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*Declaration of Paul S. Fendt*  
Volume 3 of 3

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**AR 011564**



**King County**  
**Department of Natural Resources**  
 Director's Office  
 King Street Center  
 301 South Jackson Street, Suite 700  
 Seattle, WA 98104-3855

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August 3, 2001

**Ann Kenny, Senior Permit Specialist**  
**Washington Department of Ecology**  
**Northwest Regional Office**  
 3190 - 160th Avenue Southeast  
 Bellevue, WA 98008-5452

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**ENVIRONMENTAL  
 HEARINGS OFFICE**

**Dear Ms. Kenny:**

King County is pleased to have had the opportunity to assist the Department of Ecology by making its technical review capacity and knowledge of local stormwater conditions available for the review of the Port of Seattle's *Comprehensive Stormwater Management Plan (SMP)* for Master Plan Improvements at SeaTac International Airport. This effort has set an excellent example of how state and local government can work cooperatively in addressing pressing issues facing the region.

As with our previous reviews of this project, it is important to keep in mind the limitations of the work that we have performed. First, this review is limited to ascertaining whether the SMP attained minimum compliance with the 1998 *King County Surface Water Design Manual*. Compliance with the technical provisions of the Design Manual does not mitigate all potential impacts of development and may not provide sufficient information to allow for approval under other codes and regulations. Compliance with the Design Manual is, however, a good start towards mitigating the impacts of this large and complex project.

It is also important to remember that this review is limited to those development activities identified by the Port of Seattle as being Master Plan Update Improvements. While other projects of varying magnitude are being proposed for this area, only those projects included in the formal SMP submission were reviewed for this comment letter. No assumption of concurrence with the technical details or effectiveness of additional projects should be assumed without our specific written comment.

Our reviewers found this version of the SMP is consistent with the technical requirements of the *King County Surface Water Design Manual*. The SMP demonstrates a feasible conceptual strategy for complying with the technical provisions of the *King County Surface Water Design Manual* and effectively demonstrates that the proposed improvements could fully comply with Design Manual requirements.

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Ann Kenny  
August 3, 2001  
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Enclosure 1 provides general commentary on how the SMP responds to the specific core and special requirements of the *King County Surface Water Design Manual*, as well as an overview of the review scope and limitations.

Enclosure 2 provides a summary of the various surface water facilities proposed for construction, along with specific information on each facility, such as the volume of the facility, the drainage area served, and the amount of impervious area tributary to each facility.

Thank you for this opportunity to work together on behalf of the region. If you have any questions, please contact David Masters, Senior Policy Analyst, or Kelly Whiting, Senior Engineer, both with the Water and Land Resources Division. David can be reached at (206) 296-1982 or via e-mail at [david.masters@metrokc.gov](mailto:david.masters@metrokc.gov). Kelly can be reached at (206) 296-8327 or via e-mail at [kelly.whiting@metrokc.gov](mailto:kelly.whiting@metrokc.gov).

Sincerely,



Pam Bissonnette  
Director

PB:rv F968

Enclosures

cc: The Honorable Ron Sims, King County Executive  
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Paul Tanaka, County Administrative Officer, Department of County Administration  
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Enclosure #1 - Final Review Comments - December 2000 (as revised July 2001) Comprehensive Stormwater Management Plan - Master Plan Update Improvements - Seattle-Tacoma International Airport - Port of Seattle - Parametrix Inc.

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## ENCLOSURE 1 OVERVIEW OF REVIEW SCOPE AND LIMITATIONS

The December 2000 Comprehensive Stormwater Management Plan (SMP), as revised in July, 2001 has been reviewed for consistency with the technical provisions of the 1998 King County Surface Water Design Manual (KCSWDM). The review has concluded that the SMP has demonstrated that the mitigations proposed in the SMP are consistent with the standards set forth in the KCSWDM. This enclosure details key findings regarding this compliance assessment.

Review has been limited to those development activities identified by the SMP as being Master Plan Update (MPU) Improvements (see SMP Table A-3). Projects not included in the SMP were not reviewed and therefore no presumption of consistency with KCSWDM should be drawn for these projects. Review was performed per the KCSWDM technical requirements which would have applied under Full Drainage Review (see KCSWDM excerpts in text box on page 2), except where the SMP identifies performance goals exceeding the KCSWDM standards. Compliance with King County's technical standards may not be sufficient for project approval under other codes and regulations, and these standards are known to be insufficient to fully mitigate all potential impacts of development. Specifically excluded from the review scope are all procedural requirements of the KCSWDM.

Review and concurrence of a stormwater management plan is primarily a review of design concepts and assumptions to determine if the proposed mitigations demonstrate a feasible approach to comply with the identified performance goals. As the proposed MPU development projects move from the planning stages to development of construction plans, the proposed stormwater mitigations may need to be updated to reflect any changed conditions. Prior to construction of specific projects, additional review and approval of the final construction drawings and associated technical information report is typically required. Oversight and monitoring are key elements to successful implementation of any stormwater management plan. It is recommended that Ecology and the Port develop a plan to oversee and monitor compliance with the mitigations set forth in the SMP. One option is to create an Ecology "Compliance Team", representing the necessary disciplines, to work with the Port to achieve compliance with the goals and objectives laid out in the SMP and related documents.

It has not been determined what legal vesting an Ecology approved SMP affords the future development activities identified within. The SMP includes projects where specific flow control and water quality mitigation approaches and conceptual plans have been identified, but which may be adjusted during final design. The SMP also lists other development projects which do not have specific mitigations identified (see SMP Table A-3). Ecology and King County are working on updated stormwater standards needed to implement Clean Water Act and Endangered Species Act protection objectives. Review of the SMP against these draft standards was not performed. If final facility designs include revised on-site performance goals, Ecology may wish to review the final proposed facilities against the standards in effect at that time.

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## **EXCERPT FROM 1998 KCSWDM**

### **1.14 DRAINAGE DESIGN BEYOND MINIMUM COMPLIANCE**

This manual presents King County's minimum standards for engineering and design of drainage facilities. While the County believes these standards are appropriate for a wide range of development proposals, compliance solely with these requirements does not relieve the professional engineer submitting designs of his or her responsibility to ensure drainage facilities are engineered to provide adequate protection for natural resources and public and private property.

Compliance with the standards in this manual does not necessarily mitigate all probable and significant environmental impacts to aquatic biota. Fishery resources and other living components of aquatic systems are affected by a complex set of factors. While employing a specific flow control standard may prevent stream channel erosion or instability, other factors affecting fish and other biotic resources (such as increases in stream flow velocities) are not directly addressed by this manual. Likewise, some wetlands, including bogs, are adapted to a very constant hydrological regime. Even the most stringent flow control standard employed by this manual does not prevent increases in runoff volume which can adversely affect wetland plant communities by increasing the duration and magnitude of water level fluctuations. Thus, compliance with this manual should not be construed as mitigating all probable and significant stormwater impacts to aquatic biota in streams and wetlands, and additional mitigation may be required.

In addition, the requirements in this manual primarily target the types of impacts associated with the most typical land development projects occurring in the lowland areas of the County. Applying these requirements to vastly different types of projects, such as rock quarries or dairy farms, or in different climatic situations, such as for ski areas, may result in poorer mitigation of impacts. Therefore, different mitigation may be required.

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## OVERVIEW OF CORE AND SPECIAL REQUIREMENTS

### Core Requirement #1 Discharge at Natural Location

The Master Plan Update (MPU) development activities will result in modifications to the constructed and natural drainage systems within the Seattle-Tacoma International Airport (STIA) area. Below is a summary of STIA areas per the landuse tables in Appendices A and B. The differences in basin sizes can mostly be attributed to the collection and conveyance of potentially polluted stormwater runoff to the Industrial Waste Treatment System (IWS).

#### Summary of Drainage Basin Areas (acres)

	Calibration	PreDev	PostDev
Des Moines STIA	1672	1585	1577
Walker STIA	234	234	234
Miller STIA	1247	1212	1184
<b>Total STIA Storm</b>	<b>3153</b>	<b>3031</b>	<b>2995</b>
Des Moines IWS	285	331	375
Walker IWS	0	0	0
Miller IWS	0	86	80
<b>Total STIA</b>	<b>3438</b>	<b>3448</b>	<b>3450</b>

Note: numbers taken from landcover tables dated 12/00

### Core Requirement #2: Downstream Analysis

Downstream analysis is provided in Appendix P of the document. Identified downstream problems include channel erosion and potential existing flooding problems in Miller Creek. The associated on-site mitigations for these problem types include:

Channel erosion - apply Level 2 streambank erosion standard

- The Level 2 standard is the base standard being applied across the project site. The entire airport site is being retrofitted back to predevelopment conditions corresponding to 75% forested, 15% grass, and 10% effective impervious. This will serve to reduce the existing rates of erosion, although the benefit will be diminished further downstream due to other existing development not having been retrofitted to the same level of protection. Implementation of the Des Moines Creek Basin Plan and development and implementation of a Miller/Walker Creek Basin Plan will help address stormwater needs across the entire basins.

Existing flooding problem - match 100-year peak flows in addition to the Level 2 standard.

- The SMP includes the matching of 100-year peak flows as a specific performance goal and was achieved through the flow control mitigations proposed.

### Core Requirement #3: Flow Control

The SMP uses a flow control performance standard equivalent to the KCSWDM Level 3 standard. This includes the control of the duration of high flow discharges between 50% of the 2-year and the full 50-year peak flows. In addition, the 100-year peak discharge is controlled to the predeveloped 100-year level.

The SMP predevelopment landcover assumptions of 75% forest, 15% grass, and 10% maximum impervious provides a target flow regime that is more protective than the current "Existing Site Condition" requirements of the KCSWDM. Using general stream stability guidelines a basin consisting of 75% forest, 15% grass and 10% impervious would provide a flow regime predicted to be geomorphically stable, but

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which may have some water quality and base flow concerns. However, since the airport drainage areas comprise a small portion of the entire stream basin, the instream benefits will be less than if all properties in these basins were retrofitted to this standard. Additional mitigations are being proposed to address summer low-flow impacts through a series of low-flow augmentation vaults. Water quality treatment and monitoring is proposed to help ensure that water quality standards would be met.

Under the KCSWDM, flow controls (detention/infiltration) would only be required for new added impervious. Under the draft updates to the Ecology stormwater manual and KCSWDM currently in preparation, flow control retrofits would likely be required for any replaced impervious surfaces. The Port is providing flow control retrofits for all impervious surfaces to the 75/15/10 landcover conditions described above, although this would not be required by the Ecology manual or by KCSWDM.

The enclosed table (Enclosure 2) provides an overview of the storage reservoirs reviewed under the SMP and the associated landcover (impervious and pervious) assumptions used to size these facilities. Enclosure 2 also provides a list of MPU projects identified to be served by each proposed facility.

The detention ponds located around the toe of the fill embankment could potentially be deep enough to intercept seasonal high groundwater. The SMP proposes that final facility design may be altered to maintain the live storage volume above the groundwater level. If this occurs, it may require raising of berm heights, increasing side slopes, or as a last resort, expanding the facility footprint. Facility footprints may not be able to increase due to site constraints. Modifications to SDN3A may result in that facility exceeding the threshold of State Dam Safety regulations.

The SMP uses a special PERLND calibration for the embankment fill. This calibration was based on limited monitoring data collected from a 1998 embankment area. The effect of this calibration is for fill soils to produce higher runoff than till-grass, but less than impervious. The SMP assumption is that the final embankment will react hydrologically similar to the smaller 1998 embankment area. The SMP has not changed this assumption since it was first proposed during the Miller Creek calibration meetings in Spring of 2000. Ecology's June, 2000 PGG report provides a range of expected soil characteristics for the fill embankment. The expectation is that fill soils will have a hydrologic response more similar to outwash grass with flat slopes than to the previous embankment fill calibration work. At this point in time there was a separation in assumptions between how the fill is characterized in the embankment modeling (used primarily for low stream flow assessment and wetland mitigation) and the SMP modeling (used primarily for high flow assessments, and flow control mitigation sizing). Based on the June 2000 characterization of the embankment's hydrologic response, the SMP assumptions would provide some conservatism in the design of flow control mitigations.

The SMP hydrologic models have assumed that all airport impervious areas are 100% effectively connected to the downstream drainage system. Therefore, the modeled impervious areas equal the total impervious areas. This assumption was used consistently in the HSPF models for all 3 stream basins for the calibration, future and predeveloped (meaningful where use of an effective impervious fraction would result in less than 10% effective impervious) landcover assumptions. If runoff from the runway does infiltrate into the fill embankment as indicated by the June 2000 PGG report, the effective impervious assumptions would provide some conservatism in the design of flow control mitigations.

#### **Core Requirement #4: Conveyance Systems**

The SMP indicates that all existing conveyance systems provide at least a 10-year level of capacity. All new conveyance systems will be designed to at least a 25-year level of capacity and will meet the spill containment provisions of the KCSWDM.

The project site includes the challenge of conveying flows down from the runway elevation to the detention and sediment control ponds at the foot of the embankment. The SMP provides, in Appendix W, conceptual designs for energy dissipation structures that will be used to control the high velocity flows at those outfalls.

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#### **Core Requirement #5: Erosion and Sediment Control**

The SMP provides preliminary erosion and sediment control plans for the proposed 3<sup>rd</sup> runway embankment. Additionally, the SMP indicates that an erosion control specialist will be responsible for overseeing the installation and performance of these facilities. This is an important aspect of achieving effective erosion/sediment controls on projects of this size.

Of concern is the close proximity of some sediment ponds to the stream channels. However, this cannot be avoided due to the close proximity of the final embankment to the stream channels. Any overtopping, bypassing, or failure of these ponds may result in sediment being discharged to Miller Creek due to the short flowpaths from the ponds to the stream. Extra diligence on erosion control is warranted to minimize sediment transport from disturbed soils (e.g., the embankment fill) to the final sediment ponds. This would include, but is not limited to,

- soil stabilization and cover measures on all disturbed soils.
- minimizing the "open" (without cover measures) areas to only those portions of the project site which are being actively worked.
- further minimizing the areas being actively worked during the wet season (October 1 through April 30), and before forecasted precipitation events.
- frequent inspections of the erosion and sediment control facilities by the erosion control specialist.
- daily inspections of the sediment ponds in close proximity to the stream channels during the wet season, and
- contingency plans developed beforehand to address potential problems which may be encountered with any of the erosion and sediment control BMPs, with emphasis on the sediment ponds serving as the last line of defense prior to discharge to stream.

#### **Core Requirement #6: Maintenance and Operation**

This KCSWDM Core Requirement is mostly procedural in nature, written specifically to implement King County's policies and codes. This review is limited to compliance with the technical aspects of the KCSWDM and specifically excludes procedural requirements specific to King County. Therefore, Ecology should ascertain that adequate provisions and agreements are made to ensure the proper maintenance and operation of stormwater facilities on this project site.

The following is the reviewers understanding of maintenance and operation responsibilities at the project site: All facilities on the project site are to be maintained by the Port of Seattle, or their designee. Where maintained by others, Port of Seattle is ultimately responsible for proper maintenance and operations under their NPDES permit.

Some of the deeper vaults exceed the maximum allowable depth to invert (measured from final surface grade) of 20 feet. The SDS7 vault is proposed as an above ground storage structure. An assessment of maintenance feasibility has been provided which supports the SMP position that the Port will be able to perform necessary maintenance activities.

#### **Core Requirement #7: Financial Guarantees and Liability**

This SWDM Core Requirement is specific to procedures required under King County policy and code. The intent is to ensure that there is adequate funding available to ensure completion of the required mitigations. It requires that construction be completed, or the posting of bonds and other financial guarantees occur prior to final permit approval.

There are substantial costs associated with the proposed mitigations. Many of the facilities are proposed as underground vaults to avoid the wildlife attraction associated with open ponds. The largest of the eight flow control vaults will have 88 acre-feet of storage, nearly 4 acres in area at 25 feet of live storage depth. The Port has provided a memo indicating the feasibility of the structural design of this facility. A commonly used estimate of vault construction costs is \$5- per cubic-foot. With a total volume for new vaults for flow control (347.1 acre-feet), water quality (4.5 acre-feet), and reserve storage (46.1 acre-feet) of 397.7 acre-feet, the total cost in vaults is at \$86.6 million. Note: SMP uses a vault cost of about \$12- per

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cubic foot in assessing feasibility of some water quality retrofits. This value would put the total estimated total vault cost at \$207.9 million.

#### Core Requirement #8: Water Quality

The SMP has provided conceptual designs for water quality treatment facilities consistent with those found in the KCSWDM Basic Water Quality Treatment Menu. The performance goal of basic water quality treatment is 80% TSS removal. The SMP proposes to provide treatment for all new pollution generating surfaces and for all existing pollution generating surfaces through a combination of biofiltration, wet vaults and reroutes to IWS system. Review of these conceptual designs has concluded that they are sized appropriately for the assumed service areas and that they can feasibly be constructed consistent with KCSWDM design standards. STIA areas not proposed for water quality treatment include:

- Approximately 80 acres of existing pollution generating impervious surfaces as shown in SMP Figure 4.4 and Table 7-8. The SMP indicates that the high cost and disruption to airport operations associated with construction of underground wet vaults for these areas make water quality retrofits impractical.

Two instances where source controls are proposed in-lieu of water quality treatment include:

- Landscape Management Plans which implement the source control objectives of the KCSWDM are proposed for all managed landscaped areas, including the runway/taxiway infields.
- Uncoated Metal Roofs are proposed to be coated to prevent leaching. Although not specifically mentioned as an option in the KCSWDM, this approach is consistent with the intent of requiring water quality treatment only for uncoated metal roofs. If the coating process is not successfully completed, water quality treatment would be required.

The above approaches were determined to be consistent with the KCSWDM application of water quality treatment standards for new and redeveloping properties. SMP Table 7-8 provides an overview of the proposed water quality treatment facilities for new and existing pollution generating impervious surfaces.

Previous comments have been provided in regards to copper (Cu) concentrations from some of the existing STIA outfalls. The SMP indicates that the stormwater collection and conveyance system design can accommodate additional water quality treatment measures if deemed necessary through continued monitoring.

The STIA Industrial Wastewater System (IWS) is regulated by Ecology under the Clean Water Act Section 402. The KCSWDM does not set standards for industrial wastewater systems, such as the IWS. The TSS removal efficiency of the IWS is not presented in the SMP. Evaluation of the IWS storage capacity using future landcover, storage capacity, and processing rates indicated that the IWS lagoons are not predicted to overflow to stream. The biggest concern is the sustainability of the assumed future processing rates. As the IWS outfall is proposed to be redirected to the sanitary sewer which may include constraints on allowable processing rates, the issue of potential overtopping should be addressed once future maximum discharge rates to sanitary sewer have been determined. The SMP results do not support the contention of the IWS feasibility report that sufficient storage exists to allow the IWS discharge to be slowed or stopped during storm events. It may be necessary for the Port to retain the use of the current outfall to Puget Sound depending on conditions placed on the proposed connection to sanitary sewer. Since specific future storm volumes cannot be reliably predicted, the IWS operation appears to require near maximum processing rates (3.2 to 4.0 mgd) whenever lagoon #3 is receiving inflows. Any additional areas being rerouted to IWS and not included in the analysis would also warrant evaluation. Note: The modeled future IWS service area includes approximately 410 acres of impervious and 24.6 acres of grassed pervious area. The ultimate storage volume is modeled as 76.9 million gallons, and the maximum sustained processing rate is assumed whenever lagoon #3 is storing wastewater.

#### Special Requirement #1: Adopted Area Specific Requirements

This would include the Des Moines Creek Basin Plan. The SMP mitigations do not rely on construction of the regional detention facility, or low flow augmentation facility for mitigating existing or new impervious

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areas. However, the SMP indicates that if conditions change (e.g., the regional facility is constructed prior to MPU development), that the SMP mitigations may be revised. Since this alternative approach was not analyzed by the SMP, Ecology review and approval of the plans and sizing for final construction may be necessary. The Port is an active member of the Des Moines Creek Basin Committee.

**Special Requirement #2: Floodplain/Floodway Delineation**

A copy of the floodplain analysis on Miller Creek is included in SMP Appendix J. MPU development has been identified within the floodplain delineation, specifically the 156<sup>th</sup>/154<sup>th</sup> roadway realignment in the Vacca farm area, and a relatively small displacement from the 3<sup>rd</sup> runway embankment near where Miller Creek turns west towards SR509. Calculations provided demonstrate that the roadway realignment is fully compensated for in the Vacca farm area at the 100-year level flood. The embankment calculations indicate that an additional 5 cubic yards is displaced by the embankment footing. The indication is that the base floodplain elevation was determined to not rise due to this amount of displacement, which in turn will not affect the flood carrying capacity of the stream.

**Special Requirement #3: Flood Protection Facilities**

This special requirement is not applicable as none of the streams are restrained by levees or revetments in the vicinity of the project site.

**Special Requirement #4: Source Control**

The SMP proposes the use of source control BMPs, many of which are currently being applied to maintenance and operations of the site. Two new source control BMPs are proposed for the site under the SMP. These include retrofitting of existing non-coated metal roofs to prevent leaching of metals, and the implementation of improved landscape management guidelines to minimize the use of pesticides and fertilizers to managed landscape areas including the infield areas surrounding the runways and taxiways. Both of these source control BMPs are consistent with the requirements of the KCSWDM.

**Special Requirement #5: Oil Control**

Several areas within the project site meet the threshold for high-use sites under the KCSWDM criteria. Most of these areas are being, or are proposed to be, diverted to the IWS which has oil control and spill containment provisions and is regulated as an industrial wastewater discharge rather than a stormwater discharge. One additional area was identified under the SMP as meeting the high-use threshold, the Terminal Drives. The SMP proposes to either install treatment BMPs to this area, or to divert these areas to the IWS. Both alternatives appear to be feasible and consistent with the requirements of the KCSWDM.

**Enclosure 2: Facility and Project Schedules Sorted by Flow Control Facility**  
 Landcover data from HSPF Input files  
 Schedule project data from VBP Table A3

Flow Control Facility	Year Facility Expires	Facility Type	Volume (Ac-Ft)	Projects Derived by Facility as Described in VBP Table A3	Year Project to be Constructed	Construction Comments	Landcover Assumptions by Facility (year)	Impervious Surfaces (acres)	Impervious Surfaces (acres)	Impervious Surfaces (acres)					
S0094	Veer Facility Expires Schedule	Facility Type	Volume (Ac-Ft)	Projects Derived by Facility as Described in VBP Table A3	Year Project to be Constructed	Construction Comments	EIA = Erosion Impervious Area	EIA	EIA	EIA					
											1985	1987	1989	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
S0097	Veer Facility Expires Schedule	Facility Type	Volume (Ac-Ft)	Projects Derived by Facility as Described in VBP Table A3	Year Project to be Constructed	Construction Comments	EIA = Erosion Impervious Area	EIA	EIA	EIA					
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
S0098	Veer Facility Expires Schedule	Facility Type	Volume (Ac-Ft)	Projects Derived by Facility as Described in VBP Table A3	Year Project to be Constructed	Construction Comments	EIA = Erosion Impervious Area	EIA	EIA	EIA					
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
S0099	Veer Facility Expires Schedule	Facility Type	Volume (Ac-Ft)	Projects Derived by Facility as Described in VBP Table A3	Year Project to be Constructed	Construction Comments	EIA = Erosion Impervious Area	EIA	EIA	EIA					
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999
											1995	1997	1999	1998	1999

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Site Name	Year Facility	Facility Type	Volume (ac-ft)	Project Served by Facility as Described in SRF Title A-3	Year Project to be Completed	Comments	LAND USE ASSUMPTIONS BY FACILITY ( acres )					IMMEDIATE IMPACTS ( acres )																																																						
							EIA	EA	CE	DE	Other	EA	CE	DE	Other	EA	CE	DE	Other																																															
Quality Name - Elton Service refuge for SRF	4	Wetland	17.1	Elton Service SRF SRF Title A-3	1995 1998 1999	new new new																																																												
CRAGO	4	Wetland	4.5	Continued Expansion of South Cargo Facility Cargo Warehouse at 24th Avenue South	01 - 05 06 - 10	refurb new																																																												
SOUTH includes PMS in existing and 1998 Wetland	8	Wetland	5.6	Replacement of South Air Cargo (ground support equipment and roadway)	1985 1998 1999	refurb new new																																																												
STANSON	4	Wetland	35.2	Intercommuting Tankways (RTS) S/L Phase 1 - 1998 Tankway Construction Phase 2 - 1999 Tankway Construction	1989 1999	refurb new																																																												
WEST existing	4	Wetland	13.9	WETP - Project 1	1989	refurb																																																												
WINWA	6	Wetland	95.5	Phase 2 - 2001/2002 Tankway (RTS) S/L	04 - 08	new																																																												
SOYIB	6	Pond	52.6	Phase 3 - 2002-2004 Runway (RTS) S/L	04 - 08	new																																																												
SONNA	5	Pond	44.8	Phase 3 - 2002-2004 Runway (RTS) S/L	04 - 08	new																																																												
SGH		Pond	0.52	ASPH site	01 - 04	new																																																												
MCPIRF	Edir	Pond		1500/1500 Spinal Retention MSP, Phase 1	02 - 03	1500/1500 providing flow control for 10% of MSP																																																												
Delayed Area Impervious Removal SRF to Interchange		Pond		Intermittent flow Retention Temporary SRF site Interchange	02 - 03	1500/1500 not included in SRF																																																												
							<table border="1"> <tr> <td>PERMANENT</td> <td>1994</td> <td>PRE</td> <td>177.0</td> <td>RETENTION</td> <td>17.2</td> <td>TEMPORARY</td> <td>175.3</td> <td>TOTAL</td> <td>481.1</td> </tr> <tr> <td>TOTALS</td> <td>1994</td> <td>PRE</td> <td>177.0</td> <td>RETENTION</td> <td>17.2</td> <td>TEMPORARY</td> <td>175.3</td> <td>TOTAL</td> <td>481.1</td> </tr> <tr> <td>EIA</td> <td>98.2</td> <td>30.4</td> <td>177.0</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>481.1</td> </tr> <tr> <td>Total Area</td> <td>485.1</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Total Live Storage</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table>					PERMANENT	1994	PRE	177.0	RETENTION	17.2	TEMPORARY	175.3	TOTAL	481.1	TOTALS	1994	PRE	177.0	RETENTION	17.2	TEMPORARY	175.3	TOTAL	481.1	EIA	98.2	30.4	177.0						481.1	Total Area	485.1									Total Live Storage														
PERMANENT	1994	PRE	177.0	RETENTION	17.2	TEMPORARY	175.3	TOTAL	481.1																																																									
TOTALS	1994	PRE	177.0	RETENTION	17.2	TEMPORARY	175.3	TOTAL	481.1																																																									
EIA	98.2	30.4	177.0						481.1																																																									
Total Area	485.1																																																																	
Total Live Storage																																																																		

Facility Name	Facility Name	Year Facility Began	Facility Type	Storage Volume (gals)	Projects Served by Facility as Described in SRP Table A-4	Year Project to be Constructed	Construction Comments	LANDCOVER ASSOCIATIONS BY FACILITY (acres)			CURRENTLY SUPPORTED BY FACILITY	
								EA	Future Conditions	Future Potential	Existing Conditions	Future Potential
SOVER	Year Facility Began: 0	Facility Type: Pond	Storage Volume (gals): 109	Projects Served by Facility as Described in SRP Table A-4: Phases 3 - 3002-2003 Runway IMPROVEMENTS	04 - 08 new	Temporary	no impervious no impervious no impervious no impervious	EA 418	Future Conditions 449	Future Potential 415	Existing Conditions 194	Future Potential 62
IMPASD Interchange	Projects not supporting Phase Confined				Temporary SR-509 Interchange	1	Impervious not included in SRP					
Valencia	Projects not supporting Phase Confined				Arborm Waterline Mitigation Miller Creek Reduction VMCRA FRRM Foundation Reduction Miller Creek Sewer Reduction Property Acquisition, Street and Utility Workover Sites 5A and 4 Phase 1 - 1997 Embankment Sloicgate Phase 2 - 1998 Embankment PII Phase 3 - 1998 Embankment FRI Phase 4 - 2000 Embankment FRI Suelka Transit Shuttle System Potholes Mill Change Expansion to South, North, East SUEBA Site Preparation Ramps off SR-514, 3 1990b Improvements Additional Expansion of Main Parking Garage	no impervious no impervious no impervious no impervious	01 - 05 not included in SRP 06 - 10 not included in SRP 09 - 10 not included in SRP					
	Projects not supporting Phase Confined				Expansion of RISEL to 6000 sq ft Additional Facility EASE on 161/DR Additional Expansion of Main Parking Garage Additional Expansion of Main Employee Parking Lot Expand North Unit Parking Structure SR-509 Expansion South Access ASDC, RWAVDS	01 - 05 not included in SRP 06 - 10 not included in SRP 09 - 10 not included in SRP 10 - 20 WISDOV pooled 02 - 01 not included in SRP						

AR 011576

**E**

**AR 011577**

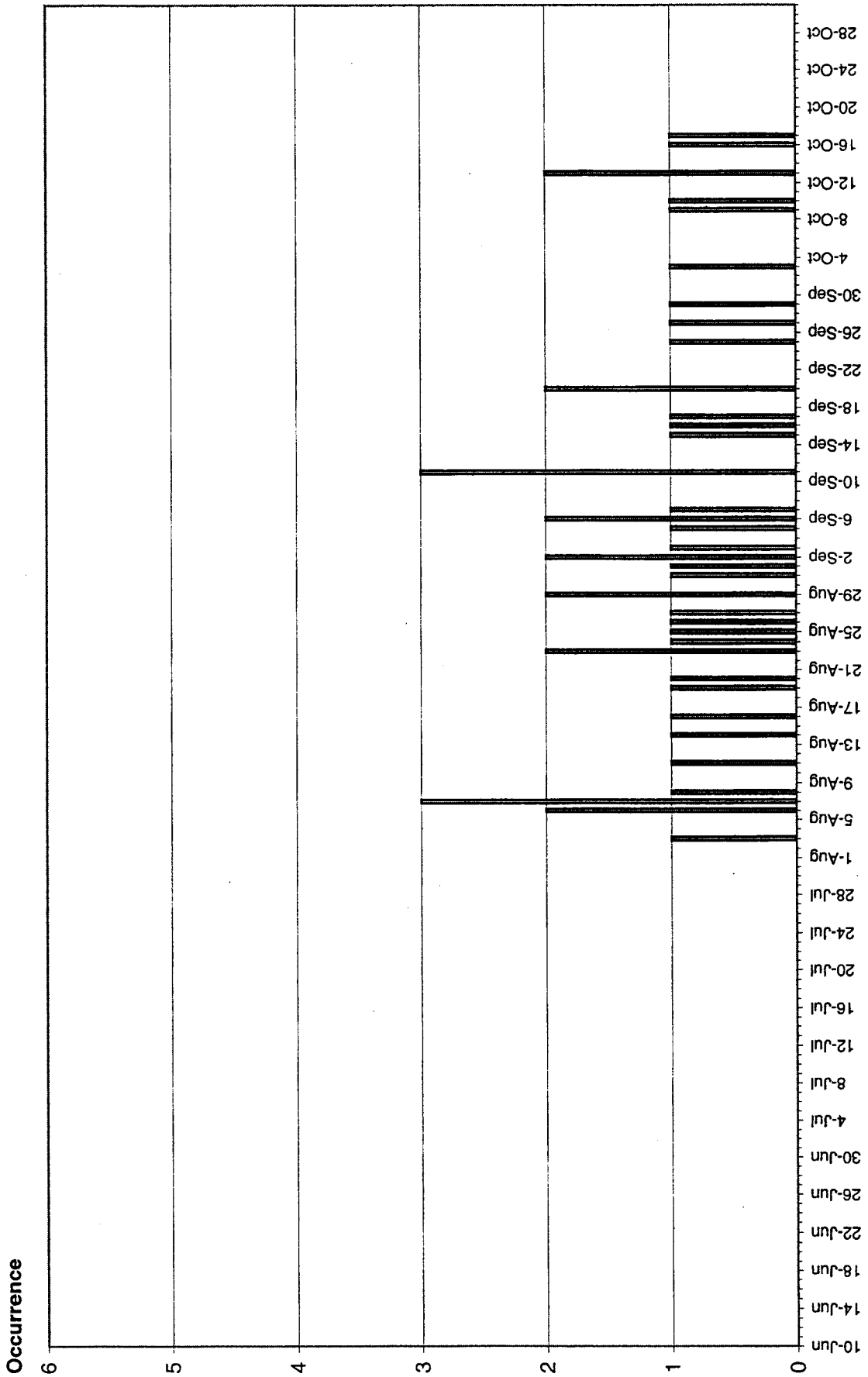
**DES MOINES CREEK**  
**7-DAY LOW FLOW OCCURRENCES IN DES MOINES CREEK**  
**(1994)**

**AR 011578**



**DES MOINES CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES**  
**IN DES MOINES CREEK (1994)**

7-Day Low Flow Occurrences in Des Moines Creek, 1949-1995 (1994 HSPF)



**DES MOINES CREEK**  
**7-DAY LOW FLOW OCCURRENCES IN DES MOINES CREEK**  
**(2006)**

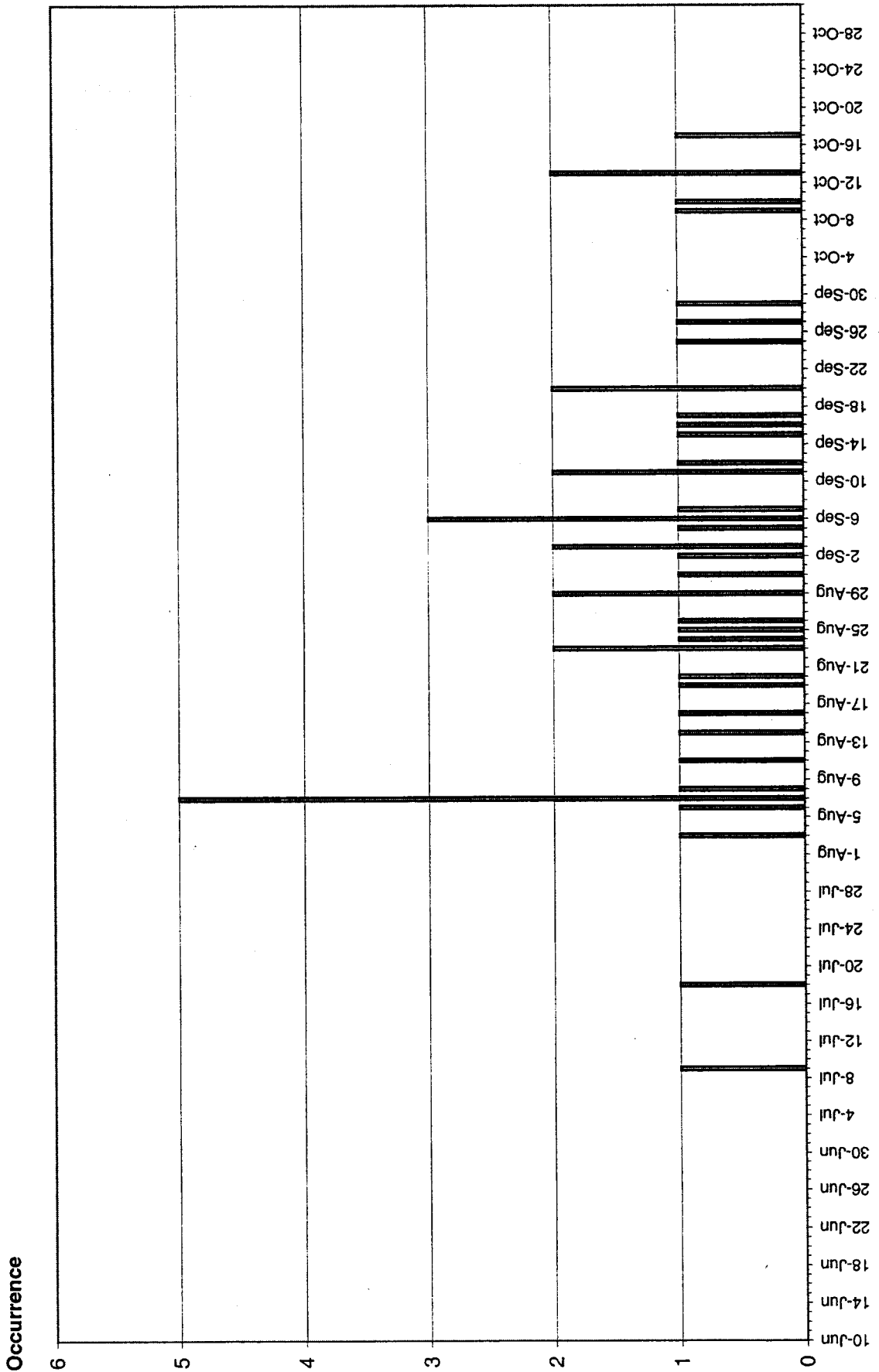


Start of 7-Day Low Flows with Average Flow Rates				Statistical Ranking of Average 7-Day Low Flows Period of Record: 1949-1995					
2006 HSPF Des Moines Creek at 200th St. / Flow cfs Average 7-Day Low Flow				Average 7-Day Lows			Return Frequency		
Date				Date	Ordered	Rank	Rank/47+1		
1949	SEP	7	0.14	1977	0.12	1	0.02	2.1	
1950	SEP	17	0.32	1949	0.14	2	0.04	4.2	
1951	AUG	20	0.25	1952	0.15	3	0.06	6.3	
1952	OCT	13	0.15	1994	0.16	4	0.08	8.3	
1953	SEP	15	0.28	1979	0.17	5	0.10	10.4	
1954	AUG	7	0.37	1988	0.18	6	0.13	12.5	
1955	SEP	6	0.25	1958	0.19	7	0.15	14.6	
1956	SEP	3	0.35	1985	0.19	8	0.17	16.7	
1957	SEP	20	0.25	1986	0.19	9	0.19	18.8	
1958	SEP	2	0.19	1993	0.19	10	0.21	20.8	
1959	AUG	24	0.28	1973	0.20	11	0.23	22.9	
1960	AUG	7	0.28	1981	0.21	12	0.25	25.0	
1961	AUG	23	0.30	1974	0.22	13	0.27	27.1	
1962	SEP	3	0.27	1987	0.22	14	0.29	29.2	
1963	SEP	27	0.31	1990	0.23	15	0.31	31.3	
1964	AUG	31	0.39	1966	0.24	16	0.33	33.3	
1965	AUG	3	0.30	1967	0.24	17	0.35	35.4	
1966	AUG	19	0.24	1975	0.24	18	0.38	37.5	
1967	AUG	25	0.24	1992	0.24	19	0.40	39.6	
1968	AUG	7	0.38	1951	0.25	20	0.42	41.7	
1969	SEP	6	0.29	1955	0.25	21	0.44	43.8	
1970	JUL	18	0.25	1957	0.25	22	0.46	45.8	
1971	AUG	14	0.31	1970	0.25	23	0.48	47.9	
1972	AUG	8	0.42	1980	0.25	24	0.50	50.0	
1973	SEP	11	0.20	1991	0.25	25	0.52	52.1	
1974	OCT	13	0.22	1962	0.27	26	0.54	54.2	
1975	AUG	11	0.24	1976	0.27	27	0.56	56.3	
1976	OCT	17	0.27	1984	0.27	28	0.58	58.3	
1977	AUG	16	0.12	1953	0.28	29	0.60	60.4	
1978	JUL	9	0.33	1959	0.28	30	0.63	62.5	
1979	AUG	7	0.17	1960	0.28	31	0.65	64.6	
1980	AUG	23	0.25	1969	0.29	32	0.67	66.7	
1981	SEP	12	0.21	1995	0.29	33	0.69	68.8	
1982	AUG	6	0.32	1961	0.30	34	0.71	70.8	
1983	OCT	10	0.40	1965	0.30	35	0.73	72.9	
1984	AUG	29	0.27	1989	0.30	36	0.75	75.0	
1985	AUG	29	0.19	1963	0.31	37	0.77	77.1	
1986	SEP	5	0.19	1971	0.31	38	0.79	79.2	
1987	SEP	6	0.22	1950	0.32	39	0.81	81.3	
1988	SEP	11	0.18	1982	0.32	40	0.83	83.3	
1989	AUG	7	0.30	1978	0.33	41	0.85	85.4	
1990	SEP	25	0.23	1956	0.35	42	0.88	87.5	
1991	OCT	9	0.25	1954	0.37	43	0.90	89.6	
1992	SEP	16	0.24	1968	0.38	44	0.92	91.7	
1993	SEP	29	0.19	1964	0.39	45	0.94	93.8	
1994	AUG	26	0.16	1983	0.40	46	0.96	95.8	
1995	SEP	20	0.29	1972	0.42	47	0.98	97.9	
				Rank = Numerical position of ordered average 7-day low flow values with the driest year equal to one.					
				N = 47					

**DES MOINES CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES**  
**IN DES MOINES CREEK (2006)**

**AR 011584**

7-Day Low Flow Occurrences in Des Moines Creek, 1949-1995 (2006 HSPF)



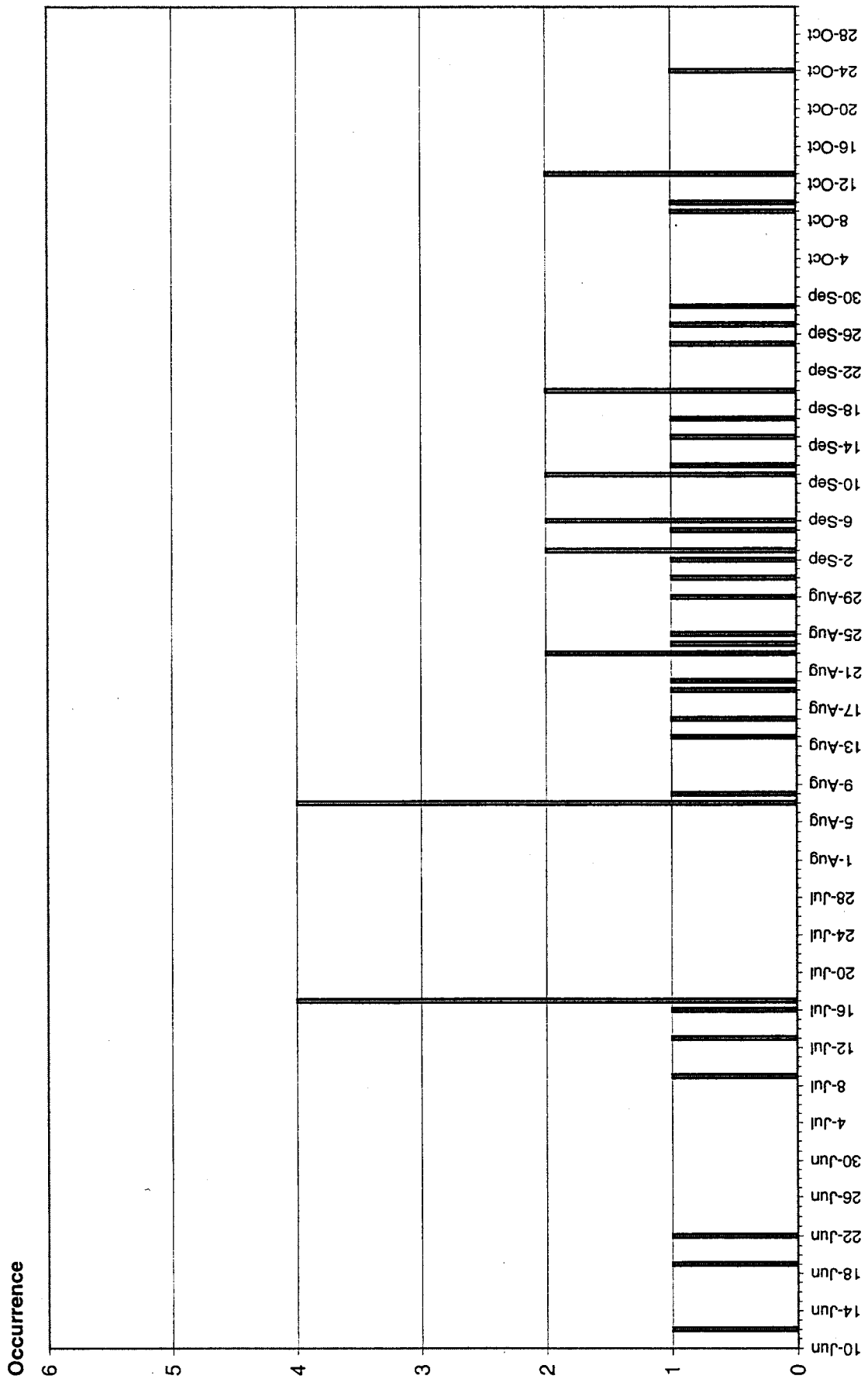
**DES MOINES CREEK**  
**7-DAY LOW FLOW OCCURRENCES IN DES MOINES CREEK**  
**(WITH MITIGATION)**

**AR 011586**



**DES MOINES CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES IN**  
**DES MOINES CREEK**  
**(WITH MITIGATION)**

7-Day Low Flow Occurrences in Des Moines Creek 1949-1995 ( 24 Jul 2006 HSPF + 0.10 cfs)



**DES MOINES CREEK**  
**COMPARISON OF 7-DAY LOW FLOW BY YEAR**

**AR 011590**



Comparison of Daily Low Flow By Year		1994 HSPF		2006 HSPF		2006 HSPF	
for Des Moines Creek		Des Moines Creek at 200th St. / Flow cfs		Des Moines Creek at 200th St. / Flow cfs		Des Moines Creek at 200th St. / Flow cfs	
Date	Average 7-Day Low Flow	Date	Average 7-Day Low Flow	Date	Average 7-Day Low Flow	Date	Average 7-Day Low Flow
1949	0.19	1949	0.14	1949	0.22	1949	0.03
1950	0.40	1950	0.32	1950	0.42	1950	0.02
1951	0.36	1951	0.25	1951	0.35	1951	-0.01
1952	0.22	1952	0.15	1952	0.25	1952	0.03
1953	0.35	1953	0.28	1953	0.38	1953	0.03
1954	0.48	1954	0.37	1954	0.47	1954	-0.01
1955	0.35	1955	0.25	1955	0.35	1955	0.00
1956	0.44	1956	0.35	1956	0.45	1956	0.01
1957	0.33	1957	0.25	1957	0.35	1957	0.01
1958	0.29	1958	0.19	1958	0.29	1958	0.01
1959	0.40	1959	0.28	1959	0.38	1959	-0.02
1960	0.40	1960	0.28	1960	0.38	1960	-0.02
1961	0.42	1961	0.30	1961	0.40	1961	-0.02
1962	0.34	1962	0.27	1962	0.37	1962	0.03
1963	0.37	1963	0.31	1963	0.41	1963	0.03
1964	0.48	1964	0.39	1964	0.49	1964	0.01
1965	0.39	1965	0.30	1965	0.35	1965	-0.03
1966	0.33	1966	0.24	1966	0.34	1966	0.00
1967	0.35	1967	0.24	1967	0.34	1967	-0.01
1968	0.47	1968	0.38	1968	0.48	1968	0.00
1969	0.39	1969	0.29	1969	0.39	1969	0.00
1970	0.33	1970	0.25	1970	0.25	1970	-0.08
1971	0.42	1971	0.31	1971	0.41	1971	-0.01
1972	0.53	1972	0.42	1972	0.52	1972	-0.01
1973	0.28	1973	0.20	1973	0.30	1973	0.02
1974	0.32	1974	0.22	1974	0.32	1974	0.00
1975	0.34	1975	0.24	1975	0.34	1975	0.00
1976	0.34	1976	0.27	1976	0.33	1976	-0.01
1977	0.15	1977	0.12	1977	0.22	1977	0.07
1978	0.42	1978	0.33	1978	0.33	1978	-0.09
1979	0.23	1979	0.17	1979	0.23	1979	0.00
1980	0.35	1980	0.25	1980	0.35	1980	0.01
1981	0.30	1981	0.21	1981	0.31	1981	0.02
1982	0.42	1982	0.32	1982	0.36	1982	-0.06
1983	0.48	1983	0.40	1983	0.50	1983	0.03
1984	0.37	1984	0.27	1984	0.37	1984	-0.01
1985	0.27	1985	0.19	1985	0.24	1985	-0.03
1986	0.27	1986	0.19	1986	0.29	1986	0.02
1987	0.30	1987	0.22	1987	0.26	1987	-0.04
1988	0.26	1988	0.18	1988	0.28	1988	0.03
1989	0.37	1989	0.30	1989	0.40	1989	0.03
1990	0.31	1990	0.23	1990	0.33	1990	0.02
1991	0.34	1991	0.25	1991	0.35	1991	0.01
1992	0.31	1992	0.24	1992	0.34	1992	0.03
1993	0.28	1993	0.19	1993	0.29	1993	0.02
1994	0.23	1994	0.16	1994	0.23	1994	0.00
1995	0.35	1995	0.29	1995	0.39	1995	0.04
	16.32		12.29		16.45		

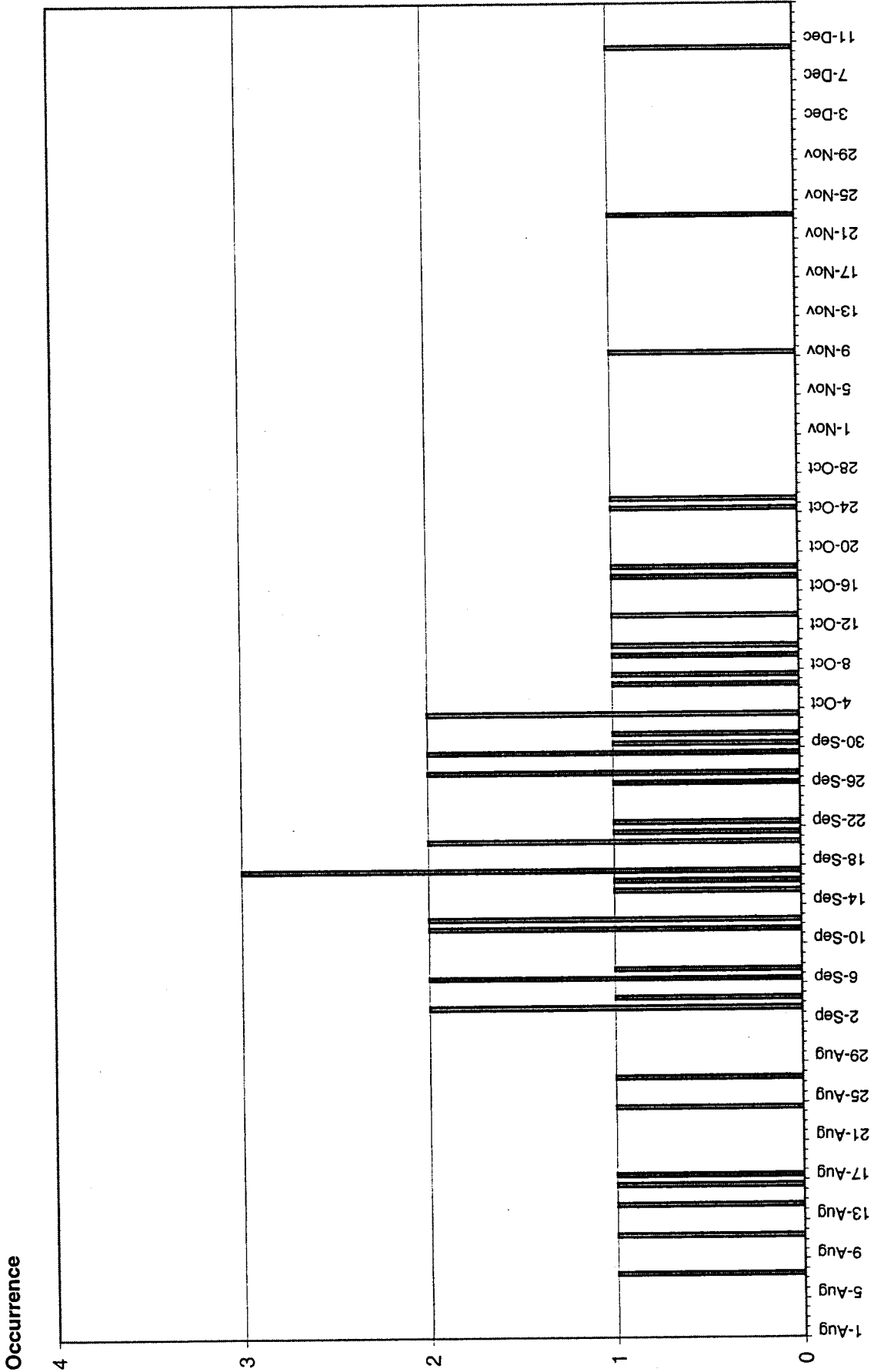
**MILLER CREEK**  
**7-DAY LOW FLOW OCCURRENCES IN MILLER CREEK**  
**(1994 HSPF)**

**AR 011592**

Start of 7-Day Low Flows with Average Flow Rates				Statistical Ranking of Average 7-Day Low Flows Period of Record: 1949-1995				
1994 Miller Creek at Hwy 509 Flow / cfs				Average 7-Day Lows			Return Frequency	
Date				Date	Ordered	Rank	Rank/N+1	Frequency
1949	SEP	7	0.42	1949	0.42	1	0.02	2.1
1950	SEP	17	0.85	1994	0.49	2	0.04	4.2
1951	SEP	17	0.78	1952	0.52	3	0.06	6.3
1952	NOV	23	0.52	1977	0.52	4	0.08	8.3
1953	SEP	15	0.74	1979	0.54	5	0.10	10.4
1954	OCT	3	0.86	1987	0.57	6	0.13	12.5
1955	SEP	6	0.82	1993	0.57	7	0.15	14.6
1956	SEP	3	0.86	1986	0.58	8	0.17	16.7
1957	SEP	20	0.77	1988	0.59	9	0.19	18.8
1958	SEP	30	0.62	1985	0.61	10	0.21	20.8
1959	AUG	24	0.87	1958	0.62	11	0.23	22.9
1960	SEP	29	0.83	1973	0.64	12	0.25	25.0
1961	SEP	21	0.82	1992	0.64	13	0.27	27.1
1962	SEP	3	0.72	1980	0.66	14	0.29	29.2
1963	SEP	27	0.70	1989	0.66	15	0.31	31.3
1964	OCT	25	0.87	1981	0.68	16	0.33	33.3
1965	SEP	27	0.77	1976	0.68	17	0.35	35.4
1966	SEP	4	0.77	1963	0.70	18	0.38	37.5
1967	SEP	22	0.73	1990	0.70	19	0.40	39.6
1968	AUG	7	0.96	1974	0.71	20	0.42	41.7
1969	SEP	6	0.81	1970	0.71	21	0.44	43.8
1970	AUG	27	0.71	1962	0.72	22	0.46	45.8
1971	AUG	14	0.91	1967	0.73	23	0.48	47.9
1972	SEP	11	1.00	1953	0.74	24	0.50	50.0
1973	SEP	12	0.64	1995	0.75	25	0.52	52.1
1974	OCT	13	0.71	1957	0.77	26	0.54	54.2
1975	AUG	11	0.77	1966	0.77	27	0.56	56.3
1976	DEC	10	0.68	1975	0.77	28	0.58	58.3
1977	AUG	16	0.52	1965	0.77	29	0.60	60.4
1978	AUG	17	0.79	1984	0.77	30	0.63	62.5
1979	OCT	7	0.54	1951	0.78	31	0.65	64.6
1980	OCT	17	0.66	1991	0.79	32	0.67	66.7
1981	SEP	12	0.68	1978	0.79	33	0.69	68.8
1982	SEP	17	0.80	1982	0.80	34	0.71	70.8
1983	OCT	10	0.89	1969	0.81	35	0.73	72.9
1984	OCT	1	0.77	1961	0.82	36	0.75	75.0
1985	SEP	29	0.61	1955	0.82	37	0.77	77.1
1986	OCT	18	0.58	1960	0.83	38	0.79	79.2
1987	OCT	24	0.57	1950	0.85	39	0.81	81.3
1988	SEP	11	0.59	1956	0.86	40	0.83	83.3
1989	OCT	3	0.66	1954	0.86	41	0.85	85.4
1990	SEP	26	0.70	1964	0.87	42	0.88	87.5
1991	OCT	9	0.79	1959	0.87	43	0.90	89.6
1992	SEP	16	0.64	1983	0.89	44	0.92	91.7
1993	NOV	9	0.57	1971	0.91	45	0.94	93.8
1994	OCT	6	0.49	1968	0.96	46	0.96	95.8
1995	SEP	20	0.75	1972	1.00	47	0.98	97.9
				Rank = Numerical position or ordered low flow data with driest year equal to one.				
				N = 47				

**MILLER CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES**  
**IN MILLER CREEK (1994)**

Low Flow Occurrences in Miller Creek, 1949-1995 (1994 HSPF)



**MILLER CREEK**  
**7-DAY LOW FLOW OCCURRENCES**  
**IN MILLER CREEK (1991-1994)**

**AR 011596**



**MILLER CREEK**

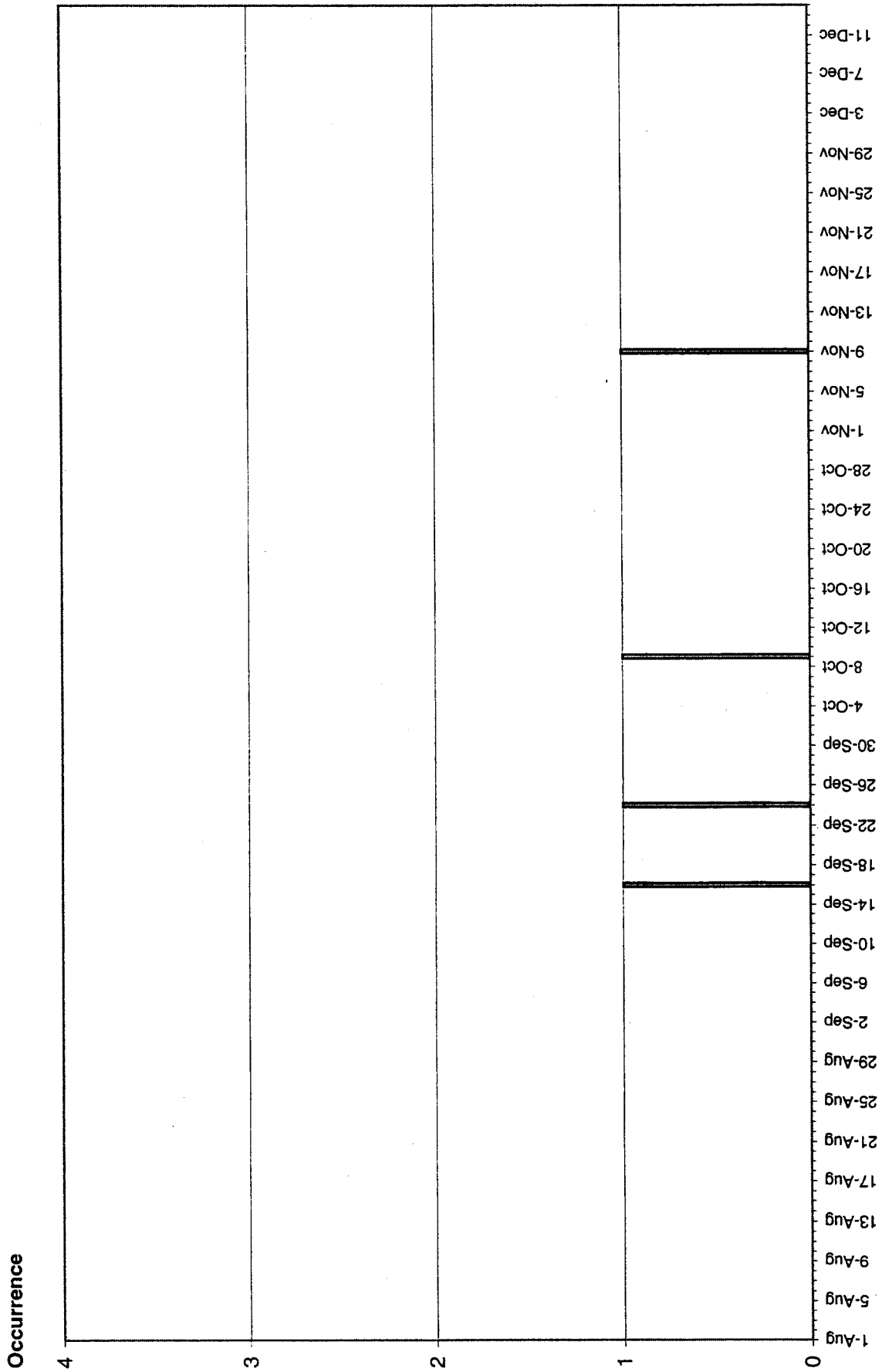
**7-DAY LOW FLOW OCCURRENCES IN MILLER CREEK 1991 – 1994,  
POST-PROJECT CONDITIONS (2006)**





