. Side channel bars were also noted along relatively straight sections of the reach. Extensive sediment deposits were noted upstream of the box culvert beneath Marine View Drive. The hydraulic restriction caused by the culvert restricts the flow in this area causing sediment deposition. Sand deposits were noted in overbank areas and bars of large gravel were seen in the channel upstream of the culvert. The culvert is capable of transporting any of the sediment sizes supplied to it; however, inspection of the culvert interior revealed no sediment deposits.

7.2.1.3 Excluded Reach – At Midway Sewage Treatment Plant between Reach 2 and Reach 3

A series of drop structures (i.e., constructed devices or channel features that allow water to cascade through steep reaches of the stream)—believed to have been installed to enhance fish habitat—and bridges are adjacent to the Midway Sewage Treatment Plant upstream of Reach 2. The segment of stream encompassing these structures was not defined as a separate reach for the WEST Consultants 1997 analysis because of the variable characteristics of the numerous structures. At the downstream end of the reach is a drop composed of large boulders; the boulders hold the channel grade stable upstream of the drop adjacent to the treatment plant. The channel bed between structures is relatively flat and has an average top width of about 30 ft. Channel bed materials are composed mainly of sand and gravel. Parametrix (1992) rated the bank stability in this reach as good, although bed stability was rated fair to poor. Bed stability was negatively affected by uneven substrate particle size distribution, high scour potential, and relatively heavy deposition of fine materials.

7.2.1.4 Reach 3 – Above Midway Sewage Treatment Plant to Station 89+46

Reach 3 contains a steep, narrow ravine that connects the plateau to the lower watershed. Typically, the channel encompasses the entire available bottom of the ravine. There is little or no overbank area throughout the ravine. Additionally, Des Moines Creek is constricted at various points by a trunk sewer pipeline that has been constructed along the west stream bank. Riprap lines the west bank through most of the reach.

Landslides and slumps were observed in several locations along the reach. Within the ravine occurrences were primarily noted along steep, high hill slopes along the east bank. Mass wasting observed was generally related to toe of the slope erosion by the stream. Other influences on hill slope failure in this area include the noncohesive nature of hill slope materials, downcutting of the channel, runoff from surrounding development, and groundwater seeps along the interface between geologic units of differing permeabilities.

Fallen trees, block slope failures, and debris in the narrow channel within the ravine exacerbated flow impingement on the toe of the slope. The rock riprap lining along the west bank throughout the ravine appeared to effectively limit erosion on that bank, but caused bank erosion and mass wasting to concentrate along the opposite bank. Only in a few locations along the west bank was the riprap observed to have been disturbed by local impingement of flow. An unused water pipeline has been exposed by channel downcutting in one location along the ravine.

Most bank and bed materials in this reach are erodible, noncohesive sediments. However, in various locations, a more erosion-resistant clay layer is exposed in the channel bed, which limits downcutting of the channel.

One of the largest tributaries to Des Moines Creek joins the stream near the upstream limit of the ravine. Bank heights near the upstream limit of the reach were on the order of 5 ft. Some headcutting along the tributary may be occurring due to incision of the channel within the ravine.

Parametrix (1992) streambank and bed stability ratings were fair to poor for the majority of sections in Reach 3. Seven of the eight worst bank stability ratings for the creek were found along this reach. For the most part, bank erosion and mass wasting was attributed to channel constrictions caused by sewerline armoring and a pipeline road in the creek channel. Other problems were created by concentrated storm water runoff from adjacent property development. Vegetation clearing also caused several areas of steep slopes to destabilize.

7.2.1.5 Reach 4 – Station 89+46 to Confluence of East and West Tributaries

The slope of Des Moines Creek flattens in Reach 4. Immediately upstream of the ravine, the channel bank heights are about 5 ft and decrease in an upstream direction. The largest wetland along Des Moines Creek occurs along the reach downstream of South 200th Street. The wetland could provide flood storage during large storm events.

The creek flows through a box culvert beneath South 200th Street. A drop of approximately 1.5 ft occurs at the downstream outlet of the box culvert. Upstream of South 200th Street, the creek flows through the Tyee Valley Golf Course passing through several drop structures placed along the channel.

Little evidence of channel instability was observed in Reach 4, although some bank erosion was observed immediately upstream of South 200th Street. The bank erosion was attributed to a localized flow obstruction caused by debris.

7.2.1.6 Upstream Tributaries

Upstream of Reach 4, the creek divides into two channels: the west tributary and the east tributary. The east tributary continues through the golf course and along the edge of the tank farm, parking lot, and associated development. An instream storm water detention facility (Tyee Pond) was constructed in the east tributary in 1989 for spill control and storm water management. Parametrix (1992) reported good bank and bed stability through most of the golf course, but poor bank and bed stability further upstream along the airport. An unstable, easily scoured substrate of fine sand, silt, and mud was common along this short reach. The open channel reach ends at a culvert at 28th Street. The creek flows in a culvert from Bow Lake to the outlet at 28th Street.

The west tributary of Des Moines Creek (referred to as Tributary A by Parametrix 1992 and west tributary by WEST Consultants 1997) flows from the Northwest Ponds through Tyee Valley Golf Course, when it joins with the east tributary downstream of Tyee Pond. The channel bank and bed stability was rated fair to poor (Parametrix 1992), due to the channel substrate of highly erodible, fine-grained channel substrate. A poor rating was assigned to the upstream segment, where vegetation was marginal and the creek channel formed an exposed, stagnant pool.

7.2.2 Hydrology

Aqua Terra Consultants (Beyerlein and Brascher 1997) modeled the watershed's hydrology using the EPA HSPF computer program. The model incorporated and modified earlier HSPF model inputs from Montgomery Water Group and King County. Table 30 summarizes estimated peak runoff rates at various concentration points in the basin. Flow duration information for each channel reach in the study area is shown in Table 31.

Table 30. Peak flow estimates (cfs) for current conditions in Des Moines Creek.

	Return Period (years)										
Reach[1]	1.05	1.11	1.25	2	5	10	25	50	100	200	500
1	102	112	126	160	206	236	274	302	331	360	399
2	95	104	118	150	194	225	264	294	324	355	398
3	88	97	109	138	178	204	237	262	288	313	348
4	70	77	87	110	143	165	193	214	236	258	289

[1] Peak flow rate given for downstream end of reach.

Table 31. Flow duration curves for current conditions in Des Moines Creek.

Reach 1 (mouth)		Reach 2		Reach 3		Reach 4	
Flow (cfs)	Percent Time Exceeded	Flow (cfs)	Percent Time Exceeded	Flow (cfs)	Percent Time Exceeded	Flow (cfs)	Percent Time Exceeded
0	100.00	0	100.00	0	100.00	0	100.00
15	10.50	12	12.29	11	11.31	10	4.44
30	4.45	24	5.29	22	4.72	20	1.22
45	2.45	36	3.05	33	2.74	30	0.42
60	1.43	48	1.88	44	1.69	40	0.16
75	0.86	60	1.19	55	1.06	50	0.07
90	0.54	72	0.77	66	0.67	60	0.03
102	0.38	95	0.34	88	0.27	70	0.02
112	0.27	104	0.2	97	0.19	77	0.01
126	0.17	118	0.16	109	0.13	87	0.00
160	0.07	150	0.07	138	0.06	110	0.00
206	0.03	194	0.02	178	0.02	143	0.00
236	0.01	225	0.01	204	0.00	165	0.00
274	0.00	264	0.00	237	0.00	193	0.00
302	0.00	294	0.00	262	0.00	214	0.00
331	0.00	324	0.00	288	0.00	236	0.00
360	0.00	355	0.00	313	0.00	258	0.00
399	0.00	398	0.00	348	0.00	289	0.00