**MILLER CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES**  
**IN MILLER CREEK 1991 – 1994,**  
**POST-PROJECT CONDITIONS (2006)**

Low Flow Occurrences in Miller Creek, 1991-1994 (2006 HSPF)



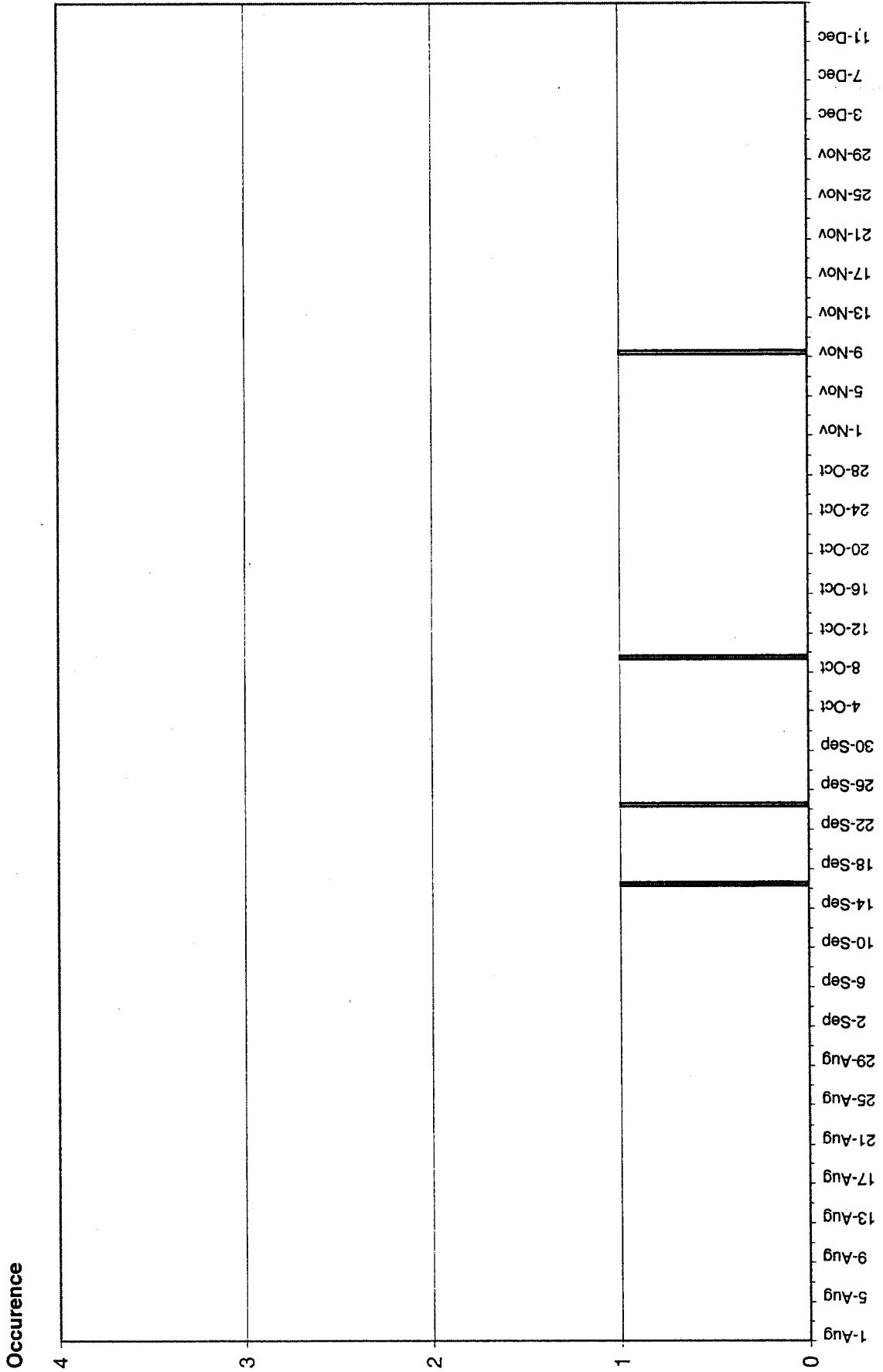
**MILLER CREEK**

**7-DAY LOW FLOW OCCURRENCES IN MILLER CREEK,  
1991 – 1994, POST-PROJECT CONDITIONS  
(2006+ MITIGATION)**



**MILLER CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES IN MILLER CREEK**  
**1991 – 1994, POST-PROJECT CONDITIONS**  
**(2006+ MITIGATION)**

Low Flow Occurrences in Miller Creek 1991-1994 (2006 HSPF + 0.13 cfs)



**WALKER CREEK**  
**7-DAY LOW FLOW OCCURRENCES IN WALKER CREEK (1994)**

**AR 011606**

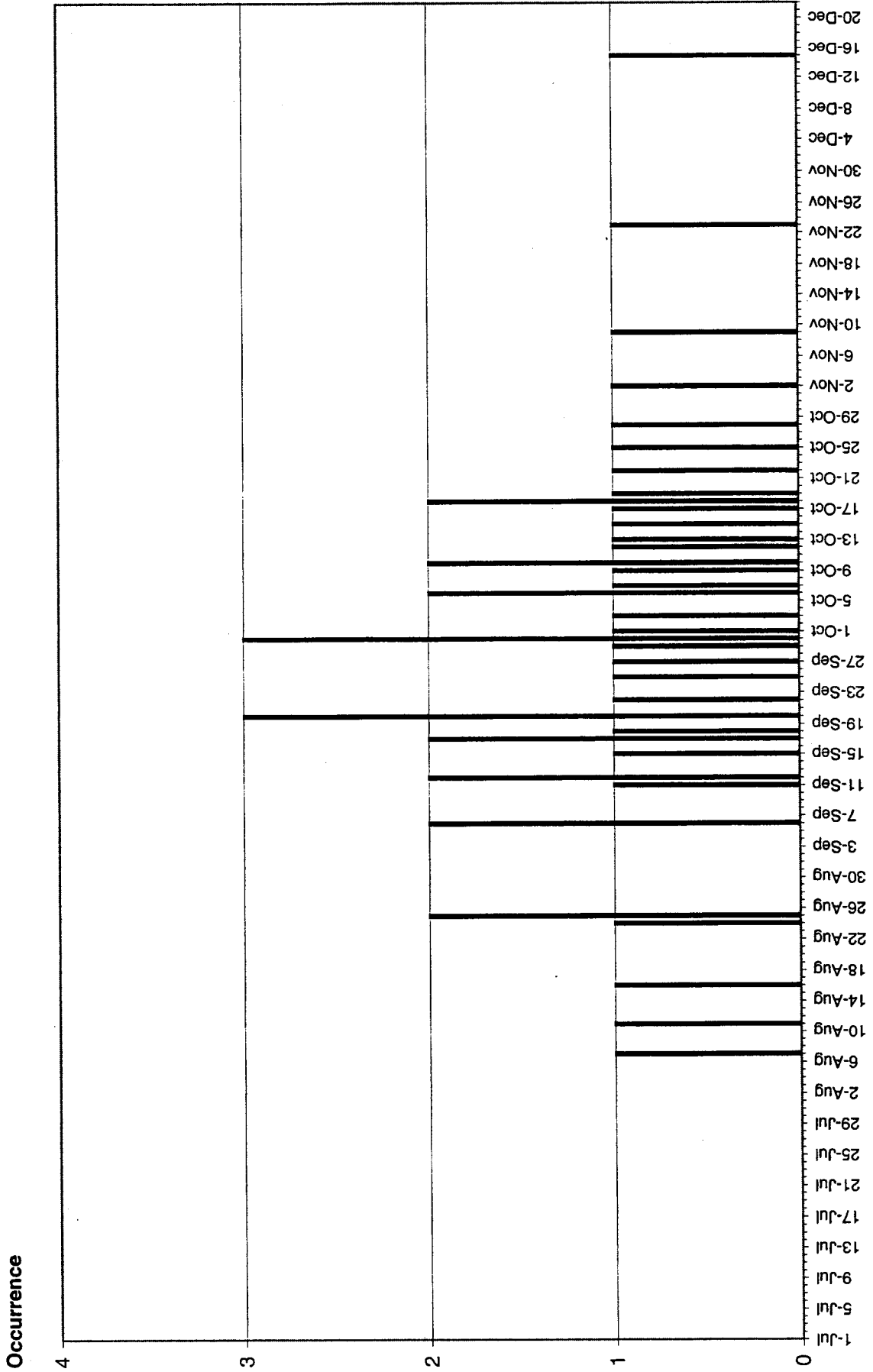


Start of 7-Day Low Flows with Average Flow Rates		Statistical Ranking of Average 7-Day Low Flows				
		Period of Record: 1949-1995				
	1994 HSPF Walker Creek at POC		Average 7-Day Lows			Return
Date	POC	Date	Ordered	Rank	Rank/N+1	Frequency
19-Oct-49	0.63	1994	0.61	1	0.02	2.1
17-Sep-50	0.83	1949	0.63	2	0.04	4.2
17-Sep-51	0.79	1979	0.64	3	0.06	6.3
23-Nov-52	0.66	1987	0.66	4	0.08	8.3
15-Sep-53	0.79	1952	0.66	5	0.10	10.4
12-Oct-54	0.89	1993	0.67	6	0.13	12.5
6-Sep-55	0.86	1988	0.67	7	0.15	14.6
18-Sep-56	0.88	1986	0.68	8	0.17	16.7
20-Sep-57	0.83	1977	0.68	9	0.19	18.8
30-Sep-58	0.72	1992	0.68	10	0.21	20.8
24-Aug-59	0.88	1985	0.70	11	0.23	22.9
15-Oct-60	0.86	1980	0.70	12	0.25	25.0
30-Sep-61	0.82	1989	0.71	13	0.27	27.1
20-Sep-62	0.81	1958	0.72	14	0.29	29.2
6-Oct-63	0.76	1981	0.73	15	0.31	31.3
25-Oct-64	0.93	1990	0.74	16	0.33	33.3
27-Sep-65	0.80	1976	0.75	17	0.35	35.4
30-Sep-66	0.79	1995	0.75	18	0.38	37.5
22-Sep-67	0.78	1963	0.76	19	0.40	39.6
7-Aug-68	0.97	1973	0.76	20	0.42	41.7
6-Sep-69	0.84	1982	0.77	21	0.44	43.8
10-Oct-70	0.78	1967	0.78	22	0.46	45.8
25-Aug-71	0.91	1970	0.78	23	0.48	47.9
11-Sep-72	0.96	1953	0.79	24	0.50	50.0
12-Sep-73	0.76	1966	0.79	25	0.52	52.1
13-Oct-74	0.79	1991	0.79	26	0.54	54.2
11-Aug-75	0.82	1974	0.79	27	0.56	56.3
15-Dec-76	0.75	1951	0.79	28	0.58	58.3
16-Aug-77	0.68	1984	0.80	29	0.60	60.4
25-Aug-78	0.81	1965	0.80	30	0.63	62.5
7-Oct-79	0.64	1978	0.81	31	0.65	64.6
17-Oct-80	0.70	1962	0.81	32	0.67	66.7
12-Sep-81	0.73	1975	0.82	33	0.69	68.8
29-Sep-82	0.77	1961	0.82	34	0.71	70.8
10-Oct-83	0.93	1957	0.83	35	0.73	72.9
1-Oct-84	0.80	1950	0.83	36	0.75	75.0
9-Oct-85	0.70	1969	0.84	37	0.77	77.1
18-Oct-86	0.68	1960	0.86	38	0.79	79.2
2-Nov-87	0.66	1955	0.86	39	0.81	81.3
6-Oct-88	0.67	1956	0.88	40	0.83	83.3
3-Oct-89	0.71	1959	0.88	41	0.85	85.4
25-Sep-90	0.74	1954	0.89	42	0.88	87.5
28-Oct-91	0.79	1971	0.91	43	0.90	89.6
22-Oct-92	0.68	1964	0.93	44	0.92	91.7
9-Nov-93	0.67	1983	0.93	45	0.94	93.8
18-Oct-94	0.61	1972	0.96	46	0.96	95.8
20-Sep-95	0.75	1968	0.97	47	0.98	97.9
Rank = Numerical position of ordered low flow data with the driest year equal to one.						
N = 47						

**WALKER CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES**  
**IN WALKER CREEK (1994)**

**AR 011608**

7-Day Low Flow Occurrences in Walker Creek, 1949-1995 (1994 HSPF)



**WALKER CREEK**

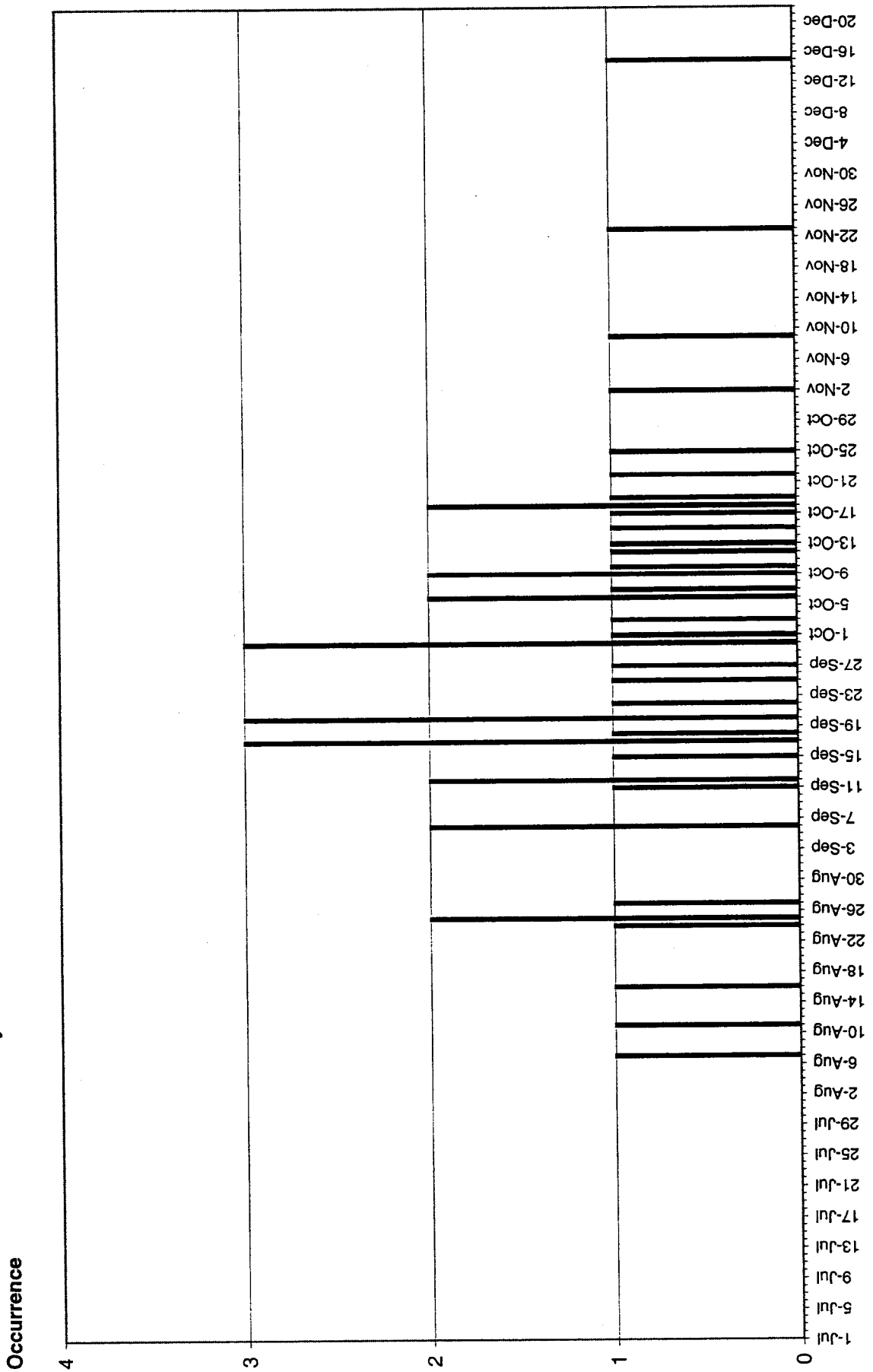
**7-DAY LOW FLOW OCCURRENCES IN WALKER CREEK (2006)**



**WALKER CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES**  
**IN WALKER CREEK (2006)**

**AR 011612**

7-Day Low Flow Occurrences in Walker Creek, 1949-1995 (2006 HSPF)



**WALKER CREEK**  
**7-DAY LOW FLOW OCCURRENCES IN WALKER CREEK**  
**(WITH MITIGATION)**

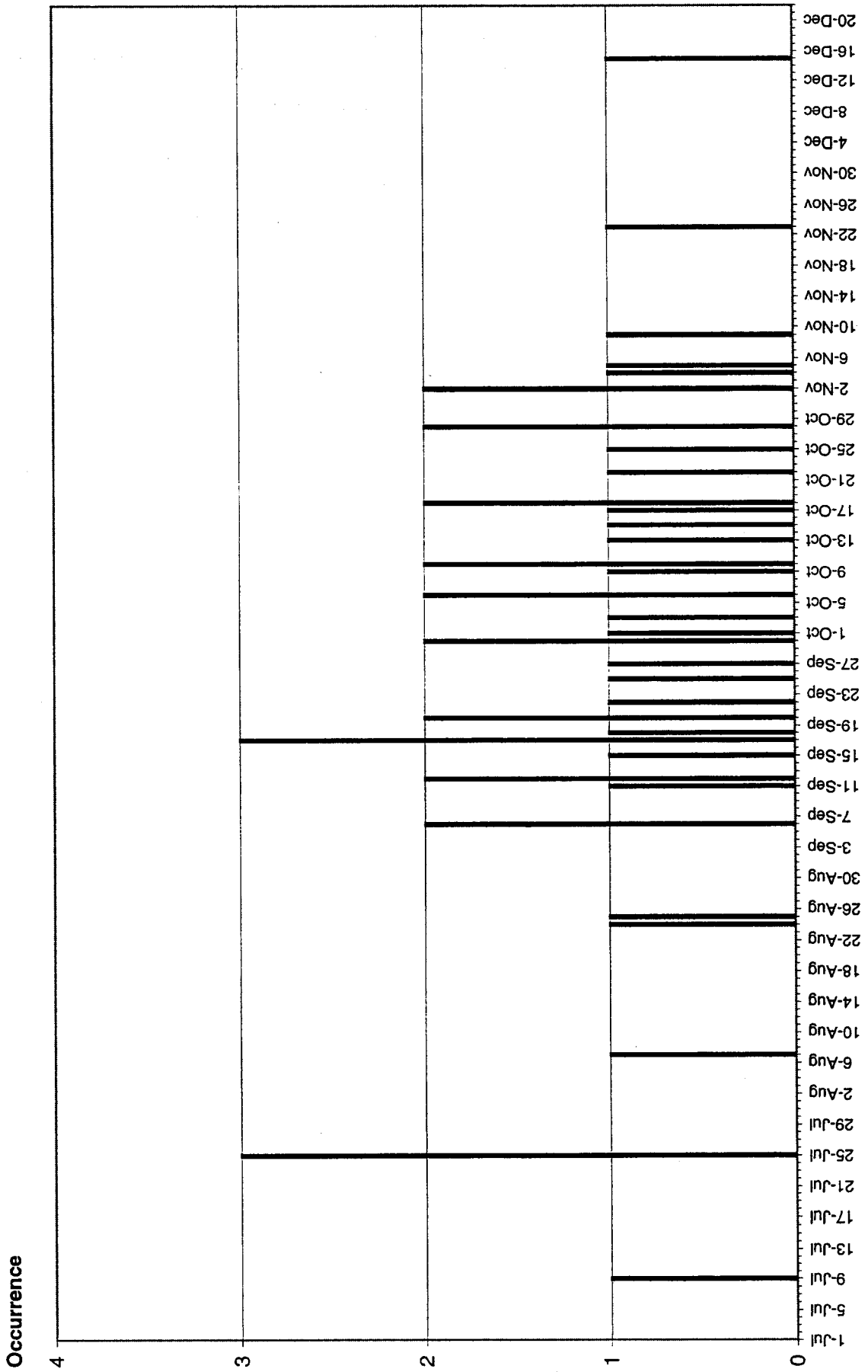
**AR 011614**



Start of 7-Day Low Flows with Average Flow Rates		Statistical Ranking of Average 7-Day Low Flows				
		Period of Record: 1949-1995				
Walker Creek at POC 2006 + AUGMENT Aug 1 - Oct 31		Average 7-Day Lows		Return		
Date	0.09 cfs	Date	Ordered	Rank	Rank/N+1	Frequency
2-Nov-49	0.64	1952	0.59	1	0.02	2.1
17-Sep-50	0.84	1987	0.60	2	0.04	4.2
17-Sep-51	0.80	1993	0.60	3	0.06	6.3
23-Nov-52	0.59	1949	0.64	4	0.08	8.3
15-Sep-53	0.80	1994	0.64	5	0.10	10.4
28-Oct-54	0.87	1979	0.65	6	0.13	12.5
6-Sep-55	0.86	1976	0.68	7	0.15	14.6
18-Sep-56	0.88	1977	0.68	8	0.17	16.7
5-Nov-57	0.83	1988	0.69	9	0.19	18.8
30-Sep-58	0.74	1986	0.70	10	0.21	20.8
24-Aug-59	0.88	1992	0.71	11	0.23	22.9
15-Oct-60	0.86	1991	0.72	12	0.25	25.0
30-Sep-61	0.83	1980	0.72	13	0.27	27.1
20-Sep-62	0.82	1985	0.72	14	0.29	29.2
6-Oct-63	0.78	1989	0.73	15	0.31	31.3
25-Oct-64	0.93	1958	0.74	16	0.33	33.3
27-Sep-65	0.81	1981	0.74	17	0.35	35.4
4-Nov-66	0.79	1990	0.75	18	0.38	37.5
22-Sep-67	0.79	1995	0.76	19	0.40	39.6
7-Aug-68	0.96	1973	0.78	20	0.42	41.7
6-Sep-69	0.85	1963	0.78	21	0.44	43.8
10-Oct-70	0.80	1967	0.79	22	0.46	45.8
25-Aug-71	0.91	1982	0.79	23	0.48	47.9
11-Sep-72	0.96	1966	0.79	24	0.50	50.0
12-Sep-73	0.78	1970	0.80	25	0.52	52.1
13-Oct-74	0.80	1975	0.80	26	0.54	54.2
25-Jul-75	0.80	1953	0.80	27	0.56	56.3
15-Dec-76	0.68	1974	0.80	28	0.58	58.3
25-Jul-77	0.68	1951	0.80	29	0.60	60.4
9-Jul-78	0.80	1978	0.80	30	0.63	62.5
25-Jul-79	0.65	1984	0.81	31	0.65	64.6
17-Oct-80	0.72	1965	0.81	32	0.67	66.7
12-Sep-81	0.74	1962	0.82	33	0.69	68.8
17-Sep-82	0.79	1957	0.83	34	0.71	70.8
10-Oct-83	0.93	1961	0.83	35	0.73	72.9
1-Oct-84	0.81	1950	0.84	36	0.75	75.0
9-Oct-85	0.72	1969	0.85	37	0.77	77.1
18-Oct-86	0.70	1955	0.86	38	0.79	79.2
2-Nov-87	0.60	1960	0.86	39	0.81	81.3
6-Oct-88	0.69	1954	0.87	40	0.83	83.3
3-Oct-89	0.73	1956	0.88	41	0.85	85.4
25-Sep-90	0.75	1959	0.88	42	0.88	87.5
28-Oct-91	0.72	1971	0.91	43	0.90	89.6
22-Oct-92	0.71	1964	0.93	44	0.92	91.7
9-Nov-93	0.60	1983	0.93	45	0.94	93.8
18-Oct-94	0.64	1972	0.96	46	0.96	95.8
20-Sep-95	0.76	1968	0.96	47	0.98	97.9
		Rank = Numerical position of ordered low flow data with the driest year equal to one.				
		N = 47				

**WALKER CREEK**  
**HISTOGRAM LOW FLOW OCCURRENCES IN WALKER CREEK**  
**(WITH MITIGATION)**

7-Day Low Flow Occurrences in Walker Creek, 1949-1995 (2006 HSPF + 0.09 cfs)



**WALKER CREEK**  
**COMPARISON OF 7-DAY LOW FLOW BY YEAR**

**AR 011618**

Comparison of Daily Low Flow by Year for Walker Creek		1994 HSPF Walker Creek at POC		2006 HSPF Walker Creek at POC		Walker Creek at POC 2006 + Mitigation Aug 1 - Oct 31 -1994	
Date		Date		Date		Date	
19-Oct-49	0.63	19-Oct-49	0.63	19-Oct-49	0.57	2-Nov-49	0.64
17-Sep-50	0.83	17-Sep-50	0.75	17-Sep-50	0.75	17-Sep-50	0.84
17-Sep-51	0.79	17-Sep-51	0.71	17-Sep-51	0.71	17-Sep-51	0.80
23-Nov-52	0.66	23-Nov-52	0.59	23-Nov-52	0.59	23-Nov-52	0.59
15-Sep-53	0.79	15-Sep-53	0.71	15-Sep-53	0.71	15-Sep-53	0.80
12-Oct-54	0.89	12-Oct-54	0.81	12-Oct-54	0.81	28-Oct-54	0.87
6-Sep-55	0.86	6-Sep-55	0.77	6-Sep-55	0.77	6-Sep-55	0.86
18-Sep-56	0.88	18-Sep-56	0.79	18-Sep-56	0.79	18-Sep-56	0.88
20-Sep-57	0.83	20-Sep-57	0.75	20-Sep-57	0.75	5-Nov-57	0.83
30-Sep-58	0.72	30-Sep-58	0.65	30-Sep-58	0.65	30-Sep-58	0.74
24-Aug-59	0.88	24-Aug-59	0.79	24-Aug-59	0.79	24-Aug-59	0.88
15-Oct-60	0.86	15-Oct-60	0.77	15-Oct-60	0.77	15-Oct-60	0.86
30-Sep-61	0.82	30-Sep-61	0.74	30-Sep-61	0.74	30-Sep-61	0.83
20-Sep-62	0.81	20-Sep-62	0.73	20-Sep-62	0.73	20-Sep-62	0.82
6-Oct-63	0.76	6-Oct-63	0.69	6-Oct-63	0.69	6-Oct-63	0.78
25-Oct-64	0.93	25-Oct-64	0.84	25-Oct-64	0.84	25-Oct-64	0.93
27-Sep-65	0.80	27-Sep-65	0.72	27-Sep-65	0.72	27-Sep-65	0.81
30-Sep-66	0.79	30-Sep-66	0.71	30-Sep-66	0.71	4-Nov-66	0.79
22-Sep-67	0.78	22-Sep-67	0.70	22-Sep-67	0.70	22-Sep-67	0.79
7-Aug-68	0.97	7-Aug-68	0.87	7-Aug-68	0.87	7-Aug-68	0.96
6-Sep-69	0.84	6-Sep-69	0.76	6-Sep-69	0.76	6-Sep-69	0.85
10-Oct-70	0.78	10-Oct-70	0.71	10-Oct-70	0.71	10-Oct-70	0.80
25-Aug-71	0.91	25-Aug-71	0.82	25-Aug-71	0.82	25-Aug-71	0.91
11-Sep-72	0.96	11-Sep-72	0.87	11-Sep-72	0.87	11-Sep-72	0.96
12-Sep-73	0.76	12-Sep-73	0.69	12-Sep-73	0.69	12-Sep-73	0.78
13-Oct-74	0.79	13-Oct-74	0.71	13-Oct-74	0.71	13-Oct-74	0.80
11-Aug-75	0.82	11-Aug-75	0.74	11-Aug-75	0.74	15-Jul-75	0.80
15-Dec-76	0.75	15-Dec-76	0.68	15-Dec-76	0.68	15-Dec-76	0.68
16-Aug-77	0.68	16-Aug-77	0.62	16-Aug-77	0.62	25-Jul-77	0.68
25-Aug-78	0.81	25-Aug-78	0.73	25-Aug-78	0.73	9-Jul-78	0.80
7-Oct-79	0.64	7-Oct-79	0.58	7-Oct-79	0.58	25-Jul-79	0.65
17-Oct-80	0.70	17-Oct-80	0.63	17-Oct-80	0.63	17-Oct-80	0.72
12-Sep-81	0.73	12-Sep-81	0.65	12-Sep-81	0.65	12-Sep-81	0.74
29-Sep-82	0.77	17-Sep-82	0.70	17-Sep-82	0.70	17-Sep-82	0.79
10-Oct-83	0.93	10-Oct-83	0.84	10-Oct-83	0.84	10-Oct-83	0.93
1-Oct-84	0.80	1-Oct-84	0.72	1-Oct-84	0.72	1-Oct-84	0.81
9-Oct-85	0.70	9-Oct-85	0.63	9-Oct-85	0.63	9-Oct-85	0.72
18-Oct-86	0.68	18-Oct-86	0.61	18-Oct-86	0.61	18-Oct-86	0.70
2-Nov-87	0.66	2-Nov-87	0.60	2-Nov-87	0.60	2-Nov-87	0.60
6-Oct-88	0.67	6-Oct-88	0.60	6-Oct-88	0.60	6-Oct-88	0.69
3-Oct-89	0.71	3-Oct-89	0.64	3-Oct-89	0.64	3-Oct-89	0.73
25-Sep-90	0.74	25-Sep-90	0.66	25-Sep-90	0.66	25-Sep-90	0.75
28-Oct-91	0.79	9-Oct-91	0.71	9-Oct-91	0.71	28-Oct-91	0.72
22-Oct-92	0.68	22-Oct-92	0.62	22-Oct-92	0.62	22-Oct-92	0.71
9-Nov-93	0.67	9-Nov-93	0.60	9-Nov-93	0.60	9-Nov-93	0.60
18-Oct-94	0.61	18-Oct-94	0.55	18-Oct-94	0.55	18-Oct-94	0.64
20-Sep-95	0.75	20-Sep-95	0.67	20-Sep-95	0.67	20-Sep-95	0.76
			33.02				36.65

**F**

**AR 011620**



**Pacific  
Groundwater  
Group**


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# **SEA-TAC RUNWAY FILL HYDROLOGIC STUDIES REPORT**

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June 19, 2000

Pacific Groundwater Group  
Seattle, Washington



AR 011621

**Sea-Tac Runway Fill Hydrologic Studies Report**

Prepared for:

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**Northwest Regional Office**  
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June 19, 2000

JE9907

**AR 011622**



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## **1.0 Executive Summary**

This report summarizes investigations conducted to assess the hydrologic effects of constructing a fill embankment for a third runway at Seattle-Tacoma International Airport. In 1999, public concerns prompted the Washington State Legislature and Governor Locke to approve this study, which focuses on aquifers, wetlands, and Des Moines, Miller, and Walker Creeks, which drain the area. The study was conducted under the Washington State Department of Ecology's oversight by a team of consultants: Pacific Groundwater Group (PGG); Earth Tech, Inc.; and Ecology and Environment, Inc., (E & E).

The study area varies depending on the issue evaluated. The largest areas considered are the Miller Creek and Des Moines creek watersheds which comprise a total of about 15 square miles surrounding the airport and include the fill borrow sources. The smallest areas considered are local drainages in the middle reach of Miller Creek where extensive riparian wetlands will be affected.

The scope of work for this project contained the following tasks:

- Reviewing existing documents
- Interviewing Port staff, community organizations, individuals, and consultants
- Collecting additional field data
- Reviewing models used by Port consultants to assess hydrologic impacts
- Providing independent evaluation of certain hydrologic effects using new and existing data
- Reviewing Port mitigation proposals
- Informing stakeholders and the public on project progress
- Reporting

Existing data were compiled and analyzed to characterize land use, surface water flow, geologic conditions, groundwater flow, groundwater recharge, wetlands, and fish in the study area. These data were used to assess potential impacts associated with the proposed runway construction. Where existing data were insufficient or required independent confirmation, additional data were collected in the field, including borehole data, streamflow quantity and quality, wetland delineations and functions, and fish population and habitat information. This study also reviewed impact assessments previously completed by the Port.

Although the study considered many potentially important effects of the proposed runway embankment and borrow-area excavations, it did not consider all Master Plan Improvements proposed by the Port. Furthermore, not all of the possible effects related to the embankment and borrow areas were evaluated. Therefore, this report does not address all hydrologic issues requiring satisfactory resolution for permitting. Consequently, it is not intended for use as a checklist by agencies during permit review.

## **1.1 Project Background**

The Port of Seattle has purchased, or is in the process of purchasing, properties in a "buy-out area" west of Sea-Tac Airport. This area contained more than 400 homes, five farms, 17 domestic water rights or claims, neighborhood and arterial roads, 380 septic drain fields, and numerous water wells. The Port has demolished many structures and removed debris.

### **1.1.1 Proposed Construction**

An embankment of fill soil is proposed to create a high, flat surface upon which the third runway would be built. The fill would be more than 150 feet thick in places. The west margin of the fill would be bounded by a slope or wall, depending on location. The east margin of the new fill would abut the existing fill, upon which the current runways are built. The volume of the fill required for the third runway embankment is reported to be 16.5 million cubic yards. It will consist of about 40 percent sand and gravel that is relatively silt-free and about 60 percent silty sand. These materials originate from glacial till and outwash soils. Additional fill is proposed for other Master Plan Improvements.

A bottom drain layer, in combination with coarse soils near the walls, has been included in the fill-embankment design. It is intended to prevent groundwater pressures near the west wall from building, a condition that could result in seepage through the wall. This drain layer is designed to direct groundwater seepage below the base of the wall to the remaining wetlands and Miller Creek.

### **1.1.2 Proposed Stormwater Controls**

The Port proposes a strategy for controlling stormwater flows for existing and future facilities. This strategy is intended to lower peak flow rates in Miller, Des Moines, and Walker Creeks below pre-1994 rates. Within the fill area, the Port proposes to reduce flows by allowing some precipitation to infiltrate the fill and by storing runoff in local and regional detention ponds and vaults while restricting the rate stormwater is released from storage. This strategy relies on the expansion and construction of large regional ponds in Miller and Des Moines Creeks.

The third runway and connecting taxiways will be paved and cover about 32 percent of the new embankment surface. In the unpaved 68 percent, the embankment will likely grow grass. Water running off the paved surfaces is proposed to flow into "filter strips," which are water-quality treatment features. Water would flow into low areas at the bottom of the filter strips, then into catch basins. Water entering the catch basins would be conveyed through pipes under the runways to detention vaults or other detention facilities prior to discharge to Miller, Walker, or Des Moines Creek. The use of perforated conveyance pipes is being considered (which would enhance infiltration).

## **1.2 Physiographic Features Related to Habitat**

Habitat conditions were evaluated by review of existing documents and collection of limited new field data. The team collected streamflow and water quality measurements on three occasions and at several locations. A stream habitat field survey was conducted on Walker Creek and fish presence and carcass surveys were conducted on all creeks. Team personnel also directly observed wetland conditions although a complete review of all previous delineations and function assessments was not conducted.

### **1.2.1 Land Use**

Immediately west of the airport, land use is a mix of residential and agricultural, with development encroaching on the Miller Creek riparian corridor. This corridor features residential areas, agriculture, upland habitats, and slope and riparian wetlands, all of which lie adjacent to the creek. Outside this area west of the airport, the narrow riparian and ravine corridors associated with Miller and Walker Creeks are the primary areas that have not been extensively developed. Larger wetland complexes are



associated with these drainages, including the Miller Creek Detention Facility and a large wetland complex that forms the headwaters of Walker Creek. About 40 acres of wetlands occur in the vicinity.

The area south of the airport contains a greater percentage of non-urban/residential land, including the Tye Golf Course and acreage acquired by the Port as part of Noise Abatement Mitigation programs. In addition, Des Moines Creek has a significant forested riparian corridor that is undeveloped. Approximately 48.5 acres of wetlands lie near the Borrow Areas and Tye Golf Course.

### **1.2.2 Surface Water**

Miller and Walker Creeks drain the west side of the airport and the buy-out area. The watershed is approximately 9 square miles. Miller Creek originates from a number of sources; Arbor Lake, Lake Reba, Lora Lake, and Lake Burién; wetlands associated with the Miller Creek detention facility; and seeps along the west side of the airport. Streamflow increases downstream as groundwater discharges to the creeks, even during times of no rainfall. Miller Creek descends from an elevation of approximately 360 feet in its headwaters to Puget Sound at the Normandy Park Cove. The Miller Creek watershed contains significant residential and commercial development, resulting in approximately 23 percent impervious surfaces. Land use in the watershed is approximately 62 percent residential, 15 percent commercial, 3 percent airport, and 20 percent undeveloped.

Precipitation at SeaTac averages about 39 inches per year. An average of approximately 54 percent of the precipitation in the basin discharges through Walker and Miller Creeks at their mouths. The remainder of the precipitation in the Miller Creek basin evaporates or discharges as groundwater to Puget Sound.

Des Moines Creek drains the south part of the airport and the borrow areas. Its watershed covers 5.8 square miles. The creek drops from an elevation of approximately 350 feet to Puget Sound at Des Moines Creek Beach Park. The east fork of Des Moines Creek originates from Bow Lake where it flows through subsurface piping for approximately 1/2 mile. The west fork of Des Moines Creek originates in the Northwest Ponds in the northwest corner of the Tye Valley Golf Course. The confluence of the two forks of Des Moines Creek lies in the central portion of the Tye Valley Golf Course. As with Miller and Walker Creeks, streamflow increases downstream as groundwater discharges to the creek, even during times of no rainfall.

An average of approximately 41 percent of precipitation in the Des Moines Creek watershed discharges through Des Moines Creek at its mouth.

### **1.2.3 Fish Habitat**

Despite the habitat degradation that has resulted from urbanization, anadromous and resident fish live in Miller and Walker Creeks. Adult Coho salmon use the Creeks from the mouth to the 1<sup>st</sup> Avenue South culvert and have been reported above 1<sup>st</sup> Avenue South. Juvenile Coho are distributed throughout, likely because of Trout Unlimited's releases from the Miller Creek Hatchery. A small population of resident cutthroat trout is distributed throughout much of the watershed. Water-quality data collected for this project during base flow periods indicate that low dissolved-oxygen levels may limit fish production. This project did not analyze or review stormwater quality data.

Despite habitat and water-quality degradation, anadromous and resident fish populations are also present in Des Moines Creek. Adult coho and chum salmon use the stream reach from the mouth to the Marine View Drive culvert. Juvenile coho salmon

are distributed throughout Des Moines Creek, likely because of Trout Unlimited's releases from the Miller Creek Hatchery. Steelhead and pink salmon runs have also been reported on Des Moines Creek. A small population of resident cutthroat trout is distributed throughout much of the Des Moines Creek watershed. No water-quality concerns related to fish production were identified in the base-flow water-quality data collected for this project.

### **1.3 Hydrogeologic Characterization**

Characterization of hydrogeology was limited to the embankment and borrow areas. Existing data were used to characterize deep geology and groundwater conditions. Shallow conditions were observed by team personnel during drilling of boreholes and collection of groundwater measurements.

#### **1.3.1 Geologic Units**

The following geologic units underlie the study area:

- Recent deposits
- Qvr (Vashon recessional outwash)
- Qvt (Vashon till)
- Qva (Vashon advance outwash)
- Transitional beds
- Deeper units

These deposits are discussed below, from youngest to oldest. The Qvr, Qvt, and Qva were deposited by the Vashon glacier, which covered the study area from about 10,000 to 14,000 years ago.

The youngest natural soil unit comprises recent deposits of peat and highly organic, fine-grained soils. These deposits cover the low elevations near Lora Lake and the area surrounding the central reach of Miller Creek. They probably also cover the upper reaches of Walker Creek. The recent

deposits are typically 10 to 20 feet thick near Lora Lake but are thinner along Miller Creek, to the south. Brown silt and medium sand layers are mixed with the peat. These layers form the bulk of the recent deposits in the central Miller Creek reach.

The recent deposits are underlain by a layer of silty sand with some gravel that forms the Qvr, or Vashon recessional outwash, a regionally extensive deposit. The Qvr is the uppermost unit along the east flank of the central Miller Creek valley, near the proposed fill embankment. It may also underlie the recent deposits in the valley bottoms. The Qvr ranges in thickness from 0 to about 30 feet in the project area and is missing in places. The degree of saturation of this unit by groundwater varies widely.

The Qvr is usually underlain by Vashon till (Qvt), a dense layer of gravel and silt in a sandy matrix. This unit is often referred to as "hardpan" in driller's logs. The Qvt ranges in thickness from 0 to 20 feet in the study area. The degree of saturation of the unit by groundwater varies widely. This layer restricts the vertical migration of groundwater and promotes horizontal "interflow" on its upper surface.

The Qvt is commonly underlain by the Vashon advance outwash (Qva), another regionally extensive layer of sand with varying amounts of silt and gravel. The Qva was encountered in almost all borings that penetrated through glacial till in the area. It is the uppermost unit to be modeled by the Port's environmental consultants and comprises the "shallow regional aquifer" identified by previous investigators.

The transitional beds underlie the Qva, Qvt, Qvr, and recent deposits where they are present. These beds were deposited in quiet waters prior to advances of the Vashon glacier. They consist of silt and clay and restrict the movement of groundwater.

Several deeper geologic units are recorded in logs for deep wells in the area, including

the "intermediate" and "deep aquifers" described in the South King County Ground Water Management Plan. Because of their depth and large extent, these units are not as sensitive to local changes in recharge as are shallow deposits and groundwater-fed streams that depend entirely on local recharge. Furthermore, changes in recharge to deep units depend on changes in recharge to shallow units. Consequently, for this project, local changes to shallow groundwater recharge and discharge were analyzed and changes to deeper groundwater recharge were inferred from them.

### **1.3.2 Current Groundwater Flow Conditions**

The shallow aquifers in the region are recharged by local precipitation. In the buy-out area, they are also recharged by water that discharged from septic drain fields which was imported from outside the local area as a public water supply. In the study area, groundwater is recharged by up to an estimated 24 inches of precipitation per year depending largely on land use, soil type, and vegetation. In the residential area acquired by the Port of Seattle, an additional 3 inches of septic discharge per year contribute to groundwater recharge.

Two groundwater flow regimes were identified in the Miller Creek basin—a shallow one and a deep one. The shallow system involves the recent deposits, the Qvr, and, in some areas, the Qva. Groundwater in the recent deposits and Qvr discharges to the middle reach of Miller Creek and the upper reach of Walker Creek. The uppermost Qva groundwater may also discharge to the creeks, especially in the Walker Creek headwaters. Groundwater in the deeper system discharges year-round to deep wells, to the lower reaches of the creeks, and to Puget Sound. Near the headwaters of Walker Creek, groundwater in the Qva may discharge more easily to the creek than within the Miller Creek basin, creating an extensive wetland.

## **1.4 Impact Assessments**

### **1.4.1 Fill Chemistry Effects**

Gravel from a mine on Maury Island is being considered as fill for the proposed runway expansion. The top eighteen inches of gravel at Maury Island contain high levels of arsenic, cadmium, and lead originating from the former ASARCO smelter in Tacoma. The top 18 inches of soil at Maury Island are proposed to be contained at the island mine prior to aggregate extraction. Ecology must have assurance that the fill used for the airport project will not result in exceedances of state water quality criteria. The Port and Ecology are working to determine what screening methods and contingencies are necessary to ensure that water quality criteria are met.

This project analyzed the potential effects to ecological receptors, such as the benthic community and wildlife-consuming benthic organisms, if contaminants in the Maury Island fill were to migrate from soils to nearby sediments. Surface and subsurface soil data of the potential Maury Island fill were compared to ecological benchmarks to assess whether unacceptable ecological risks may occur. Based on the above analysis, use of subsurface soils as fill should not pose an unacceptable risk to ecological receptors.

### **1.4.2 Groundwater Recharge Effects**

The Project team assessed groundwater recharge in the project area and found that recharge could change because of the following actions:

- Changing infiltration of precipitation by changing land cover, soil type, and slope
- Conveying runoff from impervious surfaces away from local recharge areas

- Eliminating the discharge of imported water through leaks and septic systems throughout the year
- Eliminating irrigation with local and imported water sources in summer

The net effect of the changes to irrigation and imported domestic water appears to be about zero in the irrigation season (summer). In winter, recharge will be reduced by eliminating the septic discharge and leaks.

The change to *precipitation-derived* recharge was evaluated in a cross section of the proposed fill. This calculation considered the conversion of wetlands and forest to grass on the embankment fill. It also considered the widths of the only two impervious surfaces on the cross section (12<sup>th</sup> Avenue South and the third runway). The calculation suggests about an 11 percent decrease in groundwater recharge along the cross section, largely as a result of the large increase in impervious area. However, this estimated magnitude of change is probably high because no secondary infiltration of runoff from the third runway was assumed, and modeled water use by grass on the new embankment was possibly higher than expected for the fill soils.

The quantity of water seeping downward through the glacial till was also simulated with the cross-section model. The *volume* of seepage would likely change only slightly under the built condition; however, because total recharge would be reduced, the *percentage* of recharge seeping through the till would increase substantially.

The 11 percent reduction in local recharge is large, but dependent flows to local wetlands and the creeks will be reduced only in winter when abundant water is typically present anyway. A similar reduction in recharge basin-wide would cause a major impact to baseflows. To assess basin-wide impacts, the Port's recharge calculations that considered all Master Plan Improvements were reviewed. The HSPF model parameters

used in the Port's recharge analysis do not appear to correspond to those used in actual basin modeling also conducted by the Port. Therefore, a confident assessment of basin-wide recharge and baseflow impacts is currently lacking. A confident assessment of basin-wide recharge and baseflow effects should be possible by analyzing a properly implemented and documented HSPF model.

A small reduction in recharge to deeper aquifers of the Des Moines Creek upland may occur; however, the small reduction would not affect these aquifers' ability to supply water to wells. This conclusion is based on the relatively large recharge areas of these aquifers compared to the airport, the fact that the effects will be apportioned between shallow and deep aquifers, and the reported estimates of shallow recharge.

#### 1.4.3 Fisheries Effects

No direct effects on fish habitat are expected in Walker or Des Moines Creek because of construction. Miller Creek would be relocated in the Vacca Farm area but this reach currently provides poor habitat for salmonids because it features sparse riparian vegetation, a substrate dominated by sand and silt, little complexity, and no instream structure. The proposed Miller Creek channel construction will provide a net gain in habitat since it will feature a mixture of pools and riffles, gravel and cobble substrate, riparian vegetation, and replacement of woody debris. Proper construction and long-term monitoring are vital to successful Miller Creek relocation including control of turbidity during initial wetting. Some sediment transport during initial wetting is likely, and has the potential to damage habitat downstream.

An uncontrolled release of stormwater is likely at some time during construction given the size of the project and human error; however, the size and quality of a release cannot be predicted, nor can its impacts on fish be quantified. If habitat

quality is further degraded because of indirect construction effects such as an uncontrolled release of turbid water, resident populations of cutthroat trout and anadromous Coho salmon would likely decline.

The enhancements to the riparian buffer corridor and instream habitat of Miller Creek will undoubtedly benefit local stream habitat for resident cutthroat trout if they are implemented and maintained properly. However, the proposed mitigation is limited in that it will only affect localized Miller Creek habitat and resident cutthroat trout. Indirect construction and post-construction effects such as alterations to base flow, peak flow, and sediment input could affect the entire stream systems, not just the airport project area. The Port predicts reduction in summer base flow in Des Moines Creek as a result of reduced groundwater recharge and supports augmenting low summer stream flows by pumping from a Port-owned well and discharging the water into the creek.

The watershed trust funds for the Miller and Des Moines Creek watersheds can be beneficial. However, significant habitat restoration in Miller, Walker, and Des Moines Creeks will require substantially more funding than what is currently offered through the basin trust funds.

#### **1.4.4 Effects on the Hydroperiod in Local Wetlands**

A hydroperiod is the seasonal change in the timing of groundwater discharge to wetlands and streams. For this project, effects to the hydroperiod were evaluated using a cross section of the proposed embankment fill near Miller Creek. The following effects are predicted if the embankment is built:

- Recharge would be 11 percent less along the cross section, and would spread-out within the fill, causing a significant timing lag in discharge to the

wetlands and creek west of the embankment compared to the current condition.

- Discharge to remaining wetlands and the creek under the built condition would vary less throughout the year and the period of minimum discharge would be shorter. Flows would be lower in winter than under the current condition, and greater in summer compared to the current condition. The total quantity of water flowing to the wetlands would decrease because total recharge would decrease.

The timing changes would generally benefit the local wetlands that remain after filling and would slightly moderate seasonal low base flows and temperatures in Miller Creek. However, all water quantities are reduced on an average annual basis because total recharge is smaller under the built condition. Also, since the embankment is a small part of the Miller Creek watershed, the overall effect on streamflow is small. If the constructed fill has a lower silt content than was assumed for this analysis, the lag may be overestimated and the recharge volume may be underestimated.

**1.4.5 Effects on Wetland Area and Functions**

The fill activities associated with the improvement projects would result in the permanent loss of 13.88 acres of wetland in the Miller Creek watershed. In addition to the permanent impacts, construction activities would also result in the temporary loss of 1.86 acres.

Of equal importance to the acreage loss are the functional impacts that would occur. The effectiveness and opportunity for wetlands to improve water quality, provide suitable habitat, and function as floodplains were considered. An additional 1.68 acres of secondary effects may occur if the functionality of the remaining wetlands cannot be maintained. This acreage is attributed to the Wetland 18/37 complex adjacent to Miller Creek.

Given the urban character of the area, the wildlife expected to inhabit the area is restricted to common, highly adaptive species that use both wetland and adjacent upland areas. Species integrally tied to the wetland areas are likely restricted to waterfowl, amphibians, and small mammals. The construction of the airport improvements would affect local wildlife populations simply due to the size of the fill area. As indicated previously, the extent of fragmentation due to urbanization currently limits the viability of existing habitat. Reducing habitat size and availability would further reduce the suitability for small mammals and amphibians. To prevent a significant decline in the local populations, mitigation would be required to provide supplemental/alternative habitat on-site. However, the extent to which habitat could be provided is limited by the nature of the proposed project. FAA requirements limit the development of avian habitat within 10,000 feet of existing facilities to minimize the hazard of potential air strike by birds.

**1.4.6 Review of Wetland Mitigation Proposal**

Mitigation for the proposed third runway fill and safety areas must account for the permanent loss of 13.88 acres, and temporary effects in 1.86 acres within the Miller Creek watershed.

The preferred regulatory hierarchy for wetland mitigation is:

- On-site, in-kind
- Off-site, within the watershed, in kind
- Off-site, out of the watershed, in kind
- Off-site, out of watershed, out of kind

Because of environmental and regulatory constraints, it is not feasible for the Port to mitigate on-site and in-kind (on-site mitigation is restricted by FAA safety regulations).

The Port proposes the following on-site wetland mitigation measures:

- Removing existing development
- Establishing a vegetated buffer along Miller Creek
- Enhancing wetlands within the Miller Creek buffer
- Enhancing or restoring wetlands within the Des Moines Creek watershed
- Excavating the floodplain to compensate for lost flood storage
- Developing stormwater management facilities
- Restoring and enhancing 11 acres of farmland and farmed wetlands

Off-site mitigation includes developing a 67-acre site for wildlife habitat. The Port also proposes to establish Trust Funds to promote restoration projects for the Miller and Des Moines Creek basins downstream of the project area.

The overall mitigation plan is reasonably designed to compensate for wetland impacts and has the potential for success. The plan provides for in-basin compensation for the impacts to water quality and water quantity, as well as some mitigation for wildlife compensation. However, not all habitat mitigation is proposed to occur in the basin. For those impacts that cannot be entirely mitigated for in-basin, an off-site, out-of-basin mitigation plan has been developed by the Port.

Ecology and the King County Department of Development and Environmental Services have studied wetland mitigation successes and failures. King County concluded that mitigation, in general, is not being implemented, and when it has, it has often failed due to poor design, installation failure, and maintenance. Consequently, the studies call for more regulatory control and guidance during the planning, installation, and monitoring phases. They indicate that mitigation projects do not guarantee success and that closer regulatory oversight is merited for longer periods.

#### **1.4.7 Shallow Groundwater and Wetland Effects in Borrow Areas**

Des Moines Creek receives substantial base flow contributions from the Qva aquifer. It also receives contributions from shallow interflow soon after precipitation events, although this contribution is less critical for maintenance of low flows. Recharge to the Qva (shallow regional) aquifer is expected to increase slightly because of excavation in the borrow areas. The change in timing of discharge to the creek was not analyzed and could conceivably be faster or slower than under current conditions, and vary by location. Although the change is small, the change in recharge conditions would likely help dampen streamflow fluctuations and be beneficial in that regard.

Several depressional and slope wetlands may be negatively affected by excavation in

borrow areas 3 and 4. The wetlands depend on perched groundwater flow above the Qva aquifer. The excavation is likely to redirect some of the perched flow, reducing discharge to the wetlands and potentially impacting wetland biota.

### **1.5 Review of Surface Water Management Proposals**

The Project Team reviewed hydrologic analyses performed by the Port's consultants, including:

- Their approach to establishing a target flow regime for creeks
- The calibration of their surface water model
- Their designs for flow-control facilities

The results of these reviews are discussed below. The review distinguishes between *approaches* to issues and the *models* used to implement the approaches.

#### **1.5.1 Target Flow Regime Approach**

The Port consultant's approach for establishing hydraulic conditions that will preserve stable stream channels is reasonable. They characterized the current and proposed movement of surface water in the study area largely by developing hydrologic models of the watersheds. The models simulate the movement of rainfall under various land-use conditions and predict how slowly stormwater runoff from the airport should be released from storage facilities to achieve the desired flow conditions, or "target flow regime," in the creeks. Defining the target flow regime entailed calculating streamflows that would occur if the tributary drainage basins contained only 10 percent effectively impervious area (EIA). The Port used the Hydrologic Simulation Program-FORTRAN

(HSPF) model and assumed only 10 percent EIA in the watershed.

### **1.5.2 Surface-Water Model (HSPF) Calibration**

Earth Tech reviewed the HSPF watershed models to assess how well they were calibrated by comparing the total flow volumes the models predicted to observed values at two locations each in the Des Moines Creek and Miller Creek watersheds. The Miller Creek HSPF model was found to overestimate water compared to the observed flows, indicating that it is not well calibrated, despite the matching of simulated and observed peak flows for selected storm events. The Des Moines Creek model was found to be more reliable.

The poor calibration of the Miller Creek models is related to the parameters selected for model input. There are several inconsistencies in the input data between models that simulate different land-use scenarios. In addition, since the model was constructed to simulate groundwater contributions to streamflow without considering prior precipitation or groundwater storage, it ignores the rigor offered by HSPF. This project team did not find sufficient confidence in the Miller / Walker Creek model to allow detailed evaluation of the model's results. In our opinion, the model would require modification before a thorough evaluation of the performance of the model, and a corresponding evaluation of proposed surface water controls, could be completed.

### **1.5.3 Flow Control Designs**

The general approach used by the Port to size flow control facilities is appropriate. That approach involved applying the target flow regime concept, using local flow-control facilities in conjunction with regional facilities, and running the HSPF model to simulate the target, existing, and proposed watershed conditions. However, as noted above, the model used to size the flow-control facilities needs to be corrected to use this approach with confidence.

### **1.5.4 Construction Period (temporary) Impacts**

The Stormwater Management Plan states the Port applies temporary erosion and sedimentation control measures that exceed minimum requirements of Ecology's manual. These measures include: developing construction stormwater pollution prevention plans for each capital improvement project; implementing conventional best management practices; applying advanced stormwater treatment techniques where necessary; supervising and monitoring contractor compliance; and funding independent oversight of construction erosion control compliance. This project's review of the plans, and field observations of current operations, generally supports the Port's opinion. However, an embankment construction of the magnitude and duration of the third runway project is subject to a range of climatic events and human errors, and an uncontrolled release of runoff from the disturbed site is probable despite proper implementation of construction BMPs.



## **2.0 Introduction**

The Port of Seattle (Port) has proposed to place a fill embankment in an area west of the existing Sea-Tac Airport complex to build a third runway. In 1999, public concerns prompted the Washington State Legislature and Governor Locke to approve independent studies to investigate the hydrologic impacts of the fill project on aquifers; wetlands; and Des Moines, Miller, and Walker Creeks. With Ecology's oversight, consultants Pacific Groundwater Group (PGG); Earth Tech Inc.; and Ecology and Environment, Inc., (E & E) evaluated selected hydrologic impacts of the proposed project. This is the final report from that project. The study area includes the fill area and adjoining wetlands, streams, and aquifers potentially impacted by the proposed runway project. Also included in the study area are the fill borrow sources south of the current airport.

The Port has produced extensive evaluations of hydrologic impacts in the Master Plan Updates Environmental Impact Statement (Federal Aviation Administration, 1996). Wetlands Functional Assessment and Impact Analysis (Parametrix, 1999), Preliminary Comprehensive Stormwater Management Plan (or SWMP, Parametrix, 1999) and other documents. Local communities also sponsored technical evaluations including Sea-Tac International Airport Impact Mitigation Study ("HOK report" - Hellmuth, Obata + Kassabaum Inc., 1997), stream fisheries investigations, and reviews of Port documents. Communication was maintained with the Port of Seattle, Regional Commission on Airport Affairs (RCAA), and the Airport Communities Coalition (ACC) and their consultants. These parties were requested to provide pertinent technical documents and were interviewed. Informal, usually technical, meetings occurred between representatives of this project and the other parties on several occasions. A formal public

involvement process was also maintained, including small group (stakeholder) meetings, publication of three fact sheets, and two public workshops.

## **2.1 Scope, Authorization, and Limitations**

The work was authorized by Dan Silver of the Department of Ecology on September 16, 1999 and an amendment was signed on March 28, 2000 that represented scope changes in response to improved knowledge of existing data and analyses. The scope generally consisted of the following tasks:

- review of existing documents
- interviews with Port staff, community organizations, individuals, and consultants
- collection of additional field data including:
  - two rounds of base flow measurements,
  - two rounds water quality sampling,
  - geologic logging of six boreholes,
  - collection of one round of groundwater level data,
  - a water-well inventory in the buy-out area,
  - survey to review wetland delineations and conditions,
  - stream habitat surveys,
  - fish carcass survey, and
  - juvenile fish counts
- independent evaluation of certain hydrologic impacts using new and existing data, including effects on local groundwater recharge, groundwater flow, support of stream base flows through discharge of groundwater, wetland impacts, and fisheries impacts
- review and comment on Port mitigation proposals including wetlands, fisheries,

and permanent and temporary stormwater management

- review and comment on HSPF models used for stormwater designs
- informing stakeholders and the public on project progress and directions;
- reporting

The scope of this project includes changes resulting from the proposed third runway, borrow areas, and related construction, but not all Master Plan Improvements proposed by the Port. The North Employee Parking Lot (NEPL), South Aviation Support Area (SASA), Industrial Wastewater System (IWS) and terminal modifications are built or proposed improvements that were not explicitly considered by this project. This is an important distinction for large-scale environmental elements such as streamflow and groundwater recharge, because Port projects outside the purview of this project will affect these elements. The NEPL, SASA, and terminal areas are almost completely paved and account for much of the increase in impervious surface area resulting from Master Plan Improvements. In contrast, the foci of this project (proposed third runway, borrow areas, and local wetland and stream systems) will remain predominantly unpaved. This project also did not address proposed State and local surface transportation proposals being considered near Sea-Tac airport.

This project was conducted during a time of intense data gathering, modeling, data evaluation, and reporting by Port consultants, as well as review of these developments by community groups. Most documents were available during the document review period scheduled for this project in fall 1999. However, the Preliminary Comprehensive Stormwater Master Plan, Natural Resources Mitigation report, two subsurface conditions data reports, and other documents were provided during the winter of 1999 and spring of 2000. Changes to the evolving database were anticipated and accommodated to an

extent. However, accommodation of additional data or issues was largely curtailed in January 2000 to allow the project to focus on completion of its chosen tasks. Therefore, new data and issues may have arisen since then or may arise in the future.

This report identifies hydrologic issues that were addressed by this study and yet are not resolved to a level of confidence satisfactory to the authors. This report does not address or list all hydrologic issues requiring satisfactory resolution for permitting processes and therefore this report cannot be used as a checklist by agencies during permit review.

The work was performed, and this report prepared, in accordance with generally accepted practices, used at this time and in this vicinity, for sole application to the third runway and borrow projects, and for the sole use of State of Washington Department of Ecology. This is in lieu of other warranties, express or implied.

## **2.2 Report Organization**

The remainder of this report is organized into two major sections and several appendices. The two major sections of the main body cover the fill area and borrow areas, respectively, which are shown on **Figure 2-1**. Within each of those sections a description of the proposed construction is followed by a description of the character of the area, comparison to previous characterizations, analysis of effects and impacts, and a comparison to previous assessments. The exception is that fish survey results from Des Moines Creek are discussed along with the Miller and Walker Creek results. Appendices are provided to present technical detail that would interfere with communication of findings in the main text.

This report documents data and analyses generated for this project that are not available in other publications. This report does not completely document all existing data related to the project. For instance, geologic data is voluminous and generally not documented in this report. The sources of geologic and other referenced data are provided.

### **3.0 Proposed Fill Area and Miller and Walker Creeks**

#### **3.1 Proposed Construction and Environmental Precautions Related to the Third Runway**

##### **3.1.1 Acquisition of Homes and Farms**

The Port of Seattle purchased, or is in the process of purchasing, land and homes in the "buy-out area" (Figure 3-1) on the west side of the existing Sea-Tac International Airport. The built environment in this area contained:

- more than 400 homes
- five irrigated commercial properties (farms)
- 17 domestic water rights or claims
- neighborhood and arterial roads
- 380 septic drain fields (Parametrix, 1999e)
- numerous water wells

The Port has demolished structures and removed debris. The Port added a process to identify and decommission water wells after an inventory of properties and disclosure of previously unknown wells by this project (Appendix A).

##### **3.1.2 Embankment Fill and Walls**

An embankment of fill soil is proposed to create a high, flat surface upon which the third runway would be built. The top elevation of the fill would be about the same as the existing runways (390 to 410 feet elevation). The west margin of the fill would be bounded by a slope (2 horizontal to 1 vertical) or wall, depending on location. Figure 3-1 shows the locations of the proposed walls.

The walls are proposed as mechanically stabilized earth (MSE) walls. For the purposes of this project important qualities of MSE walls are that they are composed of thin, vertical members on the outside of the wall, and a lattice of horizontal, flexible, porous reinforcing members layered with compacted soil and attached to the outside members. The reinforcing members typically extend into such embankments 80 percent of the wall height (Hart Crowser, 1999a).

The embankment is proposed to be built of fill soil derived from borrow sources on current Port property at Sea-Tac, and from an uncertain offsite source. The aggregate mine on Maury Island, Washington (about 8 miles southwest of the airport) has been identified as a possible offsite source. The volume of the fill required for the third runway embankment is reported to be 16.5 million cubic yards as follows (Hart Crowser, 1999a):

- Type 1 fill: About 40 percent (6.5 million cubic yards) relatively silt-free sand and gravel.
- Type 2 fill: About 60 percent (10 million cubic yards) more or less silty sand (glacial till and outwash soils).

Additional fill is required for other Master Plan improvements.

Type 1 fill would be used near the walls, under runways, and other selected areas. Type 2 fill would be used "to the maximum extent possible, balancing relatively high availability (low cost) with limitations of trying to compact such material in wet weather" (ibid.). Appendix B discusses native soil classifications, and Appendix C contains evaluation of the likely textures of the Type 1 and 2 fills based on specifications produced for the first phase of this fill (Phase 1 fill). Comparisons are shown to samples collected from the Phase 1 fill and Maury Island deposits.

The bottom of the fill would consist of a layer of relatively silt-free soil (Type 1) that would be designed to act as a drainage layer. The drainage layer, in combination with the Type 1 fill near the wall, is intended to prevent the build-up of groundwater pressures near the wall and seepage through the wall by directing groundwater seepage below the base of the wall to the remaining wetlands and Miller Creek (Hart Crowser, 1999a).

Soft and/or organic soils in the vicinity of the walls may be reinforced or excavated and replaced by compacted inorganic fill to enhance wall stability. Dewatering of these excavations may be required during construction. Removal of organic material (grass, trees, roots) is proposed below the bulk of the embankment, but extensive removal of native soils is not likely.

### **3.1.3 Surface Water Management on and Near the Proposed Embankment**

In the Preliminary Comprehensive Stormwater Management Plan (SWMP - Parametrix, 1999e), the Port presents analyses of the current conditions under which surface water moves through the watersheds affected by the Sea-Tac Runway Fill and by other improvements planned at the airport. The Port proposes a stormwater flow control strategy for existing and planned facilities that is intended to reduce storm peak flows in Miller, Des Moines, and Walker Creeks to below flow rates that would be generated by similar storm events on land uses that existed in 1994.

Within the area of the runway fill, the Port proposes to accomplish the reduction in peak storm flow rates by storing runoff in local and regional detention ponds and vaults while restricting the rate of stormwater released from the storage facilities. This strategy further relies on expansion and construction of large regional ponds in Miller and Des Moines Creeks.

Peak flow rates may also be moderated by promoting infiltration into the fill.

Although nearly flat, the surface of the embankment will be sloped to manage runoff of precipitation. The third runway and connecting taxiways will be paved and will comprise about 32 percent of the new embankment surface (Parametrix HSPF basins SDW-1, SDW-2 and SDS-7). Grass will be grown on the unpaved 68 percent. Water running off the paved surfaces is proposed to flow into "filter strips" which are water quality treatment features. The filter strips are proposed to be 75-foot-wide, unlined, uniformly-sloping grass areas adjacent to the pavement except in connecting taxiways where the strips are proposed to be 30-foot wide. Water would flow into low areas at the bottom of the filter strips, then laterally to catch basins spaced hundreds of feet apart in the low areas. Water entering the catch basins would be conveyed through pipes under the runways to detention vaults or other detention facilities prior to discharge to Miller, Walker, or Des Moines Creek. The use of perforated conveyance pipes is being considered (which would enhance infiltration).

### **3.1.4 Wetland and Creek Protections During Construction**

The Stormwater Management Plan states the Port applies construction temporary erosion and sedimentation control (TESC) measures that exceed minimum requirements of the Ecology Manual. These measures include: storm water pollution prevention plans (SWPPPs) for each capital improvement project; conventional TESC best management practices (BMPs); more advanced stormwater treatment techniques where necessary; supervising and monitoring contractor compliance; and funding independent oversight of construction erosion control compliance.

### **3.2 Character of the Hydrologic Environment**

#### **3.2.1 Land Cover**

Materials that cover the land surface affect water quantity and quality in important ways. Vegetation of various types, water bodies, and man-made structures including pavement are examples. Detailed cover maps exist for portions of the area; for instance, wetland classifications include vegetation types, and road distributions are mapped throughout. The Master Plan FEIS includes vegetative cover descriptions for some of the area. Also, the HSPF surface water models of Miller Creek and Des Moines Creek include land cover parameters, measured as total acreage of various pervious and impervious surfaces within each sub-basin. Parametrix Inc. (SWMP) generated sets of land cover parameters for modeling conditions in 1974, 1994, "current" and 2004 conditions. These sets include parameters for all proposed Master Plan Improvements including the third runway embankment, NEPL, and SASA.

This project assigned land cover types based on field observations and design plans where detailed evaluations were performed. The land cover types used in detailed assessments near the embankment are summarized below.

Near the proposed west wall of the embankment, the existing slope is forested and underlain by a thin mantle of outwash soils, or glacial till. Twelfth Avenue South is paved, and separates the slope on the east from grassy and forested wetlands to the west near Miller Creek. This condition is consistent in the embankment area, except that extensive areas of grass, forest, and landscape vegetation occur on outwash and till soils in addition to the wetlands west of 12<sup>th</sup> Avenue. The Vacca Farm has wetland-type soils and is fallow. Houses are sparse to moderately dense in this buy-out area and

paved roads are sparse compared to most urban areas.

Under the proposed built condition, the forested slope and some low areas, including wetlands, would be covered with compacted fill which would grow grass. In addition, all houses, and presumably utilities, would be removed from the buy-out area.

#### **3.2.2 Geology**

The sequence of geologic units present in the fill area is described in this section. Surface materials have been characterized through geologic mapping (Booth and Waldron, in press). Subsurface conditions have been explored specifically for various construction and environmental projects at the existing airport by Port consultants. Subsurface data are also available from off-site wells that are recorded with the Washington State Department of Ecology. Associated Earth Sciences Inc. (AESI) was hired by the Port to compile a computer and hard-copy database of boring logs that includes onsite and offsite well data. Parts of the database were provided to this project along with AESI's interpretations of subsurface geologic structure.

Pacific Groundwater Group described soils from six borings in the project area and observed the activity of the Port's drillers and geotechnical consultant, Hart Crowser. The boring logs generated by Hart Crowser indicate generally the same densities, soil types, and contacts as logs generated by Pacific Groundwater Group. Boring logs are documented in numerous reports generated by Port consultants. The most recent work in the embankment and borrow areas is documented in several "conditions reports" by Hart Crowser (1999b, 1999d, 2000a, 2000b) listed in the references.

The geologic units are described below from youngest to oldest. In a classic sequence of units, all the units would be present, with the youngest on top. However, prehistoric

erosion, landslides, reworking of units by water, and uneven original distributions commonly create conditions where not all units are present. Also, since each unit is not composed of a unique soil texture, density, or color, absolute identification of each unit is seldom certain.

This project focused on relatively shallow hydrologic processes. Specifically, our effort included understanding the soil units in the hydrologic regime that are responsible for base flow in the creeks. We found that groundwater below the Vashon Advance (Qva, shallow regional) aquifer does not discharge to the creeks. Therefore, geologic units deeper than the Qva received less scrutiny and are discussed together below.

### **3.2.2.1 Fill**

The youngest unit of soil in the project area is fill used in construction of the existing airport runways. Its extensive distribution at the airport is indicated on the geologic map of **Figure 3-2**. However, the fill unit is also mapped in additional areas disturbed by cut and fill operations. The fill is generally described in boring logs as silty sand with gravel. Lower portions of the fill are saturated with groundwater at least seasonally. The characteristics of this fill were not considered in detail because it is east of the proposed third runway fill embankment.

### **3.2.2.2 Recent Deposits**

The youngest natural soil unit consists of peat and highly organic fine-grained soils generated from recent and current geologic processes. This unit is not distinguished from the Vashon Recessional Outwash (Qvr) by Booth and Waldron (in press; **Figure 3-2**) but actually warrants a separate mapping unit. The recent deposits are present in the topographic low areas near Lora Lake, the central reach of Miller Creek,

and probably the upper reaches of Walker Creek.

The deposit is typically 10 to 20 feet thick near Lora Lake and is somewhat thinner along Miller Creek south of there. The recent deposits appear to be only a few feet thick in the headwaters of Walker Creek. The peat is generally a dark-brown, soft, silty soil composed of decayed and compressed organic matter. Brown silt and medium sand layers are mixed with the peat, and constitute the bulk of the recent deposits in the central Miller Creek reach.

Hart Crowser reported estimates of horizontal hydraulic conductivity for soils that consist of mixed recent and Qvr deposits. The conductivities range ranging from  $9 \times 10^{-5}$  to  $5 \times 10^{-3}$  cm/sec. The recent deposits are generally finer than the Qvr, and likely account for the lower hydraulic conductivities in the range. Because of its low physiographic position, virtually the entire deposit is saturated with groundwater year-round. A hydrograph of groundwater levels measured by Hart Crowser, in a well screened in recent deposits, is shown as **Figure 3-3**. Pacific Groundwater Group accompanied Hart Crowser and participated in gathering one round of water level data from wells in the embankment area. The procedures used by Hart Crowser were observed by Pacific Groundwater Group and were found to be standard. However, the equilibration of water levels in the wells to atmospheric pressure (once the wells were opened) was not confirmed during the field work. The water levels could be erroneous if equilibration was not achieved.

### **3.2.2.3 Qvr**

Older than the recent peat, silt, and sand is a unit of silty sand with some gravel that constitutes the regional Qvr deposit. This unit was presumably the basis for Booth and Waldron's mapping the Qvr unit (**Figure 3-2**). It is the shallowest geologic unit along the east flank of the central Miller Creek

valley near the proposed fill embankment. It may also underlie the recent deposits in the valley bottoms, but it is commonly absent in that position based on boring logs.

Based on interpretations by AESI (undated) and Hart Crowser (1999b and 2000a), the Qvr ranges in thickness up to 30 feet in the project area, but is missing in places. Hart Crowser reported estimates of horizontal hydraulic conductivity for combined recent and Qvr deposits between  $9 \times 10^{-5}$  and  $5 \times 10^{-3}$  cm/sec. The Qvr deposits are generally coarser than the recent deposits, and likely account for the higher hydraulic conductivities in the range. Because of its widespread physiographic distribution, saturation of the unit by groundwater varies widely. The entire unit remains saturated year-round in the valley bottoms where it may occur below recent deposits. The lower several feet of the unit remain saturated in some intermediate and upland positions as documented with water level measurements collected by AESI and Hart Crowser. A representative hydrograph of groundwater levels measured by Hart Crowser, in a well screened in the Qvr, is presented in Figure 3-3. In other locations, the Qvr may be only seasonally saturated, or may remain unsaturated year round.

Whether or not a geologic unit is saturated is important because it aids in interpreting how groundwater may be moving within the unit. The absence of saturation indicates that groundwater is probably moving downward via unsaturated flow (except within the root zone where upward flow may occur). The presence of saturation is less diagnostic because horizontal, upward, or downward flow may be occurring.

#### 3.2.2.4 Qvt

Glacial till (Qvt, hardpan) is recorded in most borings drilled in the project area. It is a dense unit of gravel and silt in a sandy matrix. It is usually massive and not stratified. In the project area it is similar in

texture to the Qvr, although denser, and this likely explains the term "till-like soil" used by Hart Crowser (2000a). Till was compressed by direct contact with glacial ice. Booth and Waldron (in press) mapped glacial till at or near land surface immediately west of the existing runway fill as well as on other nearby uplands (Figure 3-2). In these mapped areas, a soil profile (commonly the Alderwood soil series) has developed on the till, but the geologic map reflects the glacial till underlying the soil. The till appears to be absent at borings HC00-B110 and HC00-B111 logged by Pacific Groundwater Group south of the cross section location.

Based on interpretations by AESI (undated) and Hart Crowser (1999b, 2000a), the Qvt ranges in thickness up to 20 feet in the project area, but is missing in places. Hart Crowser interpreted well tests indicating hydraulic conductivity values for Qvt-like deposits ranging from  $1 \times 10^{-4}$  to  $5 \times 10^{-4}$  cm/sec. This infers higher groundwater recharge potential than typically measured for glacial till aquitards (Booth, Massmann, and Horner, 1996; Bauer and Mastin, 1996). Reasons for the anomalously high results probably include the fact that lower hydraulic conductivity units such as till do not yield water to a well during drilling, and therefore are commonly not screened or tested. This results in a high bias in hydraulic conductivity based on well tests. Also, since groundwater generally moves vertically in aquitards, vertical hydraulic conductivity is of more interest than the horizontal values measured by Hart Crowser's slug tests. The term "till-like soils" used by Hart Crowser (2000a) to describe the soils in this category of testing results suggests that they included soils with texture, but not density, similar to till.

Because of its varied physiographic position, saturation of the till by groundwater varies widely. It is commonly thought to be unsaturated based on visual observations because water does not readily flow out of it when penetrated. Water percolating



downward commonly accumulates on top of till because of its relatively low hydraulic conductivity relative to percolation rates and the hydraulic conductivity of overlying strata. The presence of water in overlying units is an indirect indicator of saturation within the till. The entire unit remains saturated year-round where it occurs below recent deposits and/or the Qvr in the valley bottoms. The unit remains saturated in some intermediate and upland positions as inferred by the occurrence of groundwater in the overlying Qvr. In other locations, the Qvt may be only seasonally saturated, or remain unsaturated year round.

### 3.2.2.5 *Qva*

The Vashon Advance Outwash (Qva) deposit is a widespread unit of sand with varying amounts of silt and gravel that commonly underlies glacial till. It was encountered in almost all borings that penetrated through glacial till in the area. However, many borings in the embankment area and buy-out area were terminated *within* the till and therefore data on the distribution and properties of the Qva are sparse. Booth and Waldron mapped the unit as comprising the land surface on a slope in the central buy-out area (**Figure 3-2**). The basis for this mapping is unknown. Borings logged by Pacific Groundwater Group in the vicinity (HC00-B111 and HC00-B110) encountered a thick silt, suggesting that the mapping may be erroneous, or that the Qva was interpreted by Booth and Waldron to be a silt at that location. Interpretations for this project assume the mapping to be erroneous and the slope to be comprised of transitional beds (Qtb) discussed below.

The Qva is the upper-most unit that will be explicitly modeled by Port consultants' (AESI and Papadopoulos and Associates) regional groundwater (Modflow) model. AESI (undated) interprets the Qva to occur below the entire project area at a thickness of about 10 feet to more than 50 feet, with a top contact elevation as high as about 380

feet under the existing runways. The top of the Qva is interpreted at a depth of about 30 to 60 feet below the runways based on the AESI analysis. Near Miller Creek, the AESI analysis indicates the top of the Qva at an elevation between 220 and 240 feet based in part on the surface outcrop mapped by Booth and Waldron (in press), which is questioned as noted above. The presence of recent deposits and till extending to a depth of more than 26 feet near Miller Creek (HC00-B124) would indicate a maximum possible top elevation of 204 feet for the Qva at that location. If the Qva outcrop of Booth and Waldron discussed above is actually Qtb, then the AESI interpretation of complete continuity of the Qva must be incorrect. Since the Qva is the shallow regional aquifer, this difference could affect local groundwater flow.

The Qva observed by Pacific Groundwater Group during this project near Lora Lake, is a gray, slightly silty, fine sand. Gravels are occasionally present in the Qva and the unit is often stratified. It is usually distinguished from glacial till based on lower fines (silt and clay) content, stratification, and lack of cementation.

The Qva is the shallow regional aquifer of the South King County Groundwater Management Plan (South King County Ground Water Advisory Committee, 1989). Its regional extent, the perennial presence of groundwater in its lower portions, and its ability to yield water to wells in useful quantities, made this an important water supply source for residences prior to the availability of public water supplies in the area. Currently, potable supplies generally come from deeper aquifers. Below the uplands, groundwater in the Qva is unconfined (a water table exists), and the top of the unit is not saturated. Near the creeks, the Qva is completely saturated, and groundwater within it is confined below the overlying, less permeable Qvt and recent deposits.

The hydraulic conductivity of the Qva was not a matter of concern for this project, no tests were performed, and existing data were not reviewed.

### **3.2.2.6 Qtb**

The transitional beds were deposited in quiet water environments prior to advances of the Vashon glacier and the bed therefore occur below the Qva, Qvt, Qvr, and recent deposits. The unit is composed of silt and clay. Based on texture, Pacific Groundwater Group interprets the thick silt encountered from 20 feet to 97 feet depth (elevation 264 to 187 feet) in boring HC00-B111 to be Qtb. However, as discussed above, Booth and Waldron (in press) appear to have mapped this unit as Qva.

Regardless of its name, the presence of silt from 20 feet to 97 feet in HC00-B111 indicates the lack of a "shallow aquifer" corresponding to the Qva at that location. Conditions at boring HC00-B110 to the southwest are similar.

### **3.2.2.7 Deeper Geologic Units**

Several deeper geologic units are recorded in logs of deep water wells in the area. These include the "intermediate" and "deep aquifers" of the South King County Ground Water Management Plan. The top of the intermediate aquifer is commonly encountered 200 to 250 feet below ground in the airport area. The top of the deep aquifer is encountered at roughly 300 to 400 feet below ground in that area. Although the aquifers are not uniformly transmissive, groundwater flow to these deep aquifers occurs over virtually the entire Des Moines upland (used here as the glacial upland between Puget Sound and the lower Green River Valley). Because of their depth and large lateral extent, these units are less sensitive to local changes to recharge and discharge than are shallow groundwater

resources and groundwater-fed streams that are entirely dependent on local recharge. Furthermore, changes in recharge to deep units is dependent on changes to recharge to shallow units. Therefore this project analyzed local changes to shallow groundwater recharge and discharge, and used those results to infer changes to deeper groundwater recharge. Detailed characterizations of the deeper geologic units is not necessary for that analysis and was not performed.

### **3.2.2.8 Comparison to Previous Geologic Interpretations**

Two differences exist between the shallow stratigraphy described above, and that being used by Port consultants. The interpretation of 20 to 30 feet of moderate and low hydraulic conductivity sediments (recent and Qvt units) overlying the Qva aquifer in the middle Miller Creek reach is one difference. Booth and Waldron (in press) mapped Qvr as present throughout this area and did not differentiate the recent deposits documented in the borings by Hart Crowser (the borings may not have been available at the time of mapping).

The second difference is that Booth and Waldron (in press) map an extensive slope outcrop of Qva on the east flank of the middle Miller Creek reach near the proposed embankment. Logs of borings HC00-110 and HC00-111 indicate the slope is probably composed of silt and clay, which is not typical for the Qva (the borings were not available at the time of mapping). A related issue is that AESI (undated) implies a continuous Qva aquifer below the creek, which is not indicated by the logs of the two noted boreholes.

A review of the deeper stratigraphic interpretations generated by Port consultant Associated Earth Sciences, Inc. (AESI) was also performed by Pacific Groundwater Group (Appendix D). AESI's work is part of the development of a regional

groundwater flow model being commissioned by the Port. The general geologic layering presented by AESI in cross sections is consistent with Pacific Groundwater Group's interpretation. However, local inconsistencies were identified and in several cases the structural contouring of the units does not agree with the cross sections. See **Appendix D** for details.

### **3.2.3 Soil Water Balance Components**

#### **3.2.3.1 Water Sources**

Precipitation and imported public water supplies are the two independent water sources to the area. Precipitation at SeaTac was used in calculations for this project. **Appendix B** provides details.

Drinking water to homes near the buy-out area is provided by local water districts that produce water from wells and buy water from the Seattle Water Department. The Seattle Water Department and the districts maintain wells in the intermediate and deep aquifers. Because the recharge area for these water sources extend far beyond the buy-out area, this water source is effectively "imported" from outside the area for the purposes of assessing changes to recharge resulting from the buy-out. Approximately 400 homes, each with a residential water supply will be removed. It is assumed that the pipes that supply water to the area will be decommissioned such that no leaks will occur.

#### **3.2.3.2 Groundwater Recharge Estimates**

Percolation of precipitation from the land surface was estimated with a proprietary spreadsheet model developed by Pacific Groundwater Group (Recharge model - **Appendix B**). Field observations of land covers were used to characterize the factors

that significantly influence the recharge process. Soil types, land cover, and the presence/absence of shallow till were compiled from existing data and unique combinations thereof were assigned to individual "recharge classes." The recharge model was then used to estimate monthly and annual recharge for each recharge class. The model performs a daily water-balance calculation, but used average monthly values for precipitation and ambient temperature. Along with climatic data, information regarding plant water demand, soil hydraulic properties, and depth to till (where present) was used to perform the daily water balance. In the case of a perched upper aquifer, the model was calibrated to seasonal saturation of the soils above glacial till by adjusting till hydraulic conductivity.

Overland runoff from the recharge classes that were analyzed was assumed to be zero, and the effects of runoff were instead considered in interpretation of the output. Predicted runoff values are less than a tenth of an inch annually for various soils with forest cover, to about one inch annually for grass on till soils according to the HSPF water balance analysis presented in **Appendix F** of the SWMP. That model indicates 2 to 3 inches of runoff from the runway infields. Runoff from runways themselves is assumed to be 100 percent, and no secondary infiltration of runoff is assumed for this project or the Miller Creek HSPF models even though substantial secondary infiltration may occur.

Land-cover was divided into three categories (grass, forest, and barren). Water requirements for grass were used to represent the current and proposed runway infields and wetland meadows. Water requirements for coniferous and deciduous trees were averaged to represent the forested wetlands and forested uplands.

The spatial distribution of soils was based on surficial geology (Booth and Waldron, in press) and field observations. Soils were

considered to be outwash, till, or wetland (saturated).

The recharge model was run for the unique combinations of land cover and soil occurrence discussed above. For Upland till areas, the model allowed shallow groundwater to accumulate above the till and slowly percolate downward based on a till permeability chosen to create seasonal saturation above the till (the assigned till permeabilities for this model do not affect other models). A detailed description of the method for estimating recharge is presented in **Appendix B**.

**Figure 3-4** presents the average monthly estimates of recharge for the recharge classes near the proposed embankment. The estimates were calculated at the bottom of the root zone or the water table, whichever was shallower. Estimates range from 14.4 inches of recharge per year for wetland areas to 24.2 inches per year in mixed-forest areas on outwash soils. Barren outwash has a higher recharge (25.6 inches) than the vegetated classes, but was only considered in evaluation of borrow areas (Section 4). In general, the riparian wetland areas do not contribute to deep groundwater recharge; however, percolation does occur to the water table and that is plotted in **Figure 3-4**.

Wetland and till areas indicate negative recharge in summer. In those areas, water is extracted from the saturated zone by plant roots and thus a net loss of water occurs. Unlike HSPF analyses presented in the SWMP and elsewhere, interflow above glacial till is included as groundwater recharge in these analyses.

### **3.2.3.3 Comparisons to Previous Soil-Water Estimates**

Applied Geotechnology Inc. (AGI), (Port of Seattle, 1996), Parametrix (1999e), and Hart Crowser (1999c), conducted water balance calculations for the proposed third runway. The AGI calculations related to Miller Creek

watershed were not reviewed. The Parametrix and Hart Crowser calculations are complementary, with Hart Crowser calculating subsurface flow within the embankment using output from the Parametrix work.

The Parametrix water balance was based on the HSPF models of Miller and Des Moines Creeks. As discussed in Section 3.6.2, inconsistencies in model parameters between versions of the Miller Creek model, and poor calibration of the Miller Creek model, create a lack of confidence for use of that model in water-budget analyses.

The water budgets for the various land classifications used in the HSPF analysis in Appendix F to the SWMP are subject to some, but not all, of the Miller Creek model problems. Therefore, the results of that analysis were considered. Because these calculations compare current and proposed future conditions, they are discussed in Section 3.6.6 – Comparisons to Previous Groundwater Assessments.

## **3.2.4 Water Circulation**

### **3.2.4.1 Shallow Groundwater Circulation and Discharge**

Groundwater moves laterally and vertically from areas of higher potential energy (head) to areas of lower potential energy (influence of topography), and is influenced by the distribution of hydraulic conductivity (geology) because it tends to follow paths of high hydraulic conductivity. Head is measured by surveying the elevation of water levels. In the proposed fill area, higher head occurs where recharge enters the ground and lower head occurs in streams, in deep aquifers, and in the ultimate base level body, Puget Sound.

Two groundwater circulation patterns (regimes) were identified in the Miller Creek

basin based on their scale and discharge locations. One regime is relatively shallow and discharges entirely to the local creeks. The other regime consists of groundwater that circulates deeper, and discharges year-round to deep wells, the lower reaches of the creeks, and Puget Sound. The deeper regime could probably be subdivided into subcategories, but that is not necessary for the purposes of this project. At the headwaters of Walker Creek, Hart Crowser (2000b) interprets Qvt to be discontinuous. In that case Qva groundwater may discharge more easily to the creek than within the Miller Creek basin, possibly explaining the extensive wetland in the Walker Creek head waters.

Evidence supporting the division of groundwater flow into two regimes is three fold: hydrostratigraphy, the vertical distribution of groundwater heads, and analysis of base flow in Miller Creek. This evidence is presented in the following paragraphs.

As described in Section 3.2.2, the recent and Qvr deposits have moderate hydraulic conductivity and are in direct contact with the middle reach of Miller Creek and the upper reach of Walker creek. Groundwater in these units is not impeded in its discharge to the creeks. The recent and Qvr deposits are typically underlain by Qvt, which has low hydraulic conductivity. Below the glacial till may lie a second aquifer, typically the Qva aquifer. The Qva aquifer is physically separated from the middle reach of Miller Creek by till and sometimes silt. As noted above, discontinuous till in the Walker Creek headwaters may create a more direct avenue of discharge between Qva groundwater and the creek there. Groundwater moving within the Qva aquifer is impeded from discharging to Miller Creek in most of the proposed embankment area by low hydraulic conductivity units. Some upward discharge through those units may nonetheless occur.

The second type of evidence used to identify the scale of the groundwater flow regime responsible for base flow to Miller Creek was the vertical distribution of groundwater heads near the creek. Hart Crowser has installed numerous monitoring wells in the proposed embankment area. Most of the wells monitor heads in the upper aquifer composed of recent and Qvr deposits within 25 feet of ground surface. A few wells monitor heads in a second aquifer. Where the second aquifer is separated from the upper aquifer by till, it can be formally considered the Qva aquifer. The more general term "second aquifer" may consist of the Qva in many cases but may also be a sandy unit near the bottom the Qvr. Since groundwater moves from zones of high to low head, groundwater in the second aquifer must have higher head than groundwater in the intervening recent/Qvr aquifer if it is going to discharge to a local creek. Water levels (heads) from nearby wells screened in the recent/Qvr and second aquifers were compared to assess the potential for this upward flow. Heads in the second aquifers were found to be lower or equal to heads in the recent/Qvr aquifer. Thus, upward discharge of deeper groundwater from the second aquifers to the streams was not indicated in those areas at those times.

Although the review described above indicates that inter-aquifer flow is predominantly downward, one example of upward inter-aquifer flow was noted, as was a case for upward flow from the probable Qva aquifer where it is not overlain by a shallower aquifer.

Upward inter-aquifer flow is inferred near the Miller Creek Detention Facility (MCDF) at well HC99-B43A which flows when uncapped, indicating sufficient head to flow into the Miller Creek detention facility (MCDF). A shallower Qvr aquifer exists there as well. This area is near the area proposed for expansion of the MCDF. That expansion would be created by excavation which could breach the aquitard that confines the high-head groundwater.

Breaching such an aquitard could cause uncontrolled groundwater discharge, erosion and discharge of sediment to the MCDF, and loss of stored groundwater. Further evaluation of the potential for that problem to occur is warranted.

Upward discharge of groundwater also occurs near the headwaters of Walker Creek at well HC00-B208. At that location water levels in the well stand above the adjacent ground surface. Also, the boring log for that well indicates the presence of only a thin mantle of recent deposits, underlain by a thick sandy unit that began to discharge groundwater at 34 feet depth. That sandy unit may be the Qva aquifer, in which case direct discharge of Qva groundwater to the creek is indicated.

The third type of evidence used to identify the scale of the groundwater flow regime responsible for base flow to middle Miller Creek was comparison of rates of gain in base flows in Miller creek to results from a local groundwater model. A simple finite difference slice model was developed to simulate shallow groundwater flow on the east flank of Miller Creek at cross section A-A' (Figure 3-2). Appendix E explains details of the model and Section 3.2.4.2 below explains the stream flow measurements used for comparisons to groundwater model predictions. Figure 3-5a shows the idealized geometry assumed for the Qvt aquitard and Qvr/recent aquifer for this model. Simulation included accounting for groundwater recharge only within the area of the proposed embankment fill (the section extends about 1250 feet east from Miller Creek at that location).

Figure 3-6 presents the results of the slice model for current conditions. The figure shows predicted water flow over a year. Water outflow is divided into surface flow, groundwater discharge, and seepage downward through the till. Overland ('surface') flow and groundwater flow contribute water to wetlands and the creek near the proposed west wall. The plotted

values for surface and groundwater flow are flow to the west end of the cross section model. The plotted values of recharge and percolation through the till ("till seepage") are sums across the entire cross section. In a conceptual sense the till seepage reaches the Qva aquifer. This downward seepage is not accounted for further within the cross section. Units of measurement are cubic feet per day, per foot of width (cfd/f). The total volume of recharge, surface flow, till seepage, and groundwater flow are indicated in the legend. The plot shows how those volumes are distributed over the year.

Although the model was never intended to be calibrated to base flow gain rate, the sum of modeled groundwater flow, modeled surface flow, and septic discharge was in the range expected for base flow contributions from east of the creek for the current conditions. The analysis suggests that base flow consists mostly of local, shallow groundwater flow and that contributions from the Qva aquifer are small in this reach. Further explanation of base flow measurements follows in Section 3.2.4.2.

#### **3.2.4.2 Streamflow**

King County has maintained stream gaging stations at various locations over selected periods on Miller, Walker, and Des Moines creeks. This review focused on the data used in the calibration of HSPF models by Port consultants. Flow duration curves for two gages on Miller Creek, and one gage on Walker Creek, are presented as Figure 3-7. The gage locations are shown on Figure 2-1. The "observed" values on Figure 3-7 are hourly data from the gages. The flow duration curves indicate that data from gages 42A (mouth of Miller Creek) and 42E (mouth of Walker Creek) include some inaccurate readings in the low flow range. The sharp drop off in observed flow data suggests problems with the gages recording lower flow rates. Simulations using the calibration-scenario HSPF models prepared by the Port's consultants produce durations

for most flow rates in excess of observed values.

Pacific Groundwater Group measured base flows in Miller and Walker Creeks at numerous locations in October 1999 and January 2000 to assess gains in base flow. Measurements were made with a Swiffer current meter on a wading rod. **Table 3-1** and **Figure 3-8** present the data along with King County measurements for those dates. The October 1999 measurements preceded the onset of seasonal rains and represent low flow conditions for 1999 (which was a very wet year). The January 2000 measurements also occurred after a period of no rainfall and represent winter base flow conditions plus discharge of stormwater from MCDF.

The measurements indicate that flow increases downstream at both times of year and that the flow rate varies depending on the season. Flows in Miller Creek increased substantially from October to January. About half of the increase at the Kiwanis Club appears to result from the release of stored groundwater and stormwater from the Miller Creek Detention Facility. The other half comes from increased shallow groundwater flow to the stream in the project area.

To assess contributions to base flow from the embankment area, the rate-of-gain per foot of stream reach was estimated using the Miller Creek data from the Lora Lake and SR-509 stations. **Table 3-2** summarizes the calculations, which indicate that Miller Creek gained approximately 6 cubic feet of water per day per foot (cfd/f) of stream length in October, and 11 cfd/f in January. Examination of the flow records of the King County gages indicates that base flows in average rainfall years are on the order of 50 to 70 percent of the 1999 and 2000 measurements.

The slice groundwater model described in **Appendix E** used average recharge rates over the area of the proposed embankment and so must be compared to average

streamflow contributions (not to the 1999 data) from the east flank of the valley. The slice model results plus estimated septic discharge contributions account for 2 cfd/f of base flow gain in middle Miller Creek in the fall, compared to the 1.5 to 3 cfd/f estimated from measurements. The slice model results plus estimated septic discharge contributions account for 8 to 9 cfd/f of base flow gain in middle Miller Creek in the winter, compared to the 4 to 8 cfd/f estimated from measurements. This is relatively good agreement.

#### **3.2.4.3 Water Circulation in Wetlands**

The hydrologic functions of various wetlands are described in Section 3.3.3. Slope, depression, and riparian wetlands occur in the project area.

#### **3.2.4.4 Comparison to Previous Base-Flow Interpretations**

The SWMP provides a description of Miller, Walker, and Des Moines Creeks in the context of stormwater management for the proposed master plan projects. The descriptions rely heavily on HSPF models of the basins. Because the analyses are largely comparative (pre- and post- development), model review is discussed in Section 3.6 – Analysis of Selected Impacts.

AESI (undated) used land surface in the Miller Creek and Walker Creek drainages as “control points” on Qva heads. Although numerically this approximation may be acceptable, base flow should not be solely linked to Qva aquifer discharge as implied by use of these “control points”. The 20 to 30 feet of low hydraulic conductivity sediments commonly present between the Qva and the streams, and the presence of shallow groundwater flow within those sediments, should be considered.

Hart Crowser (1999b Figure 7) mapped horizontal groundwater circulation in the

embankment area's "shallow regional aquifer". The shallow regional aquifer is elsewhere defined as the Qva (AESI undated). However, Hart Crowser uses data from wells clearly screened in recent deposits near the creek (above till). Given the preponderance of low hydraulic conductivity units in the near surface, heads in the various shallow aquifers should not be assumed equal, and data from wells screened in different stratigraphic positions should not be lumped without justification and acknowledgement.

### **3.2.5 New Water Quality Data**

The water quality in Miller, Walker, and Des Moines Creeks was analyzed for a wide range of parameters that help define the environmental health of a creek. Surface water quality parameters, including oxygen, temperature, and turbidity, were measured during field visits. Other parameters were measured at Analytical Resources, Inc. (Appendix F). Tables 3-3 and 3-4 present the results.

For both rounds of measurements, turbidity was highest just downstream of the Miller Creek Detention Facility and improved downstream. Groundwater and wetland discharges are typically very low in turbidity; therefore, Miller Creek turbidity improves as groundwater and wetland water flow into the creek downstream of the detention facility. In October, oxygen levels increased from 6 mg/L at Lora Lake to 9 mg/L at the Kiwanis Club. However, in January, oxygen levels ranged from 5 to 7 mg/L with no clear trend in water quality moving downstream. Water temperature ranged from 10 to 11, and 5 to 7 degrees C with no apparent trends, in October and January, respectively.

Discussion of water quality as it pertains to fish habitat is discussed in Sections 3.4 and 4.4.

### **3.3 Character of the Wetland Environment**

The project area surrounding Sea-Tac Airport is primarily urban/residential. Immediately west of the airport, land use is a mix of residential and agricultural, with development encroaching on the Miller Creek riparian corridor. This corridor consists of a mosaic of land uses with residential areas, agriculture, upland habitats, and slope and riparian wetlands, all located adjacent to the creek. Outside the immediate vicinity, areas that have not undergone extensive urban development are restricted primarily to the narrow riparian and ravine corridors associated with Miller and Walker creeks. Larger wetland complexes are associated with these drainages, including the Miller Creek Detention Facility, and a large wetland complex which forms the headwaters of Walker Creek. In addition to these riparian, ravine and wetland systems, the only other major non-urban areas include the successional woodlots west of the airport acquired as part of previous Noise Abatement Mitigation projects (which had been residential but are now upland woodlots), Vacca Farm, and scattered lakes, ponds, and local recreational parks. No other significant parcels of undeveloped land were identified.

Approximately 11 acres of wetlands are present in the vicinity of in the Runway Safety Area Extension and 40.65 acres of wetlands occur in the vicinity of the Third Runway Impact Area (Parametrix 1999a). Figure 3-9 identifies the wetlands within the project area based on mapping by Parametrix. This acreage does not include larger complexes (including the approximate 43-acre headwater wetland of Walker Creek), wetlands associated with Tub Lake, Arbor Lake, and Burien Lake, and smaller isolated wetlands that occur north of State Route 518, and west of State Route 509. Based on the field survey, extensive riparian wetland complexes also occur along both



Miller and Walker creeks within ravine areas west of SR 509. These all fall outside the bounds of the project area and are not discussed further.

### 3.3.1 Document Review and Field Analysis

Wetland field verification surveys were conducted during the week of December 4, 1999. Surveys were conducted throughout the Miller Creek drainage basin to assess the regional context of the project area.

Before conducting the field surveys, the following documents were reviewed:

- Available National Wetland Inventory Mapping (United States Fish and Wildlife Service);
- Available aerial photography of the project area;
- Wetland Delineation Report (Parametrix, Inc., Revised Draft, August 1999);
- Wetland Functional Assessment and Impact Analysis (Parametrix, Inc., Revised Draft, August 1999);
- Natural Resources Mitigation Plan (Parametrix, Inc., Revised Draft, August 1999); and
- Biological Assessment (Parametrix, Revised Draft, November 1999).

The field surveys focused on confirmation of the wetland delineations, evaluation of the wetland quality assessment, and analysis of the proposed mitigation.

### 3.3.2 Wetland Delineation

As a component of the EIS for the Port's Master Plan improvement projects, numerous consultants conducted wetland delineations within the proposed project area. Areas where access was denied were not delineated but rather best professional judgement was used in estimating the wetland boundaries. Following completion of delineation efforts, and in conjunction with the United States Army Corps of Engineers (USACE) Section 404 permitting effort required for the project, wetland scientists from the USACE conducted in-field verification surveys of delineated wetlands. E&E's field survey confirmed that boundaries as flagged in the field accurately depict the extent of wetlands, and are correctly depicted on available wetland maps. The field surveys also did not identify any wetlands that previously had not been delineated.

### 3.3.3 Wetland Characterization

To evaluate the potential effects on wetlands, it is necessary to characterize wetlands with respect to each other, their role in the watershed, and their functionality. The different methods of classifications used to categorize and assess the value of the wetlands in the project area are described below. The field survey and literature review were used to evaluate the previous classifications and assess their functionality in order to make an independent analysis.

#### 3.3.3.1 Wetland Classifications

Parametrix classified wetlands in the project area by physiographic setting (e.g., slope, depression, or riparian) and by regulatory class as defined by the *Washington State Wetlands Rating System* (Washington State Department of Ecology, 1993). During the field survey, both classifications were evaluated.

Table 3-5 lists the wetlands that E&E identified as potentially impacted by the fill activities, lists their classifications, and provides brief description of the wetlands' location and condition. Expanded discussions of the wetland areas are provided in the Wetland Delineation Report (Parametrix 1999a).

Most wetlands within the project area that are likely to be affected are slope wetlands. These wetlands are hydrologically driven by hillside groundwater seeps, with additional input from precipitation. The slope wetlands range in size from very small (the 0.05 acre Wetland 13) to the extensive Wetland 18/37 complex, located west of the existing airport. In addition to the slope wetlands, depressionnal and riparian wetlands are present. The depressionnal wetlands likely have resulted from segmentation of once larger wetland systems that have systematically been filled, or, have developed on low permeability fill soils. All riparian wetlands delineated in the vicinity are associated with Miller Creek.

E&E is in general agreement with the wetland classifications assigned by Parametrix (1999b) based on field surveys completed for the project. No wetlands in the project area are Class I, the highest quality and most significant wetlands in the state. Class I wetlands include those that contain documented occurrences of recognized species of concern, are recognized as regionally significant, or perform irreplaceable ecological function (i.e., bogs, mature forested wetlands, or estuarine wetlands). While Miller Creek is documented to contain protected fish species in its lower reaches, there is no documentation of these species occurring within the wetlands in the project area. Although there are forested wetlands in the project area, the evident local disturbance, and the estimated ages of the existing trees do not meet criteria established for Class I wetlands.

### 3.3.3.2 Functional Assessment

Wetlands are recognized for the value they provide on an ecosystem level. This value varies based on wetland size, location in the landscape, and on surrounding land use. To better estimate the value or quality a wetland provides within an ecosystem, it becomes necessary to assess specific functional attributes of a wetland.

Evaluation of wetland functions is an inexact science. Numerous models have been developed within the scientific community to specifically evaluate wetland functional capabilities, yet they all recognize that while certain functions can be directly measurable, oftentimes professional judgement is necessary to correctly apply the models. Furthermore, existing models have been developed to evaluate the functionality of wetland types (i.e., depressionnal or riparian) with the results between types not being comparable. Therefore, the use of models for large diverse projects usually does not provide useful data. Therefore, E & E assessed the quality of wetlands, using best professional judgement and scientifically established parameters. Our assessment is loosely based on the principles established in *Methods for Assessing Wetland Functions* (Hruby et al. 1999), which has been published for depressionnal and riparian wetlands within Western Washington.

Three basic categories of functional capability were assessed: water quality improvement, hydrology (or water quantity), and habitat suitability. Water quality function includes the ability of the wetland to effectively trap sediment, nutrients, and contaminants. Hydrologic function focuses on the ability of a wetland to provide flood storage, prevent downstream erosion, and potential for recharging aquifers. Habitat suitability is a broad-ranging category including both flora and fauna diversity, and the export of organic carbon, which can be beneficial to adjacent aquatic communities.

The qualitative assessment component of **Table 3-5** focuses on those wetland functions that E&E believes are likely to be affected by the airport improvement projects and on those functions that differentiate the wetlands within the project area. For example, most project area wetlands have little direct bearing on resident fish populations and are therefore all equally considered to be low quality. The exceptions to this (e.g., Wetlands 18 and 37) are specifically noted within the qualitative assessment column in the table. This assessment approach is conservative because wildlife was broadly grouped together rather than differentiating amphibians, and small mammals. The bird habitat functions of the wetlands are more related to the vegetative cover type and size. The larger and more diverse wetlands (particularly those with a forested component) provide moderate-to-high quality habitat for migratory bird species, while the smaller, typically emergent wetlands, offer low-to-moderate quality bird habitat.

In addition to evaluating the specific functions of a wetland, E & E assessed the effectiveness of a wetland to provide a specific function and also the opportunity to provide that function. The opportunity for a wetland to provide a particular function is driven by its size, the surrounding landscape (land use), and by the wetland's location within the watershed. Thus, while a depressional wetland is an ideal basin for storage of floodwaters and highly effective as a nutrient/sediment trap, a small headwater depressional wetland located in an undisturbed environment would have little opportunity to provide this function and thus would have a low functional assessment.

This qualitative discussion is based on a combination of the field survey conducted, and data provided as part of previous investigations in the project area. Prior to utilizing any data acquired previously, data comparisons were made for those wetlands where information was available from both

previous field reports and the field survey. The validity of this previously acquired data was analyzed using professional judgement before incorporating the data into this assessment.

As indicated in the table, wetlands in the project area are important nutrient and sediment traps that filter-out anthropogenic inputs prior to discharge to Miller Creek. Refer to Section 3.4 for a more detailed discussion of the fish habitats available in local water resources. The riparian and larger depressional wetlands also provide flood retention capabilities in a highly urbanized watershed. Flooding is a recognized concern, and the Miller Creek detention facility, located immediately upstream from the project area is designed specifically to dampen flood flow through Miller Creek. From a wildlife population perspective, the wetlands within the project area provide necessary habitat/open space in an urban setting. Because of the urban development and fragmentation of the resource, the local wetland habitats benefit small amphibian and small mammal populations, as well as the more mobile avian species. Discussions of aquatic habitats are discussed in Section 3.4.

### **3.3.4 Comparison to Previous Wetland Characterizations**

Project area wetlands were evaluated to verify the accuracy of the delineations and qualitative assessment completed as part the Wetland Delineation Report (Parametrix 1999a). Based on the field surveys completed, which represented a random sampling of wetlands within the project area, the wetland delineations presented in the delineation report provide an accurate representation of the extent of wetlands that occur in the project area.

Wetland delineation is an interpretive skill that requires professional judgement, particularly at wetland boundaries, where the available vegetative, hydrologic, and soil

indicators can be marginal at best. Based on the wetland flagging present in the project area, the delineations completed within the project area are conservative in estimating the extent of wetlands, meaning that the marginal areas were more likely to be included as wetland area, rather than upland.

In reviewing the functional assessment completed for the project, the analysis also showed that the qualitative assessment provided a reasonable representation of functional ability of wetlands within the project area. The framework used for this analysis used *Methods for Assessing Wetland Functions* (Hruby et al. 1999) which was not available during the preparation of the previous studies completed at STIA.

Methodologies and references referred to in the Wetland Functional Assessment and Impact Analysis included *the Wetland Evaluation Technique* (WET) (Adumus et al. 1987), *Hydrogeomorphic Classification of Wetlands* (Brinson 1993) and *Wetland Values: Concepts and Methods for Wetland Evaluation* (Reppert et al 1979). However, to some extent, professional judgement is the key to the analyses presented in the report. While neither previous wetland evaluations, nor the quality and functional assessment conducted as part of this analysis provide numerical quantification of wetland impacts, both approaches effectively identify those functions that would be impacted by the implementation of the Sea-Tac improvement projects. Numerical quantification of wetland impacts would not necessarily improve the overall qualitative assessment of impacts, particularly in light of the fact that a significant portion of the wetland impacts are to slope wetlands, for which there are no recognized/approved models.

### 3.4 Character of Fish Habitat and Populations

This discussion of fish habitat in Miller, Walker, and Des Moines Creeks focuses on the abilities of these creeks to support salmonid species. Different salmonid species and life history stages have different optimal habitat preferences that fall within a range of acceptable values. The optimal habitat preferences for juvenile and adult coho salmon (*Oncorhynchus kisutch*) are presented in Tables 3-6, 3-7, and 3-8 for comparison purposes with existing habitat conditions. Only those habitat parameters that commonly limit salmonid survival and production are presented. Because optimal habitat preferences for coho salmon are generally more restrictive than cutthroat trout (*O. clarki*), decision making based on coho salmon habitat preferences should also be protective of cutthroat trout.

**3.4.1 Miller Creek**

**3.4.1.1 General Watershed Description**

The Miller Creek watershed is approximately 9 square miles and encompasses 5 governmental jurisdictions: the cities of Normandy Park, Burien, and SeaTac, Port of Seattle, and unincorporated portions of King County. Water flow for Miller Creek originates from Arbor Lake, Lake Reba, Lora Lake, Lake Burien, wetlands associated with the Miller Creek detention facility, and from seeps into the channel and riparian wetlands, especially located along the west side of the airport. Miller Creek falls from an elevation of approximately 360 feet in its headwaters to sea level at Puget Sound at the Normandy Park Cove. Significant residential and commercial development exists within the Miller Creek watershed, resulting in approximately 23 % impervious surfaces. Land use consists of approximately 62% residential, 15% commercial, 3% airport, and 20% undeveloped (Montgomery Water Group 1995).

Trout Unlimited (TU) operates the Miller Creek Hatchery located at the Southwest Suburban Sewer District in Normandy Park. The hatchery has been in operation for approximately 15 years. Annually, TU receives coho salmon eggs from the Washington Department of Fish and Wildlife (WDFW). Although the number of eggs received annually varies, the maximum number of eggs the Miller Creek Hatchery can raise is 300,000. TU reports egg to juvenile survival that usually approaches 100%. TU plants juvenile coho throughout Miller, Walker, and Des Moines Creeks. Fish plantings are conducted at various times throughout the spring and with different size fish in an attempt to maximize survival of planted fish. Coho salmon released by the Miller Creek Hatchery are not tagged or identified with any distinguishing marks.

**3.4.1.2 Watershed Development**

Urbanization has degraded salmonid habitat in Miller Creek. The stream habitat lacks complexity and variability and is dominated by fast water riffle/run habitat. Sedimentation is prevalent throughout the watershed. Optimal habitat parameters for salmonids such as presence of woody debris, undercut banks, and overhanging vegetation are absent throughout much of the stream system. Pool to riffle ratio is reported to be approximately 15:85, well below the optimal 50:50 ratio (Batcho 1999a). Development and impervious surfaces in the watershed have significantly affected the stream's hydrograph, causing less wetland and groundwater storage and resulting in high peak flows and lower base flows. These factors cumulatively result in limiting habitat factors for different salmonid life stages, particularly high-quality gravel for spawning adult salmonids and refuge habitat for age-0 juvenile salmonids (i.e., fish that emerged this year).

**3.4.1.3 Water Quality Related to Fish**

Miller Creek's water quality has also been degraded by urbanization in the watershed. MacCoy and Black (1998) reported toxic metals such as arsenic, lead, and mercury in Miller Creek sediment and sculpin (bottom-dwelling/feeding fish) tissue at concentrations exceeding the probable-effects level developed by the Canadian Council of Ministers of the Environment (CCME). Probable-effects levels identify a threshold above which adverse effects are predicted to occur frequently; concentrations exceeding these guidelines may or may not result in an adverse effect on aquatic organisms but are intended to indicate potential sediment quality problems that warrant further study. MacCoy and Black (1998) also reported polynuclear aromatic hydrocarbons at concentrations in Miller Creek sediments exceeding the CCME threshold effects level, which defines the

concentration below which adverse effects to aquatic organisms are expected to be rare.

Voss et al. (1999) reported the presence of numerous pesticides in Miller Creek. The insecticides carbaryl and diazinon were present at concentrations exceeding the chronic aquatic life criteria recommended by the U.S. Environmental Protection Agency (1998). Voss et al. (1999) noted that the ecological effects to the stream are unknown because the duration of exposure to pesticide concentrations above the chronic aquatic life criteria is unknown.

Pacific Groundwater Group collected surface water samples during fall and winter base flow periods throughout the upper portion of the Miller Creek watershed and analyzed for in situ water quality parameters (pH, temperature, conductivity, turbidity, and dissolved oxygen (Table 3-3)). These parameters appear to be within expected values for the region; however, dissolved oxygen levels as low as 4 mg/L likely limit salmonid utilization in the sampled area. Water samples also were analyzed for total metals, total suspended solids (TSS), ammonia, nitrate, nitrite, total phosphorus, ortho-phosphorus, biological oxygen demand, and total oil and grease (Table 3-4). Washington State Surface Water Quality Standards include maximum concentration levels (MCLs) for arsenic, cadmium, copper, lead, and zinc (WAC 173-201A 1997). Arsenic and cadmium were not detected in Miller Creek. Based on the calculated hardness in Miller Creek of 95 to 150 mg/L, detected concentrations of copper and zinc were well below the Washington State MCLs. One out of four lead concentrations was above the MCL based on the calculated hardness of 95 mg/L for that sample. The maximum TSS value was 17 parts per million (ppm), indicating minimal suspended particles (of which sediment is one component) in the water column during these base flow periods. Total oil and grease was below 2 ppm, indicating minor inputs of petroleum constituents at the time of sampling. Significant changes to water

quality likely occur during stormwater runoff events.

Stormwater at the airport falls into one of two types of catchments: the Stormwater Drainage System (SDS) and the Industrial Wastewater System (IWS). This project did not independently review original SDS or IWS water quality data or discharge data. The following brief discussion is from the FEIS (FAA, 1996) and other sources.

In general, the IWS collects water close to the airline gates where fueling and plane de-icing operations occur while the SDS collects water from the taxiways and runways. The IWS drains are connected to one of three storage lagoons where the water is treated and discharged to Puget Sound. The IWS lagoons are not hydrologically connected to the Miller creek watershed. On the other hand, SDS drains are connected to drainage ditches and, hence, discharge to the Miller Creek and Des Moines creek watersheds. Chemicals specific to airport operations, that are potentially present in SDS runoff, include de-icing chemicals draining off planes during taxi and take-off and de-icing chemicals used on the runway. The FEIS (FAA, 1996) indeed reports occasional glycol and ammonia detections in SDS discharges from those sources, and also reports that copper and zinc occur at elevated concentrations in SDS discharges.

Other SDS water quality parameters were reported to be similar to other basin stormwater. Analyses of seven water quality parameters in SDS discharge (total suspended solids, biochemical oxygen demand, oil and grease, total phosphorus, total copper, total lead, and total zinc) were reported in the FEIS (FAA, 1996). Results were compared to the total basin loading for these parameters in Miller Creek. It was reported that discharge from the airport contributes between 0.5 and 4.3 % of the total basin loading for these parameters. These values are less than the 5% of the Miller Creek watershed that the airport encompasses.

#### 3.4.1.4 Fish Populations

Despite habitat and water quality degradation as a result of urbanization, anadromous and resident fish populations are present in Miller Creek. Adult coho salmon are known to use the stream reach from the mouth to the 1<sup>st</sup> Avenue South culvert, however, adult coho have been reported in Miller Creek above 1<sup>st</sup> Avenue South (Batcho 1999a, personal communication). Juvenile coho salmon are distributed throughout Miller Creek, likely because of Trout Unlimited's Miller Creek Hatchery release efforts. Steelhead (*O. mykiss*) runs have been reported on Miller Creek, but this was not field verified. A small population of resident cutthroat trout is distributed throughout much of the Miller Creek watershed. Pumpkinseed sunfish (*Lepomis gibbosus*) reportedly have been introduced to Miller Creek; E&E observed one pumpkinseed in the lower portion of Miller Creek. Three-spined stickleback (*Gasterosteus aculeatus*) has been observed in the vicinity of Lake Reba, however E & E did not verify stickleback presence. E & E did not document the distribution of pumpkinseed or three-spined stickleback in Miller Creek.

#### 3.4.2 Walker Creek

##### 3.4.2.1 General Watershed Description

Walker Creek is a major tributary of Miller Creek; however, information about the creek is lacking because it is commonly not discussed as an exclusive watershed. Walker Creek originates in a series of wetlands located within a triangle formed by Des Moines Memorial Drive, Highway 509, and South 176<sup>th</sup> Street. The original confluence of Walker Creek and Miller Creek was downstream of First Avenue South, but decades ago Mr. Walker altered the stream (Gower, pers. comm. 1999).

Walker Creek currently parallels Miller Creek downstream of First Avenue South and drains into Miller Creek approximately 0.25 mile from the mouth of Miller Creek at the Normandy Park Cove area.

##### 3.4.2.2 Watershed Development

Urbanization has degraded salmonid habitat in Walker Creek. The stream habitat lacks complexity and variability and is dominated by fast water riffle/run habitat. Sedimentation, which is detrimental to salmonid production, is prevalent throughout the watershed. Habitat parameters such as presence of woody debris, boulder cover, and undercut banks are absent throughout much of the stream system. Overhanging vegetation is present throughout most of the system and is dominated by shrubs and trees; this provides cover for fish and shading to minimize water temperature increases above tolerable levels for salmonids. However, grass is common streamside vegetation in residential areas throughout the watershed. Grass possesses little value as riparian vegetation because it does not provide overhanging cover, substantial inputs of organic matter to the stream, or streambank stabilization below the top soil unit, all of which are important habitat parameters for salmonid production.

##### 3.4.2.3 Water Quality

PGG measured temperature, pH, conductivity, turbidity, and dissolved oxygen during base flow periods in October and November 1999 and January 2000 at two locations in Walker Creek: near the First Avenue South retaining wall and near the mouth at the intersection with 12<sup>th</sup> Avenue South. These water quality parameters also were measured in November 1999 at two locations west of Highway 509 (Table 3-3). The results indicated low dissolved oxygen levels that may limit fish production. In November

1999, dissolved oxygen levels of 3 mg/L at both the First Avenue South retaining wall and the intersection at 12<sup>th</sup> Avenue South could substantially limit salmonid usage of the creek in the sample areas. In addition, the dissolved oxygen levels of 0.2 mg/L and 0.4 mg/L measured in Walker Creek west of Highway 509 likely prevent salmonids from using this area.

#### **3.4.2.4 Fish Populations**

Despite habitat degradation, anadromous and resident fish populations are present in Walker Creek. Adult coho salmon are known to use the stream reach from the mouth to the 1<sup>st</sup> Avenue South culvert; however, adult coho have been reported in Walker Creek above 1<sup>st</sup> Avenue South (Batcho 1999). Juvenile coho salmon are distributed throughout Walker Creek, likely because of Trout Unlimited's Miller Creek Hatchery releases. A small population of resident cutthroat trout is distributed throughout much of the Walker Creek watershed.