Sea-Tac Airport's share of peak flood flows to Des Moines Creek was computed using simulated data generated for the January 9, 1990 flood event (see Appendix F, Tables 9 and 10). Sea-Tac Airport's contribution to total peak flow (at the mouth of Des Moines Creek) was determined to be 44 percent of flow (Beyerlein and Brascher 1997). The Airport's share of peak flood flows ranged from 82 percent of the flows from the Northwest Ponds to 32 percent of the flow in Bow Lake Creek above Tyee Pond. Sea-Tac Airport's annual average contribution at the mouth of Des Moines Creek was determined to be 24 percent of all streamflow (Beyerlein and Brascher 1997).

7.2.3 Bed Profile

The surveyed profile of the Des Moines Creek thalweg (the deepest point of the main channel) is shown in Figure 2 of Appendix F. Channel slope in Reach 3 is greater than in the other reaches. The greatest breaks in slope are located at the channel drop structures adjacent to the wastewater treatment plant. A summary of slopes for the four reaches is presented in Table 32. Slopes range from about 0.0090 (48 ft/mile) on Tyee Valley Golf Course (Reach 4) to 0.0300 (158 ft/mile) within the ravine of Reach 3.

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...isting channel slopes by reach along Des Moines Creek.

Length (ft)	Water Surface Slope (ft/ft)	Bed Slope (ft/ft)
2,157	0.0100	0.0100
1,880	0.0170	0.0170
3,626	0.0260	0.0300
4,081	N/A	0.0090

.2.4 Bed Material

The bed material along Des Moines Creek has been characterized, sampled, measured, and reviewed in several studies (WEST Consultants 1997b; Resource Planning Associates et al. 1994; Parametrix 1992). Generally, it consists of gravel-sized material, although deposits of sand and cobble-sized materials also occur along the stream. Coarse material is found in the steeper, faster flowing areas; fine-grained sediments are generally found in areas where the flow is retarded by hydraulic controls. No samples of the clay materials along the stream were taken. Field observations generally indicate that the clay is more erosion resistant than other noncohesive sediments found along the stream. Table 33 summarizes average sediment size by reach.

Table 33. Des Moines Creek average sediment diameter[1] (mm) by reach.

Reach	D_{16}	D_{50}	D_{84}
1	9.21	29.72	86.21
2	9.21	29.72	86.21
3	16.55	79.77	284.84
4	5.18	24.16	75.88

[1]The sediment size for which 16, 50, or 84 percent of the sample is finer than by weight.

7.2.5 Hydraulic Analysis

A limited hydraulic analysis of Des Moines Creek was performed using the U.S. Army Corps of Engineers Hydraulic Design Package for Channels (USACOE 1993). The analysis was undertaken to define the hydraulic conditions along Des Moines Creek for the range of expected flow conditions. The analysis was also used to define the general hydraulic capacity within the various reaches of the Des Moines Creek.

The hydraulic analysis was limited in that it did not consider the effect of backwater conditions on the hydraulics of flow; rather flow hydraulics were determined by normal depth calculations for a representative cross section in each defined reach. Because backwater is ignored by the analysis, the specific influence of tidal effects or hydraulic structures, such as the box culvert beneath Marine View Drive, are not considered.

A range of flows representative of the entire flow duration curve for the stream were considered in this hydraulic assessment. Included were both frequently occurring floods and extreme events. To define how the identified hydraulic conditions varied along the stream, plots of the hydraulic parameters of velocity, top width, and width/depth ratio are shown in Figures 8, 9, and 10 of Appendix F, respectively, for the 2- and 100-year return period floods.

Sediment transport rates are highly dependent on channel velocity. Stream flow velocity is highest in Reach 3, followed in decreasing order by reaches 1 and 2. Reach 4 has the lowest average velocity. These results are consistent for both the 2-year and 100-year floods.