#### **3.4.3 Carcass Surveys**

Previous studies have investigated the composition of natural and hatchery fish in the anadromous salmonid returns in Miller, Walker, and Des Moines Creeks (WDFW 1996, BioAnalysts 1998, Batcho 1999). However, reported composition has varied; thus uncertainty exists in the composition of natural and hatchery fish in the anadromous salmonid runs in these creeks. All fish released from WDFW hatcheries receive an adipose fin clip to indicate their hatchery origin. However, not all privately permitted fish releases require fish to receive adipose fin clips. For example, the Miller Creek Hatchery does not clip coho salmon adipose fins because of the small size of fish at the time of release and the labor intensive nature of fin clipping (Batcho 1999). Hence, fin-clipped fish found in Miller, Walker, or Des

Moines Creek are likely straying fish from another nearby hatchery or net pen operations (Batcho 1999). The two most likely sources of fin-clipped coho in the adult salmon return are the Des Moines Creek Net Pen operated by TU or the Soos Creek Hatchery operated by the WDFW. Non fin-clipped fish in Miller, Walker, or Des Moines Creeks could have four possible origins: first generation fish from the Miller Creek Hatchery, second (or greater) generation fish from the Miller Creek Hatchery, wild fish that have sustained a population, or wild fish that have strayed from nearby populations.

E & E conducted carcass surveys to establish the proportion of marked and unmarked fish in Miller, Walker, and Des Moines Creeks. **Figures 3-10 and 3-11** show survey locations. These data can serve as an indicator of the creeks' ability to support natural anadromous fish spawning populations and the success of the Miller Creek Hatchery in reestablishing these spawning populations. However, carcass survey data are limited because identifying the presence of returning adult salmon does not establish that successful spawning (i.e., a naturally reproducing population) is occurring on the creek. Juvenile fish surveys are more suited for this purpose as described in Section 3.4.4.

##### **3.4.3.1 Methods**

In December 1999, E&E performed carcass surveys by walking upstream (in the stream when possible) from the creek mouth to a predetermined upstream boundary. The Miller and Walker Creek upstream boundary was 1st Avenue South and the Des Moines Creek upstream boundary was Marine View Drive. E&E classified every carcass encountered by species, sex, presence of an adipose fin clip, and the estimated percent of egg voidance in females (egg voidance is the measure of eggs expended by the female during spawning). Because a substantial amount of time had elapsed since the salmon



had expired, many carcasses were in an advanced state of decay and, as a result, one or more data parameters were unidentifiable.

### **3.4.3.2 Results**

Data from the carcass surveys are presented in **Table 3-9**. The majority of fish were coho salmon; two chum salmon were observed in Des Moines Creek and one in Walker Creek. Most females appeared to void the majority their eggs, although the range of egg voidance was 0-100 percent. Egg voidance numbers should be interpreted with extreme caution because significant decay and subsequent washout of the carcasses had occurred since the fish expired. Therefore, the reported percentages are likely overestimates of the actual percent of egg voidance.

On Miller Creek, E&E observed eleven coho salmon in the sample reach (**Table 3-10**) Sex and adipose fin determination could not be made on two of the eleven coho observed. Of the nine identifiable coho, six were female and three were male. Eight fish were identified as WDFW hatchery fish (i.e., adipose fin clips) while one fish still possessed an adipose fin. Egg voidance in female coho on Miller Creek ranged from 0-100, but most females had voided >80% of their eggs.

On Walker Creek, 42 fish were observed in the sample reach; 41 fish had expired and one live fish was observed downstream of the 13<sup>th</sup> Avenue South culvert in Normandy Park (**Table 3-11**). Species determinations were made on 21 fish: 20 were coho salmon and one was a chum salmon. Sex determination was made on 24 fish: 12 female and 12 male salmon were observed. Adipose fin determination was possible on 18 fish: 12 fish were identified as WDFW hatchery fish and six had the adipose fin. Egg voidance in female coho on Walker Creek ranged from 70-95%.

On Des Moines Creek, nine fish were observed; six fish had expired and three live fish were observed in quiet water downstream of the Marine View Drive culvert in Des Moines (**Table 3-12**). Species determinations were made on nine fish: seven were coho salmon and two were chum salmon. Sex determination was made on six fish: two female and four male salmon were observed. Adipose fin determination was possible on six fish: one fish was identified as a WDFW hatchery fish and five still had an adipose fin. Egg voidance in female salmon on Des Moines Creek ranged from 0-90%.

### **3.4.3.3 Conclusions**

WDFW hatchery fish comprise the majority of anadromous coho salmon runs on Miller and Walker Creeks. Because no WDFW hatchery is located within the Miller Creek basin, these hatchery fish are likely straying from the Soos Creek or Keta Creek Hatchery in the Green River watershed or from the Des Moines Creek net pen. Conversely, only one of six anadromous salmon on Des Moines Creek was identified as a WDFW hatchery fish. This result was unexpected because of the proximity of the Des Moines Creek net pen operated by TU. The non-WDFW hatchery fish in the anadromous salmon returns on Miller, Walker, and Des Moines Creeks could fall into one of four categories as described above. Because non-WDFW hatchery fish comprise only a small portion of the anadromous salmon returns on Miller and Walker Creeks, the Miller Creek Hatchery does not appear to be successfully contributing significant numbers of coho to the salmon run based on the data collected for this field survey.

### **3.4.4 Juvenile Fish Survey**

E&E used the presence of juvenile salmon in Miller, Walker, and Des Moines Creeks

as an indicator of the ability of each creek to support a naturally reproducing anadromous salmon run. Carcass surveys can establish various characteristics of the returning adult population such as proportion of fin-clipped fish or sex ratios. However, in addition to the presence of adult salmon, a multitude of other criteria need to be satisfied for adult salmon to successfully produce viable juveniles. These factors include, but are not limited to, water flow, water temperature, dissolved oxygen, and degree of gravel sedimentation. Therefore, the presence of age-0 salmon in Miller, Walker, or Des Moines Creeks prior to annual Miller Creek Hatchery releases indicates that adequate conditions currently exist for the survival of fertilized eggs to emergent fry.

#### **3.4.4.1 Methods**

E & E conducted juvenile fish surveys on March 24 and 25, 2000. No planned Miller Creek Hatchery releases had occurred on Miller or Walker Creeks prior to the juvenile fish surveys. However, accidental releases of approximately 100 fish occurred in early March (Yonkers 2000). TU released juvenile coho salmon in the upper portion of Des Moines Creek near the Tyee Valley Golf Course approximately 2 weeks before the Des Moines Creek juvenile fish survey. This hatchery release is expected to have insignificant effects on the results of the Des Moines Creek juvenile fish survey because hatchery fish were released approximately 3 miles from the juvenile fish study area, juvenile coho often establish territories and remain in the same location for extended periods of time (Hoar 1958), and recently emerged coho in the creek are distinguishable from Miller Creek Hatchery coho based on size.

The juvenile fish survey study area for Miller and Walker Creeks consisted of the reach from the mouth to the downstream intersection with First Avenue South. The Des Moines Creek juvenile fish survey study area consisted of the reach from the mouth

to the downstream intersection with Marine View Drive. E&E conducted the surveys by walking from the mouth toward the upstream boundary. Sample locations were biased to habitat preferred by juvenile salmon, such as pools, backwaters, undercut banks, or areas with instream or overhanging cover. Biased sampling locations were limited because preferred slack water habitat was not abundant. Juvenile fish were captured with a 1/16" delta mesh fully hung beach seine measuring 6 feet deep and 20 feet long. Certain habitat was inaccessible with the beach seine because of substrate irregularities or debris. A small mesh dip net was used as an alternate capture method when juvenile fish were observed but could not be accessed with the beach seine. Sampling frequency was dependent upon juvenile fish capture success; the goal of sampling locations and sampling frequency was to identify juvenile fish distribution throughout the study area. If a significant number of fish were captured at any sampling location, the number of fish anesthetized and measured was limited to 20. The remaining fish were enumerated and released at the point of capture.

Corralled fish were led to the streambank where they could be netted and transferred to a 5-gallon holding tank. Captured age-0 fish were individually anesthetized in a separate 5-gallon tank containing a solution of tricaine methanesulfonate (MS-222; 50 mg/L) to reduce handling stress and allow for rapid fish identification and length measurements. Fish were handled immediately after signs of equilibrium loss. Fish greater than or equal to age-1 were large enough to identify and measure quickly without anesthetic. After data collection, fish were immediately transferred to a third 5-gallon fresh water recovery tank and remained until equilibrium was regained. All fish were released at the point of capture. General habitat characteristics of sampling locations and location in the stream system were described for all areas where fish were captured. Species and length data were used to document the

presence or absence of different species and age classes of fish.

Capture success with the beach seine was approximately 50%. Numerous fish were observed during beach seine deployment but were not retained because of interference with submerged logs and other obstructions. Fish also may have escaped through gaps in the bottom of the net before the beach seine could be completely sealed.

#### **3.4.4.2 Results**

The Miller Creek juvenile fish survey results are presented in **Table 3-13**. E & E captured fish at 7 sampling locations throughout the sampling reach (i.e., mouth to First Avenue South). Two species were identified: coho salmon and cutthroat trout. E & E captured cutthroat trout (likely age 2-5) throughout the sampling reach; cutthroat were often associated with deep water, commonly at the upstream edge of a plunge pool. Coho salmon (age-0) were also distributed throughout the sampling reach. A total of 15 age-0 coho were captured in Miller Creek. Age-0 coho length ranged from 26-50 millimeters (mm) fork length (FL), with an average length of 37.5 mm. Age-0 coho were typically found at about 6 inch depth in slack water associated with side channels, edge habitat, or instream structure such as logs or boulders. Biased sampling locations were difficult to identify because slack water preferred by age-0 coho appeared to be limited. E & E observed numerous age-0 fish (presumably coho) in slack water habitat between sampling locations but beach seine or dip net capture methods were not employed because of sample gear inaccessibility or because of proximity to another sampling location.

The Walker Creek juvenile fish survey results are presented in **Table 3-14**. E & E captured fish at 8 sampling locations throughout the sampling reach (i.e., mouth to First Avenue South). Two species were identified: coho salmon and cutthroat trout.

Cutthroat trout (likely age-2) were captured throughout the sampling reach; cutthroat were often associated with deep water, commonly at the upstream edge of a plunge pool. Coho salmon (age-0) were also distributed throughout the sampling reach. Sixty age-0 coho were captured in Walker Creek; however, only 32 were retained for length measurement. Age-0 coho length ranged from 26-45 mm FL with an average length of 38.25 mm. Age-0 coho were typically found at about 6 inch depth in slack water associated with edge habitat or instream structure such as logs or boulders. Side channel habitat is scarce throughout Walker Creek. Biased sampling locations were moderately difficult to identify because slack water preferred by age-0 coho appeared to be somewhat limited. Although, slack water habitat associated with edge habitat or instream structure was more prevalent on Walker Creek compared to Miller or Des Moines Creeks. E & E observed numerous age-0 fish (presumably coho) in slack water habitat between sampling locations but beach seine or dip net capture methods were not employed because of sample gear inaccessibility or because of proximity to another sampling location.

The Des Moines Creek juvenile fish survey results are presented in **Table 3-15**. E & E captured fish at 2 sampling locations in the upper portion the sampling reach (i.e., mouth to Marine View Drive). Two species were identified: coho salmon and cutthroat trout. One cutthroat trout (likely age-2) was captured at Station 1 in the upstream portion of a mid-channel pool. A total of 6 age-0 coho were captured in Des Moines Creek. Age-0 coho length ranged from 34-38 mm FL, with an average length of 35.8 mm. Age-0 coho captured at Station 2 were found at about 6 inch depth in slack water associated with edge habitat and instream boulders. Biased sampling locations were difficult to identify, particularly in the lower portion of the sampling reach, because slack water preferred by age-0 coho appeared to be limited.

### 3.4.4.3 Conclusions

Age-0 coho salmon were present throughout the sampling reach in each stream system. Despite degraded habitat on Miller, Walker, and Des Moines Creeks that likely limits coho salmon production, adequate habitat and water quality conditions currently exist to allow for some coho salmon egg to age-0 survival. No age-0 chum salmon or steelhead were captured during the juvenile fish surveys. As a result, it is unlikely that viable spawning populations of these species exist on Miller, Walker, or Des Moines Creeks.

### 3.4.5 Habitat Survey

Many organizations have surveyed in-stream and riparian habitats of Miller and Des Moines Creeks with the goal of evaluating the habitat for current or potential use by salmonids, primarily coho salmon, cutthroat trout, steelhead, and chum salmon (Trout Unlimited 1993, Resource Planning Associates 1994, Shapiro and Associates 1994, Parametrix, Inc. 1999c, BioAnalysts, Inc. 1998). Although it is difficult to compare specific results obtained by the different habitat assessment methods, the habitat surveys performed thus far have reached the same general conclusion: adequate salmonid habitat exists on Miller Creek in the stream reach from Puget Sound to the 1st Avenue South culvert while upstream of this culvert the habitat is marginal. In Des Moines Creek, adequate habitat exists from Puget Sound to South 200<sup>th</sup> Street, however, much of this reach is inaccessible because of the migration barrier at Marine View Drive. Local agencies agree with these general descriptions (Masters 1999, Schnieder 1999). In general, urbanization degraded the creeks, but the creeks do support small resident fish populations, including salmonids. Limiting factors for the ability of these creeks to

support fish populations include degraded physical habitat, water quality, increased peak flows, and migration barriers. Despite the degraded stream habitat, anadromous salmon runs (primarily coho salmon) exist on Miller, Walker, and Des Moines Creeks.

In contrast to Miller and Des Moines Creeks, only one habitat survey has been completed on Walker Creek. Therefore, E&E performed a brief field survey of Walker Creek habitat in December 1999, to confirm the baseline habitat characteristics, using methods found in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Second Edition* (EPA 1999).

#### 3.4.5.1 Methods

E&E surveyed five, 100-foot habitat stations on Walker Creek.

1. Normandy Park Cove area.
2. Residential area upstream of 13th Avenue in Normandy Park.
3. Relatively undisturbed area in the Walker Preserve.
4. Upstream of 1st Avenue South.
5. Residential area upstream of Ambaum Avenue.

Habitat stations were randomly selected within separate geomorphic segments as defined by BioAnalysts (1999). Data from the habitat surveys are presented in Table 3-16. Specific habitat parameters were scored through a consensus of two biologists as described in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Second Edition* (EPA 1999). Each habitat parameter score was then summed to obtain the total habitat score for the sample station. Station 3 received the highest habitat score, which was expected based on the relatively undisturbed habitat in the Walker Preserve. The other four stations fall into the marginal or the low end of the suboptimal habitat categories, indicating degraded habitat. Water quality data collected for Walker

Creek included temperature, ranging from 6.5-7.6 °C; dissolved oxygen, ranging from 12.14-13.32 mg/L; and pH, measuring 7.70-7.88. These water quality parameters are within acceptable ranges for salmonid species. Turbidity measurement at Station 2 was high compared to the other stations; the reason for this deviation is unknown. The major substrate components of most of the habitat stations were sand and gravel. These results are consistent with the results of the detailed Walker Creek habitat survey performed by BioAnalysts (1999).

### **3.4.5.2 Conclusions**

The results of this field survey of Walker Creek are consistent with the results of the habitat survey performed by BioAnalysts (1999). The lack of channel complexity (i.e., optimal pool:riffle ratio of 50:50), the high degree of sedimentation, the lack of available cover, and the sparse riparian vegetation appear to be the habitat parameters that limit salmonid production in Walker Creek. Habitat quality is below optimal throughout most of the watershed, especially in residential areas.

## **3.4.6 Comparison to Previous Fish Habitat and Population Studies**

### **3.4.6.1 Literature Review**

Significant volumes of information and data have been collected regarding the proposed expansion of the airport and natural resources in the vicinity of the airport. Documents were prioritized and reviewed for pertinence to the project scope and the source of the document. Information obtained from objective sources, such as the King County Department of Natural Resources, the WDFW, or scientific literature, was weighted with greater significance. Information generated by sources directly or indirectly involved with the proposed airport expansion was reviewed with a critical eye. These sources include, but are not limited to, the Port of Seattle, public interest groups, or private citizens. Biota-related fieldwork performed during this project was designed to clarify contradictions in available information.

### **3.4.6.2 Proportion of Marked Fish in Anadromous Salmon Population**

Uncertainties associated with anadromous fish returns in the Miller, Walker, and Des Moines Creeks remain after review of the existing data (TU 1993, Shapiro 1995, WDFW 1996, Parametrix 1999d, BioAnalysts 1998, Batcho 1999). The proportion of marked (adipose fin clip) and unmarked (no adipose fin clip) fish reported in annual fish returns is inconsistent. All fish released from WDFW hatcheries receive an adipose fin clip to indicate their hatchery origin. The Miller Creek Hatchery operated by TU does not clip coho salmon adipose fins because of the size of fish at the time of release. The anadromous fish return data collected during the carcass surveys generally agreed with data reported by TU (Batcho 1999) and BioAnalysts (1999). All surveys indicate that hatchery fish comprise

the majority of anadromous salmon returns to Miller, Walker, and Des Moines Creeks. Although differences exist in carcass survey results and previously documented percentages of adipose fin clipped fish in the salmon return, these differences can be explained by natural annual variability in salmon returns and different sample sizes among the three studies.

#### **3.4.6.3 Spawning Activity**

Reports of the occurrence of spawning on Miller, Walker, and Des Moines Creeks are inconsistent. The WDFW (1996) reported no evidence of spawning activity, but TU (numerous years) and BioAnalysts, Inc. (1999) reported anadromous fish spawning in the creeks. E&E originally planned to do redd counts but these were not performed since a significant amount of time had elapsed since salmon had entered the creeks and completed any spawning behavior. Therefore, visual indicators such as observed spawning behavior or freshly overturned gravel were absent and conclusive determination of redd locations was not possible. However, at the time of the carcass surveys, E&E met with a resident living on Miller Creek upstream of the SWSSD who had filmed anadromous salmon returning and holding in Miller Creek throughout the month of November. Video footage conclusively shows a pair of salmon exhibiting spawning behavior such as nest building and quivering body movement (Fish 1999). Therefore, information gathered during this project supports observations by TU and BioAnalysts, Inc., that salmon spawning activity is occurring on Miller, Walker, and Des Moines Creeks.

#### **3.4.6.4 Juvenile Fish Presence**

No known organization or agency has performed age-0 juvenile fish surveys shortly after fry emergence from the gravel

on Miller, Walker, or Des Moines Creeks. Therefore, juvenile fish surveys cannot be compared to previous characterizations and are considered baseline information. Juvenile fish survey results identify that adequate habitat and water quality exists for fish survival from the egg to fry stage.

#### **3.4.6.5 Aquatic Habitat**

Many organizations surveyed in-stream and riparian habitat of Miller and Des Moines Creeks in order to evaluate the habitat for current or potential use by salmonids, primarily coho salmon, cutthroat trout, steelhead, and chum salmon (TU 1993, Resource Planning Associates 1994, Shapiro 1995, Parametrix 1999c and 1999d, BioAnalysts 1999). The reports generally make the same conclusions, but with some exceptions. In general, urbanization has degraded the creeks, but the creeks still support small resident fish populations, including salmonids. Limiting factors for the ability of these creeks to support fish populations include physical habitat, water quality, hydrology, and migration barriers. Physical habitat limitations include a lack of habitat complexity, a low pool:riffle ratio, and limited in-stream structure, especially large woody debris. Water quality limitations include high summer water temperatures and low dissolved oxygen levels. Hydrology limitations include rapid fluctuations in water flow, extreme variation between peak winter flow and low summer flow. Local agencies (i.e., King County and WDFW) agree with the habitat descriptions reported for Miller and Des Moines Creeks. In addition, E&E biologists confirmed that the reported physical habitat characteristics on Miller and Des Moines Creeks reflect field conditions.

Only one habitat survey has been performed on Walker Creek (BioAnalysts 1999). This habitat survey was performed to verify previous study results and confirm the existing habitat characteristics. Although different methods were used to assess the

habitat condition, the results of the surveys conducted on Walker Creek were consistent with the BioAnalysts (1999) habitat assessment. In general, the habitat assessments identified that the primary limiting characteristics for the maintenance of salmonid populations are fine-sediment in streambed pools, lack of woody debris and complex in-stream structure, and sparse riparian vegetation.

### **3.4.7 Regional Significance of Local Fishery**

Puget Sound coastal watersheds in King County encompass 92 square miles. In southern King County, Miller and Des Moines Creek watersheds encompass 9 and 6 square miles, respectively, and are two of the largest Puget Sound coastal streams. Coastal Puget Sound streams are typically small stream systems that drain highly urbanized areas. In 1992, 67% of the land use in coastal Puget Sound watersheds in King County was urban/residential. King County estimates that urban residential land use will increase to 77% in these watersheds by the year 2012. Forest and park land use is not expected to change over this same time period, however, rural land use is expected to decrease from 23% to 14% to compensate for the increase in urbanization (King County 1995).

Historically, these watersheds have supported abundant anadromous and resident fish populations. Today, many of the coastal Puget Sound streams support small salmonid populations. Although coastal Puget Sound streams do not support regionally significant numbers of fish, they are important locally. Numerous community-based restoration efforts have begun in a number of the watersheds to enhance salmonid habitat and to plant salmon within the creeks. For example, in 1993, the Hylebos Creek/Lower Puget Sound Basin Plan was the first comprehensive basin plan developed for an urban stream in King County. The basin

plan identifies that the costs of restoration are very high, and even if completely implemented, full restoration of the basin is not possible (King County 1995).

Two major river systems exist in the area: the Green River/Duwamish River watershed and the White River watershed. The lower watersheds of both of these river systems are highly urbanized, with similar urban/residential land use estimates compared to the percent of urban land use reported above for small coastal Puget Sound watersheds. Significant portions of the upper watersheds in both of these river systems remain undeveloped. However, projected increases in urbanization would modify the existing land use in the watersheds and likely result in habitat and water quality degradation.

Annual escapement estimates for the four-year period of 1988 through 1991 indicate that the Green River/Duwamish River Watershed supports a total of 44,928 anadromous salmonids: 14,048 are considered wild and 30,880 are cultured. Wild fish are defined as any fish that spawns naturally, which could include hatchery fish that are successfully reproducing. Two fish hatcheries in the watershed contribute to the cultured anadromous salmonid returns: the Soos Creek Hatchery operated by the WDFW and the Keta Creek Hatchery operated by the Muckleshoot Indian Tribe. The Green River/Duwamish River salmonid escapement comprises 50% coho salmon, 45% chinook salmon, 4% chum salmon, and 1% winter steelhead.

Salmonid escapement estimates for the same four year period on the White River indicate a total run of 20,967 anadromous salmon: 5,563 wild fish and 15,404 cultured fish. The White River Hatchery operated by the Muckleshoot Indian Tribe is a significant contributor to the total annual salmon production in the White River watershed. The White River salmonid escapement comprises 75% coho salmon, 15% chinook salmon, and 9% chum salmon. The White

River supports the White River spring chinook population which is a distinct stock not found in other basins (King County 1995).

Therefore, regional river systems support orders of magnitude greater numbers of anadromous salmonids than do Miller, Walker, and Des Moines Creeks. Thus, population effects to salmonids in Miller, Walker, and Des Moines Creeks would be local; no significant regional effects to salmonid populations would occur if population declines in these local creeks were to occur.

### **3.5 Threatened and Endangered Species**

This section provides information on aquatic wildlife species (state and federal listed species), which may occur in the project vicinity. Two federal agencies, acting in accordance with the Endangered Species Act (ESA), manage threatened and endangered species populations: the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). Federal projects that could affect listed species under the ESA are subject to consultation with both agencies. Among the federally listed species that might occur within the area include threatened coastal/Puget Sound bull trout and threatened chinook salmon. The USFWS is responsible for the threatened coastal/Puget Sound bull trout. The threatened chinook salmon is managed by NMFS whom also manages other anadromous threatened and endangered aquatic species.

Management of other sensitive wildlife species varies, and usually is conducted in cooperation with State wildlife agencies. The federal action agency for this project is the FAA and they are directed to plan, implement and consult on projects, which might impact federal listed species.

However, other laws and regulations effect wildlife control at airports.

Only one aquatic species, the threatened coastal/Puget Sound bull trout (*Salvelinus confluentus*) potentially occurs in the project area. The bull trout has very specific life history requirements such as cold water temperature and clean gravel and cobble substrate that is often associated with unaltered stream systems. Because of its specific habitat requirements, the bull trout has difficulty inhabiting or adapting to stream systems with anthropogenic or natural perturbations. Therefore, the bull trout is not expected to be present in Miller, Walker, or Des Moines Creeks. In addition, E&E could not find conclusive records indicating that the bull trout historically inhabited these creeks.

NMFS manages anadromous threatened and endangered aquatic species. In Puget Sound, no anadromous salmonids are listed as endangered, but chinook salmon is listed as threatened. Unconfirmed data indicate that chinook salmon have been observed in Miller Creek, however, no conclusive records could be found supporting this observation (Fish 1999). The Puget Sound/Strait of Georgia evolutionary significant unit (ESU) of coho salmon is currently a candidate species being considered for listing under the ESA. Small spawning populations of coho salmon exist on Miller, Walker, and Des Moines Creeks. Therefore, outcome of the NMFS ESA listing process for Puget Sound coho salmon will have significant impacts on the protection and habitat restoration efforts for the species and the allowable activities within watersheds with known coho salmon populations. Two additional anadromous salmonids documented to occur in Miller, Walker, or Des Moines Creeks include chum salmon and steelhead. Small numbers of chum salmon were observed in Walker and Des Moines Creek during the carcass surveys; steelhead presence in the creeks was not confirmed. NMFS has determined that the Puget Sound chum salmon ESU and



the Puget Sound steelhead ESU are not warranted for protection under the ESA at this time.

The WDFW does not consider any fish species as threatened or endangered. The three fish species are listed as sensitive in the State of Washington: Olympic mudminnow (*Novumbra hubbsi*), margined sculpin (*Cottus marginatus*), and pygmy whitefish (*Prosopium coulteri*), have not been documented to occur in Miller, Walker, or Des Moines Creek. Thirty-eight fish species are identified as State Candidate Species. Only two freshwater or anadromous candidate species occur in the Puget Sound region: chinook salmon and river lamprey (*Lampetra ayresi*). Neither of these species are expected to be present in Miller, Walker, or Des Moines Creek.

The WDFW also maintains the Priority Habitats and Species (PHS) list, which serves as a catalog of species and habitat types identified as priorities for management and preservation. A priority species is defined as fish and wildlife species requiring protective measures and/or management guidelines to ensure their perpetuation. Species are included on the PHS list if they satisfy one of three criteria: 1.) State Listed and Candidate Species; 2.) aggregations that are vulnerable to significant population declines by virtue of their inclination to aggregate (such as fish spawning and rearing areas); and, 3.) species of recreational, commercial, and/or tribal importance that are vulnerable to habitat loss or degradation. The three fish species known to occur on Miller, Walker, and Des Moines Creek (i.e. coho salmon, cutthroat trout, and chum salmon) are included on the PHS list. Coho salmon are considered a priority species because they satisfy criteria 2 and 3, cutthroat trout are a priority species because they satisfy criteria 3 only, and chum salmon satisfy all three priority species criteria. However, the chum salmon state listing is for populations separate from this region of Puget Sound (WDFW 1999).

### **3.6 Analysis of Selected Impacts**

This section describes independent analyses of possible third runway project impacts, and comments on impact analyses provided by the Port of Seattle.

#### **3.6.1 Effects on Ecology from Possible use of Maury Island Fill**

Gravel from a mine on Maury Island is being considered as fill for the proposed runway expansion. The top eighteen inches of gravel at Maury Island contain high levels of arsenic, cadmium, and lead originating from the former ASARCO smelter in Tacoma. The top 18 inches of soil at Maury Island are proposed to be contained at the island mine prior to aggregate extraction. Ecology must have assurance that the fill used for the airport project will not result in exceedances of state water quality criteria. The Port and Ecology are working to determine what screening methods and contingencies are necessary to ensure that water quality criteria are met.

This project analyzed the potential effects to ecological receptors, such as the benthic community, if arsenic, cadmium, and lead in the Maury Island fill were to migrate from soils to nearby sediments. Surface and subsurface soil data of the potential Maury Island fill were compared to ecological benchmarks to assess whether unacceptable ecological risks may occur. Based on this comparison, metals in the potential Maury Island fill soil should not pose an unacceptable risk to the environment. Appendix G contains further details and the Maury Island data.

#### **3.6.2 Effects on Streamflow**

The SWMP presents a strategy intended to mitigate the long-term effects on streamflow due to proposed improvements to the

airport. The effects of concern include stormwater peak flow rates and durations, base-flow rates, and water quality. The stormwater plan was developed using HSPF computer model analyses described in the Section 3.6.2.1.

The Port proposes to control stormwater runoff from the airport using a combination of local and regional facilities to regulate the rate at which stormwater is released to Des Moines, Miller and Walker Creek watersheds. It is intended to control stormwater discharges so as to limit peak flow rates and durations of high flow rates to those that would occur under a hypothetical land-use scenario wherein the effective impervious surface area (EIA) is 10 percent in each watershed. Effective impervious areas are hardened ground surfaces that absorb a minimal amount of rainfall (pavements, rooftops) that are hydraulically connected to the receiving streams without flow attenuation. The flow conditions estimated to result under the hypothetical 10 percent EIA condition is termed the target flow regime. The target flow regime is identified in the plan as the proposed Level 2 discharge condition below the respective regional detention facilities in Miller Creek and Des Moines Creek.

**3.6.2.1 Miller Creek HSPF Model Review**

The HSPF watershed models were provided to Earth Tech for evaluation by this project. The modeled discharge volumes were examined to assess the models' calibration in accounting for the water budget. Total flow volumes predicted by the HSPF models were compared to observed values at two locations each in the Des Moines Creek and Miller Creek watersheds.

The period of flow rate calibration data used for the Miller/Walker Creek HSPF model is from October 1, 1992 to August 30, 1996. This four-year period of time is adequate to sufficiently calibrate the HSPF model.

In the Miller Creek basin, predicted volumes were compared to observed values for water years 1993 through 1996 at gages below Lake Reba and near the creek mouth. Table 3-17 compares the total flow volumes, expressed as equivalent inches of precipitation across the area draining to each gage.

At both gages the HSPF model produces excessive volumes of water compared to the observed flows, indicating the model is not well calibrated, despite the matching of simulated and observed peak flows for selected storm events presented in Figure B-3 in the Appendix B to the SWMP. The poor calibration results from the parameters used in construction of the HSPF model for the Miller Creek/Walker Creek watershed.

There are several inconsistencies in the input data between models developed to simulate different land use scenarios in the watershed. In addition, the model simulates groundwater contributions to streamflow in a manner that is unconnected to prior precipitation and therefore does not take advantage of the rigor offered by HSPF. Miller Creek and Walker Creek share the same input files and parameter values. As a result they are discussed together in this report. Four Miller Creek/Walker Creek HSPF models, each representing a different land use scenario, were reviewed:

MILL-C	calibration land use conditions
MILL-PRE	pre-developed land use scenario (target flow conditions)
MILL94	1994 land use base scenario
MILL04	2004 land use scenario

Some model parameters describing how the watershed responds to rainfall are inconsistent with features in the Miller Creek/Walker Creek basin. The water imbalance described above may be

attributed to how the model simulates the infiltration of rainfall into the shallow groundwater zone and the discharge of groundwater to the stream systems. The HSPF program is capable of tracking the portion of rainfall that infiltrates to the shallow and deep groundwater zones. This feature is important to the analysis of the base flows and flow durations of Miller and Walker Creeks, because the model can account for water in the groundwater zones available to resurface in the creek downslope. As rainfall patterns vary over time, the stored groundwater volume changes correspondingly, which influences the base flows in the streams. However, rainfall that percolates to groundwater is not tracked within the HSPF model constructed for the Miller and Walker Creek watersheds. Instead, the groundwater contribution to streamflow is simulated by a constant year-round flow rate introduced to a lower reach of Miller Creek. By constructing the model this way, the base flows modeled in the stream are disconnected from the amount of shallow groundwater that has been accumulated from prior rainfall. The simulated base flows are also not representative of the distributed and varied discharges from seeps observed in the watersheds.

The Miller/Walker Creek HSPF model incorporates time series inflows of groundwater. These inflows are equivalent to a constant 3.27 cfs total. If these time series represent springs, then the flows from these springs should be generated directly by the groundwater conditions computed by the model. The model would then simulate groundwater inflows to streams based on computed seasonal groundwater fluctuations.

PERLND parameters in the models were reviewed with respect to watershed conditions and consistency between models for the various scenarios.

Groundwater Deep Fraction (DEEPFR) is set in the models at a value of 0.3 for all

land surface types except for outwash and fill types where DEEPFR has been set at 0.8. The DEEPFR parameter specifies how much of the infiltrated water continues downward into the deeper aquifer and how much travels laterally through an upper stratum. The DEEPFR should be set equal for all PERLND types unless there is a specific reason to alter this. No such reason is cited in the Preliminary Comprehensive Stormwater Management Plan.

Analyses with the slice groundwater models (Sections 3.2.4.1 and 3.6.4) suggest that the percent of recharge that percolates through the till would change from the current to the built conditions. In the current condition slice model, 46.5 percent of recharge flows down through the till and in the built condition slice model 53.5 percent of the (reduced) recharge flows down through the till. The DEEPFR parameter should be set accordingly and all airport fill parameters should be consistent for all HSPF model scenarios for both the Des Moines Creek and Miller Creek watersheds.

The two constant groundwater inflow series to the creek should be removed from the model, and the deep fraction should be adjusted to appropriately account for the variable inflow generated by groundwater storage. It is not appropriate to have the deep fraction active in the model while simultaneously introducing a constant groundwater inflow based on a time series. The combination of these two actions renders the model unusable for analyzing flow volumes and peaks. The model would require modification before a thorough evaluation of the performance of the model, and a corresponding evaluation of proposed surface-water controls, could be completed.

The MILL94 HSPF model parameter values (1994 land-use scenario) differ from the other three models in five instances. The specific parameters are KVARY, AGWRC, DEEPFR, INTFW and IRC. No explanation for the parameter differences between the models is provided in the Preliminary

Comprehensive Stormwater Management Plan. Adjustment of these parameters affects model calibration, base flow, storm flow peaks, storm recession rates and interflow.

It is possible that after changing the DEEPFR parameter and eliminating the groundwater inflow time series that several other parameters would need to be adjusted, specifically AGWRC, INTFW and IRC. These parameters can affect model estimates of peak and low flows.

Total watershed area is not consistent for the four model scenarios as shown in **Table 3-18**. Watershed area is greatest for the pre-developed scenario and smallest for the 2004 land use scenario, and the calibration scenario model contains 2.1 percent more gross watershed area than the 2004 scenario model. All PERLND types change between the four model scenarios. For example the pre-developed condition has 2345 acres of till soils, 2170 acres of outwash soils and 514 acres of impervious surface. This is changed under the 2004 land use scenario to 1377 acres of till, 2101 acres of outwash and 1206 acres of impervious surface. It is presumed that much of the difference is a result of historic and proposed fill placement at the airport, but a difference of more than 100 acres is not accounted for. A quantified description of the sources of land use changes, particularly within the airport site, would aid interpretation of model results.

With a larger percentage of the watershed assumed covered by till soils in the target flow scenario, the model will simulate more runoff volume and higher peak flows. With a larger percentage of outwash soils assumed in the 2004 land-use scenario, the model will simulate lower runoff volumes and rates. When attempting to size facilities that limit runoff from future land-use conditions to target flow rates, the effect of the shift from till to outwash soils between scenarios would be to undersize the facilities.

FTABLEs define the relationship between the volume and flow rate of water within a reach of the stream or within a facility. In reviewing the FTABLEs in the Miller and Walker Creek model, several were found to have values that are suspected to be inaccurate because in some of the FTABLEs the surface area of the reach decreases with increasing water depth. The suspect FTABLEs include those numbered: 66, 62, 54, 63, 1, 111, 11, 15, 16, 17, 34, 35, 38, 50, 53, 60.

The interception storage (CEPSC) parameter is set at 0.1 for all PERLND types. This includes both forest and grass. The value of this variable should vary depending on vegetation coverage.

In reviewing the Walker Creek portion of the HSPF model, it was found that although a portion of the runway fill embankment is to be situated in the headwaters of the Walker Creek drainage, this change in land use was not reflected in the land use within the 2004 scenario model.

Walker Creek shares the same PERLND parameters as Miller Creek within the HSPF model and therefor could have similar calibration and parameter problems.

### *3.6.2.2 Target Flow Regime*

After analyzing the Port's target flow regime proposal, Earth Tech agrees that basing target flows for the stormwater management strategy on theoretical 10 percent EIA is a reasonable approach to establishing hydraulic conditions that would support stable stream channels.

The land uses inferred by the target flow regime represent a large reduction in impervious surface area from the 1994 existing condition baseline. EIA in the Miller/Walker Creek watershed exceeds 22 percent (refer to **Table 3-18**) under existing conditions. In the Des Moines Creek watershed, EIA exceeds 36 percent of the

watershed when excluding areas tributary to the IWS. Therefore, if achieved, control of stormwater flows to a regime equivalent to that of 10 percent EIA would benefit the structural stability of the stream channels. Research conducted on local watersheds (Booth, 1989) indicates that increased EIA corresponds to dramatic increases in both flood flows and sediment transport in streams.

The representations of the target flow regime in the HSPF models for Des Moines Creek and Miller/Walker Creek watersheds were reviewed. Both models, termed "predevelopment", represent 10 percent of the gross watershed area as impervious surface. In the Miller/Walker Creek model, however, the amount of outwash soils in the remaining 90 percent of the watershed is inconsistent with the HSPF models representing other land use scenarios. Under predeveloped (target flow regime) conditions, the watershed is modeled as containing 2170.6 acres of outwash soils, whereas under the calibration and 1994 (existing) conditions models, the acreage of outwash soils assumed in the models increases to 2226.6 and 2225.7 acres, respectively. With increasing development, it would be expected that the amount of outwash soils would decrease as they are replaced with impervious surfaces and covered by fill. This change needs to be resolved in order to assess how well the model predicts the flow regime that would result under the assumed land use conditions.

The target flow regime HSPF models were not developed to represent hydraulic conditions that were present historically. Channel reaches and flood plains are not defined in their historic dimensions, and natural depression storage within the watershed is not included in the hydraulic routing in the models. The target flow regime models do not include existing natural storage or historic storage depressions that were eliminated in the course of urbanization. The result of the

lack of storage in the models results in increases in estimated peak-discharge rates under the target flow regime scenario above what they would be if storage were included in the models. It is also expected that storage in the upper subbasins of the watersheds would increase the duration of low flows; therefore, the target flow regime model is suspected of underestimating low flow durations.

It is acknowledged that the target flow regime is intended, within the context of the plan, to be a hypothetical characterization of a low-development condition in the watersheds and not as an accurate recreation of a specific historic state. However, the plan does not qualify the results in this fashion, and the model results could be misinterpreted.

The target flow regime model results are affected by the inappropriate modeling of groundwater flow to the creeks perhaps to a greater degree than those of the various development scenarios. Under a less developed watershed condition, there is greater opportunity for precipitation to infiltrate the soils and maintain a supply of groundwater to the streams. Without a connection between the rainfall infiltration, groundwater storage, and the discharge of groundwater to the streams, a direct comparison of proposed conditions to the target flow regime cannot be adequately performed.

### **3.6.2.3 Proposed Flow Control Measures**

The general approach to sizing flow control facilities, as presented in the SWMP, is appropriate. That approach included: applying the target flow regime concept, using Level 1 flow control facilities in conjunction with regional facilities to achieve Level 2 control, and using the HSPF model to simulate the target, existing and proposed watershed conditions. However, as noted above, confident technical execution of the approach requires

corrections to the models used to size the flow control facilities.

**Table 3-19** summarizes how the limitations in the modeling, if not corrected, would affect the sizing of flow control facilities. The effects are qualitatively assessed. Because of the fundamental concerns about the models' construction, the effect the model changes would have on facility size could not be reasonably quantified within the scope of this project.

The flow-control plan in Miller Creek relies on the expansion of the proposed regional Miller Creek Detention Facility (MCDF) at Lake Reba. Implementation of this project should be reviewed with regard to possible breaching of an aquitard near the excavation proposed for that project (Section 3.2.4.1). No alternatives are specified for provision of additional stormwater detention capacity in lieu of expanding the MCDF.

### 3.6.3 Effects on the Soil Water-Balance

Changes to total groundwater recharge in the project area could occur from the following actions:

- Changing infiltration of precipitation by changing land cover, soil type, and slope
- Conveying runoff from impervious surfaces away from local recharge areas
- Eliminating the discharge of imported water through leaks and septic systems throughout the year
- Eliminating irrigation with local and imported water sources in summer

#### 3.6.3.1 Changes to Non-Precipitation Water Sources

Non-precipitation water sources would change in the buy-out area under the proposal. The net change in non-precipitation water sources to the buy-out area is summarized below. All the changes are likely to directly affect base flow of Miller Creek.

- -66,000 gallons per day (gpd), or -46 gallons per minute (gpm) year-round from cessation of septic discharge of imported water
- +84,000 gpd, or +58 gpm, in summer as a result of cessation of irrigation with local water sources
- -10,000 gpd, or -7 gpm, in summer as a result of cessation of excess lawn irrigation with imported water
- unknown changes resulting from leakage from water supply pipes
- net change: approximately zero in summer, and -66,000 gpd, or -46 gpm, in the non-irrigation season

The following three paragraphs explain these estimates.

An estimated 66,000 gpd of imported residential water supply is discharged through the 380 septic drainfields that would be abandoned in the buy-out area. **Table 3-20** summarizes the calculations. They are based on 80 gpd per person, 2.5 people per household, and 87 percent source-to-drainfield efficiency. This water is discharged to surface soils and is distributed throughout the buy-out area. This water contributes to recharge in the shallow groundwater regime that is closely tied to Miller and Walker Creeks. Calculations in **Table 3-2** suggest that the portion of this septic effluent in the middle Miller Creek reach may comprise 12 to 25 percent (1 of 4-to-8 cfd/f) of winter base flow *gains* in the middle reach of Miller Creek. The effect on total base flow would be smaller. These

calculations assume that none of the effluent recharges deeper aquifers.

Cessation of irrigation with local water sources (the creek or shallow wells) would cause an increase in irrigation-season in-stream flow as a result of reduced evapotranspiration. Cessation of irrigation with imported water would cause a reduction in irrigation-season streamflows, assuming some excess irrigation occurs. SWMP Appendix G presents an analysis of commercial irrigation using local water sources in the buy-out area but does not consider excess irrigation with local or imported water sources. SWMP Appendix G estimates that 0.13 cfs (84,000 gpd) are pumped from local sources during the summer months and implies a corresponding increase in summer base flows. That estimate is probably high assuming some excess-irrigation water returns to the streams.

A rough calculation of lawn irrigation with imported water suggests that possibly 10,000 gpd over the summer recharges groundwater as a result of over-irrigation. That recharge source would terminate with the removal of public water supply to the area. The estimate is based on 400 homes, 0.25 acres of lawn per home, 1 foot of summer lawn irrigation, and 25 percent loss to deep percolation (excess irrigation).

The net effect of these changes appears to be about zero in the irrigation season (summer). In winter, the rate of base flow gain in middle Miller Creek may be reduced by the elimination of septic discharge. The change in winter base flow from these effects would be expected to be about -46 gpm, or -0.1 cfs. However, summer base flows are more critical than winter base flows for fish habitat.

### **3.6.3.2 Changes in Recharge from Precipitation**

Change to *precipitation-derived* recharge in a cross section of the proposed fill was evaluated by this project. The calculation considered conversion of wetlands and forest to grass on the embankment fill, and the widths of the only two impervious surfaces on the cross section (12<sup>th</sup> Avenue South and the third runway). The calculation indicated about 11 percent decrease in groundwater recharge along the cross section, largely as a result of the increase in impervious area. This estimate is probably high because no secondary infiltration of runoff from the third runway was assumed, and a deeply-rooted healthy grass crop was assumed for the new fill. This calculation is applicable to a relatively small area proposed for change and is not representative of changes anticipated from the combined Master Plan Improvements.

The 11 percent reduction in local recharge is large, but dependent flows to local wetlands and the creeks will be reduced only in winter when abundant water is typically present anyway. A similar reduction in recharge basin-wide would cause a major impact to baseflows. To assess basin-wide impacts, the Port's recharge calculations that considered all Master Plan Improvements was reviewed. The HSPF model parameters used in the Port's recharge analysis do not appear to correspond to those used in actual basin modeling also conducted by the Port. Therefore, a confident assessment of basin-wide recharge and baseflow impacts is currently lacking. A confident assessment of basin-wide recharge and baseflow effects should be possible by analyzing a properly implemented and documented HSPF model.

### **3.6.4 Effects on Shallow Groundwater Circulation**

Changes to the direction of groundwater flow would not be expected as a result of the embankment construction because the general locations of recharge and discharge remain the same. However, changes to the timing of groundwater discharge to wetlands along Miller Creek is likely. Analyses were performed to assess changes between the relative amounts of groundwater recharge to the shallowest two aquifers, and changes in timing of discharge from the shallowest aquifer to wetlands. These evaluations were made using the following three models:

- Recharge Model
- Hydrus-2D
- Finite-difference slice model (slice model)

The recharge model was used to estimate groundwater recharge for the current and proposed post-construction conditions at the third runway fill and borrow sources south of the runways (Section 3.2.3.2). Hydrus-2D was used to model circulation of water between the root zone and the water table assuming construction of the runway fill. The slice model was used to accumulate and move recharge downgradient under current and built conditions, to the Miller Creek riparian wetlands. The slice model also simulates groundwater circulation to the second (Qva) aquifer. **Appendices B, C, and E** discuss the structure and input to these models.

The recharge model and other soil-water balance models can calculate only quantity of water in the water budget. In order to assess the timing of discharge of groundwater to aquifers and wetlands, the Hydrus and slice models were necessary. These models use equations of groundwater flow, continuity, and mass balance to calculate groundwater movement. For the current condition, the slice model used recharge output from the recharge model

directly because no embankment exists to retard movement of water to the saturated zone where predominantly horizontal flow occurs. For the built condition, recharge model results were input to Hydrus-2D, and then Hydrus-2D results were used as input to the slice model. The slice models used for the current and built conditions were similar except for the presence of the embankment and drainage layer (**Figure 3-5**).

The Hydrus-2D model simulated the spreading of recharge fronts as they are predicted to move downward through the proposed embankment fill. **Figure 3-12** shows model results for recharge to the top of the modeled embankment, and outflow to the drain layer at the bottom of the embankment for different fill thicknesses. Independent models were run for fill thicknesses of 150, 130, 110, 90, 70, 50 and 30 feet. The model suggests that substantial spreading of seasonal recharge is likely within the fill, with the amount of spreading increasing with increasing fill thickness as expected. Some discharge at the bottom of the fill is predicted to occur all year. **Appendix C** presents more information on the Hydrus-2D model.

The texture of the modeled fill was calculated based on specifications for Phase 1 fill (installed in 1998 and 1999) and proposed embankment composition described by Hart Crowser (1999e). The calculations were also compared to the texture of Phase 1 fill based on soil samples collected by Terra Associates (1998). **Appendix C** describes that the 55 percent gravel fraction and 16 percent fines fraction calculated for the general embankment by this method is near the middle of the range observed at the Phase I fill. However, most samples were observed to be coarser than the modeled fill. Also, the fraction of silt-plus-clay, as a percentage of the matrix, varied widely in the samples. The value calculated for the general embankment is



near the middle of the range observed in Phase I soils. However, most field samples were measured to have a lower silt content than the modeled fill.

A simple finite difference slice model was developed to simulate horizontal and vertical groundwater flow within the drain layer and existing soils below the embankment. It is similar in structure to the slice model of the current condition presented in Section 3.2.4. Both slice models are described further in **Appendix E**. For the built condition slice model, outflow from the Hydrus-2D model was used as input to the simulated drain layer. **Figure 3-5** presents the geometry of the embankment slice model.

The slice model was used to simulate groundwater flow for both the current and built conditions. Two versions of the model were constructed to represent expected differences in flow system geometry and hydraulic properties. The slice model is based on a quasi-two-dimensional finite-difference formulation of the partial differential equation describing transient groundwater flow through a saturated medium. Model cells were only connected to laterally adjacent neighbors as opposed to overlying or underlying cells – thus the quasi-two-dimensional nature of the model. Each model cell can contain up to three different “soil layers”, differing in thickness and hydraulic conductivity. The bottom elevation of each cell is defined by the top of the till layer, and downward flow through the till can be simulated. For each cell, the model also specifies storage coefficient and recharge per time-step. The model assumes unconfined flow (variable transmissivity) under horizontal gradients defined by head differences between adjacent cells. The model was implemented in a Microsoft Excel spreadsheet, using direct (explicit) methods to solve the finite-difference equation.

**Figure 3-13** shows results of the embankment (built condition) slice model. It summarizes water outflow at the bottom of the proposed west wall in terms of drain outflow and groundwater flow (horizontal flow in soils below the drain layer). Recharge to the drain layer at the bottom of the fill (Hydrus-2D output) and seepage through the till to a second (Qva) aquifer are also shown but are summed over the entire cross section). Units of measurement on the plot are cubic feet per day, per foot of width (cfd/f). The water volumes summed over the year are listed in the legend. Changes between current and built conditions were interpreted by comparing **Figures 3-6 and 3-13** and indicate that:

- Recharge would be 11 percent less along the cross section, and would spread-out within the fill, causing a significant timing lag in discharge to the wetlands and creek west of the embankment compared to the current condition.
- Discharge to remaining wetlands and the creek under the built condition would vary less throughout the year and the period of minimum discharge would be shorter. Flows would be lower in winter than under the current condition, and greater in summer compared to the current condition. The total quantity of water flowing to the wetlands would decrease because total recharge would decrease. Based on the total volumes and the timing plots, the model suggests that 71 percent of surface flow predicted by the model under the current condition would discharge from the drain below the wall under the built condition. The surface flow occurs in winter and spring, whereas the modeled drain discharge is less seasonally variable (more detailed interpretation of the timing of modeled discharge is inappropriate, especially for the built condition, for which no confirmatory field observations are available).

- The *volume* of seepage downward through the till would likely change only slightly under the built condition; however, the *percentage* of recharge seeping through the till would increase substantially.

A formal model sensitivity analysis was not conducted. However, the distribution of water quantity between surface/drain flow and till seepage is known to be sensitive to assigned hydraulic conductivity for the till. Higher hydraulic conductivity for the till allows more water to seep downward, and less is left over to discharge horizontally. Appendix E presents the assumptions and basis for modeling the till with a hydraulic conductivity of 0.004 ft/day ( $1.4 \times 10^{-6}$  cm/sec) in both models. Although the *water quantities* are sensitive, the model results indicate that change in the *timing* of surface and drain flows between the current and built conditions is generally consistent over a range of till hydraulic conductivities.

The timing changes would generally benefit the local wetlands that remain after filling and would slightly moderate seasonal low base flows and temperatures in Miller Creek. However, all water quantities are reduced on an average annual basis because total recharge is smaller under the built condition. Also, since the embankment is a small part of the Miller Creek watershed, the overall effect on streamflow is small. If the constructed fill has a lower silt content than was assumed in the model, the lag may be overestimated and the recharge volume may be underestimated.

### 3.6.5 Effects on Deeper Aquifers

The intermediate and deep aquifers of the Des Moines upland supply water to the Seattle Water Department and Highline Water District. The aquifers are laterally extensive, underling virtually the entire Des Moines upland from Federal Way on the south, to nearly West Seattle on the north.

They underlie the Qva aquifer which is the deepest geologic layer discussed in detail elsewhere in this report.

The precipitation that infiltrates below the root zone over the large aquifer area is apportioned between shallow, intermediate, and deeper groundwater flow regimes. The shallow regime includes all the groundwater discussed in this report. The deeper regimes include flow within the intermediate and deep aquifers. The regimes are somewhat interdependent, with reductions in recharge to the surface being equal to reductions to stream base flow plus reductions to recharge in lower aquifers. Conversely, pumping from deep aquifers can affect the quantity of water in the shallow regime and thus base flow in creeks. The proper tool for evaluation of these large scale effects is a multi-layer groundwater flow model. The Port is generating such a model at this time.

The small reduction in groundwater recharge to deep aquifers of the Des Moines upland would not materially affect the ability of these aquifers to supply water to wells. This conclusion is based on the relatively large recharge areas of these aquifers compared to the airport, the fact that the effects would be apportioned between shallow and deeper effects, and the shallow recharge estimates reported herein and in Port documents.

### 3.6.6 Comparisons to Previous Groundwater Assessments

Changes in shallow groundwater recharge resulting from cessation of septic discharges in the area have not previously been reported.

Appendix F to the SWMP presents analyses related to potential base flow impacts from the proposed airport improvements, including the runway embankment fill. Table F-2 of the appendix summarizes the proposed changes in land use upon which the Port derives conclusions regarding base

flow effects. Comparisons between the land areas cited in Table F-2 and those used the HSPF modeling of various scenarios revealed inconsistencies between the modeled land uses. **Table 3-21** compares the Table F-2 values to the corresponding existing- and proposed- conditions HSPF model input data. The differences in gross basin acreage amount to several percent, and large discrepancies are found in the relative proportions of till and outwash soils in the Miller Creek and Walker Creek watershed. These differences could significantly influence the estimates of base flow effects.

The analysis presented in Appendix F to the SWMP uses the HSPF parameter input to generate a "recharge index". The index is independent of the groundwater accounting problem within the Miller Creek model; but, as implemented by Parametrix, the index is sensitive to the HSPF input parameters. Parametrix included interflow as a groundwater component from the HSPF "airport fill" land use type but excluded it from other land use types. The models of groundwater movement generated by Pacific Groundwater Group indicate that interflow would not occur within the airport fill. Therefore, although the HSPF model is inappropriate for generating interflow within airport fill, Parametrix correctly compensated for this problem by including interflow as "groundwater" in this analysis.

The exclusion of interflow in calculating the recharge index for other land use types is neither correct nor incorrect, but a judgement dependent on the definition of groundwater. The Parametrix index effectively excludes water that enters streams within about one to seven days of a precipitation event (i.e.: interflow). Using data in Appendix F to the SWMP, recharge reduction would total 2.8, 3.3, and 6.6 percent if interflow were included for all land types. These values are compared to 1.8, 2.0, and 6.8 percent calculated by Parametrix for all of Miller Creek, Miller Creek below SR518, and Des Moines Creek basins, respectively.

The anticipated major changes in land-use classes involve changes to impervious surfaces, and conversion of forest and grass to airport fill; therefore comparisons between water budget components for these land classifications are summarized. The HSPF results are from Appendix F to the SWMP. As noted above, the HSPF parameters of that appendix are apparently not the same as the parameters used for other Miller Creek HSPF model analyses.

- The HSPF model estimates that 59 to 62 percent of precipitation becomes interflow or groundwater recharge in forest areas. This value compares well to 64 percent for the PGG recharge model of the mixed forest.
- The HSPF model estimates that 71 to 74 percent of precipitation becomes interflow or groundwater recharge in grassy areas. This value is substantially higher than the 59 percent estimated by the PGG recharge model. The difference between these rates is caused primarily by different amounts of calculated evapotranspiration, but the reason for the differences in the evapotranspiration rates is not known. Evapotranspiration is calculated within the recharge model using the Blaney-Criddle method, published crop factors for grass (Dunne and Leopold, 1978), and an assumed 24-inch rooting depth as used within Bauer and Vacarro's deep percolation model. Although they are standard, the crop factors and rooting depth used by the PGG recharge model may be excessive for the grass that is likely to grow on the embankment. In that case, more recharge would be calculated by the PGG recharge model, and the numbers would be closer.
- The HSPF model estimates that 63.5 percent of precipitation becomes interflow or groundwater recharge in the new fill areas. That value compares reasonably well to the 59 percent estimated by the recharge model (modeled as grass on outwash). The

difference results from the aforementioned difference in evapotranspiration estimates, and the offsetting assumption wherein the HSPF model assumed 6.6 percent runoff while the recharge model assumed no runoff.

Hart Crowser's water balance calculations (Appendix B to Hart Crowser, 1999c) used both the total quantity of groundwater recharge, and the groundwater distribution (interflow, shallow, deep) from the Parametrix HSPF model of Miller Creek (which version is not clear). As noted above, the accounting of groundwater in the Miller Creek model is unreliable but the quantity not lost to runoff and evapotranspiration should be acceptable if the land class parameters are correct. The details of the Hart Crowser calculations were not provided and therefore no detailed review was possible.

Runoff from the runways is modeled in HSPF as 100 percent of precipitation. Although not quantified by independent analyses during this project, secondary infiltration of this runoff into the embankment fill may be substantial. The filter strips that would receive runoff are unlined grassy slopes with catch basins spaced hundreds of feet apart and would provide an opportunity for infiltration of pavement runoff. Also, the conveyance pipes that would transfer water from the catch basins to stormwater detention facilities may be perforated. The perforated pipes would serve to drain saturated ground if it develops below the runways, and to infiltrate runoff where the ground is not saturated. These features could cause secondary infiltration of runoff from the runways and taxiways on the embankment fill.

Two related estimates of changes to the timing of groundwater discharge have been attempted. First, the Miller Creek HSPF model was modified to address the changing soil layering, and, thus, partitioning of groundwater between shallow and deeper

systems within the embankment area. Second, Hart Crowser's water-balance analysis (Appendix B to Hart Crowser, 1999c) included analysis of a slice similar to the west-wall slice model presented in this report. However, they used Miller Creek HSPF output, including partitioning of interflow, shallow groundwater flow, and deeper groundwater recharge. Details of Hart Crowser's calculations were not provided. Both analyses are questionable because of the inherent limitations on HSPF groundwater modeling, and the particular problems with HSPF groundwater accounting in the Miller Creek model. Therefore, we did not compare either estimate to those prepared for this study.

### **3.6.7 Impacts to Wetlands Including Mitigations**

In order to evaluate potential impacts to wetland resources that would occur as a result of the proposed Seattle Tacoma International Airport (airport) third runway expansion, E&E conducted field surveys and reviewed literature. The purpose of the field surveys was to provide E&E wetland scientists with an understanding of the existing conditions, proposed changes, and the regional context. Using the gathered data, E&E assessed the existing wetland conditions, evaluated the functionality and value of the wetlands potentially impacted, estimated the effects of the potential impacts, and evaluated proposed mitigation measures.

For discussion purposes this analysis is broken into two discussions, the first regarding the size of the potential impact, and the second regarding the functional impacts that would result.

#### **3.6.7.1 Acreage Impact**

Based on previous reports coupled with the field verification of wetland boundaries,

E&E calculated that the fill activities associated with the airport improvement projects would result in the permanent loss of 13.88 acres of impact in the Miller Creek watershed. In addition to the permanent impacts, construction activities would also result in the temporary loss of 1.86 acres in the Miller Creek watershed (Table 3-22). As shown in Table 3-23, 36 wetlands would be impacted. Of these 36 wetlands, 11 wetlands would have impacts greater than 1/3 acre. These 11 wetlands account for 11.26 acres (>60%) of the direct impacts from the entire project.

E&E also evaluated secondary (indirect) impacts, defined where a loss of about 50 percent or more of existing wetland acreage would occur. Additional secondary impacts are identified because loss of that much acreage within a wetland could have significant ramifications on the functional ability of the remnant wetland. Based on these assumptions, an additional 1.68 acres of secondary wetland impact could be associated with the project if the functionality of the remaining wetland cannot be maintained. This potential acreage loss is attributed to the Wetland 18/37 complex adjacent to Miller Creek.

Table 3-23 presents a summary of impacts compiled by E&E, associated with proposed construction activities. These impacts are presented by hydrogeomorphic classification, as well as by cover type.

### 3.6.7.2 *Functional Impact*

Of equal importance to the acreage loss is the functional impact that would occur. The effectiveness and opportunity of wetlands to provide functions associated with water quality improvement, water quantity, and habitat was discussed in Section 3.3.3.3.

The Miller Creek watershed is located within a highly urbanized area. The undeveloped areas (both upland and wetland) provide some filtering of runoff

prior to discharge into the creek. As a result, the larger wetlands within the watershed have a moderate-to-high potential to provide nutrient and sediment trapping. The functionality of the slope wetlands within the project area is somewhat lower due to the rate of water flow through them. Even with this reduction, the wetlands are frequently cited as providing moderate-to-high capability because of the influx of urban runoff. The creation of over 50 acres of new impervious surface as proposed as part of the Master Plan Update could increase overland flow to Miller Creek, and carry with it an increased sediment load. As a result, the loss of 0.14 acres of wetlands in the Runway Safety Area, and 13.74 acres of wetlands in the embankment area could have significant consequences if not mitigated.

Most wetlands in the project area serve to provide base flow to Miller Creek rather than absorb and temporarily store floodwaters. Wetlands that contribute to the flood storage capability and that would be significantly impacted by the proposed airport expansion projects are restricted primarily to the riparian Wetland 18/37 complex, Wetland A1 located adjacent to Lora Lake, and 41a and b which is a farm pond and pasture. Construction of the airport improvement projects would result in a reduction of wetlands that seep to Miller Creek and floodwater retention capability of the watershed. Any proposed mitigation would need to account for these losses by providing equal or greater base flow to Miller Creek and sufficient flood detention to prevent any increase in downstream flooding.

Being located in an urban area, the wildlife expected to occur in the project area is restricted to common, highly-adaptive species that use both wetland and adjacent upland areas. Species integrally tied to the wetland areas are likely restricted to waterfowl, amphibians, and small mammals. The extensive fragmentation of the available habitat, in conjunction with the surrounding urban character limits the suitability of the

project area to highly mobile species and smaller species requiring only minimal habitat sizes. The construction of the airport improvements would have an impact on local wildlife populations simply due to the size of the fill area. Reduction of habitat size and availability would further reduce the suitability for small mammals and amphibians. To prevent a significant decline in the local populations, mitigation would be required to provide supplemental/alternative habitat on-site. However, FAA requirements limit the development of avian habitat within 10,000 feet of existing facilities to minimize the potential bird air strike hazard.

### 3.6.7.3 Mitigation

Mitigation for the proposed third runway fill and safety areas must account for the permanent loss of 13.88 acres of wetland within the Miller Creek Watershed and 1.86 acres of temporary impacts. Based on E&E's analysis, mitigation should include development of a contingency plan that addresses the potential indirect impacts associated with significant reduction of wetland acreage in the remaining wetlands that are only partially impacted by fill activities and temporary construction activities.

The preferred regulatory hierarchy for wetland mitigation is:

- on-site, in-kind,
- off-site, within the watershed, in-kind,
- off site, out of the watershed, in-kind, and
- off site, out of watershed, out-of-kind.

Based on environmental and regulatory constraints, it is not feasible for the Port to offer mitigation on-site and in-kind. The difficulty and uncertainty of creating slope wetlands, and the lack of suitable sites

within the basin restricts mitigation opportunities for creation of slope wetlands. Furthermore, the FAA policy of minimizing available wildlife habitat within 10,000 feet of the airport further restricts the opportunity for extensive in-basin mitigation. The Miller Creek and Des Moines Creek watersheds are quite small and are extensively developed, which restricts the mitigation opportunities.

Rather than replacement of a specific wetland type, E&E recommends that mitigation measures focus on the replacement of wetland functions. Therefore, in evaluating in-kind versus out-of-kind, the functions served by lost wetlands should drive the mitigation process.

As shown in Tables 3-22 and 3-23, a significant number of the wetlands impacted are slope wetlands. Impacts that need to be mitigated include water quality, water quantity, and habitat suitability as discussed in Section 3.3.3.2.

The Port has proposed the following wetland mitigation measures (Parametrix 1999a):

- On-site mitigation includes removing existing development, establishing a vegetated buffer along Miller Creek, enhancing wetlands within the Miller Creek buffer, enhancing/restoring wetlands within the Des Moines Creek watershed, excavating floodplain to compensate for lost flood storage, developing stormwater management facilities, and restoring and enhancing 11 acres of converted farmland and farmed wetland to shrub wetlands.
- Off-site mitigation includes developing a 67-acre site to mitigate for wildlife habitat. FAA safety regulations restrict on-site mitigation.

- Establishing a Trust Fund to promote in-basin restoration projects for Miller Creek and Des Moines Creeks downstream of the project area.

E&E believes that the overall mitigation plan is reasonably designed to compensate for wetland impacts discussed in Section 3.6.7 and has the potential for success. The plan provides for in-basin compensation for loss of water quality and water quantity functions, as well as some mitigation for wildlife compensation. For losses that cannot be entirely mitigated by in-basin remedies, an off-site, out-of-basin mitigation plan has been developed by the Port. The off-site mitigation site offers advantages over other in-basin sites including its size, the ability to create a single large complex versus numerous smaller wetlands, and its location adjacent to the Green River. Recognizing the concerns over the success of planned mitigation, additional safeguards would provide assurances that the mitigation plans would be implemented, and result in the successful replacement of lost functions. Additional recommendations for mitigation are presented in Section 3.6.7.5.

Loss of water quality functions can be mitigated through proper implementation of Best Management Practices (BMPs) during construction and the development/improvement of the buffering capacity of Miller Creek. Under current conditions, Miller Creek meanders through a residential neighborhood and an active muck farm. Elimination of anthropogenic nonpoint source pollution, including septic systems, fertilizers and pesticides, in combination with the stormwater management system proposed for the airport, development of a vegetated buffer along Miller Creek, and the restoration activities proposed at Vacca Farms should mitigate for the loss of water quality functions.

Loss of water quantity effects can be mitigated through implementation of a stormwater management program.

Additionally, seepage from the embankment should provide the seepage necessary to maintain remaining local slope wetlands.

While significant loss of wildlife habitat would occur in conjunction with the fill activities, the proposed mitigation has the potential to increase the habitat suitability of the project area by creating a single contiguous open space along Miller Creek. Because of the FAA restrictions within the project area, off-site mitigation is required for the avian wildlife component. The development of this off-site mitigation would similarly provide a single large contiguous parcel that would attract all types of wildlife, not merely avian species.

#### **3.6.7.4 Mitigation Ratios**

No standardized mitigation ratios are currently in effect to establish the appropriate level of compensatory mitigation required. In a Mitigation Memorandum of Agreement between the USEPA and USACE (Mitigation MOA effective February 7, 1990), it was established that a permit applicant is required to replace the functional value of wetlands being impacted at a ratio consistent with the policy of "no net loss" and with an adequate margin of safety to reflect the expected degree of success of the mitigation plan. These requirements essentially require a case-by-case determination of appropriate mitigation ratios. To supplement this, Ecology has issued standardized ratio determinations to provide permit applicants with more guidance.

As part of the Washington State Wetlands Rating System (Ecology 1993), replacement ratios of 3:1 (3 acres of mitigation wetland to 1 acre of wetland lost) and 2:1 are proposed for Class II and Class III wetlands, respectively. A ratio of 1.25:1 is proposed for Class IV wetlands. These ratios are essentially doubled for enhancement of wetland areas. These ratios are only general guidelines, with the final ratios determined

based on the likelihood of success of the proposed mitigation site. The stated goal of the policy is a 1:1 functional replacement of wetlands. Because of the historic trend of failed wetlands, the ratios have been increased.

However, a more recent publication presents mitigation ratios that are somewhat lower than presented in the 1993 report. The proposed ratios presented in the 1999 Washington State Department of Ecology draft Compensatory Wetland Mitigation Banks guidelines are:

- Wetland Restoration 1:1
- Wetland Enhancement 2:1
- Buffer Enhancement 5:1

These ratios recognize the value of wetlands, but also recognize the need for wetlands to be integrated into a much larger habitat that has upland components. While not receiving equal benefit, as it should not, the development of a large buffer area would be counted as part of the overall compensation package. Based on these guidelines, the proposed mitigation seems adequate and appropriate to compensate for the loss of wetlands.

### **3.6.7.5 Effectiveness of Wetland Mitigations**

The King County Department of Development and Environmental Services published the *Results of Monitoring King County Mitigations* (Mockler et. al. 1998) which concluded that mitigation, in general, is not being implemented, and those that are have not been successful due to design failure, installation failure, and poor maintenance. The document itself does not call for an abandonment of wetland mitigation, but rather for more regulatory control and guidance provided during the planning, installation, and monitoring phases of the project. In response to this document, among others, Ecology also initiated a study

to evaluate mitigation compliance on a statewide level.

Ecology is currently finalizing this report that presents a statewide perspective of the effectiveness of wetland mitigation in the recent past. The draft is expected to be issued in spring of this year. This is a two-phase project with only the first phase being completed (MacMillan, personnel communication 2000). Phase I focused on three issues: (1) if the site was constructed; (2) if the final design was constructed according to plan; and (3) if the wetland is operating up to performance standards. The project has shown that while over 90% of the projects were constructed, only 1/2 adhered to the final construction design, and only 1/3 of those that had performance standards are meeting all of their standards. This initial phase assessed compliance and did not account for any functional assessment of the wetlands to gauge if they were truly successful. Functional success of mitigation projects will be developed in Phase II. Without closer scrutiny of the data, it is impossible to assess the significance of the data, but two conclusions can be drawn:

- Constructed mitigation projects are not a guaranteed success, and
- Closer regulatory oversight is necessary for longer periods to monitor mitigation projects.

While the Port Mitigation Plan offers a reasonable opportunity for success, based on the cursory conclusions drawn, two additional mitigation elements should be considered. The first is financially driven, requiring the establishment of a bond by the project sponsor to insure that 1) the project is properly implemented, and 2) provide funding for contingency planning if the project did not meet performance standards, and additional action needs to be taken to rectify the deficiencies. The second mitigation element would be the establishment of a third-party environmental



monitor, funded by the project sponsor, but under the directive of the regulatory agencies. This monitor would be able to verify the completion of the mitigation as per specification, and note/approve any modifications to the original design plans that were implemented based on site specific conditions. The Port has proposed a monitoring program for the current airport mitigation plan.

### **3.6.7.6 Comparison with Previous Permitted Projects**

To provide a basis of comparison for the airport wetland mitigation plan, a previously permitted project, of similar size to the airport project, was evaluated.

Auburn Racing built a thoroughbred horse racing facility on a 165-acre site in Auburn, Washington. The project impacts included filling of approximately 17.4 acres of palustrine wetlands, including 0.3 acre of scrub-shrub wetlands, and 17.1 acres of emergent wetlands. Additional acreage of on-site wetland was converted to a regional stormwater detention facility for the City of Auburn. FAA wildlife hazards were not an issue for the racetrack, and development in the project area was not as expansive as that which occurs in the vicinity of airport. The mitigation project was sited within the same watershed as the racetrack. The functionality of this site in relationship to the airport mitigation site cannot be directly compared since a primary objective of the Auburn racetrack site was creation of waterfowl habitat.

The racetrack mitigation plan was designed to achieve a net gain in wetlands functions and to help achieve objectives of the Mill Creek Drainage Basin Special Area Management Plan. The mitigation site included an approximately one-quarter-mile reach of Mill Creek, which was restored, and a total of 56.5 acres of adjacent existing wetland and uplands used for wetland creation (1.5 acres), restoration (9.2 acres),

and enhancement (45.8 acres). For permitting purposes, this application used compensation ratios of 1.5:1 or 2:1 for creation and restoration activities, and 3:1 and 4:1 for enhancement activities, resulting in a net functional gain of 4.6 acres.

### **3.6.8 Effects on Fish Habitat and Populations**

Small populations of anadromous coho salmon and resident coastal cutthroat trout exist on Miller, Walker, and Des Moines Creeks. Despite the presence of salmonid populations in the creeks, the documented limitations of aquatic habitat likely limit the size of fish populations. Perturbations within the watershed that result in habitat loss or degradation would likely reduce the fish population because of the limited habitat and sensitivity of existing fisheries. Conversely, habitat restoration and supplementation of limiting habitat characteristics can allow for growth in the fish population.

#### **3.6.8.1 Effects of Streamflow Changes on Fish**

The streamflow regime is currently a limiting factor for water quality and aquatic habitat in Miller, Walker, and Des Moines Creeks. Proposed construction at the airport has the potential to significantly alter the streamflow regime in Des Moines Creek because the airport currently occupies approximately 1/3 of the Des Moines Creek watershed area. Conversely, the western and northern portions of the airport only occupy a small area within the Miller and Walker Creek watersheds. Proposed airport construction therefore has less potential to affect Miller and Walker Creek streamflow.

The slice model described in Section 3.6.4 predicts significant changes to surface and groundwater flow near the fill embankment. The fill embankment is predicted to serve as

a water storage compartment that causes a time lag of water discharge to the wetlands and creek compared to existing conditions. Because of the lag time through the embankment, the model predicts that winter precipitation would express itself as surface water through the west wall drain in the summer months. This delayed surface water expression would have a generally positive effect on the local wetlands that remain, and a less-pronounced effect on low summer base flow in Miller Creek in general. Although model predictions are limited to the geologic cross section at the west wall, the model suggests that a similar effect on wetland and summer base flow would occur in Walker Creek.

The effects of contribution from the fill embankment to stream summer base flow in Miller and Walker Creeks should not be overstated. The embankment represents a small portion of the total Miller and Walker Creek watershed area.

#### **3.6.8.2 Habitat Parameters**

No direct construction impacts are expected for stream habitat in Walker or Des Moines Creek.

Direct construction impacts to Miller Creek stream habitat include the relocation of Miller Creek in the Vacca Farm area. This portion of Miller Creek provides poor habitat for salmonid fish populations because it has sparse riparian vegetation, substrate dominated by sand and silt, a lack of habitat complexity, and a lack of instream structure and large woody debris. Since the proposed Miller Creek channel construction includes a mixture of pools and riffles, gravel and cobble substrate placement, riparian vegetation planting, and large woody debris replacement, the proposed Miller Creek relocation has the potential of providing a net gain of salmonid habitat within the Miller Creek watershed. Proper construction and long-term monitoring are vital to successful Miller Creek relocation

including control of turbidity during initial wetting. Some sediment transport during initial wetting is likely, and has the potential to damage habitat downstream.

Indirect effects to stream habitat in Miller, Walker, and Des Moines Creeks include alterations to base flow, peak flow, and sediment input to surface water. These habitat parameters currently limit salmonid populations. Low summer base flows affect habitat quality because exposed portions of the channel are no longer available for use which limits available slack water habitat for juvenile salmon refugia, riffles for macroinvertebrate production, and quality pools for resident salmonids. Lower flow also tends to increase water temperature in stream channels exposed to solar radiation. The Port predicts reduction in summer base flow in Des Moines Creek as a result of a six percent reduction in groundwater recharge in the Des Moines Creek basin. The Port supports augmenting low summer stream flows by pumping from a Port-owned well and discharging the water into the creek (Parametrix, 1999e).

Extreme peak flows degrade stream habitat by scouring stream banks and beds, and transporting coarse sediment too quickly through the stream system. High peak flows also washout streambank slack water areas used by juvenile salmonids and often displace smaller fish downstream because of their limited swimming ability. Substrate in Miller, Walker, and Des Moines Creeks have high fine-sediment content from urbanization throughout the watersheds which limits stream substrate available for salmonid spawning and age-0 fish refugia.

#### **3.6.8.3 Effects on Populations**

Direct construction impacts would likely have little effect on fish populations because direct impacts are limited to the Miller Creek reach at Vacca Farm. This reach of Miller Creek provides poor quality habitat for salmonids. Therefore, cutthroat trout, if

present, are expected to be limited. Also, Miller Creek relocation can be conducted in such a way as to physically remove any fish from this reach of Miller Creek prior to being covered by fill material.

An uncontrolled release of stormwater is likely at some time during construction given the size of the project and human error; however, the size and quality of a release cannot be predicted, nor can its impacts on fish be quantified. Existing habitat in Miller, Walker, and Des Moines Creeks appear to limit salmonid population production; therefore, minor habitat degradation would likely have substantial effects on the local salmonid populations.

#### **3.6.8.4 Comparisons to Previous Fish Impact Assessments**

E & E's assessment of localized changes to Miller Creek habitat and resident cutthroat trout populations is consistent with information presented in the Biological Assessment (BA) for Master Plan Update Improvements at airport (Parametrix 1999). However, the BA does not address proposed construction impacts on a watershed level and does not provide sufficient detail to comprehensively evaluate how mitigation would be implemented and maintained to achieve the desired effects. More specifically, the BA evaluates construction effects primarily within the airport project area only. However, indirect construction effects from airport expansion such as alterations of water flow or changes to sediment input to the streams would have effects throughout the each watershed.

The Miller Creek riparian buffer corridor enhancement and the Miller Creek instream habitat enhancements, if implemented and maintained properly, would undoubtedly benefit local stream habitat for resident cutthroat trout in the airport project area. Actual design and implementation of the instream habitat enhancements could not be evaluated because these projects are still in a conceptual stage (Kleindl 1999). However,

proposed mitigation is limited in that it would only affect localized Miller Creek habitat and resident cutthroat trout. Miller Creek riparian buffer and instream habitat enhancement would not mitigate for construction impacts to other portions of Miller Creek, other creeks such as Walker or Des Moines Creek, or other fish species such as coho salmon. For example, as described in Section 3.6.8.2, indirect construction and post-construction affects such as alterations to base flow, peak flow, and sediment input would occur throughout the stream systems and not just in the airport project area.

Conceptually, the watershed basin trust funds for the Miller and Des Moines Creek watersheds can be beneficial. Without specific information regarding habitat restoration projects that would be acceptable for the basin funds and the accessibility of money through the trust fund, concerns of the actual implementation of habitat restoration through the basin trust funds exist. In addition, significant habitat restoration that is necessary in Miller, Walker, and Des Moines Creeks would require substantially more funding than what is currently offered through the basin trust funds. Although restoration of the entire watersheds is not the responsibility of the Port, a more proactive and comprehensive approach to aquatic habitat restoration would provide a greater benefit to the Miller, Walker, and Des Moines Creek watersheds.

#### **3.6.9 Water Quality Impacts During Construction**

The Stormwater Management Plan states the Port applies construction temporary erosion and sedimentation control (TESC) measures that exceed minimum requirements of the Ecology Manual. These measures include: developing construction stormwater pollution prevention plans (SWPPPs) for each capital improvement project; implementing conventional TESC best management practices (BMPs); applying

more advanced stormwater treatment techniques where necessary; supervising and monitoring contractor compliance; and funding independent oversight of construction erosion control compliance.

### **3.6.9.1 TESC Measures**

The Port has had TESC monitoring plans prepared for four projects related to the Third Runway program:

- North Employee Parking Lot (Herrera, 1998)
- Property Acquisition and Demolition (Herrera, 1998)
- Taxiway Construction (Herrera, 1998)
- Embankment Construction, Phase I (Herrera, 1998)

Of these four plans, the Embankment Construction, Phase I TESC Monitoring Plan is most relevant to this review effort as it describes the Port's approach to controlling impacts from construction of a large embankment. In addition, the Port has had prepared construction drawings and specifications detailing TESC measures for the Third Runway Embankment Construction - Phase I (Project No. airport-9763-T-1, March 9, 1998).

The monitoring plan document contains preliminary grading and drainage plan and site erosion and sedimentation control plans for the first phase of the Third Runway embankment construction. The project site is situated immediately south of S. 156th Way and between 12th Avenue S. and the Perimeter Road. The elements of the work are similar to those anticipated for subsequent planned phases of the embankment construction except that Phase I does not include a retaining wall. The work elements include:

- clearing and grubbing of vegetation and unsuitable materials
- excavation and embankment fill placement and compaction

- temporary erosion and sedimentation controls
- placing and spreading of topsoil
- seeding, fertilizing and mulching disturbed areas

The construction plans and specifications include more detailed descriptions of the TESC measures and procedures to be implemented in completing the embankment construction. The methods and details presented in the plans appear to generally conform to those of the Stormwater Management Manual for the Puget Sound Basin (Department of Ecology, 1992). Engineering calculations for sizing the facilities were not provided or reviewed. Provisions of the construction plans and specifications that are notable from a TESC perspective are itemized below:

- Placement of fill materials with higher fines content is restricted to the period from June 16 to September 16.
- A Sedimentation and Erosion Control Representative is to be provided by the Contractor with responsibility for TESC installation, inspection, maintenance and emergency response.
- Contractor's inspection and maintenance procedures and schedule are to be documented and submitted to Port for approval. The minimum frequency for inspection is specified to be weekly and following any storm event greater than 0.5 inches precipitation over a 24-hour period. A conflicting drawing note (Sheet C-120) requires daily inspection of TESC facilities.
- BMPs are to be installed prior to land disturbing activities commencing.
- The contractor is instructed to protect downstream properties from erosion damage due to increases in stormwater runoff volume, velocities and peak flow rates discharged from the site. However, the construction documents do not specify that increases in runoff volume, velocity or peak flow rate are to be prevented on site. Again, detailed engineering calculations that may

demonstrate the ability of the sedimentation pond system to control discharge rates were not provided for review. However, it would appear that smaller storm discharges would be controlled to a degree by the 2-inch diameter orifice specified in the outlet structure.

- The direction and maximum slope of the top of the embankment fill is specified to be controlled at the end of each workday.
- Although a temporary ditch is specified to be maintained along the east (up slope) edge of the fill placement, it would be advisable to construct the interception ditch on the far east boundary of the project area at the first stage of the project so as to minimize the flow of offsite water into the work area. The plans call for the interception ditch to be constructed at a later phase of the work.
- Reference is made to seeding final graded slopes prior to completion of other fill placement, but the contractor is not explicitly required to restrict or minimize the total disturbed area throughout the project duration.

During reconnaissance of the construction site in October 1999, it was observed that the sedimentation pond was in place and functional with grass lined swales draining to the pond from the north and south sides of the construction site. In addition, a batch treatment facility was on-site as a contingency measure to provide treatment beyond the sedimentation that occurs within the pond.

### **3.6.9.2 Critical Construction Planning and Execution Factors**

Beyond the design of technical provisions to control erosion and sediment on the project site, the successful prevention of erosion and sedimentation problems from a large embankment project are dependent on critical planning and execution of the TESC

installation and maintenance. Without rigorous implementation, monitoring and maintenance, the Port increases the risk of releasing a massive load of sediment into area streams as occurred during construction of the North Employee Parking Lot on Miller Creek. Following are critical planning and execution factors identified for the runway embankment fill that should be addressed:

- A contingency area was set aside at the base of the Phase 1 embankment project area in the event additional treatment capacity was needed or desirable. Similar provisions for supplemental treatment of flow control capacity need to be made available for subsequent phases of embankment construction in the event the project encounters exceptional climatic effects or construction problems.
- The subgrade for the embankment fill is till soils that are structurally vulnerable to moisture when disturbed. Construction operations should minimize the extent of subgrade exposed to rainfall and the movement of equipment on exposed subgrade.
- The top of the fill must be continuously graded during fill placement to direct runoff away from the tops of the embankment slopes and toward controlled drainage paths.
- The side slopes of the embankment should be fully stabilized with vegetation prior to crowning of the fill. Once the crown is completed, runoff that passes from the crown and over the face of the embankment would erode slopes that are not fully stabilized.

The Port's NPDES permit requires a Department of Ecology-approved Stormwater Pollution Prevention Plan for each construction project on the airport. Also, under the governor's certificate for the project, the Port is required to hire a third party to review and ensure all TESC plans are followed during construction. Vigorous and *independent* review of TESC practices

by qualified personnel throughout construction is critical to minimize the chance of an oversight and to maximize control of runoff from the site.

All construction personnel should be trained in proper erosion control practices and informed of the manner in which the project's TESC systems are designed to operate. Personnel should be informed of the consequences of TESC failure to the receiving streams and the potential for a failure to cause a shut down of construction activities. Because of the potential damage that can be caused to a receiving water body by a single error on a project of this magnitude, training of all staff is critical to minimizing the potential for mistakes.

An embankment construction of the magnitude and duration of the third runway project is subject to a range of climatic events and human errors, and an uncontrolled release of runoff from the disturbed site is probable despite proper implementation of construction BMPs. The role of the TESC efforts is to minimize the probability and extent of such a release.

### **3.6.10 Long-term Temperature Effects**

The changes in land coverages within the embankment fill area were reviewed for their potential effects on receiving water temperatures during warm weather low flow periods in the streams. Conditions both during dry periods and during rainfall events were considered.

During periods of extended low flow in Miller, Walker and Des Moines creeks, the discharge is supplied predominantly by groundwater. Absent rainfall, elevated temperatures in the streams can be caused by direct sunlight and surface contact with warm air. The majority of the precipitation falling on the proposed runway embankment would infiltrate through the fill, remain cool within the fill's mass, and discharge through the subdrainage layer at the base of the fill as cool groundwater to the stream systems.

This condition is expected to have a beneficial effect on the receiving streams.

The potential for warm runoff from runway and taxiway pavement areas to enter streams and elevate temperatures was also considered. Such temperature effects are limited by frequency because intense rainfall typically occurs during periods of obscured sunlight and only infrequently during warm-weather periods. The majority of the precipitation falling during warmer weather would infiltrate the fill, even during intense rainfall events, because of low antecedent soil moisture during this period. Pavement runoff would flow to the shoulders of the taxiways and runway, with some runoff infiltrating to the fill or through the perforated storm drainage system (if constructed). The discharge of runoff subject to pavement warming would be a small fraction of the precipitation falling on the embankment fill. Temperature buffering within the fill would likely be high as discussed further below and inferred in the Section 3.6.4 discussion of time-lags within the embankment.

The potential for the proposed retaining wall to elevate stream temperatures was also reviewed. The retaining wall's planimetric footprint is very small, and its westerly exposure is subject to solar gain during a portion of the daylight hours in the warmer weather months of concern. The coincidence of high solar gain with rainfall is limited climatically, and the temperature within the wall is regulated by the mass of cool earth behind it. The small footprint of the wall also limits the amount of rainfall that comes in contact with the wall's surface. The small volume of stormwater directly contacting the wall and the limited opportunity for the wall to significantly elevate the temperature of the runoff suggest that the wall would not contribute to elevated temperatures in receiving streams.

The discharge of runoff subject to warming on pavement within the embankment area is small, most warm weather precipitation

would be infiltrated into and cooled by the fill mass, and the year-round infiltration of precipitation through the fill would enhance warm weather low flows in streams with cool groundwater. Based on this combination of effects, the runway embankment is not expected to create adverse temperature effects during the critical low flow periods in the streams.

## 4.0 Proposed On-Site Borrow Areas and Des Moines Creek

### 4.1 Proposed Excavation

The Port of Seattle proposes to excavate soils from three areas south of the airport to supply a portion of the fill necessary for the third runway. Figures 2-1 and 4-1 show the areas. These areas were acquired by the Port previously, and all structures and foundations were removed at the time of acquisition. Minimal pavement on some roads remains currently. Otherwise, area 1 is covered by grass and sparse forest, and areas 3 and 4 are largely forested. All areas are within the Des Moines Creek drainage. The excavations are proposed to include glacial till soils and underlying glacial advance outwash as generally indicated by the cross sections of Figures 4-2 and 4-3.

### 4.2 Character of the Hydrologic Environment

#### 4.2.1 Soils and Geology

Figures 4-2 and 4-3 present geologic cross sections generated for this project based on previous soil borings. All the geologic units also occur in the Miller Creek drainage and were described in Section 3. In borrow area 1 the general geologic sequence within the depth of interest is: glacial recessional outwash, over glacial till, over glacial advance outwash. However, glacial till is at land surface on the south two-thirds of the site. A till-like aquitard occurs above the water table in the glacial advance deposits. Saturated conditions were not reported in the recessional outwash nor on the till-like aquitard in the glacial advance deposits. The glacial advance aquifer is unconfined except near Des Moines Creek where it is confined below the till. Wetlands are

mapped within area 1, some of which are proposed to be excavated.

In borrow areas 3 and 4 the general geologic sequence is the same; however, advance outwash is at land surface on the north end where the till and recessional deposits are missing and recessional deposits lie directly on advance deposits on the southeast. Also, groundwater is perched above the aquitard (till-like soil) above the water table of the glacial advance aquifer. Hart Crowser has referred to the resulting saturated zone as the "perched water-bearing zone". A portion of the aquitard and perched water bearing zone are proposed to be excavated in borrow area 3.

Depression and slope wetlands occur within area 3. The proposed excavation does not include the wetlands, and includes only areas downslope from the wetlands. No wetlands occur in area 4.

#### 4.2.2 Soil Water-Balance Components

Section 3 and Appendix B describe the soil-water balance calculations for conditions that include the land cover and soil types present in the borrow areas. Figure 3-4 shows the seasonal trend of groundwater recharge for the land classifications. The analyses indicate about 23 inches of annual recharge to local groundwater under mixed-forest-on-till conditions, 22.5 inches in areas of grass growing on outwash, and 25.6 inches on barren outwash.

#### 4.2.3 Character of Water Circulation

##### 4.2.3.1 Groundwater Circulation

Conceptually, groundwater circulation in the borrow areas is very similar to that in the proposed embankment area. A shallow groundwater regime occurs in most areas within the Qvr and the "shallow regional



aquifer" occurs below the till in the Qva aquifer. Both aquifers appear to discharge primarily to Des Moines Creek. Unlike the embankment area, little potential for Qva groundwater to flow under the creek is suggested.

#### **4.2.3.2 Streamflow in Des Moines Creek**

King County currently maintains three stream gaging stations on Des Moines Creek and additional sites have been used over the past 10 years. Flow duration curves for two gages are presented in **Figure 4-4**. The gage locations are shown on **Figure 2-1**. The sharp drop in the curve for observed data at the mouth of the creek suggests a problem with accurate recording of low flows.

Pacific Groundwater Group measured base flows in Des Moines Creeks at two locations in October 1999 and January 2000 to assess gains in base flow. **Table 3-1 and Figure 4-5** presents the data along with King County measurements for those dates. The October 1999 measurements preceded the onset of seasonal rains and represent low flow conditions for 1999 (which was a very wet year). The January 2000 measurements also occurred after a period of no rainfall and represent winter base flow conditions.

The measurements indicate that flow increases downstream over most of the creek at both times of year and that the flow rate varies depending on the season. However, some uncertainty in the interpretation exists because of moderate disagreement between King County and Pacific Groundwater Group measurements near the Tyee ponds. Flow in Des Moines Creek increased substantially from October to January. The downstream gains result from groundwater discharge to the creek. The gains vary substantially for different reaches. These data suggest large groundwater contributions upstream of South 18<sup>th</sup> Street, and little contributions downstream of that location. Comparison between the area of gain and the geologic map of Booth and Waldron (in

print) suggests that most of the groundwater contributions come from groundwater within the Vashon glacial aquifers, and not deeper aquifers which outcrop near the creek downstream. The borrow areas are upstream of the South 18<sup>th</sup> Street measurement station.

#### **4.2.4 New Water Quality Data for Des Moines Creek**

This project collected samples of water from Des Moines Creeks and analyzed them for a wide range of parameters that help define the environmental health of a creek. Surface water quality parameters, including oxygen, temperature, and turbidity, were measured at every streamflow station in the field. Other parameters were measured at Analytical Resources, Inc. (**Appendix F**). **Tables 3-3 and 3-4** summarize the measurements.

Section 4.4.3 discusses the water quality in relation to fish health.

### **4.3 Character of Wetlands Environment**

The methodology used in the development of this section is similar to that previously discussed for the Fill Area. Refer to Section 3.3 for a more complete discussion of the methodology.

#### **4.3.1. Project Area Description**

The area surrounding the airport is primarily urban/residential in nature. The area south of the airport contains a greater percentage of non-urban/residential land; however, due to the existence of the Tyee Golf Course and significant acreage of successional land that was historically residential but which was acquired by the Port as part of Noise Abatement Mitigation programs. In addition to these areas, Des Moines Creek has a significant forested riparian corridor that is undeveloped. Wetland areas within the Des

Moines Creek watershed but outside the project area include Bow Lake, and numerous riparian wetlands associated with Des Moines Creek that fall south of the project area.

Approximately 48.5 acres of wetlands are present within the Borrow Areas, and Tyee Golf Course (Parametrix 1999a). Based on existing aerial photography, extensive riparian wetland complexes occur along Des Moines Creek on its course to Puget Sound. Obviously, these all fall outside the bounds of the Port project area, and thus were not included in the Parametrix report.

#### **4.3.1 Field and Literature Analysis**

As discussed in Section 3.3, field surveys and a literature review were conducted to evaluate wetlands in the project area.

##### **4.3.1.1 Wetland Delineation**

As discussed in Section 3.3.2, E & E's field survey verified that wetland boundaries as flagged in the field reasonably depict the extent of local wetlands, and that the representation of these areas in existing reports is also reasonable. The field surveys did not identify any wetlands that previously had not been delineated. Figure 4-6 shows the delineated wetlands and borrow areas.

##### **4.3.1.2 Wetland Characterization**

Table 4-1 identifies wetlands that could be directly impacted by excavation of on-site borrow areas as compiled by E&E. Expanded discussions of the wetlands are provided in the Wetland Delineation Report (Parametrix 1999a). Impacts to wetlands larger than 1/3 acre are shaded in the table. Discussion regarding the Ecology Class determination is provided in Section 3.3.3.1. In addition, wetlands in borrow area 3 may be indirectly affected by reduced water flows as discussed in Section 4.5.4.

##### **4.3.1.3 Functional Assessment**

Refer to Section 3.3.3.2 for a discussion of the functional assessment presented as part of Table 4-1.

#### **4.3.2 Comparison to Previous Characterizations**

Biologists evaluated project area wetlands to evaluate consistency with the wetland delineations and qualitative assessment completed as part of prior studies and presented in the Wetland Delineation Report (Parametrix 1999a). Based on the field surveys completed for this project, which represented a random sampling of wetlands within the project area, the wetland delineations presented in the delineation report provide an accurate representation of the extent of wetlands that occur in the project area. The USACE confirmed this assessment.

Refer to Section 3.6.7.2 for a comparison relating to functional assessment evaluations.

#### **4.4 Character of Fish Habitat and Populations**

##### **4.4.1 General Watershed Description**

The Des Moines Creek watershed covers 5.8 square miles and measures 3.5 miles long. The creek drops from an elevation of approximately 350 feet to Puget Sound at Des Moines Creek Beach Park. The East Fork of Des Moines Creek originates from Bow Lake where it flows through subsurface piping for approximately 1/2 mile. The West Fork of Des Moines Creek originates in the Northwest Ponds in the northwest corner of the Tyee Valley Golf Course. The confluence of the two forks of Des Moines

Creek is in the central portion of the Tye Valley Golf Course.

In addition to the Miller Creek Hatchery that releases age-0 coho throughout Des Moines Creek, Trout Unlimited (TU) manages a net pen operation in the Des Moines Marina. Annually, TU obtains 30,000 coho and 30,000 chinook salmon (*O. tshawytscha*) smolts from the WDFW. All WDFW fish have received an adipose fin clip. TU feeds the fish for approximately 6 months and then releases them. These fish are believed to remain within Puget Sound during their ocean migration (Batcho 1999). Because of the proximity to Des Moines Creek, net pen fish could use Des Moines Creek for spawning.

#### **4.4.2 Watershed Development**

Most of the watershed is heavily urbanized with residential and commercial land uses throughout the cities of SeaTac and Des Moines. Surface water runoff in the watershed directly below Bow Lake has been greatly altered and is almost exclusively confined to culverts, roadside ditches, and storm drain piping. The Des Moines Creek forks are not heavily utilized by salmonid species, especially in the summer months when water quality parameters such as low dissolved oxygen and high temperature limit salmonid usage. When water quality has been good, cutthroat trout have been found in the upper watershed (DMCBC 1997). Downstream of the confluence of the two forks, the creek gradient increases, additional water enters the creek, and riparian vegetation density increases; as a result, dissolved oxygen increases and temperature decreases making the creek more hospitable to salmonids. Downstream of South 200<sup>th</sup> Street, the creek flows through a large wetland complex with well developed riparian vegetation. After the wetland complex, Des Moines Creek enters a natural ravine that has substantially eroded because of increased peak flows caused by urbanization in the upper

watershed (DMCBC 1997, Masters 1999). Salmonid usage through the ravine reach is limited because of a lack of gravel for spawning and food production and a lack of slow water refuge from peak flow events (Masters 1999). Most of the streambed gravels have been scoured from this area, leaving a substrate of hardpan clay. Downstream of the ravine, the creek is channelized through the Midway Treatment Plant. Below the treatment plant, the topography widens and the creek flows through a floodplain with a meandering channel and well developed riparian vegetation. The creek flows through a 225-foot long box concrete culvert under Marine View Drive that is impassable to salmonids under most water conditions because the combination of high water velocity and shallow water depth is beyond adult coho swimming ability. The remaining 1/2 mile of creek flows through Des Moines Beach Park. This lower reach of Des Moines Creek is utilized by anadromous salmonids: coho and chum salmon were observed in this reach during December, 1999. Steelhead are also reported to use this creek reach, but their presence was not verified during this study. Adequate salmonid habitat reportedly exists between Marine View Drive and the Midway Treatment Plant, however, usage is limited because of the Marine View Drive culvert (DMCBC 1997).

#### **4.4.3 Water Quality Related to Fish**

PGG measured in-situ water-quality parameters (pH, temperature, conductivity, turbidity, and dissolved oxygen) during base flow periods in October 1999 and January 2000 at two locations in Des Moines Creek: upstream of South 200<sup>th</sup> Street at the Tye Valley Golf Course and near the intersection with 18<sup>th</sup> Avenue South (Tables 3-3 and 3-4). No water quality concerns related to fish production were identified. Water samples also analyzed for total metals, TSS, ammonia, nitrate, nitrite, total phosphorus, ortho-phosphorus, biological oxygen

demand, and total oil and grease. Based on the calculated hardness in Des Moines Creek of 83 to 100 mg/L, the detected concentrations of copper and zinc are below the Washington State standards (other heavy metals were undetected). The maximum TSS value was 3.8 parts per million (ppm), indicating minimal suspended particles (of which sediment is one component) in the water column. The total oil and grease results were below 2 ppm, indicating minor inputs of petroleum constituents at the time of sampling.

Voss et al. (1999) reported the presence of numerous pesticides in Des Moines Creek. Diazinon was present at concentrations equal to the chronic aquatic life criteria recommended by the EPA(1998). Voss et al. (1999) noted that the ecological effects to the stream is unknown because the duration of exposure to pesticide concentrations at the aquatic life criteria is unknown.

Stormwater at the airport falls into one of two types of catchments: the Stormwater Drainage System (SDS) and the Industrial Wastewater System (IWS). This project did not independently review original SDS or IWS water quality data or discharge data. The following brief discussion is from the FEIS (FAA, 1996) and other sources. Refer to Section 3.4.1.3 for more discussion.

The Des Moines Creek watershed receives discharge from the SDS that drains the taxiways and runways. Samples of SDS discharge were analyzed by the Port for seven water quality parameters (total suspended solids, biochemical oxygen demand, oil and grease, total phosphorus, total copper, total lead, and total zinc) and the results were compared to the total basin loading for these parameters in Des Moines Creek (FAA, 1996). According to that analysis, discharge from the airport contributes between 3.5 percent and 39 percent of the total basin loading for these water quality parameters. The total copper contribution of 39 percent exceeds the approximate 30 percent of the Des Moines

Creek watershed area that is comprised by the airport. All other loading by the airport to the Des Moines Creek watershed was reported to be less than 25 percent.

#### **4.4.4 Fish Populations**

Despite habitat and water quality degradation, anadromous and resident fish populations are present in Des Moines Creek. Adult coho and chum salmon are known to utilize the stream reach from the mouth to the Marine View Drive culvert. Juvenile coho salmon are distributed throughout Des Moines Creek, likely because of TU Miller Creek Hatchery release efforts. Steelhead (*O. mykiss*) and pink salmon (*O. gorbuscha*) runs have been reported on Des Moines Creek, but this was not field verified. A small population of resident cutthroat trout is distributed throughout much of the Des Moines Creek watershed. Pumpkinseed sunfish and largemouth bass (*Micropterus salmoides*) reportedly have been introduced to lakes in the Des Moines Creek basin; however, the presence or distribution of pumpkinseed or largemouth bass in Des Moines Creek were not documented during this study.

### **4.5 Analysis of Selected Impacts**

#### **4.5.1 Des Moines Creek HSPF Model Review**

In the Des Moines Creek basin, flow volumes predicted by the HSPF model were compared to observed values for the water years 1994, 1995 and 1996 at gages upstream of the Tyee pond and near the mouth of the creek. Table 4-2 compares the total flow volumes, expressed as equivalent inches of precipitation across the drainage area tributary to each gage.

The period of flow rate calibration data used for the Des Moines Creek HSPF model is

from October 1, 1995 to March 30, 1996. This six-month period of time is not adequate to sufficiently calibrate the HSPF model. Normally a minimum of two years is required to adequately calibrate a watershed.

The calibration at each stream flow gage is reasonable but may be improved. There are two rain gages established in the Des Moines Creek watershed: the Sea-Tac gage located at the airport and the Tyee Pond gage located lower in the basin. Total precipitation recorded at the Tyee Pond gage is approximately 94 percent of the rainfall recorded at the Sea-Tac gage and seasonal variations are similar. The HSPF model utilizes only the Sea-Tac rain gage record for precipitation input. The model's calibration could be strengthened by utilizing rainfall input from both gages, applying the Sea-Tac gage record for the upper reaches of the watershed and the Tyee Pond data to the lower subbasins. This would allow better calibration at the upper gage site without overestimating volumes at the lower gage site.

A review of the Des Moines Creek HSPF model did not reveal serious limitations, and the calibration of the model appears to be reasonable for characterizing current surface water flow conditions in the watershed. However, several changes were disclosed in the input data between models developed to simulate different land use scenarios. Because the purpose of these models is to make relative comparisons of flow volumes and rates under proposed and target flow conditions, the inconsistencies present a significant limitation in the modeling. Four Des Moines Creek HSPF models, each representing a different land use scenario, were reviewed:

DM-C - calibration land use conditions  
DM-PRE - pre-developed scenario (target flow conditions)  
DM94- 1994 land use base scenario  
DM04 - 2004 land use scenario

Groundwater Deep Fraction (DEEPFR) parameter defines how infiltrated groundwater behaves when it reaches a soil horizon. The DEEPFR parameter specifies how much of the infiltrated water continues downward into the deeper aquifer and how much travels laterally through an upper stratum. The DEEPFR parameter is set at 0.7 for the pre-developed (target flow) and calibration scenarios but is set to 0.6 for the 1994 and 2004 land use scenarios. Within the runway embankment fill area, the DEEPFR parameter in the calibration scenario model was set to 0.9, and it was changed to a value of 0.8 in models of the 1994 and 2004 land use scenarios. No explanation is provided in the project documentation for these apparent discrepancies.

The significance of the DEEPFR parameter in the Des Moines Creek model is that it applies to the amount of groundwater that is transmitted to a deeper aquifer and becomes unavailable to feed base flows in the stream. For outwash soils, all precipitation that infiltrates through the soil is subject to this parameter. This is over 99 percent of all runoff generated by outwash soils. For till soils, all precipitation that infiltrates through the soils and eventually through the hard till unit is subject to this parameter. This is usually less than half of the total runoff from till soils. The documentation does not explain why different DEEPFR values were used for a single land type.

Analyses with the slice groundwater models (Sections 3.2.4.1 and 3.6.4) suggest that the percent of recharge that percolates through the till would change from the current to the built conditions. The current condition slice model suggests 46.5 percent of recharge flows down through the till and the built condition slice model suggests 53.5 percent of the (reduced) recharge flows down through the till. The DEEPFR parameter should be set accordingly and all airport fill parameters should be consistent for all HSPF model scenarios for both the Des Moines Creek and Miller Creek watersheds.

Total watershed area is not consistent between the four model scenarios as shown in Table 4-3. There are also several changes between the models in defining the proportion of various soil types present within the watershed. Watershed area is greatest for the calibration scenario and smallest for the 2004 land use scenario. When diversions to the IWS are accounted for, the total watershed areas for the calibration and 2004 scenarios still differ by 7.6 percent.

All land types show changes between the four models. For example, the pre-developed condition has 2079 acres of till soils, 1223 acres of outwash soils, and 375 acres of impervious surface. This is changed under the 2004 land use scenario to 1002 acres of till, 851 acres of outwash and 1219 acres of impervious surface. Much of the shift is presumed attributable to the placement of fill for the airport and diversion to the IWS; however, there is no clear explanation provided for the changes, nor for the net change in gross watershed area between the models.

With a larger percentage of the watershed assumed covered by till soils in the target flow scenario, the model will simulate more runoff volume and higher peak flows. With a larger percentage of outwash soils assumed in the 2004 land-use scenario, the model will simulate lower runoff volumes and rates to be generated. When attempting to size facilities that control runoff from future land use conditions to target flow rates, the impact of the shift from till to outwash soils between scenarios would be to undersize the facilities.

Another set of HSPF model values are termed FTABLEs. FTABLEs define the relationship between the volume and flow rate of water within a reach of the stream or within a facility. In reviewing the FTABLEs in the Des Moines Creek model, several were found to have values that are suspected to be inaccurate because in some

of the FTABLEs the surface area of the reach decreases with increasing water depth. The suspect FTABLEs include those numbered: 1, 2, 25, 44,64, 100, 105, 110, 115, 135, 140, 150, 190, 193, 198, 200, 203, 204, 205, 206, 207, 222, 360, 390.

#### **4.5.2 Proposed Flow Control Measures**

Discussion of the target flow regime is presented in Section 3.6.2.2. The general approach to sizing flow control facilities for the airport within the Des Moines Creek watershed, as presented in the Preliminary Comprehensive Stormwater Management Plan, is appropriate. The proposed approach includes applying the target flow regime concept, using Level 1 flow control facilities in conjunction with regional facilities to achieve Level 2 control, and utilizing the HSPF model to simulate the target, existing, and proposed watershed conditions. However, as noted above and in prior sections of this report, the technical execution of the approach requires several corrections if the modeling is to be used to size flow control facilities that would confidently achieve the desired conditions in the stream systems.

Table 3-19 summarizes how the limitations in the modeling, if not corrected, would affect the sizing of flow control facilities. Because of the fundamental questions raised in the models' use of parameters and differences in basin areas, the impact that the changes would have on facility size could not be made without actually revising the model.

The flow control plan relies on the construction of the proposed regional detention facility (RDF) below the airport on Des Moines Creek. Implementation of this project as part of the Des Moines Creek Basin Plan is to be a joint effort between the Port of Seattle, King County and the cities of SeaTac and Des Moines. In the event the RDF is not constructed, it is proposed that additional on-site detention vaults would be

constructed at the airport to provide Level 2 control of airport runoff. No contingency locations were specified for provision of additional stormwater detention capacity in lieu of the Des Moines Creek RDF.

#### **4.5.3 Accounting for the Industrial Waste System in HSPF Models**

Portions of the airport most susceptible to contamination by de-icing and other service chemicals are drained to the Industrial Wastewater System (IWS). The IWS flows are conveyed to treatment lagoons which, in turn, discharge directly to Puget Sound. The IWS is, therefore, unconnected to the hydrology of the Des Moines Creek watershed except for the fact that the IWS consumes potential runoff and groundwater recharge area. There have been occasions where the IWS lagoons have overflowed to the Des Moines Creek system during extreme storm events.

The assumptions regarding diversion of stormwater to the IWS under each model scenario are difficult to track through the SWMP. **Table 4-3** presents the reviewers' understandings of the acreage assumed tributary to the industrial waste system in the Des Moines Creek HSPF models. The areas for the IWS increase from 292 acres to 315 acres from the 1994 land use scenario to the calibration land use scenario. The areas for the IWS increase from 315 acres in the 1994 land use scenario to 424 acres in the 2004 scenario. The increases mean a corresponding decrease in area for either the Des Moines Creek watershed areas or the Miller Creek watershed areas. However, confirmation that the IWS area is accurately accounted for is complicated by the fact that the total watershed areas for Des Moines Creek and Miller Creek do not remain constant for all four model scenarios. Inconsistent accounting for areas to be diverted to the IWS may be a source of modeled changes to total basin areas.

#### **4.5.4 Effects on Water Balance and Groundwater Flow**

Analyses using recharge model results were performed to evaluate potential changes to recharge resulting from excavation of the borrow areas. The primary change in land type would be conversion of forested outwash and till soils to barren or grassy outwash. The reviewed Port documents did not indicate plans for post-mining reclamation or the promotion of vegetation.

In borrow area 1, the excavated area covers about 95 acres, and over 25 acres the glacial till would be removed to expose outwash. Based on these areas and recharge rates for forested and barren conditions, a small amount of additional groundwater recharge (annual average of not more than 2800 cfd (0.03 cfs)) to the Qva aquifer would be expected after excavation as compared to the current condition. The timing of discharge to Des Moines Creek may change over these limited areas but was not analyzed. The removal of the vadose zone, including perching layers, could cause faster or slower discharge to the creek as compared to the current condition.

In borrow area 3, the excavated area covers about 20 acres. Based on this area and recharge rates for pre- and post-construction conditions, not more than 500 cfd (0.006 cfs) of additional annual average groundwater recharge to the Qva aquifer would be expected after excavation as compared to the current condition. The timing of discharge to Des Moines Creek was not analyzed.

The excavation at area 3 is designed to narrowly avoid seven slope and depressional wetlands (**Figure 4-6**) which are dependent on water in the perched water-bearing zone (**Figure 4-3**). Independent interpretation of water levels in the perched aquifer indicate that water moves to the wetlands from generally the northwest, with considerable uncertainty about the precise direction. The perching horizon and perched water-bearing

zone are proposed to be removed to the north and east of the wetlands, but not to the west (Figure 4-6). This arrangement was designed by Hart Crowser to avoid draining water away from the wetlands. However, a seepage face would likely develop on the west wall of the northern excavated area, and perched groundwater would seep into the excavation. The change in discharge location for some of the perched groundwater would cause groundwater elevations to decrease in the perched water-bearing zone west of the seepage face. The proposed design and existing analyses by Hart Crowser do not provide high confidence that water flow to the wetlands would be maintained at their current rate. Groundwater flow direction mapping has relied in part on moisture content interpretations from soil borings as opposed to surveyed static water level elevations, and the methods of the impact analyses indicating "a decline in groundwater level of 1.5 to 2 feet" of have not been provided (Hart Crowser, 1999c). This magnitude of water level change would likely have substantial impacts to wetland water flow, and possibly biota.

The seepage into the excavation is likely to infiltrate through the bottom of the excavation and recharge the Qva aquifer. New wetland area may be created in the bottom of the excavation in this process. Timing of discharge to the creek was not analyzed.

In borrow area 4, the excavated area covers about 35 acres and would remain within outwash soils. Based on the area of the footprint and removal of vegetation, an additional 900 cfd (0.01 cfs) of groundwater recharge to the Qva aquifer would be expected after excavation as compared to the current condition. Although the perching horizon identified in area 3 extends into area 4, the proposed depth of excavation in area 4 would not result in excavation of the perching horizon. The timing of discharge to Des Moines Creek was not analyzed.

#### **4.5.5 Comparison to Previous Hydrogeologic Impact Assessments**

Applied Geotechnology Inc. (1995) identified potential changes to groundwater recharge resulting from borrow activities but did not quantify the changes. In an appendix to the Master Plan FEIS, AGI (1996) estimated 0.32 cfs additional recharge from borrow areas which is substantially above this project's estimated maximum of less than 0.05 cfs. The basis for the difference is an unjustified assumption by AGI that recharge does not occur in till-mantled areas.

The modeling of borrow areas in the HSPF model of Des Moines Creek developed by Parametrix was not evaluated in detail; however, cursory review of the data presented in the SWMP suggests the cover type changes resulting from borrow activities were not modeled.

#### **4.5.6 Impacts to Wetlands**

This analysis evaluates the size of the potential wetland impact, and the resulting functional impacts.

##### **4.5.6.1 Acreage Impact**

Excavation of the borrow areas would result in the permanent loss of 1.45 acres of wetland in the Des Moines Creek watershed, and an additional temporary loss of 0.20 acres of wetland that would be disturbed during the construction phase of the project but restored to wetland conditions during operations. These totals are based on the information provided in previous reports coupled with the field verification of wetland boundaries. Of the 6 wetlands impacted, only one loss is greater than 1/3 acre.



Tables 4-4 and 4-5 present summaries of direct impacts expected from borrow excavation. These impacts are presented by hydrogeomorphic classification, as well as by cover type.

#### **4.5.6.2 Functional Impact**

Wetland 52, which is associated with Des Moines Creek is recognized as offering numerous functions in terms of water quality, quantity and wildlife populations. As proposed, the airport projects would only minimally impact this wetland complex. Similarly the Northwest Ponds (Wetland 28) also would not be significantly impacted. The wetlands on the golf course offer little functional value except for nutrient/sediment trapping. The wetlands to be removed at Borrow Area 1 provide a wider range of functions since they are part of a larger habitat system. However, these wetlands are located in an area that historically was residential, but was acquired as part of a noise mitigation program. The functions of the wetlands that will likely receive reduced water flows in borrow area 3 were not reported by Parametrix (1999b) nor evaluated for this project.

The large wetland complexes associated with Des Moines Creek would remain relatively unaltered, minimizing the impacts within the watershed. The primary impacts that would need to be compensated for are nutrient/sediment trapping, and wildlife populations.

#### **4.5.6.3 Mitigation**

The overall mitigation plan for the airport impacts are discussed in Section 3.6.7.

#### **4.5.6.4 Comparison to Previous Wetland Impact Assessments**

As discussed above in Section 4.5.4, Hart Crowser estimates 1.5 to 2 feet of perched

water table depression near wetlands in borrow area 3. Any water table reduction would cause reduced flow to existing wetlands and possible impacts to biota. This effect was not identified by Hart Crowser, although the excavation was designed to minimize wetland impacts. This project concurs that perched water table depression and reduced flow to wetlands is likely to occur, but has not quantified the effect. Hart Crowser did not present the methods used in its prediction and they were therefore not reviewed. This project's findings disagree with the findings in the wetland functional assessment (Parametrix, 1999b) that states that no wetland hydrologic impacts will occur.

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**Table 3-1  
Creek Base Flow Measurement Results**

Station	Total Discharge Rates (cfs)		
	10/22&23/99	11/7/99	1/27&28/00
<b>Des Moines Creek</b>			
KC-11C + KC-11G	0.5	NM	1.7
KC-11F	1.0	NM	2.0
Des Moines Creek at Tyee	0.8	NM	1.8
Des Moines Creek at South 18th	1.4	NM	3.4
KC-11D	1.3	NM	3.4
<b>Miller Creek</b>			
KC 42B	0.4	NM	2.0
Miller Creek at Lora Lake	0.4	NM	1.8
Miller Creek at S 156th St	0.9	NM	2.6
Miller Creek at 509 & Des Moines Memorial Drive	0.9	NM	2.8
Miller Creek at Kiwanis	1.5	NM	3.8
KC-42A	2.7	NM	6.0
<b>Walker Creek</b>			
Walker Creek near head	NM	1.0	0.8
Walker Creek at 1st Ave Retaining Wall	1.8	2.1	1.4
KC-42E	NI	2	2.9
Walker Creek near mouth	1.9	2.4	2.4

*NM = Not measured*

*NI = Station not instrumented*

**Table 3-2  
Comparison of Modeled and Measured Base Flow Gains in Miller Creek**

	Flow in Middle Miller Creek		Flow at Lower Miller Creek
	October-99	January-00	
Flow in middle Miller Creek at MCDF (Lora Lake) (cfs)	0.4	1.8	
Flow in middle Miller Creek at SR 509 (cfs)	0.9	2.8	
Difference in flow (cfs)	0.5	1	
Gain in baseflow per foot of reach (cfs/f)	6.59E-05	1.32E-04	
Gain in baseflow per foot of reach (cfd/f)	6	11	
Gain reduced to average condition based on 1999 wet year (divide by 1.9) (cfd/f)	3		
Gain reduced to average condition based on 1999 wet year (divide by 1.5) (cfd/f)			
Expected range from east bank (50 percent to 100 percent) (cfd/f)	1.5 to 3	4 to 8	
Slice Model (average year) surface flow plus groundwater flow (cfd/f)	1	7 to 8	
Estimated potential contribution from septic discharge (cfd/f)	1	1	
Long term dry year "low flow" (Parametrix, 1999x) (cfs)			1.4
Long term dry winter baseflow (Parametrix, 1999x) (cfs)			4
Long term dry year average baseflow (Parametrix, 1999x) (cfs)			2.4
King County Gage October 99			2.7 (1.9 times typical "low flow")
King County Gage January 00			6 (1.5 times winter baseflow)

**Table 3-3  
Field Water Quality Analyses**

Station	Date	pH	Temperature (°F)	Ec (uS/cm)	Turbidity (NTU)	DO (mg/L)
Des Moines Creek at Tyee (north of 200th St.)	10/23/99	7.23	51	212	0.7	5
Des Moines Creek at South 18th	10/22/99	6.2	50.1	288*	0.9	9
Des Moines Creek at Tyee (north of 200th St.)	11/17/00	7.23	42	193	0.6	6
Des Moines Creek at South 18th	11/27/00	7.65	45	230	2.2	6
Miller Creek North of Hwy 518 (Upstream of Tub Lake Trib.)	10/23/99	7.66	52	209	2.6	6
Miller Creek North of Hwy 518 (Downstream of Tub Lake Trib.)	10/23/99	7.36	52	209	2.5	4
Miller Creek at Lora Lake	10/22/99	6.2	51	315	15	6
Miller Creek at S 156th St	10/22/99	8.25 - 7.51	52	301	4	6
Miller Creek at 509 & Des Moines Memorial Drive	10/22/99	7.9	50	510	4	8
Miller Creek at Kiwanis (Upstream of Lake Burien Trib.)	10/22/99	7.59	52	253	2	9
Walker Creek at 1st Ave Retaining Wall (South of 168th St.)	10/22/99	7.44	52	258	4	5
Walker Creek near mouth (at 12th Ave)	10/23/99	7.77	51	252	2.5	6
Walker Creek near head in 18-inch pipe (West of Hwy 509)	1/28/00	7.06/7.17**	51	375	1.1	7
Walker Creek near head in 6-inch pipe (West of Hwy 509)	1/28/00	7.51/7.57**	44	179	7.3	6
Walker Creek at 1st Ave Retaining Wall (South of 168th St.)	1/28/00	7.84	44	364	5.4	5
Walker Creek near mouth (at 12th Ave)	1/28/00	8.15	42	210	4.3	8

\*Conductivity meter not calibrated to 1413 us/cm standard \*\*7.06/7.17 = Reading taken in pipe/Reading taken in sample collected in pipe



**Table 3-4  
Laboratory Water Quality Analyses**

Constituent	Method	WAC 173-201A	Units	Samples collected October 25 and 26, 1999				Samples collected January 28, 2000			
				Miller Creek at S 156th	Miller Creek at Kiwanis	Des Moines at Tye	Des Moines at S 18th	Miller Creek at S 156th	Miller Creek at Kiwanis	Des Moines at Tye	Des Moines at S 18th
<b>Total Metals</b>											
Arsenic	6010	0.19	mg/L	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Cadmium	200.8	*Calculated below	mg/L	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.0002 U
Calcium	6010	---	mg/L	27.8	24.8	21.8	21.0	21.0	21.0	19.3	19.1
Copper	6010	*Calculated below	mg/L	0.002 U	0.002 U	0.004	0.005	0.004	0.004	0.007	0.005
Lead	200.8	*Calculated below	mg/L	0.001	0.001 U	0.001 U	0.004	0.001	0.001	0.001 U	0.001 U
Magnesium	6010	---	mg/L	18.6	15.6	12.2	10.2	10.4	10.4	8.54	8.75
Zinc	6010	*Calculated below	mg/L	0.01	0.007	0.010	0.022	0.014	0.014	0.014	0.012
Hardness	Calculated	---	mg-CaCO <sub>3</sub> /L	150	130	100	95	95	95	83	84
<b>Conventionals</b>											
Total Suspended Solids	160.2	---	mg/L	5	1.8 U	1.1 U	17	4.1	4.1	3.8	1.7
N-Ammonia	350.1	---	mg-N/L	0.06	0.013	0.017	0.066	0.013	0.013	0.010 U	0.010 U
Nitrate+nitrite	353.2	---	mg-N/L	1.3	1.3	0.86	1.3	1.3	1.3	0.56	0.54
total phosphorous	365.2	---	mg-P/L	0.080	0.071	0.040	0.098	0.060	0.060	0.06	0.051
ortho phosphorous	365.2	---	mg-P/L	0.03	0.038	0.017	0.026	0.029	0.029	0.005	0.013
biological oxygen demand	405.1	---	mg/L	2	3 U	2	2	2 U	2 U	2	2
total oil and grease	413.1	---	mg/L	1 U	1.2	1 U	1.6	1.8	1.8	1.4	1.5

U = undetected. Instrument detection limit reported.