To determine the general hydraulic capacity of each reach, plots were developed which show the computed water surface elevation relative to the measured channel cross section. These plots are shown in Figures 11 through 14, respectively (see Appendix F). As seen from the plots, each reach can effectively handle the analyzed hydrology for the full range of frequent and infrequent flood events. Reach 3 is seen to have relatively little change in flow depth between a 2- and 500-year flood. This is attributed to the relatively steep gradient in the reach.

7.2.6 Sediment Transport Analysis

The sediment transport characteristics of each defined reach of Des Moines Creek were analyzed by using the U.S. Army Corps of Engineers Hydraulic Design Package for Channels (USACOE 1993). The analysis sought to (1) define the sediment transport capacity for each reach over the range of expected flow conditions, (2) estimate the average annual sediment volume transported along each reach, and (3) evaluate the aggradation/degradation potential of the watercourse for an extreme event.

The analysis is limited in that it relies on the same hydraulic information described previously, which did not consider the effect of backwater conditions on the hydraulics of flow. Consequently, the specific influence of tidal effects or hydraulic structures, such as the box culvert beneath Marine View Drive, are not considered.

A range of flows representative of the entire flow duration curve for the stream were considered in the sediment transport analysis; therefore, it included both frequently occurring floods and extreme events. A variety of sediment transport functions were evaluated. The Toffaletti-Schoklitch sediment transport function was used because it was specifically developed for sand- and gravel-bed streams.

:sport conditions for each defined reach of Des
ɾr each reach were integrated with the sediment
‹ge of expected flows. Results of the evaluation are

transport.

	Sediment Yield (tons)	Sediment Yield (yd³)	Mean Daily Flow (cfs)	Mean Daily Load (ton/day)	Mean Daily Concentration (mg/l)
	1,502	1,197	10.08	4	151.2
	2,561	2,040	8.26	7	314.6
,537	3,011	2,398	7.65	8	399.4
3,777	1,094	871	5.22	3	212.7

‚atest sediment transport potential occurs in Reach 3, while lowest potential is in Reach 4.

‚treme Event Sediment Transport

To estimate the sediment transport conditions resulting from an extreme event for each of the defined reaches of Des Moines Creek, the hydrograph of the 100-year return period flood for each reach was integrated with the sediment transport capacities determined for the range of expected flows. Results of the evaluation are summarized in Table 35.

Table 35. Des Moines Creek 100-year flood sediment transport by reach.

Reach	Water Yield (ac-ft)	Sediment Yield (tons)	Sediment Yield (yd³)	Mean Daily Flow (cfs)	Mean Daily Load (ton/day)	Mean Daily Concentration (mg/l)
1	416	393	131	218.6	411	695.6
2	406	861	686	213.8	898	1,556.0
3	311	1,056	841	163.6	1,109	2,494.8
4	244	244	194	128.6	255	734.0

As seen in Table 35, the greatest sediment transport during a 100-year flood occurs in Reach 3. The lowest level occurs in Reach 1.

7.2.7 Des Moines Creek Summary of Impacts

All watershed development and channel modifications affect channel erosion and sediment transport; the system is too complex to assess the impact of specific development projects or channel modifications. It is difficult to determine the point at which the natural channel processes of erosion and sediment transport are modified sufficiently to adversely impact the system. Also, it is difficult to quantify whether watershed hydrology has a more dramatic impact than channel modifications. For example, although watershed development has altered watershed hydrology, mass wasting observed in several locations was directly attributed to channel modifications (i.e., pipelines, uncontrolled runoff, rip rap bank protection, etc.). It is not possible with the available analysis to reasonably estimate the quantity of sediment erosion and deposition that are attributable tc natural processes or increased by development impacts. Therefore, it is an oversimplification of system dynamics to assume that the area or volume of basin contribution to the stream flows is proportional to the impacts of the changes.

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