Bold text exceeds WAC 173-201A Freshwater Chronic Criteria

\*WAC 173-201A Freshwater Chronic Criteria for a sample is calculated from the hardness value for that sample

Hardness (mg-CaCO <sub>3</sub> /L)	150	130	100	95	83	84
Cadmium (mg/L)	0.001	0.001	0.001	0.001	0.0009	0.0009
Copper (mg/L)	0.016	0.014	0.011	0.011	0.010	0.010
Lead (mg/L)	0.004	0.003	0.003	0.002	0.002	0.002
Zinc (mg/L)	0.15	0.13	0.10	0.10	0.09	0.09

**Table 3-5  
Wetlands Potentially Affected by Fill Areas Associated with Proposed Third Runway**

Wetland Classification	Total Wetland Size	Brief Wetland Description	Ecology Class	Qualitative Functional Assessment
<b>Runway Safety Area</b>				
5	Slope PSS	4.63	Part of a larger forested complex associated with Miller Creek Detention Facility	III M-H Wildlife M - Nutrient/Sediment trapping
<b>New Third Runway</b>				
9	Slope PFO/PEM	2.83	Part of extensive wetland complex part of the Miller Creek Detention Facility.	III M-H Wildlife H - Flood Storage M - Export of Organic Carbon and Nutrient/Sediment trapping
11	Slope PFO/PEM	0.50	Elevated Forested Emergent wetland drains downslope toward the Miller Creek Detention Facility	III M - Wildlife M - Nutrient/Sediment trapping
12	Slope PFO/PEM	0.21	Forested Hillside seep in north borrow area in AOA	III
13	Slope PEM	0.05	Forested Hillside seep in north borrow area in AOA	III
14	Slope PFO	0.19	Forested Depression located in north borrow area in AOA, adjacent to 12 <sup>th</sup> Ave.	III
15	Slope PEM	0.28	Small emergent wetland within AOA associated with stormwater drainage	III
16	Depression PEM	0.05	Small emergent wetland within AOA associated with stormwater drainage	III
17	Depression PEM	0.02	Small emergent wetland within AOA associated with stormwater drainage	III M - Nutrient/ Sediment trapping L-M - Nutrient/Sediment trapping
18	Slope-Riparian Mixed	3.56	Component of largest wetland complex in the project area. Significant disturbance from adjacent urban/residential development. Fill encroachment evident. Downslope edge is riparian to Miller Creek. Dense Himalayan blackberry evident. Connected to wetland 37.	II M-H - Resident fish populations M-H - Wildlife Populations M - Flood Storage M-H - Export of Organic Carbon and Nutrient/Sediment trapping M - Wildlife Populations M - Export of Organic Carbon and Nutrient/Sediment trapping M-H Wildlife Populations M - Export of Organic Carbon
19	Slope PFO	0.56	Ravine PFO in former noise abatement area	III L-M - Wildlife Populations
20	Slope PSS/PEM	0.57	Drainage slope PSS/PEM in AOA	II
21	Slope PFO	0.22	Drainage channel in AOA	III
22	Slope PSS/PEM	0.06	PSS/PEM slope in AOA	III
23	Depression PEM	0.77	Glassy maintained PEM slope in AOA	IV
24	Depression PEM	0.14	Maintained PEM in AOA	III H - Sediment trapping M - Flood storage M - Nutrient/Sediment trapping
25	Depression PFO	0.06	PFO depression in AOA	III
26	Depression PEM	0.02	PEM depression in AOA	IV
W1	Depression PFO/PEM	0.10	PEM at the base of slope adjacent to temp. treatment ponds in AOA	III M - flood storage L-M - Nutrient/Sediment Trapping

PFO - Palustrine Forested  
PSS - Palustrine Scrub Shrub  
PEM - Palustrine Emergent  
FW - Farmed Wetland  
AOA - Airport Operational Area  
Shading represents wetlands with a potentially large effect (>0.33 acres) from airport fill activities.

**Table 3-5  
Wetlands Potentially Affected by Fill Areas Associated with Proposed Third Runway**

Wetland	Classification	Total Wetland Size	Brief Wetland Description	Ecology Class	Qualitative Functional Assessment
W2	Depression PFO/PEM	0.22	Closed depression in AOA	III	L-M wildlife Populations M- Flood Storage M-H - Nutrient/Sediment Trapping
35a-d	Slope PFO/PEM	0.67	Drainage swale adjacent to 160 <sup>th</sup> Street, bisected by driveway fill	III	M- Wildlife Populations L-M - Export of Organic Carbon
37a-f	Slope Riparian PFO/PEM	5.76	Component of large wetland complex in the project area. Significant disturbance from adjacent urban/residential development. Fill encroachment evident. Downslope edge is riparian to Miller Creek. Dense Himalayan blackberry evident. Connected to wetland 18.	II	M-H - Nutrient/Sediment Trapping M-H - Resident Fish Populations M-H - Wildlife Populations M- Flood Storage M-H - Export of Organic Carbon and Nutrient/Sediment Trapping
40	Depression PFO	0.03	Isolated woodlot at corner of Wilson Road and 12 <sup>th</sup> Ave	III	M- Flood Storage H- Nutrient/Sediment Trapping M-H - Wildlife Populations M-H - Export of Organic Carbon
41a and b	Depression PEM	0.21	Farm pondland adjacent pasture	III	M- Flood Storage H- Nutrient/Sediment Trapping M-H - Wildlife Populations M-H - Export of Organic Carbon
41a and b	Slope PFO	3.04	Ravine leading to large offsite wetland (wetland 43) that forms headwaters for Walker Creek	II	M- Resident Fish Populations M-H - Nutrient/Sediment Trapping M-H - Wildlife Populations H- Flood Storage H- Export of Organic Carbon and Nutrient/Sediment Trapping
A1	Depression Riparian Mixed	4.51	Disturbed PFO/PSS/PEM adjacent to lake tower. Significant Himalayan blackberry in the understory.	I	M- Resident Fish Populations M-H - Nutrient/Sediment Trapping M-H - Wildlife Populations H- Flood Storage H- Export of Organic Carbon and Nutrient/Sediment Trapping
A5	Depression PEM	0.03	Maintained/mowed grassy wetland	IV	
A6	Slope PFO	0.16	Woodlot with considerable Himalayan blackberry	III	L-M Wildlife Populations L-M Nutrient/Sediment Trapping
A7	Slope PFO	0.30	Successional woodlot with significant Himalayan blackberry component	III	L-M Wildlife Populations L-M Nutrient/Sediment Trapping
A8	Slope BFO/PSS	0.38	Disturbed community with extensive Himalayan blackberry	III	L-M Wildlife Populations L-M Nutrient/Sediment Trapping
A12	Slope PSS	0.11	Slope shrub wetland drainage	III	L-M Wildlife Populations
A18	Depression PSS	0.01	Small shrub pocket	III	L-M Wildlife Populations
FW5 and 6	Depression/ Riparian FW	0.15	PEM wetlands in Vacca Farm still meeting jurisdictional criteria	IV	M- Flood Storage H- Nutrient/Sediment Trapping M- Wildlife Populations H - Flood Storage
R1	Riparian PEM	0.17	Riparian emergent adjacent to Miller Creek	III	M-H Export of Organic Carbon and Nutrient/Sediment trapping

PFO - Palustrine Forested  
PSS - Palustrine Scrub Shrub  
PEM - Palustrine Emergent  
FW - Farmed Wetland  
AOA - Airport Operational Area  
- Shading represents wetlands with a potentially large effect (>0.33 acres) from airport fill activities.

L - Low  
M - Moderate  
H - High

**Table 3-6  
Optimal Habitat Preferences for Coho Salmon Survival**

Habitat Parameter	Optimal Range	Benefit
Substrate Sedimentation	<30%	Sedimentation reduces water flow to deposited eggs and reduces available dissolved oxygen levels. Higher levels of sedimentation can be tolerated, but typically results in lower survival rates and smaller size at emergence.
Dissolved Oxygen Level	8-14.6 mg/L	Oxygen is necessary for egg survival and growth. Higher dissolved oxygen levels generally result in faster egg development and growth.
Water Temperature	4-11°C	Water temperature affects incubation time. Warmer water temperatures (up to a maximum tolerable level) generally result in shorter incubation times.

*Adapted from Groot and Margolis (1991)*

**Table 3-7  
Optimal Habitat Preferences for Juvenile Coho Salmon Survival**

Habitat Parameter	Optimal Range	Benefit
Slack Water (Velocity)	<1 foot/second	Newly emerged salmon have limited swimming ability and require low water velocity to remain stasis. As fish grow, swimming ability increases and higher water velocities can be tolerated. Off-channel pools and stream edge slack water also possess good macroinvertebrate food sources for growth.
Instream Structure/Cover	30-70%	Boulders, undercut banks, overhanging vegetation, and large woody debris provide instream structure, cover from predators, and low water velocities. Large woody debris also traps organic matter and provides habitat for macroinvertebrate production.
Food Source	NA	Adequate macroinvertebrate food sources are necessary for growth and survival.

*Adapted from Groot and Margolis (1991)*

**Table 3-8**  
**Optimal Habitat Preferences for Adult Coho Salmon Spawning**

Habitat Parameter	Optimal Range	Benefit
Gravel Size	5-15 cm	Gravel size provides interstitial pore space and allows for adequate water flow through the gravel. Gravel size is largely dependent on stream size and location within the stream system. Proper gravel size is needed to substantial depth because coho salmon have been documented to bury eggs up 40 cm into the substrate.
Water Velocity	0.5-1 m/s	Adequate water velocity is needed to keep the gravel free of sediment and provide sufficient water flow, and hence dissolved oxygen, through the gravel.
Water Depth	15-30cm	Female coho choose redd locations with adequate depth to insure sufficient water flow to eggs throughout incubation period. In areas where freezing is a factor, adequate depth insures water flow below the upper winter ice layer.

*Adapted from Groot and Margolis (1991)*

**Table 3-9  
Carcass Survey Results**

Creek	Species	Sex (M/F)	Adipose Fin Clip (Y/N)	Percent Egg Voidance	Creek	Species	Sex (M/F)	Adipose Fin Clip (Y/N)	Percent Egg Voidance
Miller Creek	Coho	F	Y	80	Walker Creek cont.	Coho	F	Y	90
	Coho	F	Y	80		Coho	F	Y	90
	Coho	F	Y	100		U	U	U	U
	Coho	F	Y	20		Coho	U	U	U
	Coho	M	N	-		Coho	M	N	-
	Coho	F	Y	0		U	U	U	U
	Coho	M	Y	-		U	U	U	U
	Coho	M	Y	-		U	U	U	90
	Coho	F	Y	95		U	F	U	70
	Coho	U	U	U		U	F	U	80
	Coho	U	U	Y		U	M	N	-
	Coho	U	Y	-		U	U	U	U
	Walker Creek	U	U	U		U	U	U	U
Coho		M	Y	-	Coho	M	N	-	
U		U	U	U	Coho	M	Y	-	
U		U	U	U	Chum	M	N	-	
Coho		F	N	80	Coho	F	Y	95	
U		U	U	U	Coho	F	N	95	
Coho		F	U	80	U	U	U	U	
Coho		M	Y	-	Coho	M	Y	-	
U*		U	U	U	U	U	U	U	
U		U	U	U	U	U	U	U	
U		U	U	U	U	U	U	U	
Coho		M	U	U	Coho	F	Y	95	
U		F	U	90	Des Moines Creek	Coho	M	N	-
Coho	M	U	-	Coho		M	N	-	
U	U	Y	90	Coho		F	Y	90	
U	M	U	-	Coho		M	N	-	
U	U	U	U	Coho		M	N	-	
Coho	F	Y	0	Coho		F	Y	80	
Coho	M	Y	-	Chum		U	U	U	
U	U	Y	-	Coho*		U	U	U	
Coho	M	Y	-	Coho*		U	U	U	
Coho	M	Y	-	Chum*		U	U	U	

\* Denotes live fish.  
U = Undetermined. Because of the fish condition, the parameter could not be conclusively determined.

**Table 3-10  
Miller Creek Carcass Survey**

Date	Fish No.	Species	Sex (M/F)	Adipose Fin Clip (Y/N)	Eggs Present (Y/N)	Location/Comments
12/2/99	1	Coho	F	Y	Y	Upstream of Normandy Park Cove Building
	2	Coho	F	Y	Y	Upstream of Normandy Park Cove Building
	3	Coho	F	Y	N	Adjacent to first residence upstream of Normandy Park Cove property
	4	Coho	F	Y	Y (80%)	50 feet downstream of 13th Ave. bridge
	5	Coho	M	N	-	Between 13th Ave. bridge and downstream edge of Southwest Suburban Sewer District (SWSSD)
	6	Coho	F	Y	Y (100%)	75 feet downstream of upstream SWSSD bridge
	7	Coho	M	Y	-	Adjacent to Mr. Brett Fish's residence; fish small (13 in.)
	8	Coho	M	Y	-	Adjacent to Mr. Brett Fish's residence
	9	Coho	F	U	Y (5%)	Adjacent to Mr. Brett Fish's residence
	10	Coho	U	U	U	Upstream of Mr. Brett Fish's residence
	11	Coho	U	Y	-	Upstream of Mr. Brett Fish's residence

*Miller Creek surveyed between mouth and 1st Ave. S. culvert*

*Note: Two unidentifiable carcasses were found approximately 50 feet downstream of the downstream SWSSD fence.*



**Table 3-11  
Walker Creek Carcass Survey**

Date	Fish No.	Species	Sex (M/F)	Adipose Fin Clip (Y/N)	Eggs Present (Y/N)	Location/Comments
12/3/99	1	U	U	U	U	50 feet upstream of Miller Creek confluence
	2	Coho	M	Y	-	20 feet upstream of 2nd wood foot bndge at Normandy Park Cove
	3	U	U	U	U	Adjacent to Normandy Park Cove parking area
	4	U	U	U	U	Adjacent to Normandy Park Cove parking area
	5	Coho	F	N	Y	Adjacent to Normandy Park Cove tennis courts
	6	U	U	U	U	Adjacent to Normandy Park Cove tennis courts
	7	Coho	F	Y	Y	Upstream edge of Normandy Park Cove tennis courts
	8	Coho	M	U	-	Upstream edge of Normandy Park Cove tennis courts
	9	U*	U	U	U	Downstream of 13th Ave. bridge; live fish
12/4/99	10	U	U	U	U	Upstream of 13th Ave. bridge, residential area
	11	U	U	U	U	Upstream of 13th Ave. bridge, in braided log jam area
	12	U	U	U	U	Upstream of 13th Ave. bridge, in braided log jam area
	13	Coho	M	U	-	GPS point N47 26 47.2, W122 20 58.7; residential area upstream of 13th Ave. bridge
	14	U	F	U	Y	100 feet upstream of fish #12; residential area upstream of 13th Ave. bridge
	15	Coho	M	Y	-	110 feet upstream of fish #12; residential area upstream of 13th Ave. bridge
	16	U	U	U	U	Residential area upstream of 13th Ave. bridge
	17	Coho	F	Y	Y (100%)	Residential area upstream of 13th Ave. bridge/adipose missing
	18	Coho	M	Y	-	Adjacent to driveway parallel to creek in residential area upstream of 13th Ave. bridge
	19	U	U	U	U	Location where creek turns NE away from driveway that parallels creek
	20	Coho	M	Y	-	Location where creek turns NE away from driveway that parallels creek
	21	Coho	F	Y	Y (10%)	Location where creek turns NE away from driveway that parallels creek
	22	Coho	F	Y	Y (10%)	Location where creek turns NE away from driveway that parallels creek
	23	U	U	U	U	GPS point N47 26 44.2, W122 20 53.6
	24	Coho	U	U	U	GPS point N47 26 44.2, W122 20 53.6; LIVE FISH
	25	Coho	M	N	-	Walker Preserve
	26	U	U	U	U	Walker Preserve
	27	U	U	U	U	Walker Preserve
	28	U	F	U	Y	Walker Preserve
	29	U	F	U	Y	Walker Preserve
	30	U	F	U	Y	Walker Preserve
	31	Coho	M	N	-	Walker Preserve
	32	U	U	U	U	Walker Preserve
	33	Coho	M	N	-	Walker Preserve
	34	Coho	M	Y	-	Walker Preserve
	35	Chum	M	N	-	Adjacent to first house in residential area upstream of Walker Preserve
	36	Coho	F	Y	Y (5%)	Residential area upstream of Walker Preserve
	37	Coho	F	N	Y (5%)	Residential area upstream of Walker Preserve
	38	U	U	U	U	Upstream of large concrete retaining wall in residential area
	39	Coho	M	Y	-	Residential area adjacent to creek/adipose clipped
	40	U	U	U	U	100 feet upstream of 1st Ave. S retaining wall
	41	U	U	U	U	Location where creek heads west away from 1st Ave. S
	12/5/99	42	Coho	F	Y	Y (5%)

Walker Creek surveyed between confluence with Miller Creek and 1st Ave. S. culvert.

Note: \* One live fish observed in shallow sandy pool downstream of 13th Ave. Bndge at tributary inflow; fish unidentifiable.

**Table 3-12  
Des Moines Creek Carcass Survey**

Date	Fish No.	Species	Sex (M/F)	Adipose Fin Clip (Y/N)	Eggs Present (Y/N)	Location/Comments
12/3/99	1	Coho	M	N	-	150 feet upstream of footbridge at creek mouth, Des Moines Beach park
	2	Coho	M	N	-	160 feet upstream of footbridge at creek mouth, Des Moines Beach park
	3	Coho	F	Y	Y	50 feet upstream of Red Building over creek, 50 feet downstream of parking lot bridge/adipose missing
	4	Coho	M	N	-	100 feet upstream of parking lot bridge, adjacent to Sun Home Lodge
	5	Coho	M	N	-	100 feet upstream of parking lot bridge, adjacent to Sun Home Lodge
	6	Chum	F	N	Y (20%)	25 feet downstream of Marine View Drive culvert, east channel
	7	Coho*	U	U	U	50 feet downstream of Marine View Drive culvert
	8	Coho*	U	U	U	50 feet downstream of Marine View Drive culvert
	9	Chum*	U	U	U	50 feet downstream of Marine View Drive culvert

*Des Moines Creek surveyed between mouth and Marine View Drive concrete culvert.*

*Note: Observed 3 live fish\* in small pool approximately 50 feet downstream of Marine View Drive culvert.  
2 appear to be coho salmon and 1 may be chum salmon.*

**Table 3-13  
Miller Creek Juvenile Fish Survey**

Station	Fish	Species	Fork Length (mm)	Station Description
1	1-1	Cutthroat	220*	Approximately 150 feet downstream of confluence with Walker Creek adjacent to Normandy Park Cove lawn area, plunge pool below deadfall log; sample area is 28 by 14 feet; thalweg depth is 24 inches; substrate is 50% gravel and cobble (plunge pool and thalweg) and 50% sand (left bank back eddy)
	1-2	Cutthroat	186	
	1-3	Coho	40	
	1-4	Coho	41	
2	2-1	Coho	37	Approximately 100 yards downstream of 13th Avenue, downstream of private lawn area; sample area is 22 by 12 feet; thalweg is 22 inches deep; substrate is primarily sand and silt with small amount of gravel
	2-2	Coho	50	
	2-3	Coho	46	
	2-4	Coho	41	
	2-5	Coho	37	
	2-6	Coho	48	
	2-7	Coho	39	
	2-8	Coho	37	
3	3-1	Cutthroat	108	Upstream of Mr. Fish's property near large fallen cedar; sample area 15 by 10 feet; thalweg is 24 inches deep; substrate is primarily gravel and cobble with 20% sedimentation
4	4-1	Coho	32	Downstream portion of Walker Preserve; sample area is backwater area, 4 by 3 feet; thalweg is 6 inches deep; substrate is cobble and boulder with approximately 15% sedimentation (fish captured with dipnet)
5	5-1	Cutthroat	91	Residential area upstream of Walker Preserve; sample location is slackwater pool below deadfall log; area is 20 by 10 feet; thalweg is 24 inches deep; substrate is 100% silt and sand
	5-2	Cutthroat	96	
	5-3	Cutthroat	95	
	5-4	Cutthroat	94	
	5-5	Cutthroat	90	
	5-6	Cutthroat	92	
	5-7	Cutthroat	94	
	5-8	Cutthroat	103	
	5-9	Cutthroat	94	
	5-10	Cutthroat	104	
	5-11	Cutthroat	101	
	5-12	Cutthroat	90	
	5-13	Cutthroat	101	
	5-14	Cutthroat	95	
5-15	Cutthroat	103		
6	6-1	Cutthroat	102	Residential area upstream of Walker Preserve; sample location is plunge pool upstream of large hardpan clay slackwater area; area is 15 by 10 feet; thalweg is 20 inches deep; substrate is 50% gravel, 20% cobble, 5% boulder, and 25% silt and sand
	6-2	Cutthroat	129	
	6-3	Cutthroat	131	
7	7-1	Coho	28	Confluence with small tributary (0.5 cfs) approximately 1/4 mile downstream of the First Avenue South retaining wall; sample location is small slackwater pool; area is 1 by 1 foot; thalweg is 4 inches deep; substrate is mostly cobble with 20% sedimentation
	7-2	Coho	34	
	7-3	Coho	26	
	7-4	Coho	27	

**Table 3-14  
Walker Creek Juvenile Fish Survey**

Station	Fish	Species	Fork Length (mm)	Station Description
1	1-1	Coho	35	Downstream of 13th Avenue culvert; sample area 15 by 20 feet; thalweg is 12 inches deep; substrate is gravel and cobble with approximately 25% sand
	1-2	Coho	35	
	1-3	Coho	26	
2	2-1	Coho	40	Upstream of 13th Avenue, adjacent to dead end road/driveway; sample area 15 by 5 feet; thalweg is 9 inches deep; substrate is primarily sand and silt with small amount of gravel
	2-2	Coho	36	
	2-3	Coho	40	
	2-4	Coho	32	
	2-5	Coho	35	
	2-6	Coho	37	
	2-7	Coho	39	
	3	3-1	Cutthroat	
4	4-1	Coho	42	Downstream portion of Walker Preserve ; sample area is 11 by 6 feet; thalweg is 11 inches deep; substrate is primarily cobble and gravel with approximately 25% sand
5	5-1	Cutthroat	97	Residential area upstream of Walker Preserve; sample location is upstream of private foot bridge; area is 14 by 5 feet; thalweg is 11 inches deep; substrate is 2-5 inch cobbles with approximately 30% sedimentation; right bank is hard pan clay, left bank is rip rap
6	6-1	Coho	38	Small plunge pool created by deadfall log with center notch for water flow in residential area upstream of Walker Preserve; sample area 8 by 5 feet; thalweg is 12 inches deep; substrate primarily sand and silt with 10% gravel and 10% cobble
7	7-1	Coho	42	Residential area approximately 200 yards downstream of the First Avenue South retaining wall; sample location is adjacent to lawn; area is 9 by 6 feet; thalweg is 22 inches deep; substrate is 90% silt, 5% gravel, and 5% cobble  Note: 28 additional age-0 coho captured and released without anesthetic or length measurement.
	7-2	Coho	42	
	7-3	Coho	43	
	7-4	Coho	45	
	7-5	Coho	33	
	7-6	Coho	39	
	7-7	Coho	41	
	7-8	Coho	40	
	7-9	Coho	41	
	7-10	Coho	42	
	7-11	Coho	42	
	7-12	Coho	45	
	7-13	Coho	32	
	7-14	Coho	34	
	7-15	Coho	40	
	7-16	Coho	43	
	7-17	Coho	41	
7-18	Coho	34		
7-19	Coho	38		
7-20	Coho	32		
8	8-1	Cutthroat	91	Downstream of South 176th St., adjacent to cedar tree and lawn area; sample area is 14 by 6 feet; thalweg is 28 inches; substrate is 100% silt and sand

**Table 3-15**  
**Des Moines Creek Juvenile Fish Survey**

Station	Fish	Species	Fork Length (mm)	Station Description
1	1-1	Coho	35	Approximately 200 yards downstream of Marine View Drive retaining wall; sample area is 30 by 10 feet; thalweg is 6 inches deep; substrate is cobble and gravel with 20% sedimentation
	1-2	Cutthroat	111	
2	2-1	Coho	34	Approximately 170 yards downstream of Marine View Drive retaining wall; sample location is small slackwater pool downstream of a series of boulders; area is 4 by 3 feet; thalweg is 12 inches deep; substrate is 70% cobble, 10% gravel, and 20% sand
	2-2	Coho	38	
	2-3	Coho	34	
	2-4	Coho	38	
	2-5	Coho	36	

**Table 3-16**

**Walker Creek Rapid Bioassessment Results<sup>1</sup>**

Characteristic	Parameter	Station 1 Rkm 0.2	Station 2 Rkm 0.7	Station 3 Rkm 1.4	Station 4 Rkm 2.2	Station 5 Rkm 2.8
Water Quality	Temperature (C)	7.6	6.5	7.1	7.2	7.6
	pH	7.88	7.71	7.7	7.88	7.76
	Dissolved Oxygen (mg/L)	12.14	13.32	12.78	12.42	12.41
	Turbidity (NTU)	5	88	4	6	4
	Conductivity (mS/cm)	0.2	0.258	0.234	0.213	0.202
Substrate (% composition)	Bedrock	0	0	3	0	2.5
	Boulder (>256 mm)	0	0	25	0	2.5
	Cobble (64-256 mm)	0	2.5	30	0	0
	Gravel (2-64 mm)	30	35	30	0	5
	Sand (0.06-2 mm/gritty)	65	60	12	90	90
	Silt (0.004-0.06 mm)	5	2.5	0	10	0
	Clay (<0.004 mm/slick)	0	0	0	0	0
Habitat <sup>2</sup>	Epifaunal Substrate/ Cover	14	12	14	4	9
	Pool Substrate (Embeddedness)	16	16	18	8	7
	Pool Variability (Velocity/ Depth Regime)	15	7	15	12	13
	Sediment Deposition	9	7	13	5	4
	Channel Flow Status	12	13	14	19	19
	Channel Alteration	9	15	20	14	7
	Channel Sinuosity (Frequency of Riffles)	4	5	17	5	4
	Bank Stability (L/R)	5/6	7/8	9/7	8/7	9/6
	Vegetative Protection (L/R)	4/7	7/7	9/8	9/6	7/4
	Riparian Vegetation Width (L/R)	1/9	9/5	10/10	10/2	6/2
	Total Score	111	118	164	109	97

1 = *Methods follow Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA 1999).*

2 = *Initial habitat parameter is for Low Gradient Stream; habitat parameter in parenthesis has been modified for High Gradient Streams. Station 3 is the only high gradient stream section sampled on Walker Creek. Values presented are on a scale of 1-20 with the following categories: 0-5 (poor), 6-10 (marginal), 11-15 (suboptimal), and 16-20 (optimal).*

C = *Celcius.*

mg/L = *Milligrams per liter.*

mm = *Millimeter.*

mS/cm = *Microsiemens per centimeter.*

NTU = *Nephelometric Turbidity Unit.*

Rkm = *River kilometer.*

**Table 3-17**  
**Miller Creek HSPF Water Volume Comparison**

Upper Gage (below Lake Reba)

Water Year	Observed Flow (inches)	Simulated Flow** (inches)	Difference (percent)
1993	6.49	9.44	45.45
1994*	4.23	5.86	38.53
1995*	7.81	11.75	50.45
1996	<u>16.35</u>	<u>19.46</u>	<u>19.02</u>
Total	34.88	46.51	33.34

Lower Gage (near mouth)

Water Year	Observed Flow (inches)	Simulated Flow** (inches)	Difference (percent)
1993	14.78	22.14	49.80
1994*	13.47	15.94	18.34
1995*	20.53	22.42	9.21
1996	<u>36.27</u>	<u>40.44</u>	<u>11.50</u>
Total	85.05	100.94	18.87

\*Volumes adjusted to account for missing data due to gage malfunction.

\*\*Simulated flow from MILL-C calibration model

**Table 3-18  
Miller and Walker Creeks HSPF Model Area Summary**

Total area by soil type							
Model Scenario	Model Name	Till (acre)	Outwash (acre)	Fill (acre)	Wetland (acre)	Impervious (acre)	Total Area (acre)
Calibration	MILL-C	1570.8	2226.6	79.2	99.7	1116.5	5092.8
Predeveloped	MILL-PRE	2345.2	2170.6	0.0	96.1	514.3	5126.2
Land use 94	MILL94	1515.5	2225.7	45.5	108.8	1114.1	5009.6
Land use 04	MILL04	1377.4	2101.2	210.8	94.3	1205.6	4989.3

Percent total area by soil type

Model Scenario	Model Name	Till (percent)	Outwash (percent)	Fill (percent)	Wetland (percent)	Impervious (percent)
Calibration	MILL-C	30.8	43.7	1.6	2.0	21.9
Predeveloped	MILL-PRE	45.7	42.3	0.0	1.9	10.0
Land use 94	MILL94	30.3	44.4	0.9	2.2	22.2
Land use 04	MILL04	27.6	42.1	4.2	1.9	24.2



**Table 3-19**  
**Effects of Model Limitations on Flow Control Facilities**

Basin	Model Limitation	Effect on Facility Requirements
All	Does not consider storage existing in the watershed to attenuate low-development condition flows	Increases target flow rates and reduces apparent size of flow control facilities needed to meet target flow rates
All	FTABLE inaccuracies	Not determined
Miller Creek	Groundwater supply to stream flow represented by constant flow rate time series	Masks the effect of changes in groundwater recharge upon base flows in stream/reduces apparent need for maintaining low flows
Miller Creek	Inconsistent DEEPFR parameter settings	Not determined, as settings vary widely between model scenarios
Miller Creek	Inconsistent soil type distributions across watershed	Reducing the area of outwash soils in the target flow scenario increases target flow rates and reduces apparent size of flow control facilities needed
Miller Creek	Total watershed area reduced by 2.7 percent from target flow regime model to 2004 conditions model	Reduces peak storm flows and volumes, thereby reducing apparent size of flow control facilities needed to meet target flow rates
Walker Creek	Runway fill not reflected in land use for 2004 conditions model	Reduces peak storm flows and volumes, thereby reducing apparent size of flow control facilities needed to meet target flow rates
Des Moines Creek	Does not use Tyee Pond rain gage data for lower portion of watershed	May increase peak flows in lower reaches of creek, creating apparent need for larger RDF to limit peak flow rates
Des Moines Creek	Inconsistent DEEPFR parameter settings	Reducing DEEPFR setting from calibration (0.9) to 2004 scenario (0.8) model increases groundwater available to supply stream and reduces apparent effect to base flows
Des Moines Creek	Total watershed area reduced by 7 percent from calibration model to 2004 model	Reduces peak storm flows and volumes, thereby reducing apparent size of flow control facilities needed to meet target flow rates

**Table 3-20  
Septic Discharge Calculations**

Middle Reach of Miller Creek			
Total number of septic systems decommissioned	380		
Buy-out area contributory to middle Miller Creek	50%		
Typical septic discharge per person	80	gpd	
Persons per household	2.5		
Percent of water supply that becomes secondary recharge	87%		Solly and others, 1993
Estimated average daily discharge in middle Miller Creek basin	33,060	gpd	
Potential contribution to baseflow in middle Miller Creek	1	cfd/f	
Total Buy-Out Area			
Total number of septic systems decommissioned	380		
Buy-out area contributory	100%		
Typical septic discharge per person	80	gpd	
Persons per household	2.5		
Percent of water supply that becomes secondary recharge	87%		Solly and others, 1993
Estimated average daily discharge	66,120	gpd	
Area of the buy-out area	12972434	ft <sup>2</sup>	
Equivalent septic R inches over the buy-out area	3	inches	

**Table 3-21  
Comparison of Watershed Land Use Coverage**

Land Use Type	Miller Creek/Walker Creek Watershed					
	Table F-2 1994 Existing Conditions (acres)	HSPF Model MILL94 1994 Conditions (acres)	Difference in Existing Conditions (acres)	Table F-2 2004 Proposed Conditions (acres)	HSPF Model MILL04 2004 Conditions (acres)	Difference in Proposed Conditions (acres)
Till (forest + grass)	1886.8	1515.5	-371.3	1771.1	1377.4	-393.7
Outwash (forest + grass)	1823.3	2225.7	402.4	1688.4	2101.2	412.8
Fill	79.2	45.5	-33.7	225.7	210.8	-14.9
Wetland	99.7	108.8	9.1	96.6	94.3	-2.3
Effective Impervious Area	1202.2	1114.1	-88.1	1313.0	1205.6	-107.4
Total	5091.2	5009.6	-81.6	5094.8	4989.3	-105.5

**Des Moines Creek Watershed**

Land Use Type	Des Moines Creek Watershed					
	Table F-2 1994 Existing Conditions (acres)	HSPF Model DM94 1994 Conditions (acres)	Difference in Existing Conditions (acres)	Table F-2 2004 Proposed Conditions (acres)	HSPF Model DM04 2004 Conditions (acres)	Difference in Proposed Conditions (acres)
Till (forest + grass)	1085.7	1088.3	2.6	1011.2	1001.8	-9.4
Outwash (forest + grass)	864.9	870.4	5.5	851.3	850.9	-0.4
Fill	408.3	542.0	133.7	332.8	326.1	-6.7
Wetland	56.7	52.4	-4.3	56.7	50.4	-6.3
Effective Impervious Area <sup>1</sup>	1409.2	1413.9	4.7	1568.7	1642.6	73.9
Total	3824.8	3967.0	142.2	3820.7	3871.8	51.1

<sup>1</sup> EIA in Des Moines Creek watershed includes areas tributary to the IWS

**Table 3-22**

**Summary of Impacts to Wetlands within Miller Creek Watershed from the Proposed Third Runway**

	Forested		Scrub-shrub		Emergent		Total	
	Perm.	Temp.	Perm.	Temp.	Perm.	Temp.	Perm.	Temp.
Slope	2.34	0.56	1.00	0.13	1.10	0.05	4.44	0.74
Slope/Riparian	4.16	0.68	0.52	0.17	2.00	0.22	6.68	1.07
Depression	0.1	0.00	0.04	0.00	1.75	0.00	1.89	0.00
Depression/Riparian	0.09	0.01	0.09	0.01	0.56	0.03	0.74	0.05
Riparian	0	0	0	0	0.13	0.00	0.13	0.00
<b>Total</b>	<b>6.69</b>	<b>1.25</b>	<b>1.65</b>	<b>0.31</b>	<b>5.54</b>	<b>0.30</b>	<b>11.93</b>	<b>1.86</b>

*Perm. = permanent*  
*Temp. = temporary*

**Table 3-23**

**Wetland Fill Impacts Associated with the Proposed Third Runway**

Wetland	Classification	Total Wetland Size	Fill Effect	Temporary/ (Secondary) Effect	Vegetation Types Effected		
					PFO	PSS	PEM
<b>Miller Creek Watershed Runway Safety Area</b>							
3	Slope	0.56		0.05	-/0.05	-	-
4	Slope	5.00		0.10	-/0.10	-	-
5	Slope	4.63	0.14	0.10	0.07/0.10	0.07	-
<b>New Third Runway</b>							
9	Slope	2.83	0.03	0.03	0.01/0.01	-	0.02/0.02
11	Slope	0.50	0.02	0.13 (0.01)	0.07/0.10	-	0.07/0.03
12	Slope		0.21		0.04	-	0.17
13	Slope		0.05		-	-	0.05
14	Slope		0.19		0.19	-	-
15	Slope		0.28		-	-	0.28
16	Depression		0.05		-	-	0.05
17	Depression		0.02		-	-	0.02
18	Slope/Riparian	3.56	2.60	0.36 (0.60)	0.07/0.10	0.52/0.67	0.78/0.11
19	Slope		0.06		0.06	-	-
20	Slope		0.07		-	0.01	0.06
21	Slope		0.22		0.22	-	-
22	Slope		0.06		-	0.01	0.05
23	Depression		0.77		-	-	0.77
24	Depression		0.14		-	-	0.14
25	Depression		0.06		0.06	-	-
26	Depression		0.02		-	-	0.02
W1	Depression		0.10		-	-	0.10
W2	Depression		0.22		0.04	-	0.18
35 and 37	Slope	5.76	4.03	0.71 (0.97)	0.05/0.05	-/0.10	0.22/0.11
40	Depression		0.03		-	0.03	-
41a and b	Depression		0.16		-	-	0.16
44a and b	Slope	0.02	0.26	0.30	0.16/0.20	0.05/0.10	-
A1	Depression/Riparian	2.51	0.35	0.03	0.09/0.01	0.09/0.01	0.21/0.02
A4	Riparian						
A5	Depression		0.03		-	-	0.03
A6	Slope		0.16		0.16	-	-
A7	Slope		0.30		0.30	-	-
A8	Slope		0.30		0.07	0.3	-
A12	Slope	0.11	0.02	0.03(0.06)	-	0.02/0.03	-
A18	Depression		0.01		-	0.01	-
FW5 and 6	Depression/Riparian		0.15		-	-	0.15
R1	Riparian	0.17	0.13	0.04	-	-	0.13

a - All effects presented in acres.

PFO- Palustrine Forested  
PEM - Palustrine emergent

PSS - Palustrine scrub shrub

**Table 4-1  
Wetlands Potentially Impacted by Borrow Areas Associated with the Proposed Third Runway<sup>1</sup>**

Wetland	Classification	Total Wetland Size	Brief Wetland Description	Ecology Class	Qualitative Assessment
<b>Borrow Area 1</b>					
28	Depression Riparian PEM	35.45	Fairway of the Tye Golf Course bounded by the Northwest Ponds	II	H- Resident Fish Populations H- Wildlife populations H-Flood Storage H - Nutrient/Sediment Trapping
48	Slope PEM	1.58	Slope wetland located at the edge of the Borrow area	II	M - Wildlife Populations L-M - Export of Organic Carbon and Nutrient/ Sediment Trapping
B11	Depression PEM	0.18	Abandoned Farm pond	III	L-M - Wildlife Populations M- Nutrient/Sediment Trapping
B12	Slope PFO	0.07	Small ravine	III	M- Wildlife Populations L-M - Export of Organic Carbon and Nutrient/ Sediment Trapping
<b>Borrow Area 2</b>					
B14	Depression PSS	0.78	Depression located at the edge of the Borrow area	III	M - Wildlife Populations L-M - Flood Storage M - Nutrient/Sediment Trapping
B15a and b	Slope PSS	2.05	Hillside slope shrubby drainage which leads to a larger wetland complex outside of the borrow areas	III	M - Wildlife Populations L-M - Export of Organic Carbon and Nutrient/ Sediment Trapping

<sup>1</sup> Does not include Borrow Area 3 wetlands that may receive secondary impacts.

PFO - Palustrine Forested  
PSS - Palustrine Scrub Shrub  
PEM - Palustrine Emergent

L - Low  
M - Moderate  
H - High

Shading represents wetland effects larger than 1/3 acre from airport fill activities.

**Table 4-2**  
**Des Moines Creek HSPF Water Volume Comparison**

Upper Gage 11C (upstream of Tyee pond)

Water Year	Observed Flow (inches)	Simulated Flow* (inches)	Difference (percent)
1994	13.32	12.3	-7.66
1995	21.03	22.84	8.61
1996	<u>34.43</u>	<u>31.8</u>	<u>-7.64</u>
Total	68.78	66.94	-2.68

Lower Gage 11D (near mouth)

Water Year	Observed Flow (inches)	Simulated Flow* (inches)	Difference (percent)
1994	9.2	7.96	-13.48
1995	14.8	16.21	9.53
1996	<u>23.2</u>	<u>22.91</u>	<u>-1.25</u>
Total	47.2	47.08	-0.25

*\*Simulated flow from DM-C calibration model*

**Table 4-3  
Des Moines Creek HSPF Model Area Summary**

Total Area by Soil Type									
Model Scenario	Model Name	Till (acre)	Outwash (acre)	Fill (acre)	Wetland (acre)	Impervious (acre)	Total Area (acre)	IWS (acre)	Basin Total (acre)
Calibration	DM-C	1104.8	870.6	408.3	55.4	1411.0	3850.1	315.3	4165.4
Predeveloped	DM-PRE	2078.8	1223.2	0.0	76.7	375.4	3754.0	0.0	3754.0
Land use 94	DM94	1088.3	870.4	542.0	52.4	1121.9	3675.0	292.0	3967.0
Land use 04	DM04	1001.8	850.9	326.1	50.4	1218.6	3447.9	424.0	3871.9

**Percent Total Area by Soil Type**

Model Scenario	Model Name	Till (percent)	Outwash (percent)	Fill (percent)	Wetland (percent)	Impervious (percent)
Calibration	DM-C	28.7%	22.6%	10.6%	1.4%	36.6%
Predeveloped	DM-PRE	55.4%	32.6%	0.0%	2.0%	10.0%
Land use 94	DM94	29.6%	23.7%	14.7%	1.4%	30.5%
Land use 04	DM04	29.1%	24.7%	9.5%	1.5%	35.3%



**Table 4-4  
Wetland Impacts Associated with the On-Site Borrow Areas<sup>1</sup>**

Wetland	Classification	Total Wetland Size	Fill Effect	Temporary Effect	Vegetation Types Effected		
					PFO	PSS	PEM
<b>Borrow Areas</b>							
28	Depression/ Riparian	35.32	0.07		-	-	0.07
48	Slope	1.58	0.14	0.10	0.03/0.10	-	0.11
B11	Depression		0.18		-	-	0.18
B12	Slope		0.07		--	0.07	-
B14	Depression		0.74			0.55	0.23
B15a and b	Slope	2.05	0.21	0.10	-	0.21/0.1 0	-

<sup>1</sup> Does not include Borrow Area 3 wetlands that may receive secondary impacts.

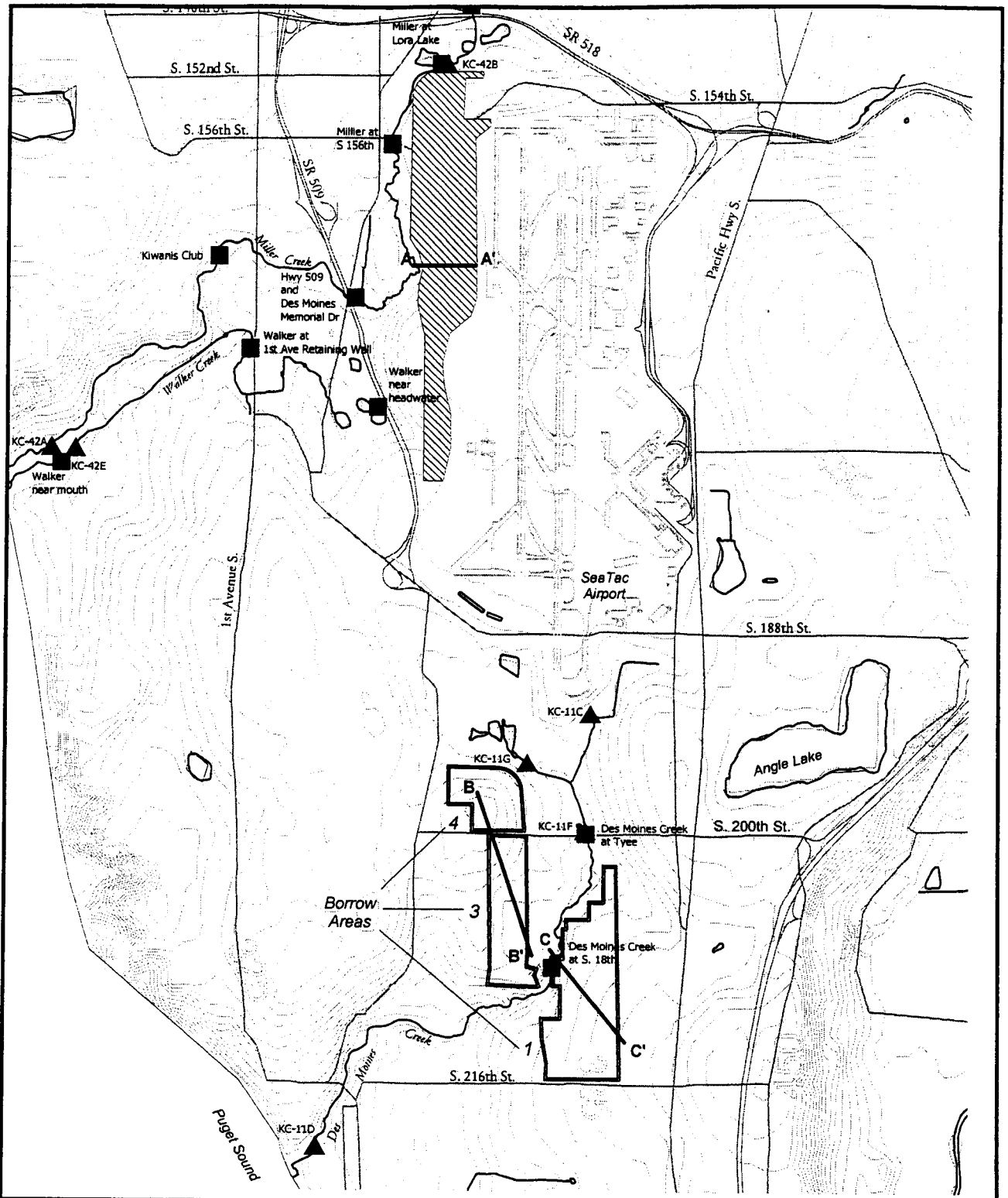
a – all effect totals presented as acres

PFO- Palustrine Forested  
PSS – Palustrine scrub shrub  
PEM- Palustrine emergent






**Table 4-5**  
**Summary of Permanent and Temporary Impacts to Wetlands within Des Moines**  
**Creek Watershed from Proposed Third Runway**

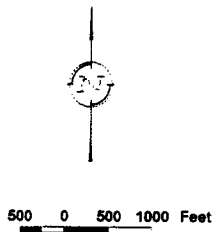
	Forested		Scrub-shrub		Emergent		Total	
	Perm.	Temp.	Perm.	Temp.	Perm.	Temp.	Perm.	Temp.
Slope	0.03	0.10	0.28	0.10	0.11	0.00	0.42	0.20
Depression	0.00	0.00	0.55	0.00	0.41	0.00	0.96	0.00
Depression/Riparian	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.00
Total	0.03	0.10	0.83	0.1	0.59	0.00	1.45	0.20

*Perm.* = permanent  
*Temp.* = temporary



**Legend**

-  Borrow Areas
  -  SeaTac International Airport Structures
  -  Proposed Fill Area
- Stream Gage Stations**
-  King County Station
  -  Pacific Groundwater Group Station

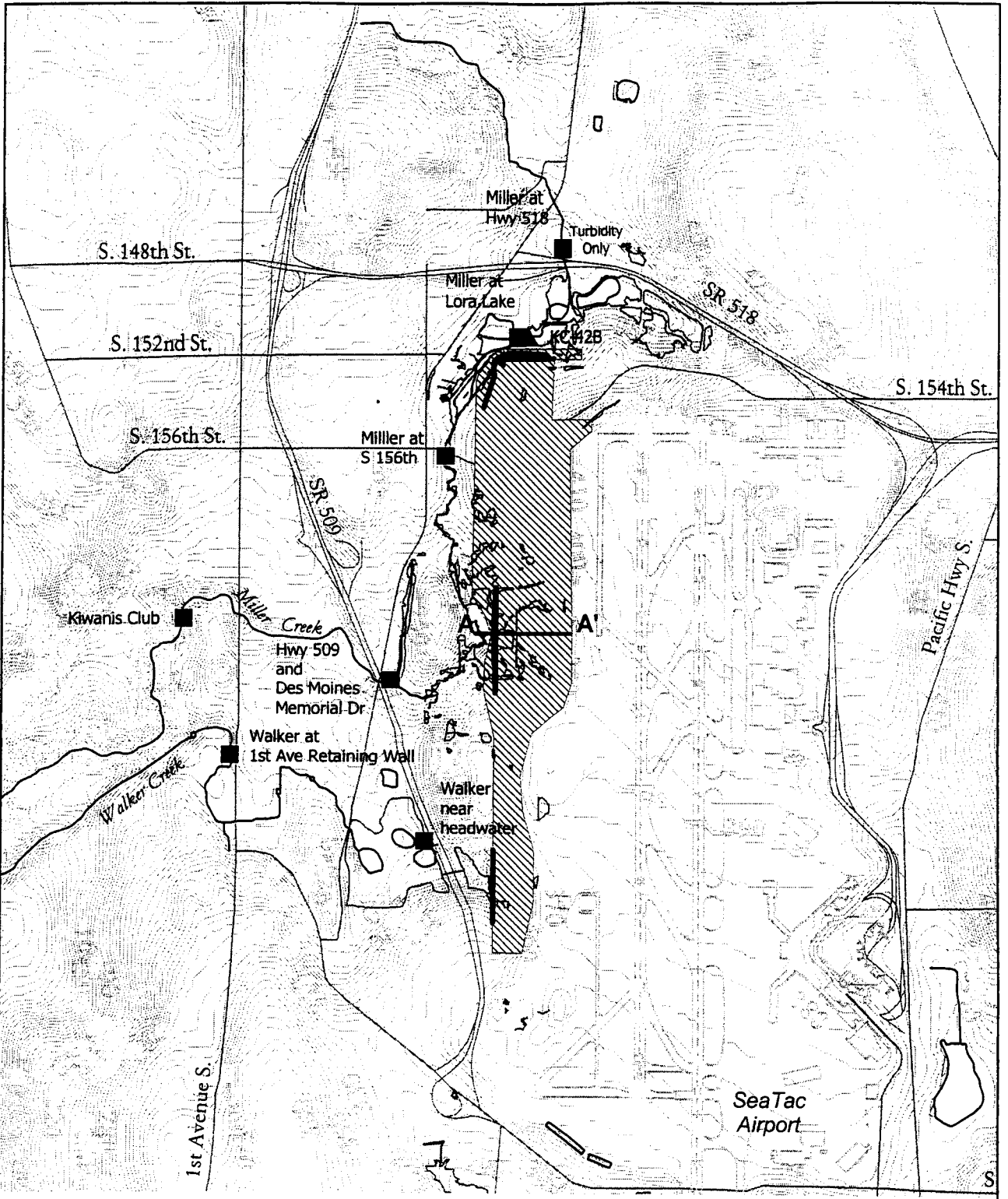


**Figure 2-1**









**Vicinity Plan Showing Fill, Borrow Areas, and Stream Gage Stations**

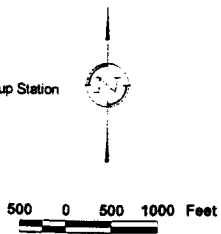
SeaTac Runway Fill  
Hydrologic Studies  
JE9907, old\_seetac\_sesi.apr, 5/2000





**Legend**

-  Proposed Fill Area
  -  Wetlands
  -  SeaTac International Airport Structures
  -  Buyout Area
  -  Cross Section Alignment
  -  Retaining Walls
- Stream Gage Stations**
  -  King County Station
  -  Pacific Groundwater Group Station

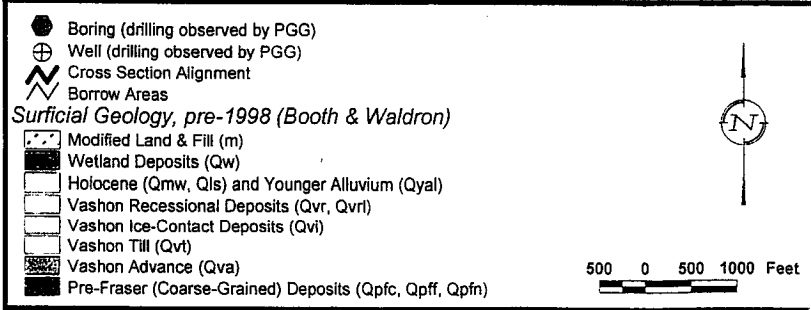
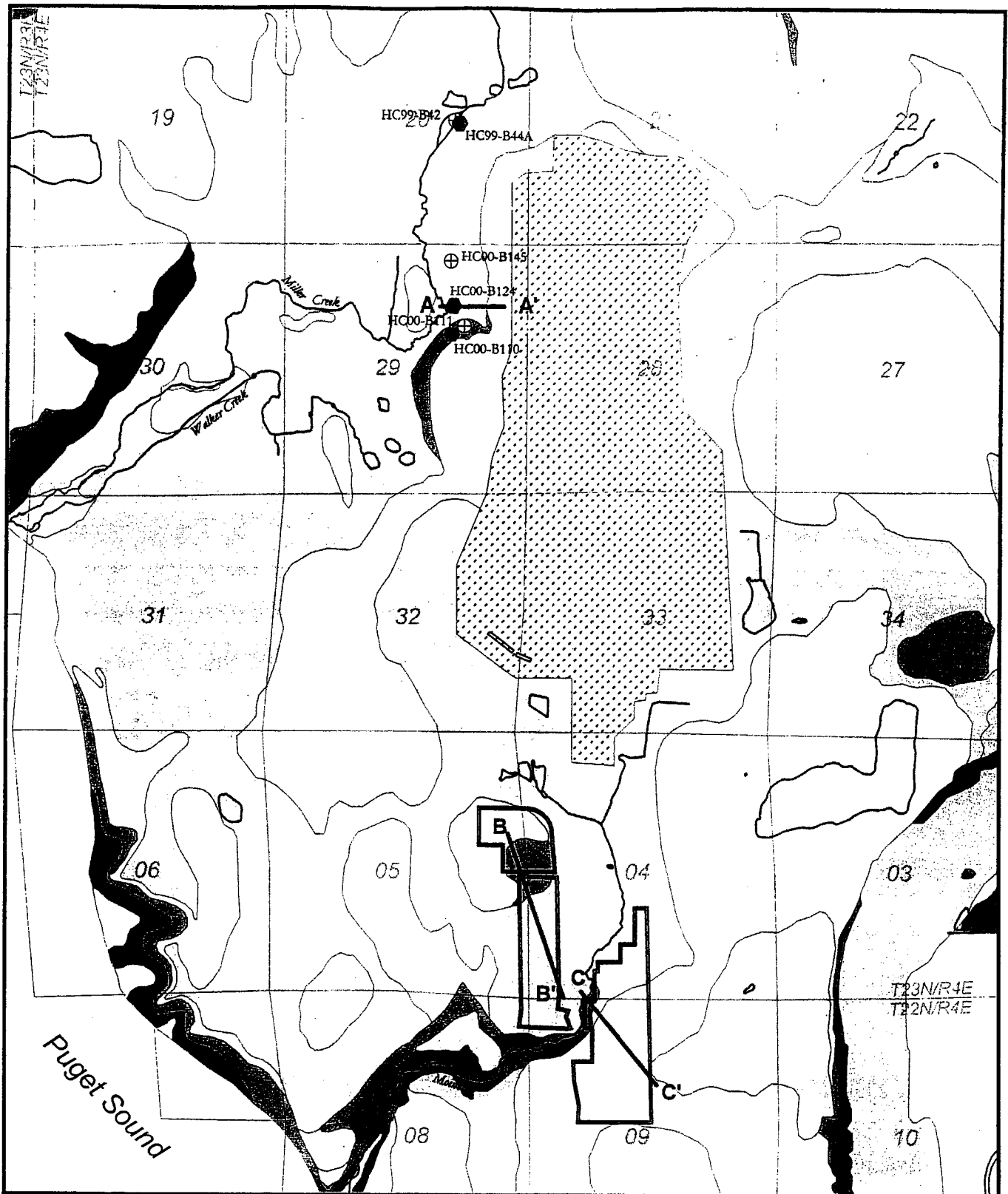


**Figure 3-1**

**Proposed Third Runway Fill Area and Buyout Area**

SeaTac Runway Fill  
Hydrologic Studies  
JE9907, old\_sstac\_aecl.apr. 5/2000





**Figure 3-2**  
**Surficial Geology, Borings,**  
**and Cross Section Alignments**

SeaTac Runway Fill  
 Hydrologic Studies  
 JE9907, old\_seatac\_aesi.apr. 5/2000

**Pacific Groundwater Group**

**Figure 3-4**  
**Recharge Model Results**

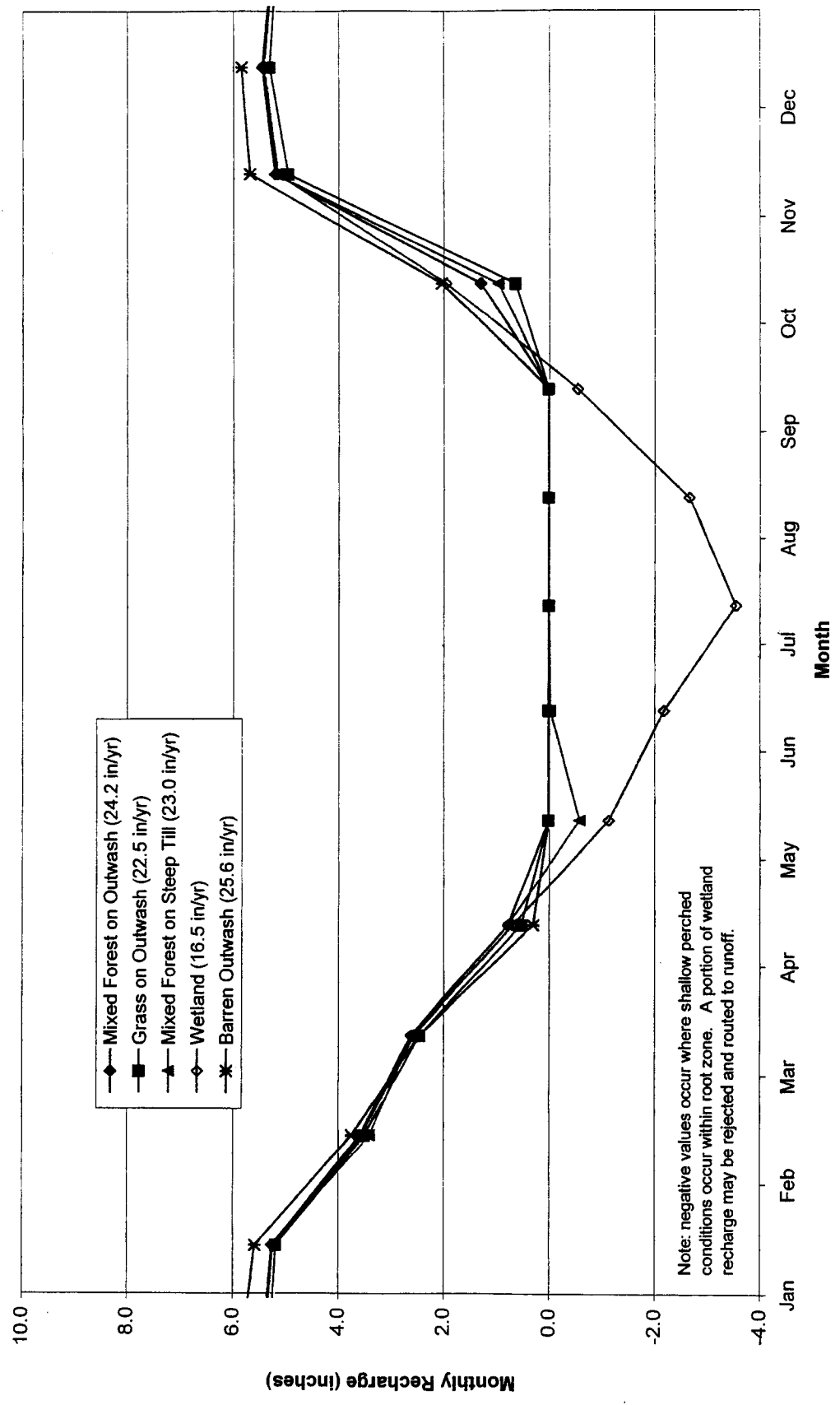
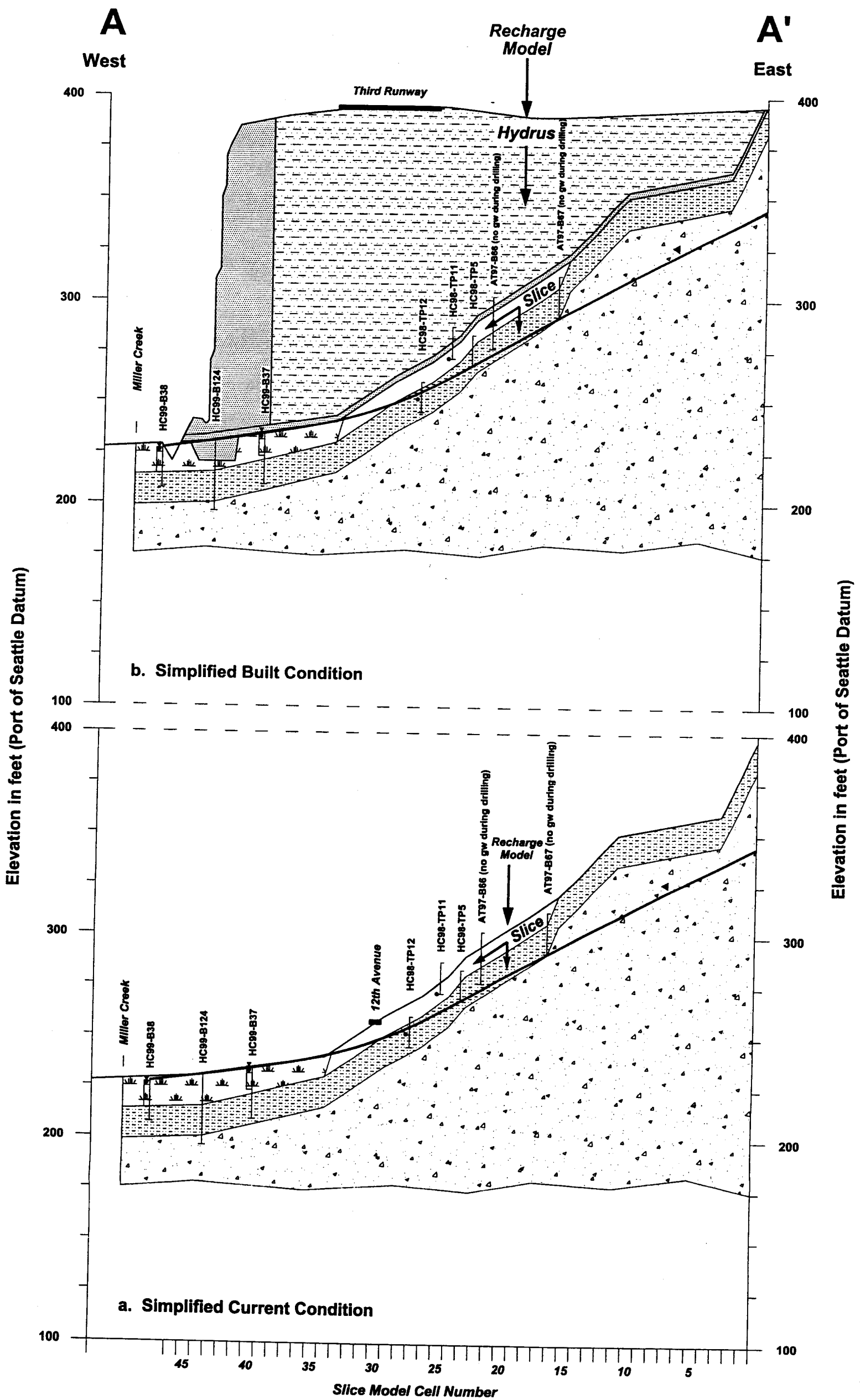
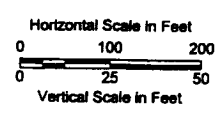


Fig3-4.xls  
6/8/00



**Legend**

- ± Groundwater Elevation (high and low 2/99 - 2/2000)
- Groundwater Seepage Elevation
- ▼ Conceptual Water Table
- [Patterned Box] Type 1 Fill
- [Patterned Box] Type 1 & 2 Fill
- [Patterned Box] Recent Deposits
- [Patterned Box] Qvr - Vashon Recessional
- [Patterned Box] Qvt - Vashon Till
- [Patterned Box] Qva - Vashon Advance



**Figure 3-5**  
**Simplified West Wall**  
**Cross Section for Modeling**

SeaTac Runway Fill  
 Hydrologic Studies  
 JE 9907, RevisedSection.DWG, 5/2000



AR 011741

**Figure 3-3  
Hydrographs**

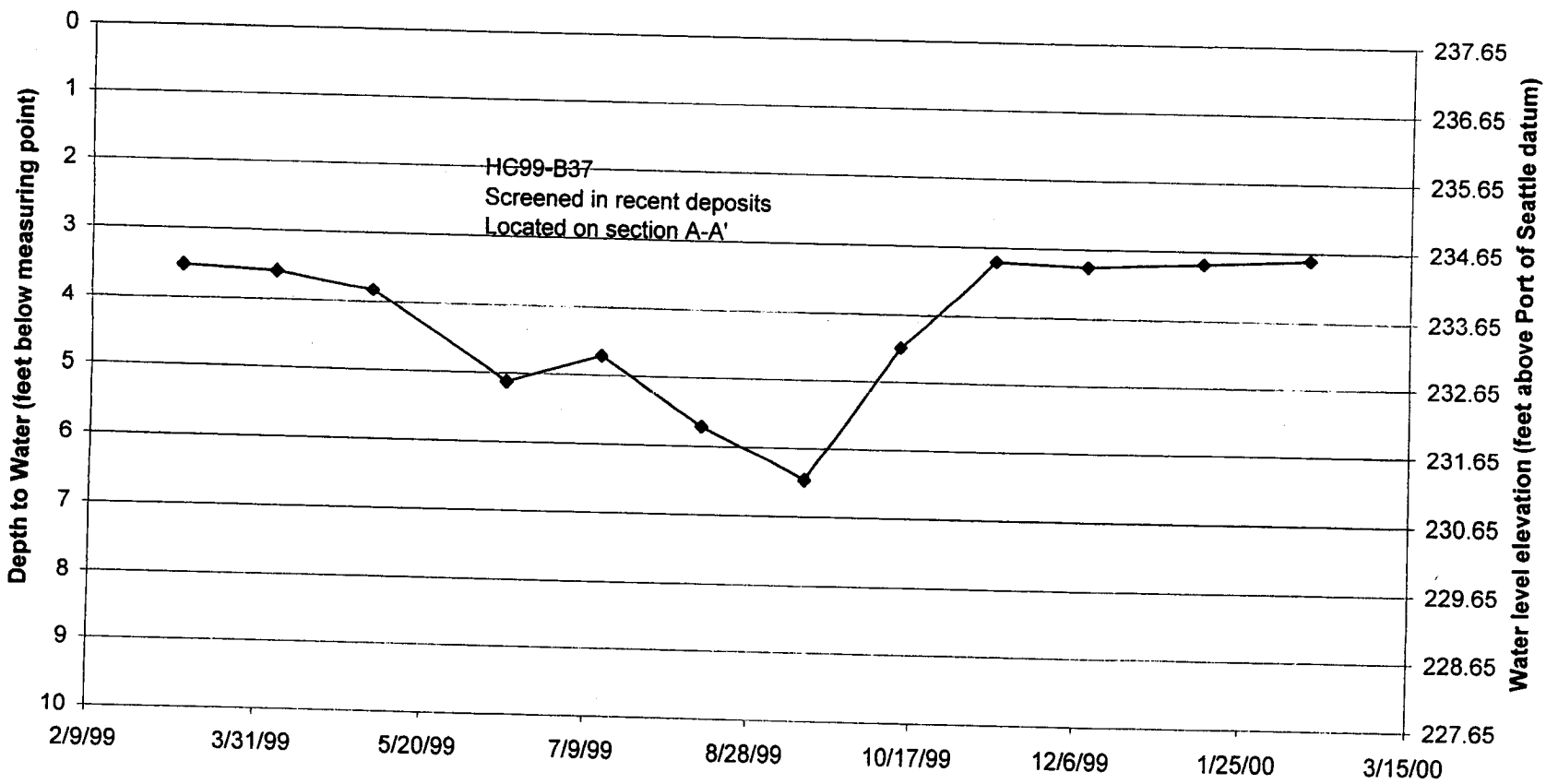
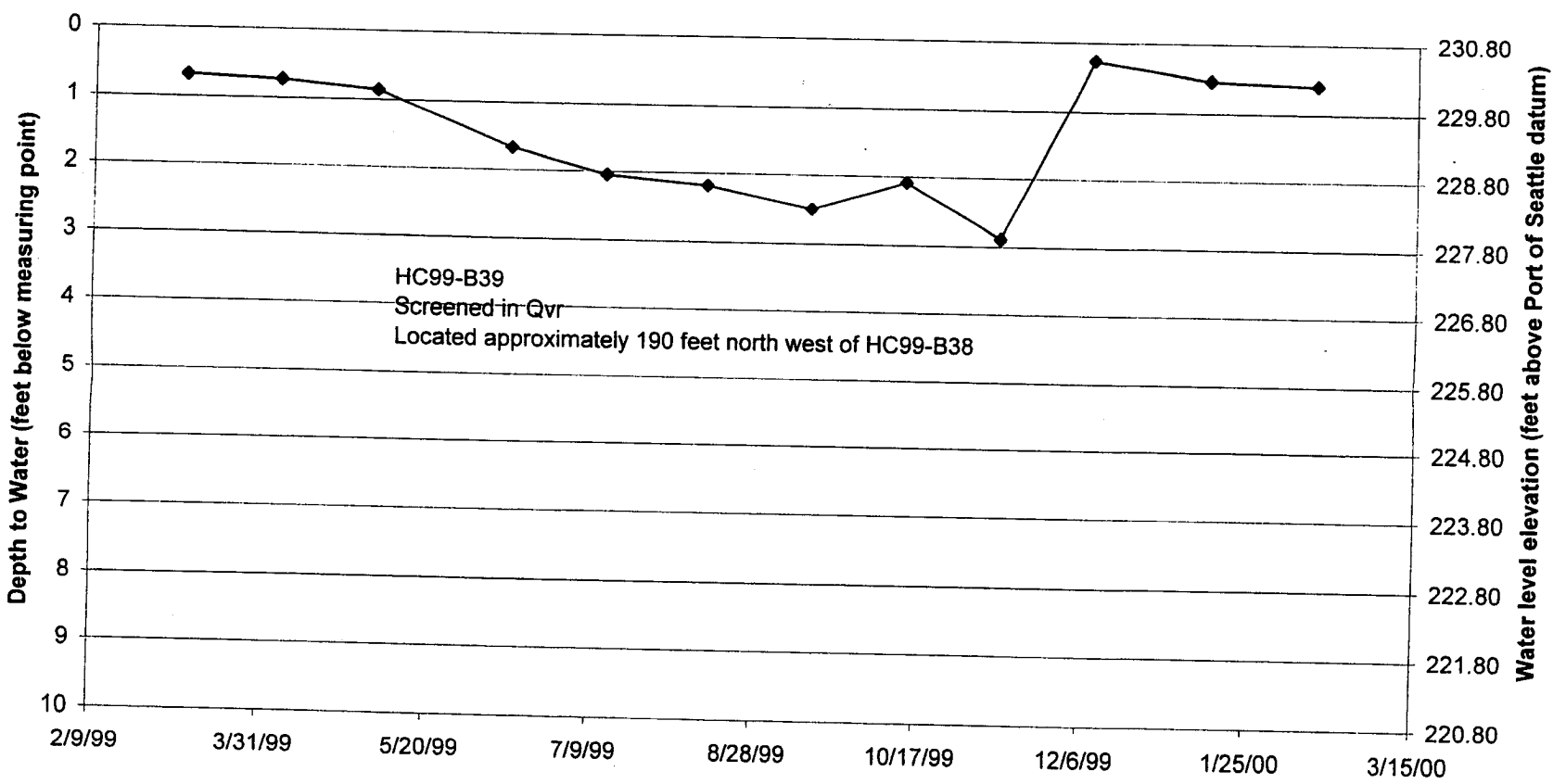
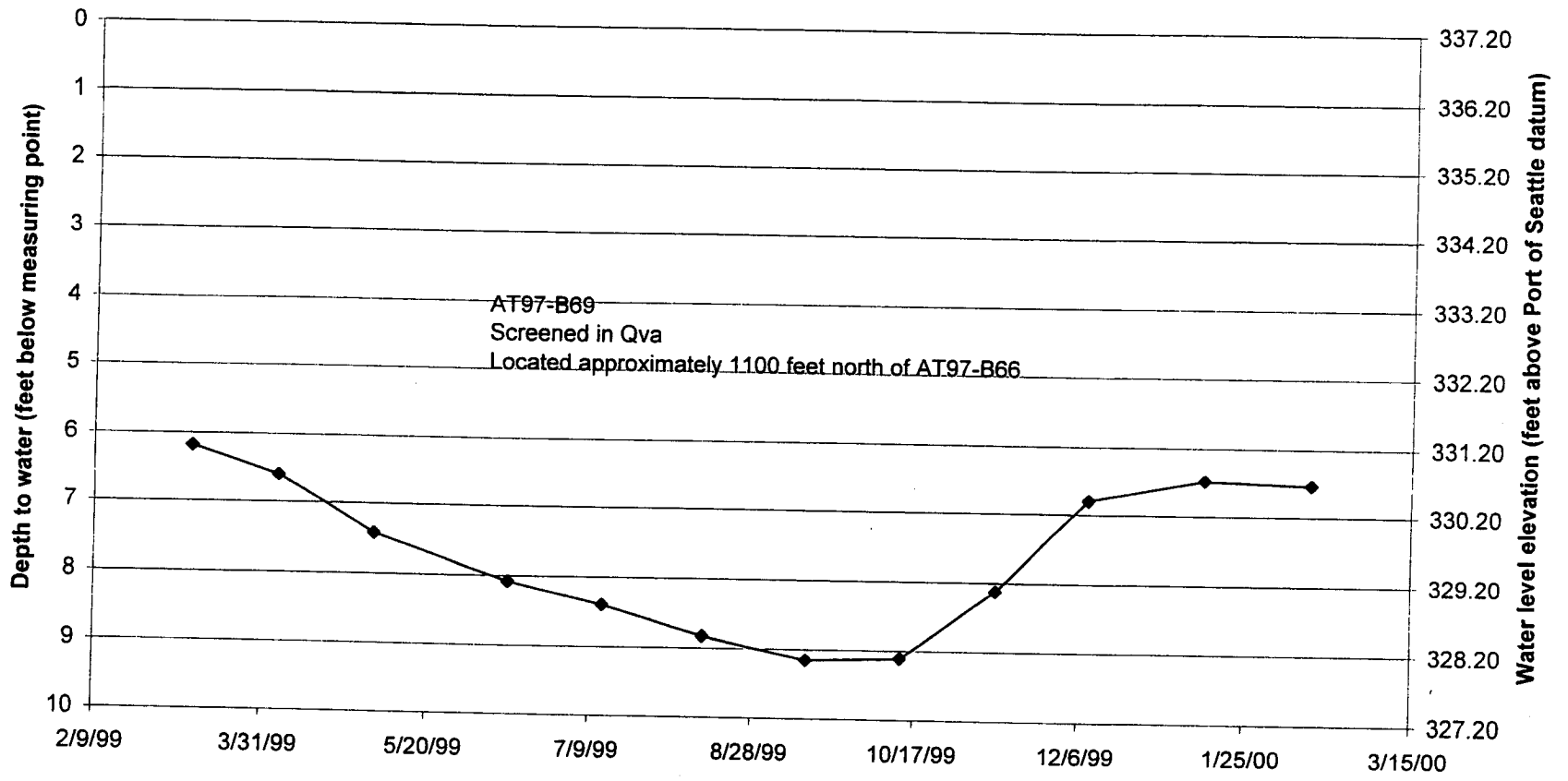


Figure 3-3  
5/12/00



**Figure 3-6  
Results of Slice Model for the Current Condition**

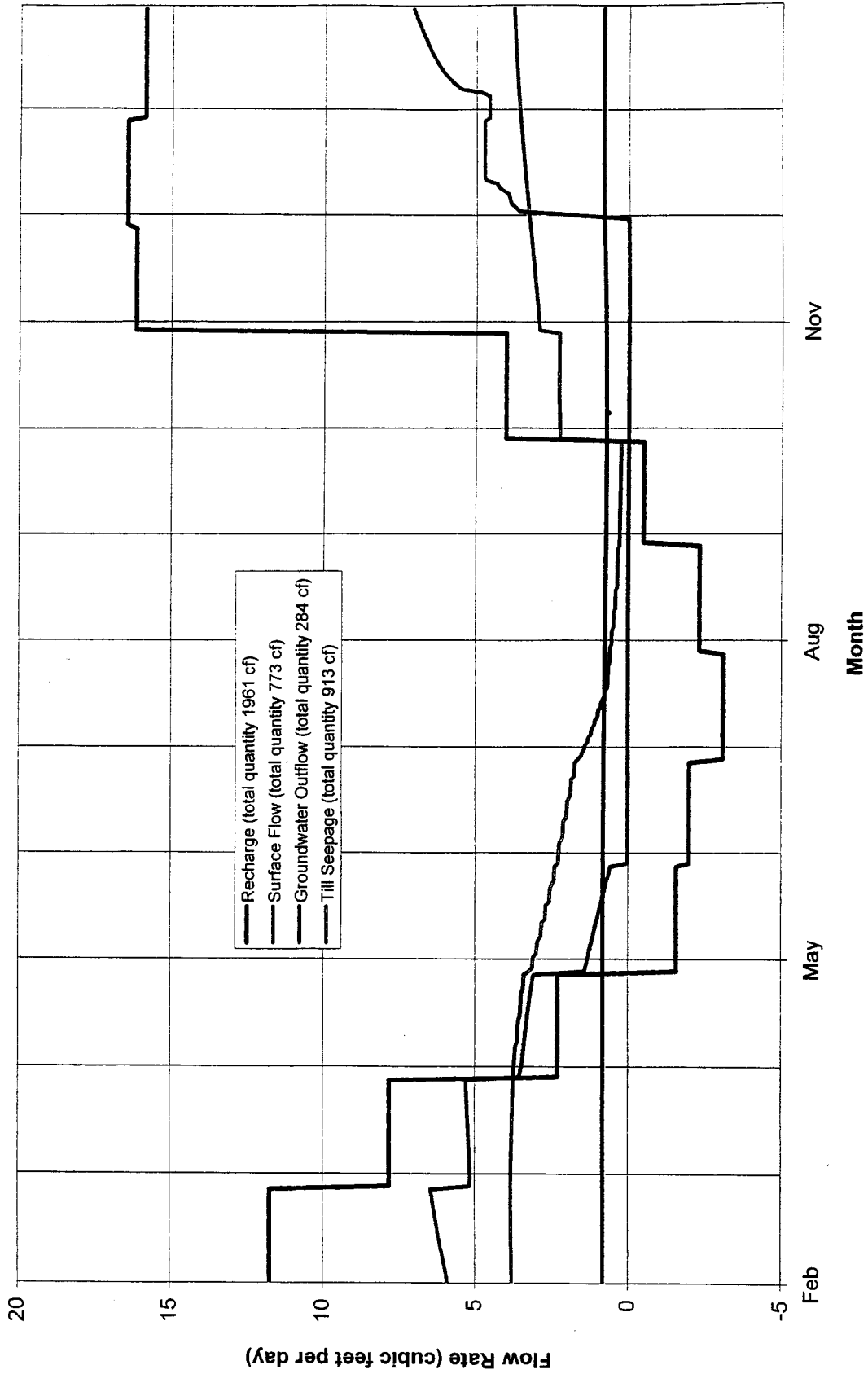
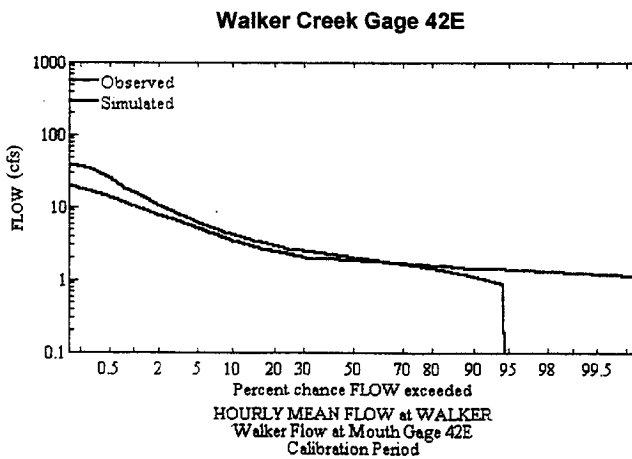
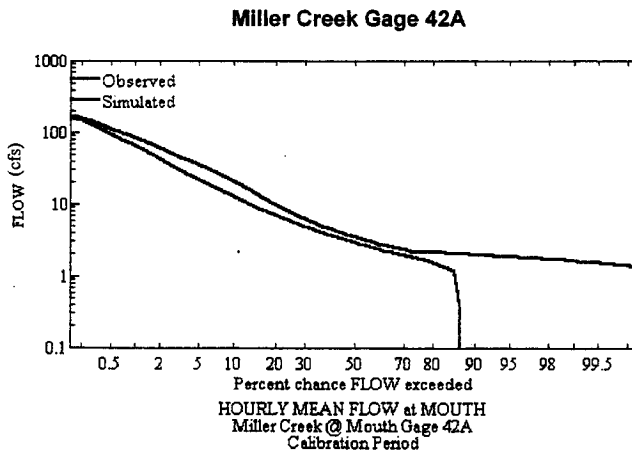
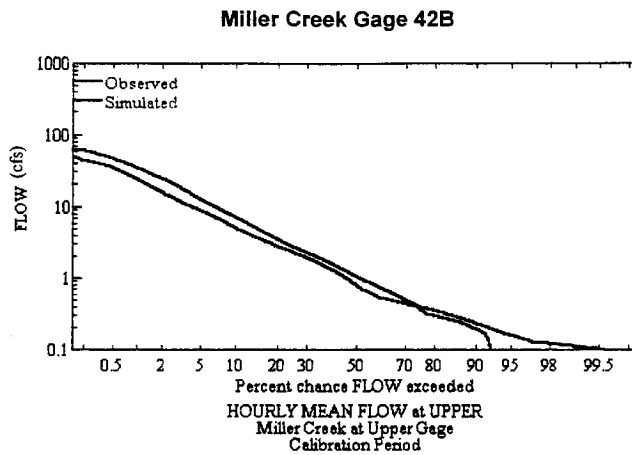


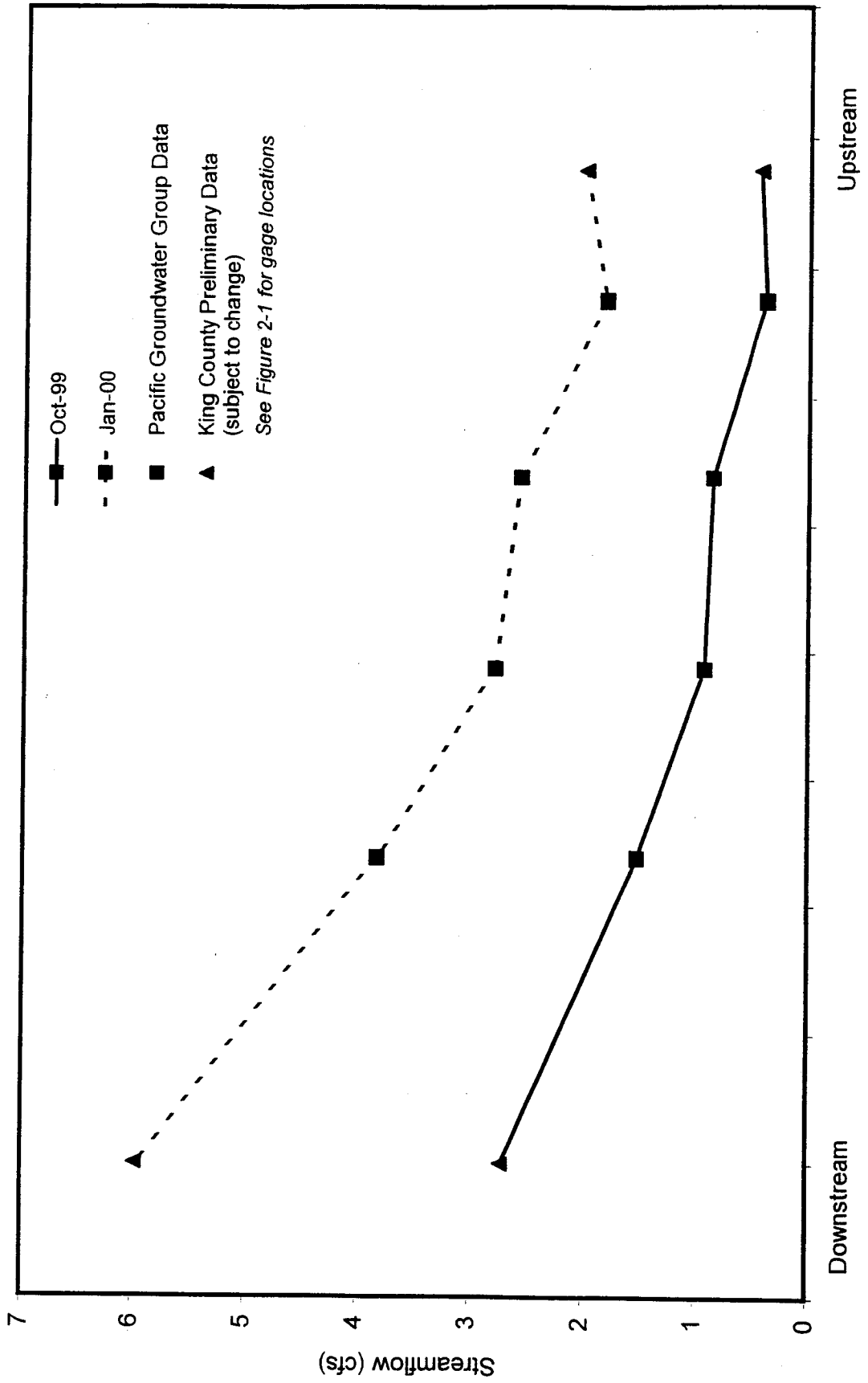
Figure 3-6.xls  
6/12/00

**Figure 3-7**  
**Flow Duration Curves for Miller/Walker Creek - King County Gages**

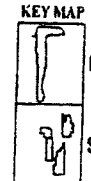
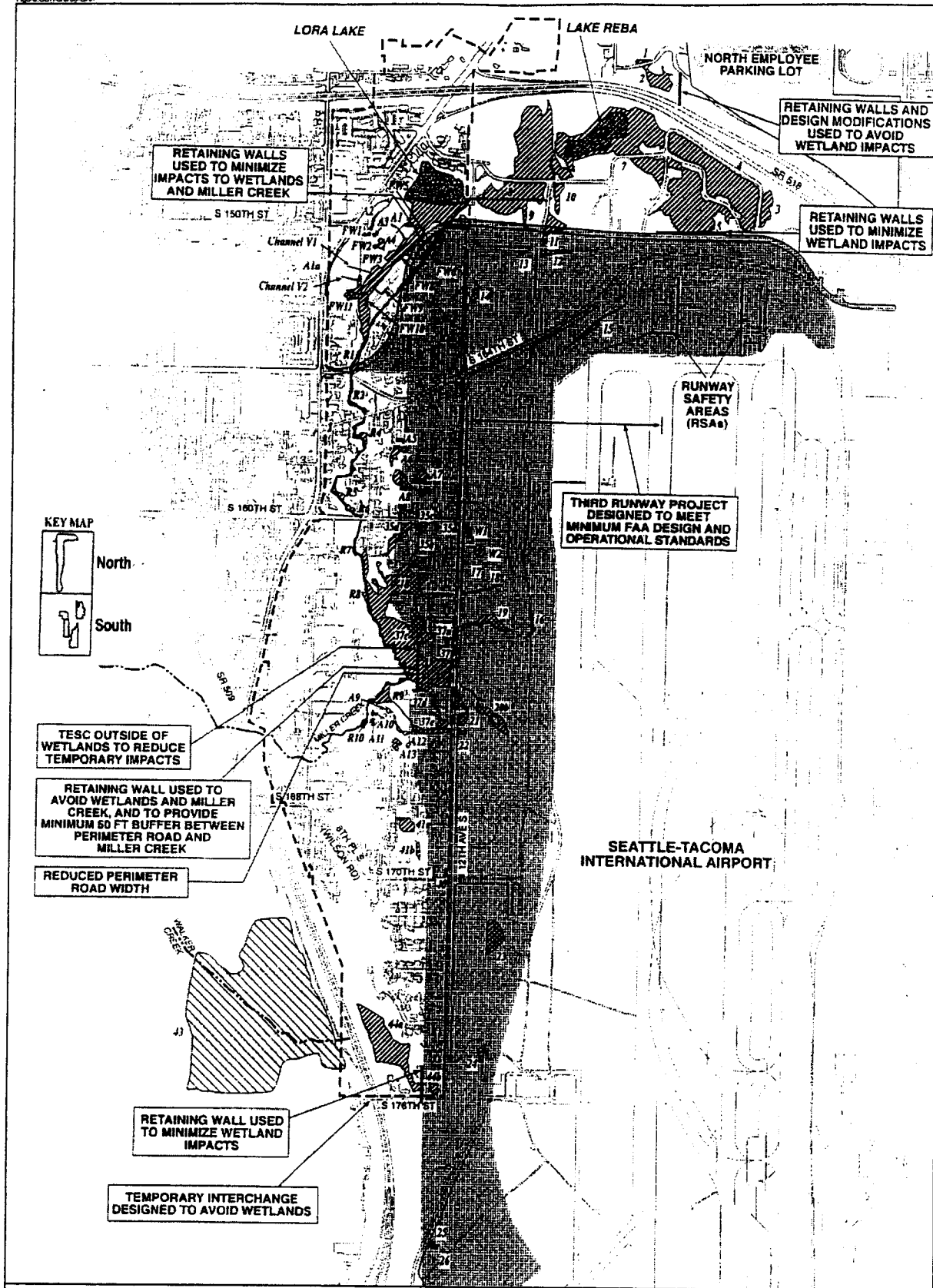


*Simulated values generated using "MILL-C" calibration model*

**Figure 3-8  
Miller Creek Base Flow Gain Survey Results**



Figures 4-5 and 3-8.xls  
5/11/00



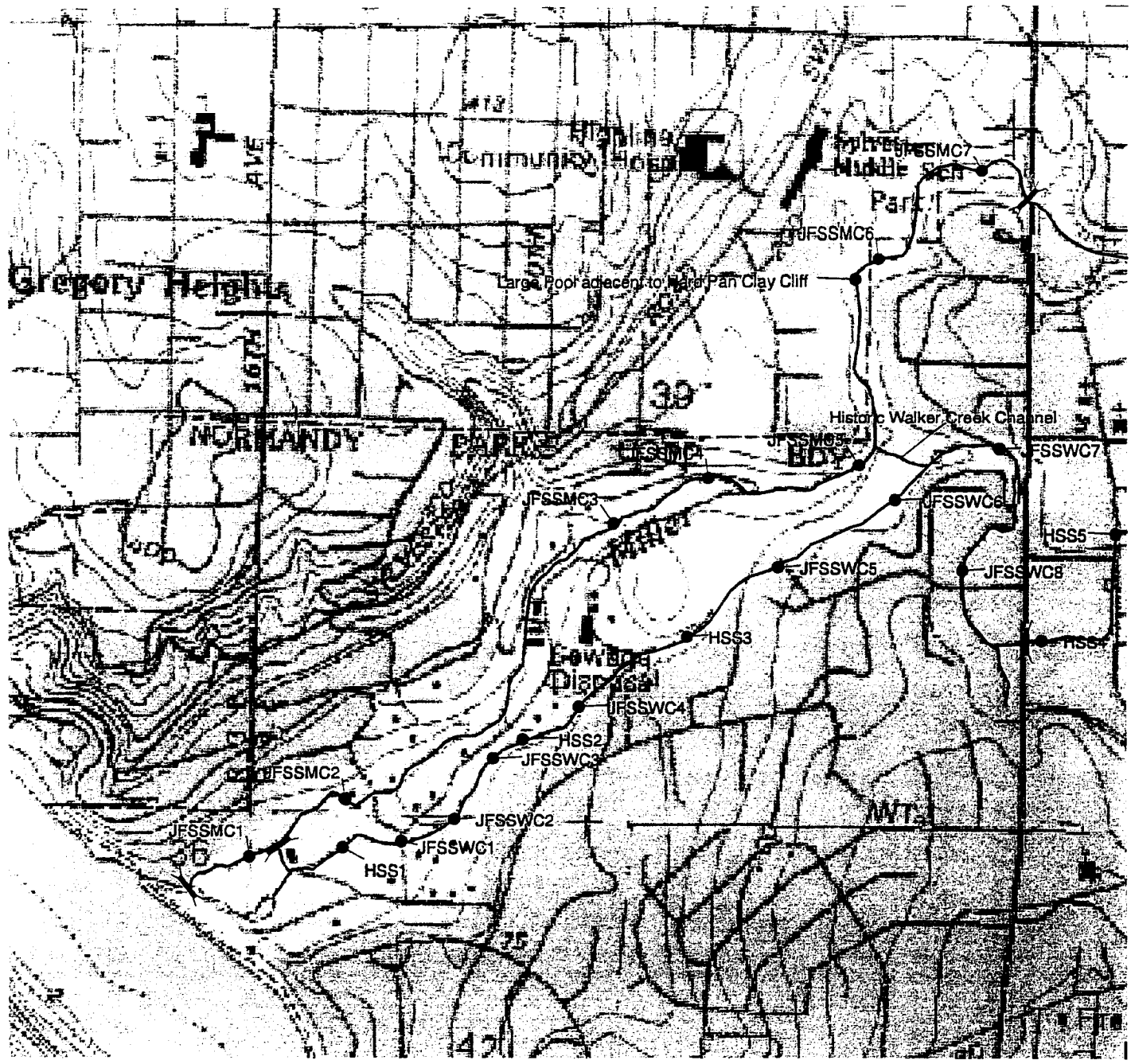
**Legend**

	Designated Wetlands Verified by ACOE		Water Features
	Wetlands Not Verified by ACOE		Third Runway Embankment, RSA's and Relocated S 154th Street
	Creek		Wetland Number
	Boundary of Acquisition Area		

SCALE IN FEET  
0 400 800

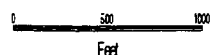
**Figure 3-9**  
**Wetland And Stream Impacts In The Miller Creek Basin**  
Sea Tac Runway Fill Hydrologic Studies

SOURCE: Parametrix 1999c



**Legend**

- HSS - Habitat Survey Station
- JFSSMC - Juvenile Fish Survey Station (Miller Creek)
- JFSSWC - Juvenile Fish Survey Station (Walker Creek)
- Carcass Survey Area Boundary

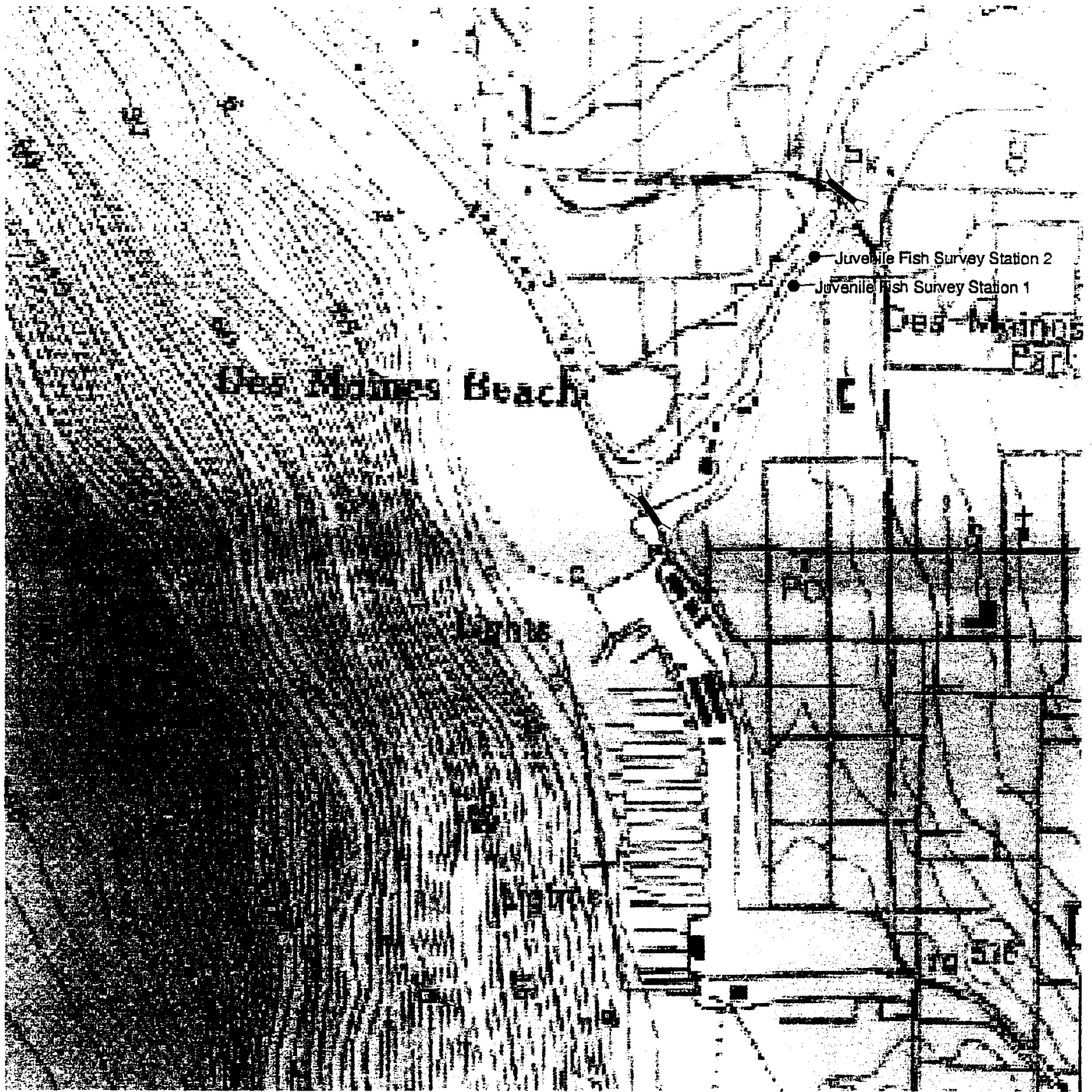


**Figure 3-10**

Walker and Miller Creek  
Biological Sampling Locations

SeaTac Runway  
Hydrologic Studies





**Legend**

- Juvenile Fish Survey Station (Des Moines Creek)
- ▬ Carcass Survey Area Boundary

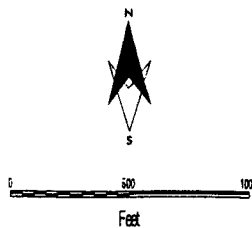
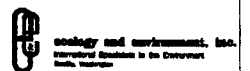


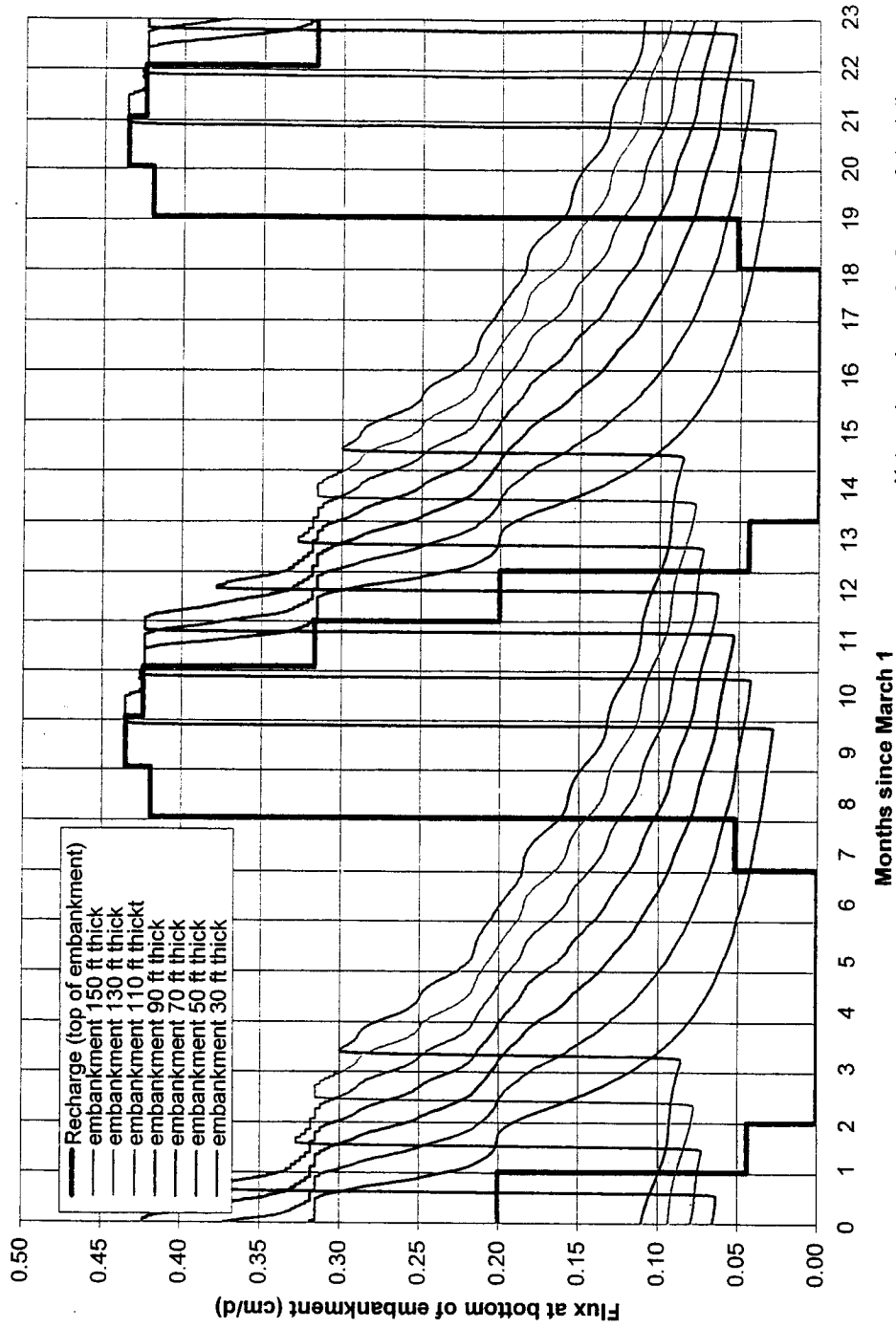
Figure 3-11

Des Moines Creek  
Biological Sampling Locations

SeaTac Runway  
Hydrologic Studies

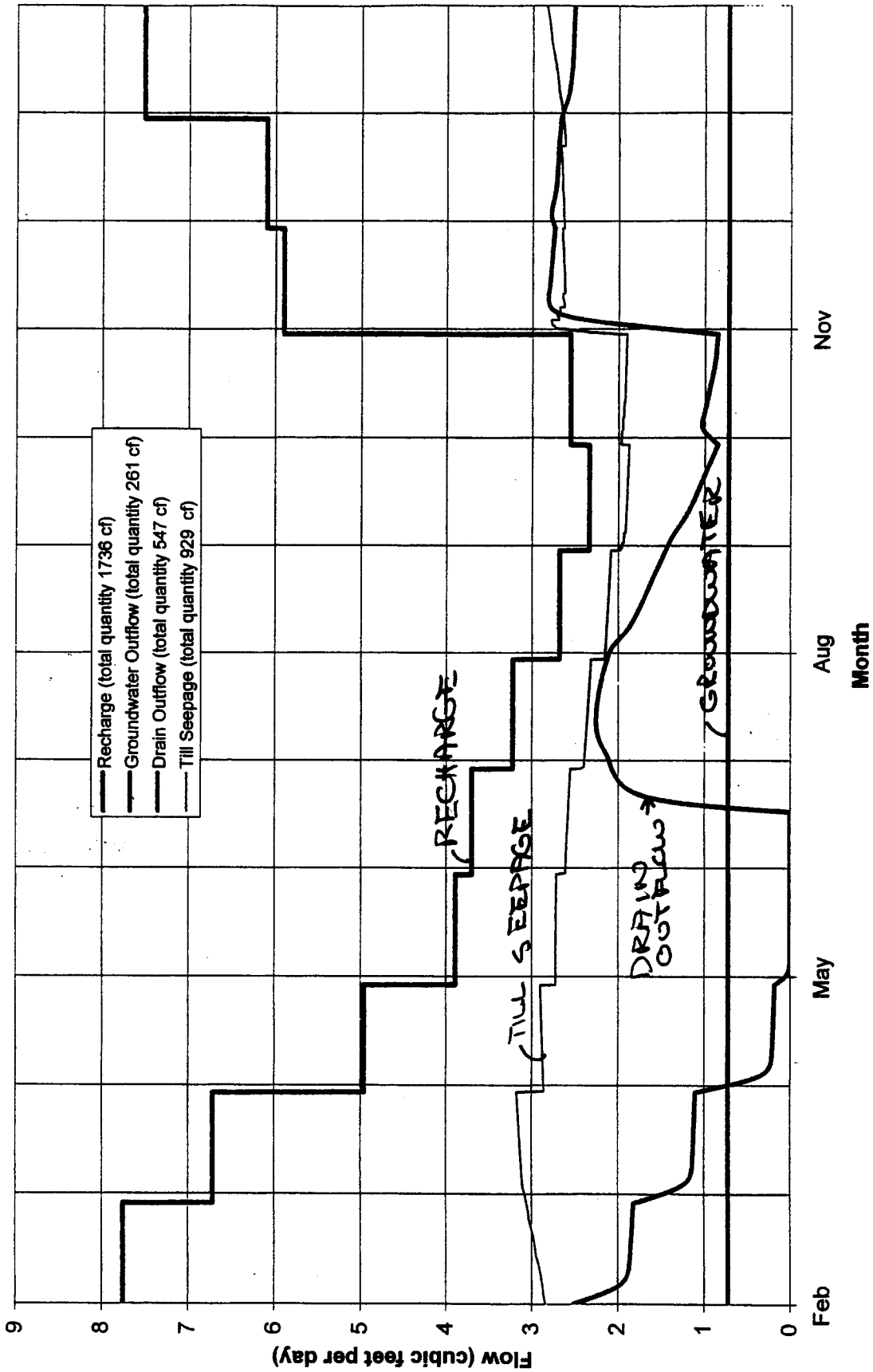


**Figure 3-12**  
**Results of Hydrus-2D Modeling of Embankment Fill**



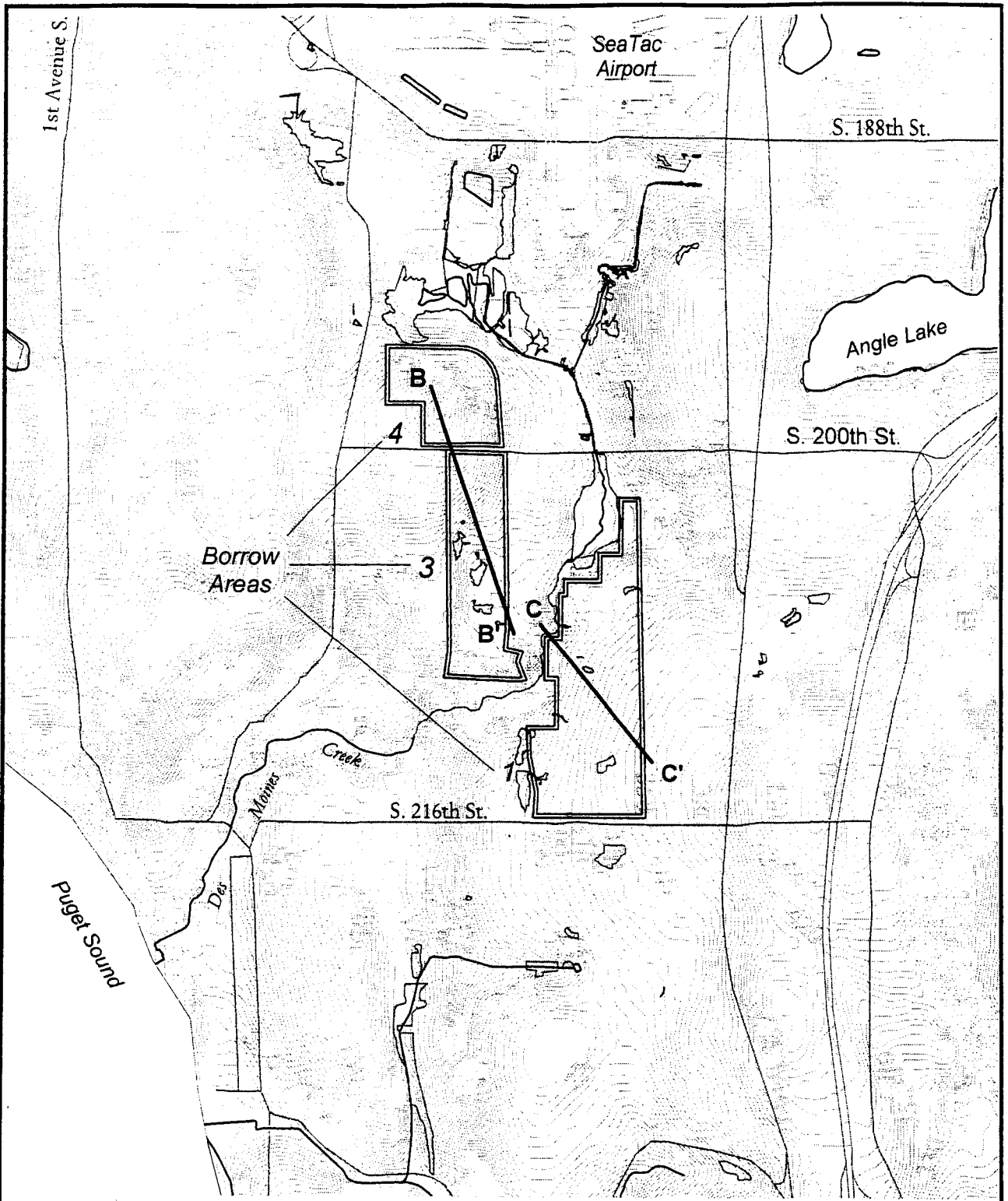
Note: values shown after 6 years of simulation.

**Figure 3-13**  
**Results of the Slice Model for the Built Condition**



AR 011750



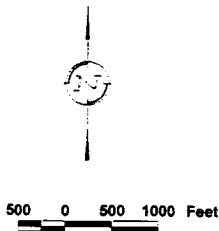


**Legend**

- Borrow Areas
- Wetlands
- Cross Section Alignment

**Stream Gage Stations**

- King County Station
- Pacific Groundwater Group Station



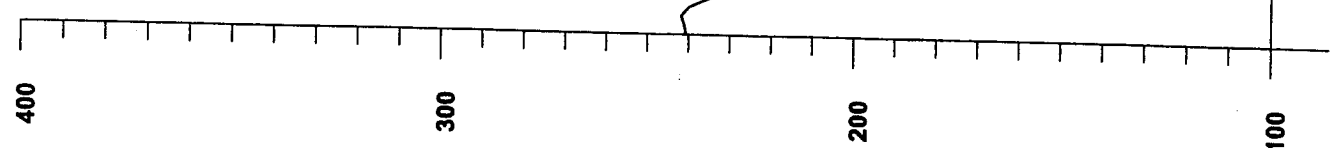
**Figure 4-1**

**On-Site Borrow Area Vicinity Plan**

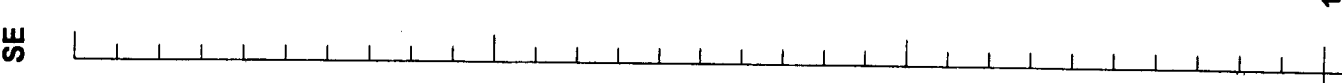
SeaTac Runway Fill  
Hydrologic Studies  
JE9907. old\_seetac\_sasi.apr. 5/2000



C NW

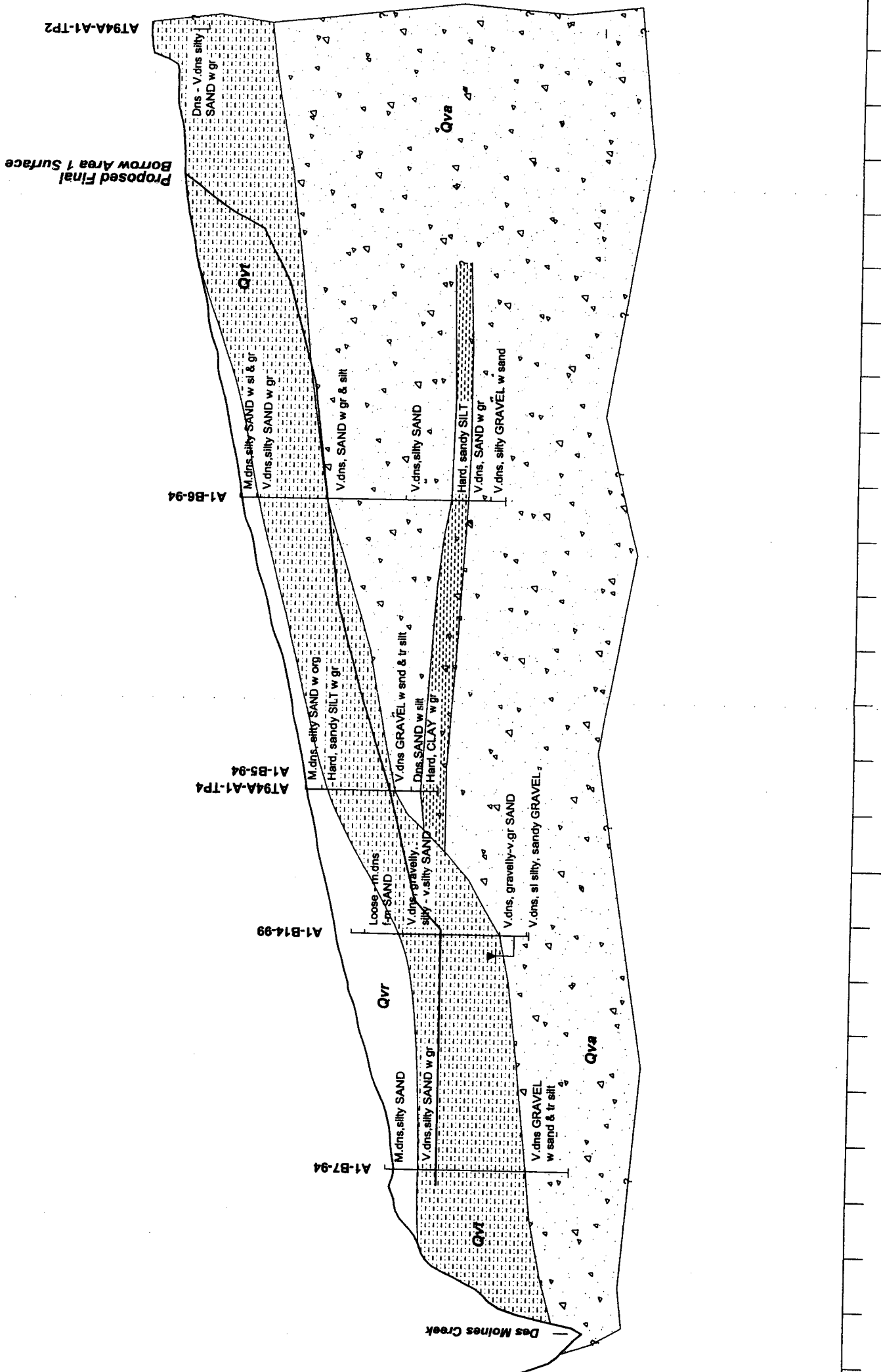


Elevation in feet (Port of Seattle Datum)



C SE

Elevation in feet (Port of Seattle Datum)



Proposed Final Borrow Area 1 Surface

Legend

- Qvr - Vashon Recessional
- Qvt - Vashon Till
- Qva - Vashon Advance
- Qva - Vashon Advance (silt/clay lens)

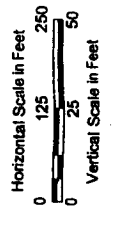


Figure 4-2 Borrow Area 1 Cross Section C-C'

AR 011752

SeaTac Runway Fill Hydrologic Studies

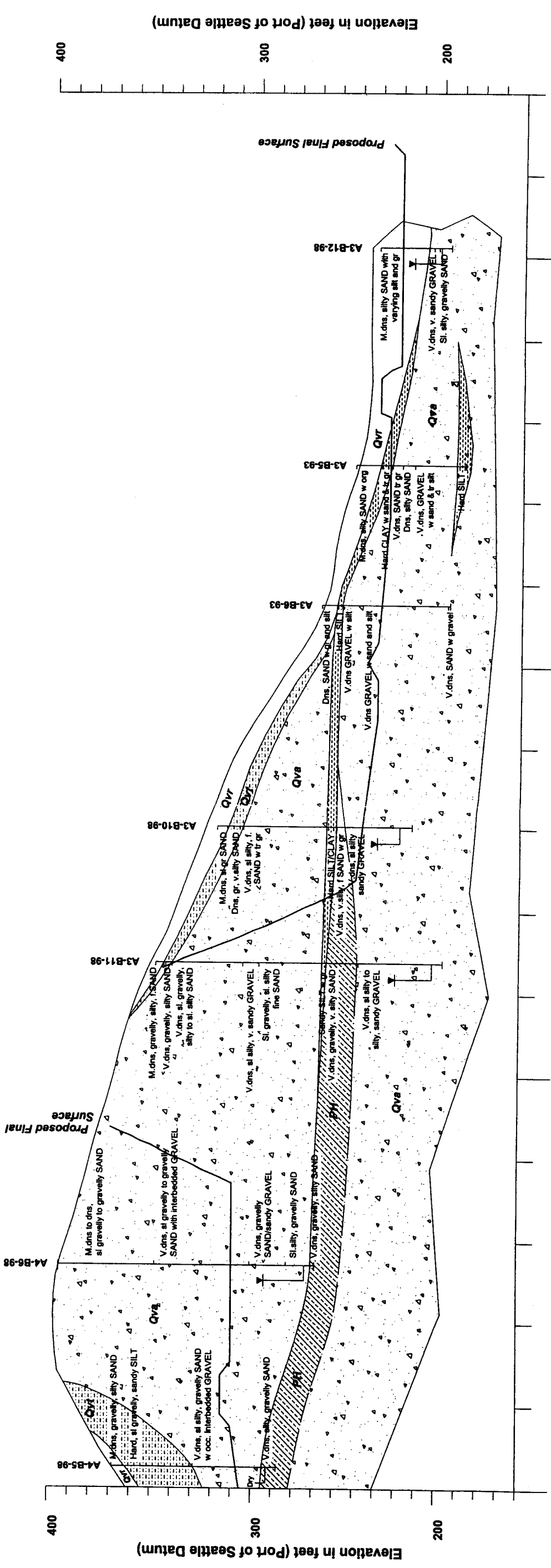


B  
N-NW

Borrow Area 4

Borrow Area 3

B'  
S-SE



Legend

- Qvr - Vashon Recessional
- Qvt - Vashon Till
- Qva - Vashon Advance
- Qva - Vashon Advance (silt/clay lens)

"Perching Horizon"

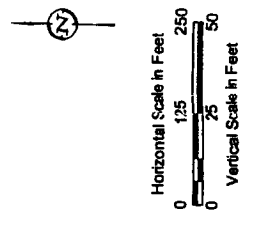
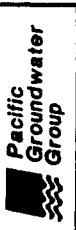


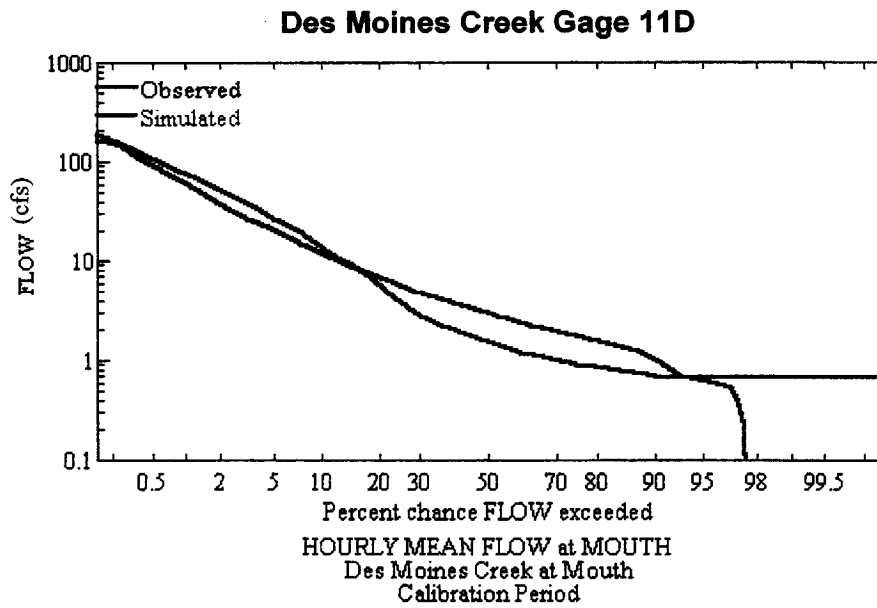
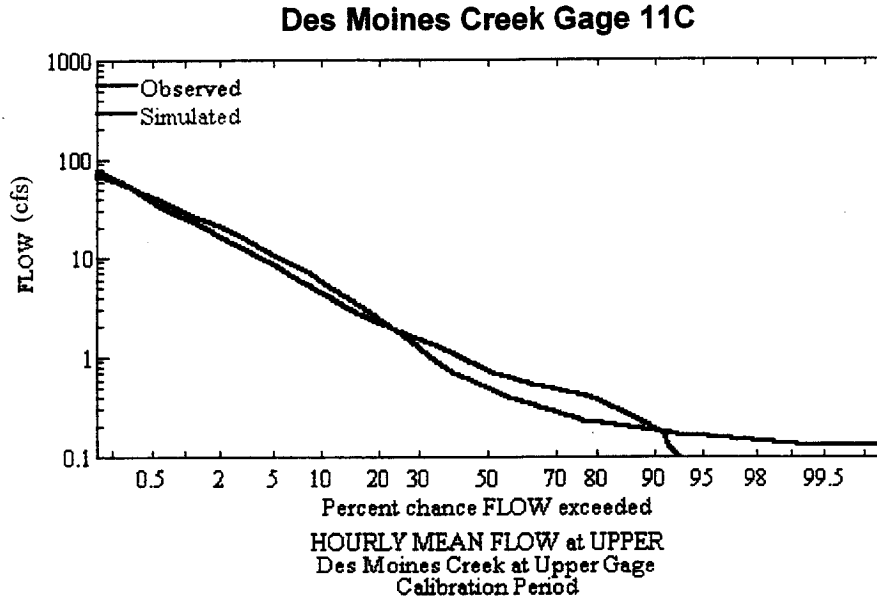
Figure 4-3  
Borrow Area 3 & 4  
Cross Section B-B'

SeaTac Runway Fill  
Hydrologic Studies  
JE9907, BA34SEC.DWG, 5/2000



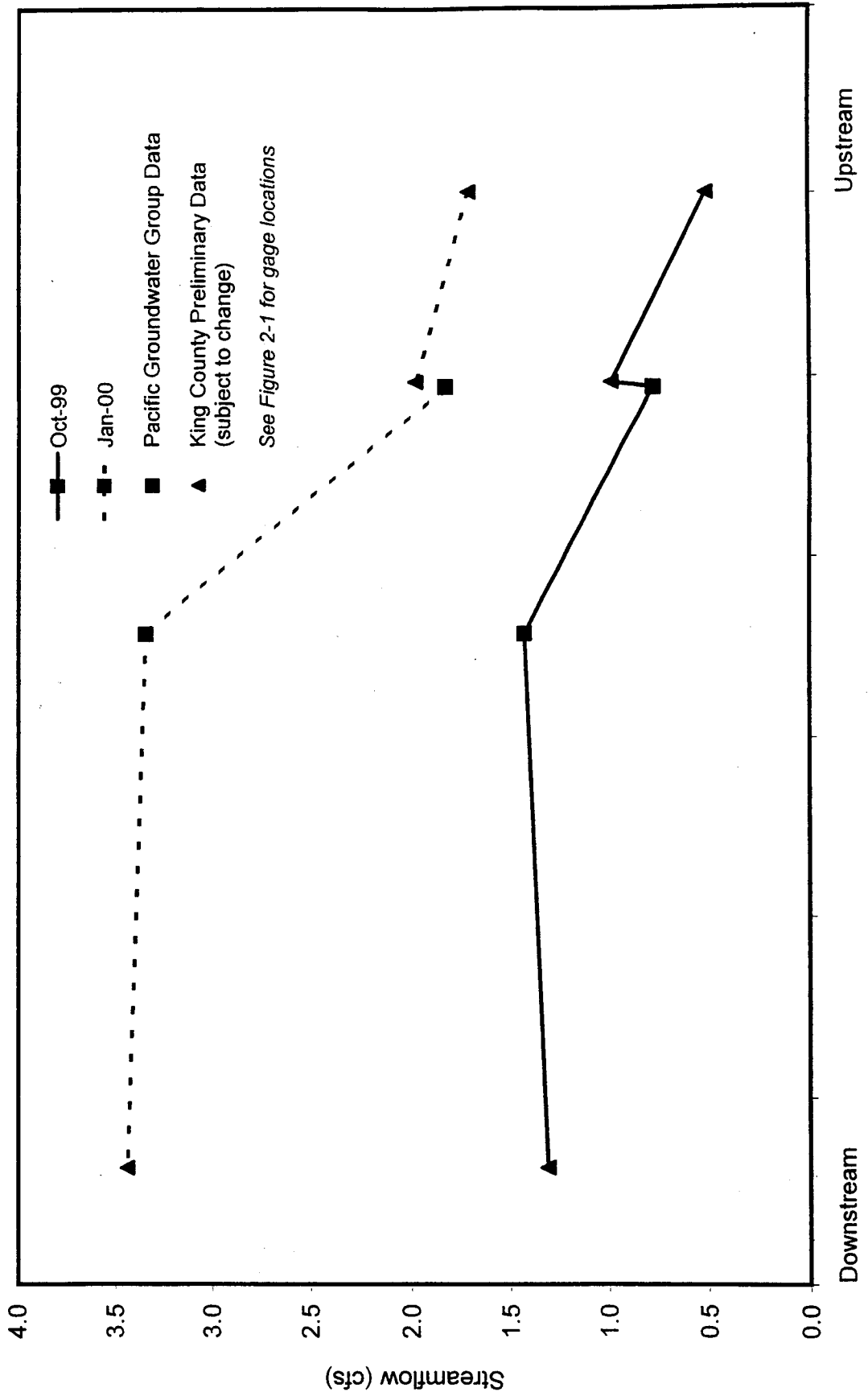
AR 011753

**Figure 4-4**  
**Flow Duration Curves for Des Moines Creek - King County Gages**

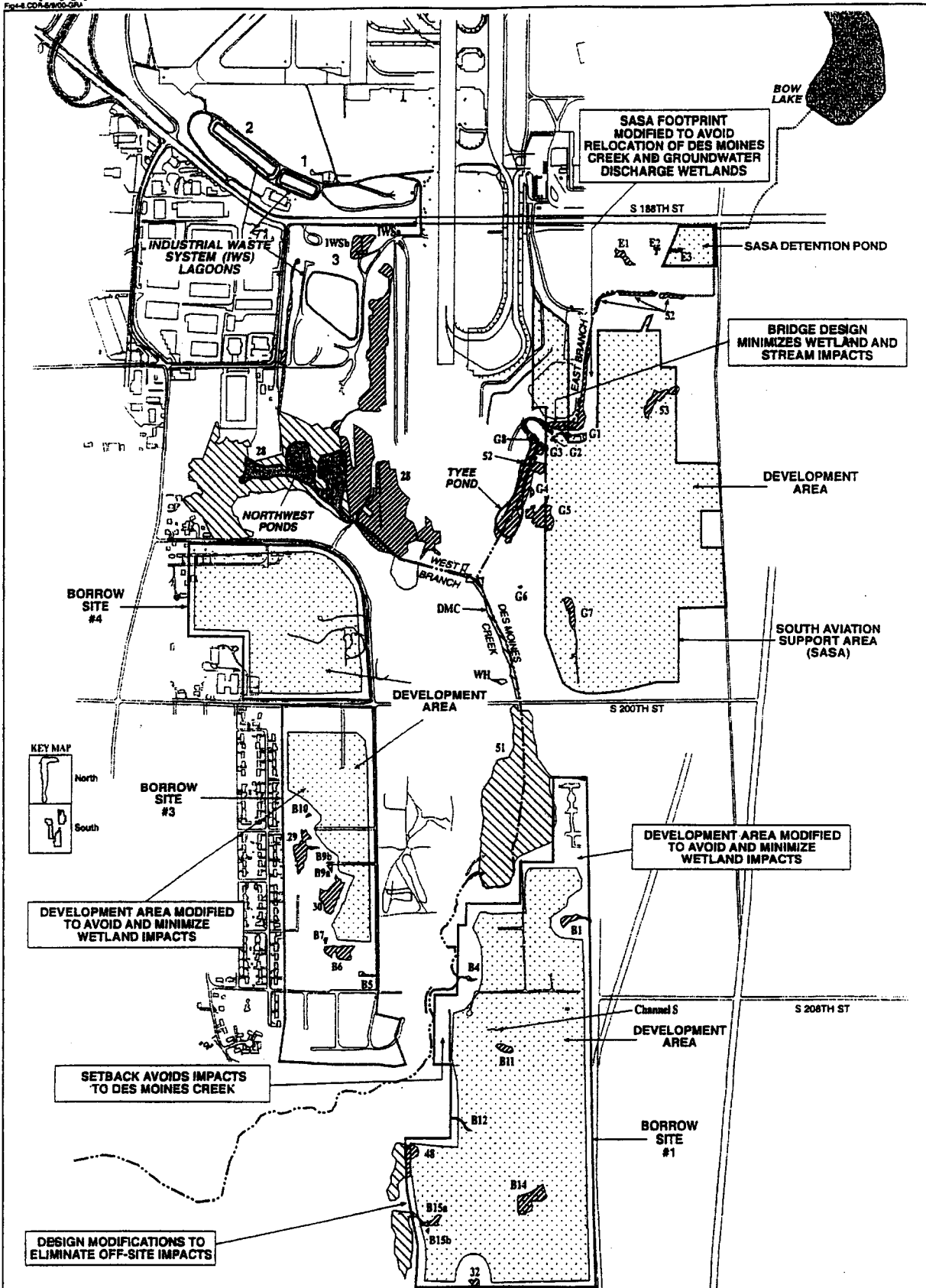


*Simulated values generated using "MILL-C" calibration model*








**Figure 4-5**  
**Des Moines Creek Base Flow Gain Survey Results**

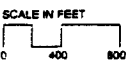


Figures 4-5 and 3-8.xls  
 5/11/00



**Legend**

- |   |                                      |   |                  |
|---|--------------------------------------|---|------------------|
|  | Water Features                       |  | Development Area |
|  | Wetlands not Verified by the ACOE    |  | Piped Creek      |
|  | Delineated Wetlands Verified by ACOE |  | Creek            |
|   |                                      |  | Wetland Number   |



**Figure 4-6**  
**Wetland And Stream Impacts**  
**In The Des Moines**  
**Creek Basin**  
 Sea Tac Runway Fill  
 Hydrologic Studies

SOURCE: Parametric 1990c

## MEMORADUM

**TO:** File  
**FROM:** Russ Prior  
**DATE:** February 17, 2000

This memorandum describes a field trip completed by Russ Prior of Pacific Groundwater Group on February 10, 2000. The purpose of the trip was to obtain preliminary information regarding privately owned wells in the buyout area for the proposed expansion of SeaTac Airport.

William Kleindl of Parametrix, Inc. was hired by the Port to accompany Mr. Prior during this field trip. Mr. Kleindl knew the buyout area well and provided thoughtful insight. Such insight included personal knowledge of the previous existence of older houses, which had already been demolished. He had previously observed some wells in the areas we traversed.

The two men covered approximately half of the area using a full day in the field. No attempt was made to look at every house in the areas traversed. In general, they focused on lots that had older (pre-1950) vintage houses. Although, it is known that some wells occur in the basement of some houses in the area, no attempt was made to search the basements of all houses visited. The attached maps indicate the general areas that were traversed.

### **Wells and Other Subsurface Features**

The following list describes the wells that were found by Mr. Prior and Mr. Kleindl on February 10, 2000. The wells were located based on a map provided by Port consultants that documents all parcels in the buyout area. The following list is organized based on those parcel numbers. Please refer to the attached figures.

#### Parcel 088

This parcel, north of South 156<sup>th</sup> Way, is in an area which has already had all the houses demolished. The streets still exist but extensive grading and reseeded has been completed. We were led to this area because Port personnel indicated the existence of a water well to Bill via cell-phone. We found several outbuildings in parcel 088 but could not find any evidence of a water well.

#### Parcel 153

This parcel immediately south of South 156<sup>th</sup> Way still has a house on it. A dug well exists along the eastern boundary line of the parcel. The well is rectangular and is made of concrete casing. The water level in the well is approximately 2 feet below ground surface.

#### Parcel 158

Immediately east of Parcel 153, this parcel had a dug well in the front yard. It is a concrete case well approximately 36-inches in diameter with a loose steel lid over the

corner was visible from outside through an opened door. Nobody was home at the time of our visit so no direct questions could be asked. It is believed that a water well of some kind exists on this parcel.

#### Parcel 187

A hole was observed in the grassy back yard of this parcel. The hole had concrete sidewalls and the remnants of wood cribbing on top. It is believed that this is a caved-in dug well.

#### Parcel 215

A dug well exists in the northeast corner of the house on this parcel. The well is accessible through a 3-foot high door that opens from the outside. The water level is approximately 2 feet below the floor of the basement. The plumbing infrastructure is in place and consists of 3-inch down-hole pipe with two (100-gallon?) pressure tanks.

#### Parcel 280

A rectangular dug well with concrete walls was observed in the patio area in back of the house in this parcel. The water level was approximately 2 feet below grade.

#### Parcel 311

A 6-inch diameter drilled well was observed adjacent to a concrete walk just in front of the garage on this parcel. The water level was measured at 55 feet below grade. The remnants of a jet pump were observed on top of the well, otherwise the well head is unprotected at the surface. The stickup of the well is approximately 2 inches. The depth of the well was not measured.

#### Parcel 312

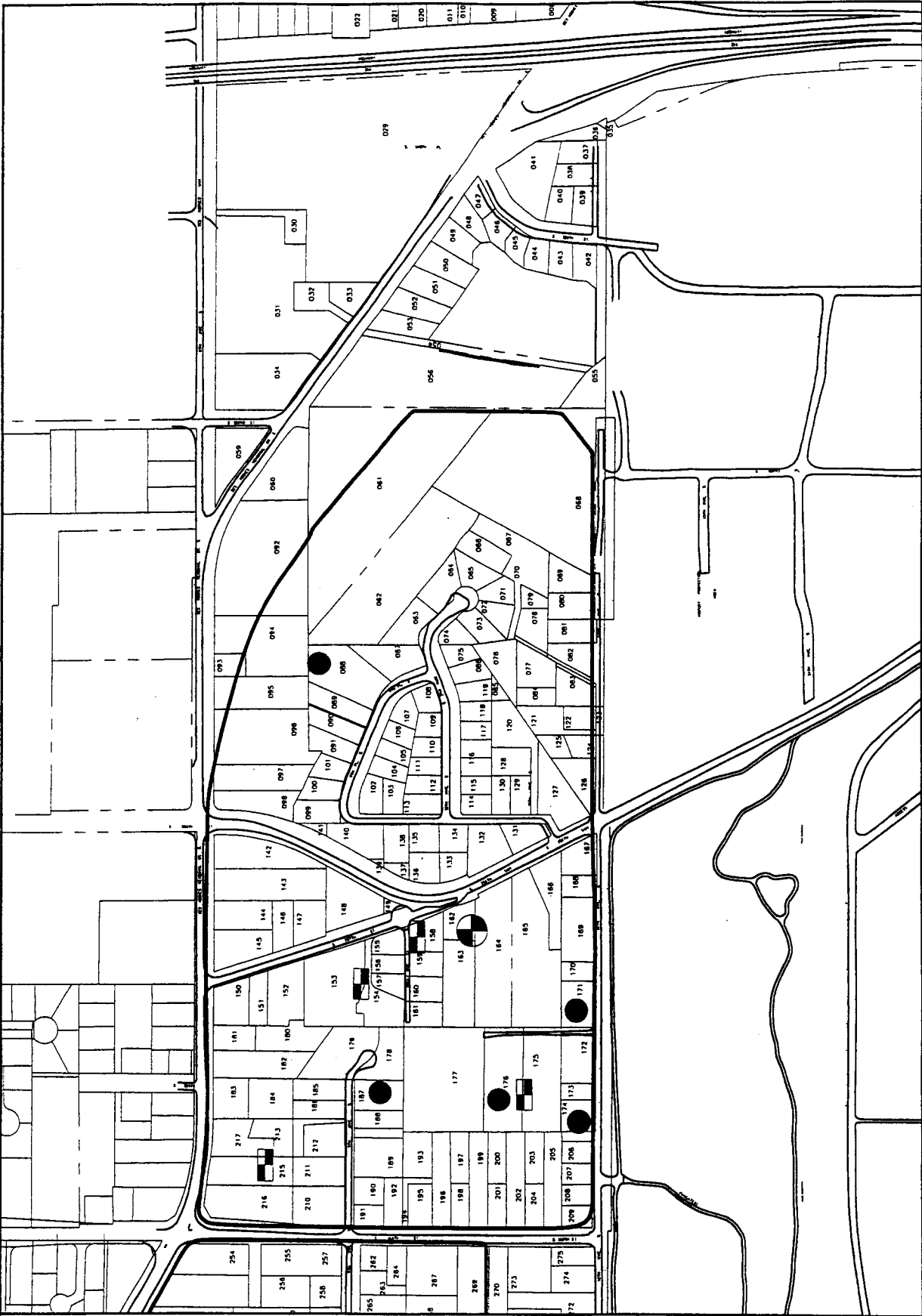
A 3-foot by 3-foot, freestanding, wood-framed structure exists on this parcel near and slightly higher than Miller Creek. It is not known if this is a pump house for a surface water diversion or a well house. The house was locked and no observations inside could be made.

#### Parcel 316

This parcel is part of a plant nursery and two wells (both along the southern boundary) were observed on it. The first is located near the eastern end of the property. It is apparently hand dug and is finished with 20-inch (?) concrete casing that sticks up approximately 2 feet. The pressure tank and pumping hardware is still plumbed in and immediately adjacent to the well. The water level in the well is approximately 6 feet below the top of the casing.

The second well is located on the western portion of the parcel in the flat area close in elevation to Miller Creek. It is a dug well and finished with 36-inch (?) concrete casing that sticks up approximately 1 foot. The water level is about 3 feet below the top of the casing.

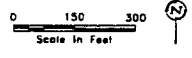




**LEGEND**

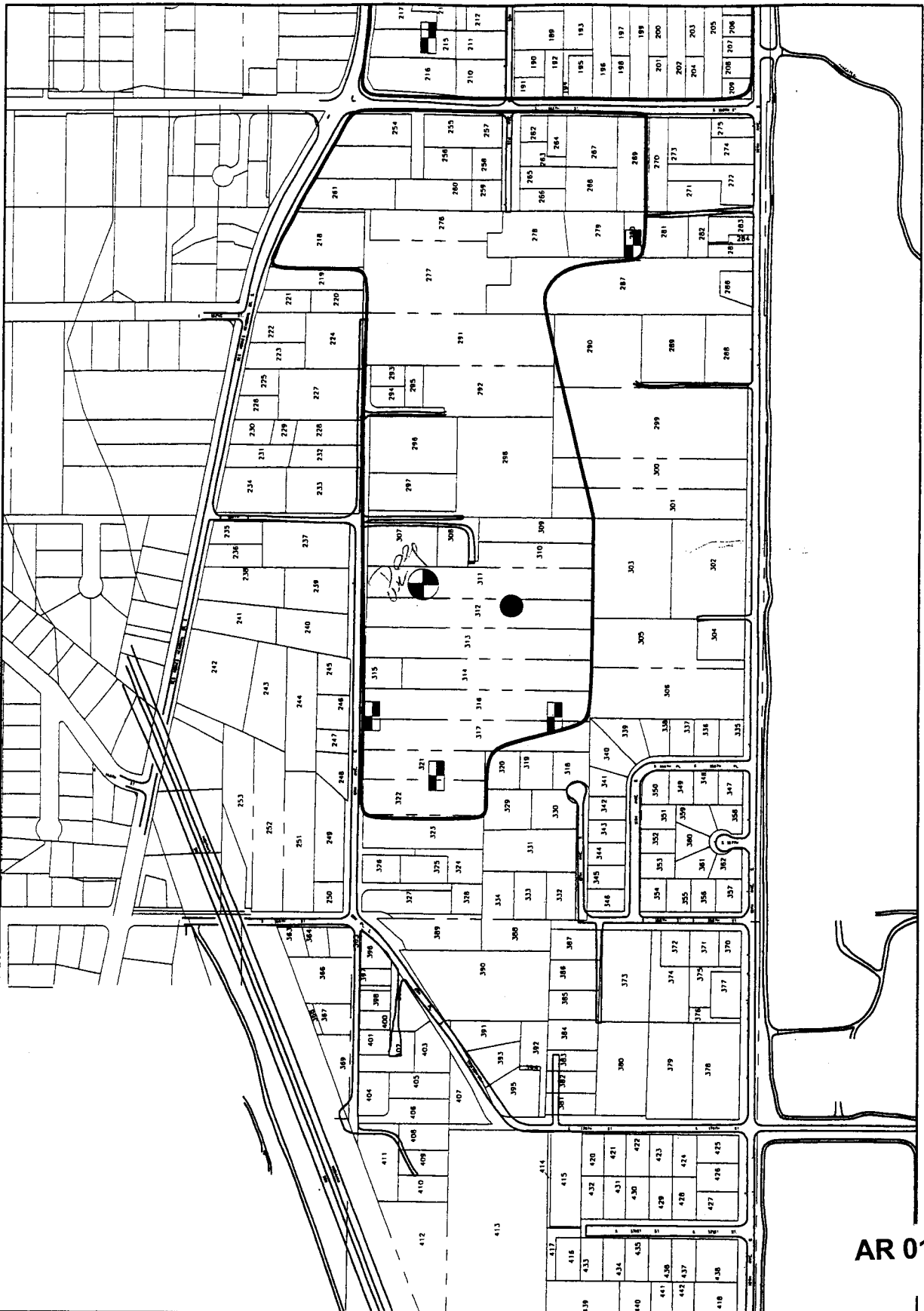
-  Drilled Well
-  Dug Well
-  Other Feature

Boundary of Area  
Traversed on 2-10-00



**FIGURE 1**  
**UNDOCUMENTED SUBSURFACE**  
**STRUCTURES IN BUYOUT AREA**  
**(NORTH)**

SEATAC EMBANKMENT STUDY  
Pacific Groundwater Group  
JERRY, SUPERVISOR, FEB/90



AR 011760

LEGEND



Drilled Well    Dug Well    Other Feature

Boundary of Area  
Traversed on 2-10-00

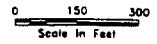


FIGURE 2  
UNDOCUMENTED SUBSURFACE  
STRUCTURES IN BUYOUT AREA  
(MIDDLE)

BEATAC EMBANKMENT STUDY  
JANUARY 2007, REVISED FEBRUARY 2008, FEBRUARY 2009



## Appendix B

### Pacific Groundwater Group Recharge Model

The following three computer-based groundwater models were used for this project:

- Pacific Groundwater Group Recharge Model
- Hydrus-2D
- Finite Difference slice model (slice model)

The recharge model was used to calculate groundwater recharge for the current and post construction conditions at the proposed third runway fill and borrow sources south of the runways. Hydrus was used to model the movement of water between the root zone and the water table assuming construction of the runway fill. The slice model was used to accumulate and move recharge downgradient under current and built conditions, to the Miller Creek riparian wetlands. At the borrow source areas, only the recharge model was used. This appendix describes the input and functions of the recharge model. The main text presents basic characterization data, model results, and interpretation.

#### 1 Method

A proprietary spreadsheet model developed by Pacific Groundwater Group was used to estimate monthly and annual recharge. The spreadsheet model is based on algorithms used in the "Deep Percolation Model" developed by the USGS (Bauer, 1996 and Bauer & Vaccaro, 1987). PGG's model employs a daily water budget to track soil moisture, perched conditions over till, runoff, snow-pack storage, and interception loss. The model estimates daily potential evapotranspiration using either the Blaney-Criddle (SCS, 1970) or Priestly-Taylor (1972) method, and calculates actual evapotranspiration as a function of soil texture and available moisture in the root zone. All water passing through the root zone is attributed to shallow recharge. When a till layer is included, the model tracks an overlying, perched water table and allows for both downward vertical seepage through the till ("deep recharge") and shallow "perched subflow" above the till. When the water table extends into the root zone, shallow recharge equals additions or withdrawals to the shallow aquifer. If the water table reaches the land surface, potential recharge is rejected and routed to the runoff term. Runoff is also modeled based on a fixed percentage of precipitation. Running the model for consecutive identical years allows simulation of a cyclic steady state. The model can be calibrated to runoff, saturation above the till, deep recharge, perched subflow, and snow-pack storage.

Observations of soil and cover conditions were used to identify five "recharge classes" based on unique combinations of land cover and surficial geology at the proposed fill and borrow areas. Land cover was broken into three categories (grass, mixed forest, and barren). Mixed forest was modeled as half-coniferous trees and half-deciduous trees. A surficial geologic map (Booth and Waldren, in press) and local boring logs were

considered in identifying three soil types for the proposed fill and borrow areas: glacial outwash, glacial till, and wetland.

At the fill area, the model was applied to a slice of ground proposed to change from current conditions to fill. Along that slice, impervious surfaces were limited to 12<sup>th</sup> Avenue for the current condition and the proposed third runway for the built condition. Runoff was assumed to be 100 percent from these impervious surfaces, with no secondary infiltration. No impervious surfaces were modeled at the borrow areas, where the model was applied to the borrow area footprints.

The following five recharge classes for the proposed fill and borrow areas were used (current and post construction conditions included, and impervious not included).

	outwash	till	wetland
grass cover	class 1	not used	class 5 (2/3 grass)
mixed forest cover	class 2	class 4	class 5 (1/3 forest)
barren	class 3	not used	not used

The fill was modeled as grass on outwash. Wetlands were modeled as 1/3 forest and 2/3 grass growing on fine-grained soils with a high water table. Post-borrow conditions were modeled as barren and grass on outwash.

The recharge calculation methods for wetlands differed from the other classes. Because portions of the root zone remain saturated year-round in the modeled riparian wetlands, water is always available for transpiration and is unimpeded by soil-moisture tension. For this reason, wetland recharge was simply calculated as precipitation minus potential evapotranspiration ( $R=P-PET$  for wetlands). Therefore, for wetland classes, negative recharge was calculated during the summer months of low precipitation and high potential evapotranspiration.

For all but the wetlands, the recharge analysis considered the water-holding capacities of existing soils using a term called available water capacity (AWC). AWC is measured in inches of water, and is the difference between field capacity and wilting point. Values of AWC published in the King County Soil Survey (Soil Conservation Service, 1973) were used for Alderwood and Everett soils, the prominent types derived from till and outwash soils, respectively. AWC for wetland soils were derived from the Snohomish soil series data. Another major discriminating factor is that Alderwood soils are underlain by a consolidated till stratum, typically encountered 24 to 40 inches below land surface (Soil Conservation Service, 1973) that may perch groundwater and therefore affect actual evapotranspiration. Table B-1 summarizes the AWC profiles of the major soil types. For each depth range, the modeled AWC value is the midpoint of the published AWC range.

Monthly precipitation and temperature averages were derived for Seatac Airport. Table B-2 shows the climatic input data for the model.

Runoff was assumed negligible for recharge modeling of pervious surfaces. Factors contributing to low runoff are the coarse fill texture, low slopes, and forest cover. Although runoff is low, an assumption of zero for all pervious classes imparts some inaccuracy to the recharge predictions.

Plant potential evapotranspiration (PET) was calculated with the method of Blaney-Criddle. Grass was assigned a root depth of 24 inches in accordance with the USGS Deep Percolation Model used for southwest King County (Woodward et al, 1995). Coniferous trees and deciduous trees were assigned rooting depths of 36 and 60 inches, respectively, except on till where all rooting depths were specified at 30 inches. Soil evaporation was calculated for the assumed barren borrow sites (down to a depth of 12 inches) with the method of Priestly-Taylor (1972).

Crop factors are used in the model to account for the plant-specific amounts of potential evapotranspiration. Interception (capture of precipitation by leaves and needles) is a part of actual evapotranspiration. Interception was not explicitly modeled because the Blaney-Criddle equation does not accommodate interception parameters. However, interception loss is known to be high in coniferous forests of the Pacific Northwest during wintertime, when advective loss of intercepted moisture can dominate evapotranspiration (Bauer & Mastin, 1997; pers. comm., Black, 1999). During the drier months (May through September), crop factors can be derived for conifers by multiplying the crop factor for grass by the ratio of Priestly Taylor "alpha" values measured for conifers and grass (0.73 and 1.26, respectively). The "alpha" parameter was developed for dry leaf transpiration based on stomatal resistance. Current methods of ET estimation have not fully developed suitable means for estimating advective losses during winter months. For these months, the best recourse for estimating forest ET is believed to be use of high-end, measured crop factors (pers. comm, Black, 1999). In this case, Blaney-Criddle crop factors for alfalfa were used between November and March, and for grass during April and October. Alfalfa has one of the highest crop factors, and grass is also relatively high (Dunne & Leopold, 1978).

Actual soil evaporation and plant evapotranspiration were calculated as a function of daily soil moisture availability, soil texture, and potential ET based on functions employed in the USGS recharge model (Bauer & Vaccaro, 1987). In general, reduced soil moisture reduces evaporation and transpiration because the remaining moisture is held with greater tension in the soil and unsaturated hydraulic conductivities are reduced.

Solar radiation data, required for the Priestly-Taylor method, were obtained from measurements made at the Seatac station. The data are maintained and reported by the National Renewable Energy Laboratory (NREL) as part of the National Solar Radiation Database, and represent a period of 1961-1990. Maximum observed daily clear sky solar radiation was not measured, but was derived from measured extraterrestrial solar radiation by applying a ratio of 0.73 (after Giles and others, 1984). The radiation data are presented in **Table B-3**. The recharge model employed a Priestly-Taylor alpha coefficient of 1.0. While a value of 1.26 is considered standard for wet surfaces, evaporation from soils ( $E_s$ ) is less than evaporation from free surfaces ( $E_o$ ).  $E_s/E_o$  ratios reported in the

literature range from 60% to 90% (Jensen et al, 1990). Sensitivity analysis showed that varying the alpha coefficient by  $\pm 0.27$  around 1.0 resulted in PET values which varied by +27% and -15%, however resulting recharge values varied by only +6% and -3%.

## 2 Recharge Estimation Results

PGG's recharge model was used to estimate monthly recharge for each recharge class. Soil property, plant, climatic, and other pertinent data were input, and the model was run for each recharge class independently. For classes with no underlying till a single model run allowed definition of the daily, monthly, and annual soil-moisture water balance. For upland till, multiple runs were required during which the vertical permeability ( $K_v$ ) of the till and the "Darcy flow coefficient" of the perched aquifer (a composite term for horizontal permeability ( $K_h$ ) times gradient ( $i$ ) per unit-width) were adjusted to match simplified site conditions (presence and absence of perched water).

Recharge for outwash areas is summarized as percolation to a presumed deep water table, below the root zone. Roots cannot extract water from the saturated zone in that case and recharge is therefore either positive or zero. Recharge in upland till areas is summarized as percolation to a presumed perched water table, which may be within the root zone. Recharge in till areas includes shallow perched subflow and deep percolation. When the water table is within the root zone, negative recharge may occur because roots may access water from below the water table (ie: more than the water stored in the unsaturated state above the water table). This condition occurred in the till upland, where the root zone was modeled to extend down to the till layer at a depth of 30 inches.

In the wetland areas where the water table is always within the root zone, recharge was approximated as simply P-PET. This approach was appropriate because the recharge model output was intended for use in the slice model, which rejects recharge when the water table is at land surface, and correctly attributes the rejected recharge as runoff.

Table B-4 shows the monthly and annual estimates of recharge predicted by the model and described above. Details of output from the recharge spreadsheet model for each recharge class is provided in Tables B-5 through B-13. Recharge for the mixed cover classes were calculated based on weighting of the discrete cover classes (example: wetlands were calculated as one-third grass-covered wetland and two-third mix-forest wetlands). Therefore, Tables B-5 through B-13 do not include the exact numbers used for mixed-cover modeling. Figure 3-4, in the main body of the report, provides a graphical representation of total recharge calculated for the different classes over time.

Table B-4 and Figure 3-4 (main text) show that predicted recharge for the wetter months is similar between all classes, but that the presence of moisture and saturation within the root zone causes negative recharge (net ET) for the till and wetland classes. Recharge is greatest in the barren condition as a result of low AET.

The recharge estimates for grass on outwash were imported to the Hydrus-2D model discussed in Appendix C for modeling of infiltration through the variably saturated third

runway fill. All values except the barren condition were imported into appropriate locations in the "current conditions" version of the slice model, which assumed no lag for vertical flow to the water table.

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**Table B-1**  
**Available Water Capacities for Modeled Soils**

Everett Series		Alderwood Series		Snohomish Series (wetland)	
Depth Range	AWC	Depth Range	AWC	Depth Range	AWC
0-17 in	0.08-0.1	0-27 in	0.09-0.11	0-17	0.20-0.24
17-32 in	0.06-0.08	Below 27 in	till	17-27	0.35-0.40
32-60 in	0.02-0.04			27-60	0.80-0.1

**Table B-2**  
**Climatic Data for Modeling**

Month	Precipitation (inches)	Average Daily Max Temp (°F)	Avgerage Daily Min Temp (°F)
Jan	5.64	44.6	34.6
Feb	4.16	49.0	36.7
Mar	3.69	52.2	38.1
Apr	2.53	57.4	41.2
May	1.63	64.3	46.4
Jun	1.44	69.4	51.3
Jul	0.77	75.1	54.5
Aug	1.10	74.7	54.8
Sep	1.77	69.4	51.3
Oct	3.41	59.4	45.3
Nov	5.87	50.4	39.5
Dec	5.85	45.4	35.8
Annual	37.86		

**Table B-3**  
**Solar Radiation Data for Modeling**

Month	Extraterrestrial solar radiation (MJ m <sup>-2</sup> d <sup>-1</sup> )	Maximum observed daily clear sky solar radiation (MJ m <sup>-2</sup> d <sup>-1</sup> )	Daytime incoming solar radiation (MJ m <sup>-2</sup> d <sup>-1</sup> )
January	10.99	8.02	3.54
February	16.53	12.07	5.96
March	24.49	17.88	10.18
April	32.82	23.96	14.70
May	39.14	28.57	19.16
June	41.88	30.57	20.91
July	40.51	29.58	21.84
August	35.30	25.77	18.56
September	27.71	20.23	13.57
October	19.42	14.18	8.00
November	12.66	9.25	4.19
December	9.54	6.96	2.89

**Table B-4**  
**Recharge for Cover and Soil Classes based on Recharge Model**  
**for SeaTac Area**

Month	Outwash Mixed Forest	Outwash Grass (and fill)	Till Mixed Forest	Grass & Mixed Forest Wetland (saturated)	Barren Outwash
January	5.26	5.17	5.18	5.23	5.58
February	3.58	3.49	3.56	3.55	3.75
March	2.62	2.44	2.60	2.55	2.45
April	0.78	0.52	0.75	0.68	0.30
May	0.00	0.00	-0.92	-1.14	0.00
June	0.00	0.00	-1.08	-2.19	0.00
July	0.00	0.00	-0.85	-3.56	0.00
August	0.00	0.00	0.06	-2.67	0.00
September	0.00	0.00	0.82	-0.55	0.00
October	1.29	0.63	2.22	1.95	2.03
November	5.20	4.95	5.22	5.15	5.68
December	5.46	5.30	5.46	5.42	5.84
Annual	24.19	22.50	23.04	14.43	25.64

**Table B-5 - Recharge for the SeaTac Project Area - Coniferous Forest on Highly Saturated Area (Wetland)**

Vegetation Data		Weather Station Data		Soil and Water Data	
Type of Land Cover	mature conifers	Nearest Weather Station	Seatac Airport	Avg. Soil Available Water Capacity (AWC)	0.23
Rooting Depth	36 in	Average Precipitation	37.9 in/yr	Ratio of Site Weather-Station Precipitation	100%
Priestly Taylor "Alpha"	N/A	Avg Annual Temperature	59.3 °F	Resulting "Effective" Precipitation (P)	37.9 in/yr (annual average)
Average Annual Fractional Foliar Cover	N/A	Latitude	47.45 °N	Portion of "P" going to immediate runoff	0%
Average Annual Foliar Interception Capacity	N/A	Longitude	-121.72 °W	Rate of Snow Ablation (SA)	N/A
		Elevation	300 feet msl	Snowmelt Rate Coefficient	N/A
				Depth to Till Layer	10 feet, based on generalized cross section.
				Thickness of Till Layer	10 feet, based on generalized cross section.
				Vertical Hydraulic Conductivity of Till	1E-09 ft/day, based on empirical maximization of wetland saturation
				Specific Yield of Perched Aquifer	0.45 based on consideration of peat properties.
				Darcy Flow Coefficient for Perched Aquifer	0.000001 based on empirical maximization of wetland saturation.

Method of Estimating Potential Evapotranspiration:

Blaney Criddle (BC)

Priestly Taylor Canopy Interception:

Not Modeled

Snowpack: Not Modeled

TIII Perching: Modeled

**RECHARGE CALCULATOR:**

**Evaporation Estimates**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	
Monthly Temp (T, °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8	Avg. T, °F
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0	Avg. T, °C
Blaney Criddle Crop Factor (k)	0.63	0.73	0.86	0.85	0.52	0.53	0.53	0.53	0.50	0.80	0.78	0.64	0.66	(Avg k)
Blaney Criddle % of Annual Light (d)	0.064	0.065	0.082	0.091	0.103	0.105	0.106	0.097	0.084	0.076	0.064	0.061	1.00	(Avg d)
Priestly Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(RN)
Potential Evapotranspiration (PET)	0.60	0.87	1.49	2.04	1.89	2.41	2.89	2.66	1.84	1.88	1.05	0.62	20.23	(PET)

**Table B6 - Recharge for the SeaTac Project Area - Grass on Highly Saturated Area (Wetland)**

Vegetation Data	
Type of Land Cover	grass
Rooting Depth	24 in
Priestly Taylor "Alpha"	N/A
Average Annual Fractional Foliar Cover	N/A
Average Annual Foliar Interception Capacity	N/A

Weather Station Data	
Nearest Weather Station	Seatac Airport
Average Precipitation	37.9 in/yr
Avg Annual Temperature	59.3 °F
Latitude	47.45 °N
Longitude	-121.72 °W
Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.27 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site:Weather-Station Precipitation	100% of official station, based on PGG linear regression analysis.
Resulting "Effective" Precipitation (P)	37.9 in/yr (annual average)
Portion of "P" going to immediate runoff	0% of effective precipitation, based on high permeability of soils
Rate of Snow Ablation (SA)	N/A
Snowmelt Rate Coefficient	N/A
Depth to Till Layer	10 feet, based on generalized cross section.
Thickness of Till Layer	10 feet, based on generalized cross section.
Vertical Hydraulic Conductivity of Till	1E-09 ft/day, based on empirical maximization of wetland saturation
Specific Yield of Perched Aquifer	0.45 based on consideration of peat properties.
Darcy Flow Coefficient for Perched Aquifer	0.000001 based on empirical maximization of wetland saturation.

Method of Estimating Potential Evapotranspiration:

Blaney Criddle (BC)

Priestly Taylor Canopy Interception:

Not Modeled

Snowpack: Not Modeled

Till Perching: Modeled

**RECHARGE CALCULATOR:**

**Evaporation Estimates**

Monthly Temp (T, °F)  
 Monthly Temp (T, °C)  
 Blaney Criddle Crop Factor (k)  
 Blaney Criddle % of Annual Light (d)  
 Priestly Taylor Net Radiation (RN)  
 Potential Evapotranspiration (PET)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
Monthly Temp (T, °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0
Blaney Criddle Crop Factor (k)	0.49	0.57	0.73	0.85	0.90	0.92	0.92	0.92	0.87	0.79	0.67	0.55	0.77
Blaney Criddle % of Annual Light (d)	0.064	0.065	0.082	0.091	0.103	0.105	0.106	0.097	0.084	0.076	0.064	0.061	1.00
Priestly Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potential Evapotranspiration (PET)	0.46	0.68	1.27	2.04	3.29	4.20	5.02	4.63	3.21	1.85	0.90	0.53	28.07

**Table B-7 - Recharge for the SeaTac Project Area - Deciduous Forest on Highly Saturated Area (Wetland)**

Vegetation Data	
Type of Land Cover	deciduous forest
Rooting Depth	60 in
Priestly Taylor "Alpha"	N/A
Average Annual Fractional Foliar Cover	N/A
Average Annual Foliar Interception Capacity	N/A

Weather Station Data	
Nearest Weather Station	Seatac Airport
Average Precipitation	37.9 in/yr
Avg Annual Temperature	59.3 °F
Latitude	47.45 °N
Longitude	-121.72 °W
Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.17 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site:Weather-Station Precipitation	100% of official station, based on PGG linear regression analysis.
Resulting "Effective" Precipitation (P)	37.9 in/yr (annual average)
Portion of "P" going to immediate runoff	0% of effective precipitation, based on high permeability of soils
Rate of Snow Ablation (SA)	N/A
Snowmelt Rate Coefficient	N/A
Depth to Till Layer	10 feet, based on generalized cross section.
Thickness of Till Layer	10 feet, based on generalized cross section.
Vertical Hydraulic Conductivity of Till	1E-09 ft/day, based on empirical maximization of wetland saturation
Specific Yield of Perched Aquifer	0.45 based on consideration of peat properties.
Darcy Flow Coefficient for Perched Aquifer	0.000001 based on empirical maximization of wetland saturation.

Method of Estimating Potential Evapotranspiration:

Blaney Criddle (BC)

Priestly Taylor Canopy Interception:

Not Modeled

Snowpack: Not Modeled

Till Perching: Modeled

**RECHARGE CALCULATOR:**

**Evaporation Estimates**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	
Monthly Temp (T, °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8	Avg. T, °F
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0	Avg. T, °C
Blaney Criddle Crop Factor (k)	0.17	0.25	0.40	0.63	0.88	0.96	0.95	0.82	0.54	0.30	0.19	0.15	0.52	(Avg k)
Blaney Criddle % of Annual Light (d)	0.064	0.065	0.082	0.091	0.103	0.105	0.106	0.097	0.084	0.076	0.064	0.061	1.00	(Avg d)
Priestly Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(RN)
Potential Evapotranspiration (PET)	0.16	0.30	0.69	1.51	3.21	4.38	5.19	4.12	1.99	0.70	0.25	0.15	22.66	(PET)

Table B-8 - Recharge / Water Balance for the SeaTac Projec Area - Deciduous Forest on Till

Vegetation Data		Weather Station Data	
Type of Land Cover	Deciduous forest	Name	Seattle Airport
Rooting Depth	30 in	Weather Station	
Priestly Taylor Alpha*	N/A	Average Precipitation	37.9 in/yr
Average Annual Fractional	N/A	Avg Annual Temperature	59. °F
Average Annual Evapotranspiration	N/A	Latitude	47.45 °N
Interception Capacity	N/A	Longitude	-121.72 °W
		Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.10 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site Weather-Station Precipitation	100% of official station, based on PGG linear regression analysis.
Residual "Effective" Precipitation (P)	37.9 in/yr (annual average)
Portion of "P" going to immediate runoff	0% of effective precipitation, based on high permeability of soils.
Rate of Snow Ablation (SA)	N/A
Snowmelt Rate Coefficient	N/A
Depth to Till Layer	2.5 feet, based on
Thickness of Till Layer	10 feet, based on
Vertical Hydraulic Conductivity of Till	0.008 in/day, based on calib. to hydrograph below
Porosity of Perched Aquifer	0.37 based on
Darcy Flow Coefficient for Perched Aquifer	0 based on empirical adjustment.

Method of Estimating Potential Evapotranspiration: Priestly Taylor Canopy Interception:  Not Included  Included Tilt Percentage:  Not Included  Included

RECHARGE CALCULATOR: Snowpack:  Not Included  Included

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	Aug. T. °C (Avg. 4)	Aug. T. °F (Avg. 6)
Evaporation Estimates															
Monthly Temp (T. °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8	11.0	51.8
Monthly Temp (T. °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0	5.2	51.8
Blaney Middle Crop Factor (R)	0.17	0.25	0.40	0.63	0.88	0.96	0.96	0.82	0.54	0.30	0.16	0.15	0.52	0.32	51.8
Blaney Middle % of Annual Light (R)	0.064	0.065	0.082	0.091	0.103	0.106	0.106	0.097	0.084	0.076	0.064	0.061	0.081	0.06	51.8
Priestly Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	51.8
Potential Evapotranspiration (PET)	0.16	0.30	0.68	1.51	3.21	4.38	5.19	4.12	1.99	0.70	0.25	0.15	22.86	0.00	51.8
Water Balance															
Effective Precipitation (P)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	0.00	51.8
Interception Loss (IL)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	51.8
Average Snowpack Storage (SS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	51.8
Snowpack Ablation (SA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	51.8
Snowmelt (SM)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	51.8
Available Throughfall (ATF)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	0.00	51.8
Runoff (RO)	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.8
Infiltration (I)	5.64	3.80	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	0.00	51.8
Average Soil Moisture in Soil Profile (SM)	8.87	9.88	8.55	7.97	4.36	2.34	4.42	3.03	2.22	0.00	0.00	0.00	12.18	0.00	51.8
Soil Moisture Deficit (PET-P)	0.00	0.00	0.00	0.00	1.58	2.94	4.42	3.03	2.22	0.00	0.00	0.00	12.18	0.00	51.8
Actual Evapotranspiration (AET)	0.16	0.30	0.68	1.51	3.21	4.38	5.19	4.12	1.99	0.70	0.25	0.15	22.86	0.00	51.8
Shallow Recharge (RS)**	5.47	3.51	3.00	1.94	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.70	0.00	51.8
Perched Subflow (PS)***	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.8
Deep Recharge (RD)***	3.51	3.36	3.69	3.41	2.91	0.00	0.00	0.00	0.00	1.35	3.02	3.39	24.74	0.00	51.8

ANNUAL SUMMARY	P	IL	SM	AET	RO	I	RS	PS	RD
	37.86	N/A	N/A	37.86	0.35	37.86	22.86	24.74	0.00

NOTES:  
 All values used in the Evaporation Estimates, Water Balance, and Annual Summary are in inches unless otherwise noted.  
 Abbreviations used in the Annual Summary are defined in the Evaporation Estimates and Water Balance.  
 \*\* Modelled runoff consists of the sum of the fact percentage of effective precipitation going to runoff and any infiltration rejected when saturation reaches the land surface.  
 \*\*\* Deep recharge can be negative if perched conditions extend up into the root zone and plant transpiration removes significant amounts of water from the shallow aquifer.  
 \*\*\*\* Shallow recharge is water that flows through the till layer. Perched subflow is lateral, saturated flow above the till layer to adjacent discharge points.

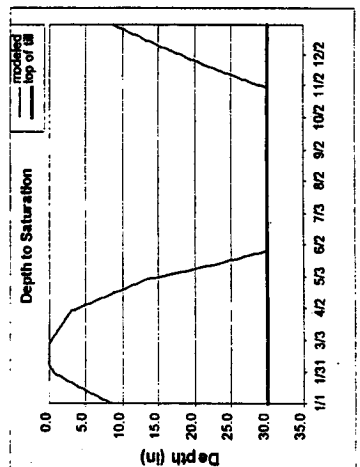




Table B-9 - Recharge / Water Balance for the SeaTac Project Area - Coniferous Forest on Till

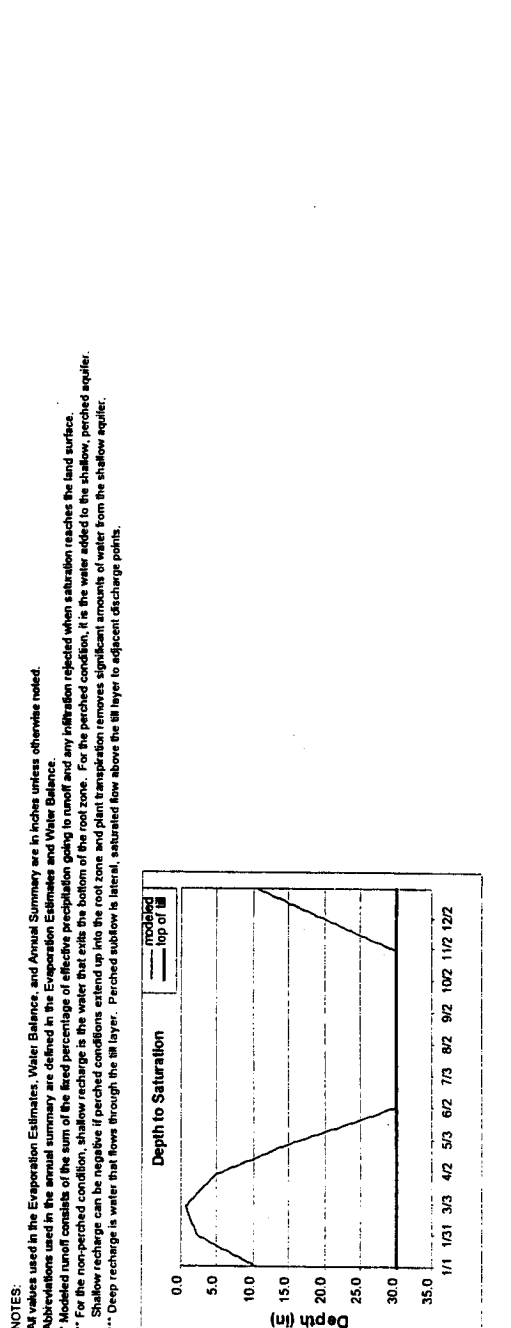
Vegetation Data		Weather Station Data	
Type of Land Cover	mature conifers	Nearest Station	Seattle Airport
Rooting Depth	30 in	Precipitation	37.9 in/yr
Priestly Taylor Alpha*	N/A	Avg Annual Temperature	59. °F
Foliar Cover	N/A	Longitude	121.172 W
Average Annual Foliar Interception Capacity	N/A	Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.10 inch/inch within root zone, based on SCS soil descriptions.
Rate of Site-Weather-Station Precipitation	100% of official station, based on PGG linear regression analysis.
Resulting Effective Precipitation (P)	37.9 in/yr (annual average)
Portion of "P" going to immediate runoff	0% of effective precipitation, based on high permeability of soils.
Rate of Snow Addition (SA)	N/A
Snowmelt Rate Coefficient	N/A
Depth to Till Layer	2.5 feet, based on
Thickness of Till Layer	10 feet, based on
Vertical Hydraulic Conductivity of Till	0.007 /day, based on calcs. to saturation hydrograph below
Porosity of Perched Aquifer	0.37 based on
Darcy Flow Coefficient for Perched Aquifer	0 based on empirical adjustment.

Method of Estimating Potential Evapotranspiration: Priestly Taylor Canopy Interception: Snowpack: Not Included Till Perching: Included

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
Evaporation Estimates													
Monthly Temp (T, °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0
Blaney Criddle Crop Factor (R)	0.63	0.73	0.86	0.85	0.52	0.53	0.53	0.50	0.40	0.20	0.18	0.64	0.66
Blaney Criddle % of Annual Light (d)	0.064	0.065	0.062	0.091	0.103	0.105	0.106	0.097	0.084	0.076	0.064	0.061	1.00
Priestly Taylor Net Radiation (RN)	0.60	0.87	1.49	2.04	1.89	2.41	2.89	2.66	1.84	1.88	1.05	0.82	20.23
Potential Evapotranspiration (PET)													
Water Balance													
Effective Precipitation (P)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Interception Loss (IL)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(IL)
Average Snowpack Storage (SS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SS)
Snowmelt (SM)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SM)
Available Throughfall (ATF)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Runoff (RO)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(RO)
Infiltration (I)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Average Soil Moisture in Soil Profile (SW)	8.46	9.57	9.23	7.47	4.71	2.51	1.50	1.07	1.48	2.82	4.99	6.35	4.90
Soil Moisture Deficit (PET-P)	0.00	0.00	0.00	0.00	0.26	0.87	2.12	1.56	0.89	1.72	1.95	0.82	16.52
Actual Evapotranspiration (AET)	5.04	3.29	2.20	0.52	-0.24	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	21.34
Shallow Recharge (RS)**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(RS)
Perched Subflow (PS)***													(PS)
Deep Recharge (RD)***	3.12	2.92	3.20	2.94	2.78	2.25	0.00	0.00	0.00	0.58	2.82	2.92	21.34



NOTES:  
 All values used in the Evaporation Estimates, Water Balance, and Annual Summary are in inches unless otherwise noted.  
 Abbreviations used in the annual summary are defined in the Evaporation Estimates and Water Balance.  
 \* Modeled runoff consists of the sum of the field percentage of effective precipitation going to runoff and any infiltration rejected when saturation reaches the land surface.  
 \*\* For the non-perched condition, shallow recharge is the water that exits the bottom of the root zone. For the perched condition, it is the water added to the shallow perched aquifer.  
 \*\*\* Deep recharge is water that flows through the till layer. Perched subflow is lateral, saturated flow above the till layer. Perched subflow is lateral, saturated flow above the till layer to adjacent discharge points.

**Table B-10 - Recharge / Water Balance for the Sea Tac Project Area - Coniferous Forest on Outwash**

Vegetation Data	
Type of Land Cover	mature conifers
Rooting Depth	36 in
Priestley Taylor "Alpha"	N/A
Average Annual Fractional Foliar Cover	N/A
Average Annual Foliar Interception Capacity	N/A

Weather Station Data	
Nearest Weather Station	Seatac Airport
Average Precipitation	37.9 in/yr
Avg Annual Temperature	59.3 °F
Latitude	47.45 °N
Longitude	-121.72 °W
Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.08 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site-Weather-Station Precipitation Resulting "Effective" Precipitation (P)	100% of official station, based on PGG linear regression analysis.
Portion of "P" going to immediate runoff*	37.9 in/yr (annual average)
Rate of Snow Ablation (SA)	0% of effective precipitation, based on high permeability of soils
Snowmelt Rate Coefficient	N/A
Depth to Till (Not Used in Model)	N/A
Till Thickness (Not Used in Model)	100
Vertical Hydraulic Conductivity of Till	10
Specific Yield of Perched Aquifer	N/A
Darcy Flow Coefficient for Perched Aquifer	N/A

Method of Estimating Potential Evapotranspiration:

Blaney Cridde (BC) ▼

Priestley Taylor Canopy Interception: ▼

Not Modeled ▼

Snowpack: Not Modeled ▼

Till Perching: Not Modeled ▼

**RECHARGE CALCULATOR:**

**Evaporation Estimates**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
Monthly Temp (T, °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0
Blaney Cridde Crop Factor (k)	0.63	0.73	0.86	0.85	0.52	0.53	0.53	0.53	0.50	0.80	0.78	0.64	0.66
Blaney Cridde % of Annual Light (d)	0.064	0.065	0.082	0.091	0.103	0.105	0.106	0.097	0.084	0.076	0.084	0.061	0.084
Priestley Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potential Evapotranspiration (PET)	0.60	0.87	1.49	2.04	1.89	2.41	2.89	2.66	1.84	1.88	1.05	0.62	20.23
Effective Precipitation (P)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Interception Loss (IL)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average Snowpack Storage (SS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Snowpack Ablation (SA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Snowmelt (SM)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Available Throughfall (ATF)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Runoff (RO)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Infiltration (I)	2.68	2.67	2.65	2.63	2.52	2.15	1.43	1.18	1.64	2.52	2.67	2.68	2.28
Average Soil Moisture in Soil Profile (SW)	0.00	0.00	0.00	0.00	0.26	0.97	2.12	1.56	0.07	0.00	0.00	0.00	4.98
Soil Moisture Deficit (PET-P)	0.60	0.87	1.49	2.04	1.81	1.95	1.57	1.07	1.07	1.77	1.05	0.62	15.82
Actual Evapotranspiration (AET)	5.04	3.30	2.22	0.51	0.00	0.00	0.00	0.00	0.00	0.95	4.80	5.21	22.04
Shallow Recharge (RS)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Perched Subflow (PS)***	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Deep Recharge (RD)***	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ANNUAL SUMMARY	P	IL	SM	ATF	RO	I	PET	AET	RS	PS	RD
	37.86	N/A	N/A	37.86	0.00	37.86	20.23	15.82	22.04	N/A	N/A

**NOTES:**

All values used in the Evaporation Estimates, Water Balance, and Annual Summary are in inches unless otherwise noted. Abbreviations used in the annual summary are defined in the Evaporation Estimates and Water Balance.  
 \* Modeled runoff consists of the sum of the fixed percentage of effective precipitation going to runoff and any infiltration rejected when saturation reaches the land surface.  
 \*\* For the non-perched condition, shallow recharge is the water that exits the bottom of the root zone. For the perched condition, it is the water added to the shallow, perched aquifer.  
 \*\*\* Shallow recharge can be negative if perched conditions extend up into the root zone and plant transpiration removes significant amounts of water from the shallow aquifer.

**Table B-11 - Recharge / Water Balance for the Sea Tac Project Area - Grass on Outwash**

Vegetation Data	
Type of Land Cover	grass
Rooting Depth	24 in
Priestly Taylor "Alpha"	N/A
Average Annual Fractional Foliar Cover	N/A
Average Annual Foliar Interception Capacity	N/A

Weather Station Data	
Nearest Weather Station	Seatac Airport
Average Precipitation	37.9 in/yr
Avg Annual Temperature	59.3 °F
Latitude	47.45 °N
Longitude	-121.72 °W
Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.08 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site Weather-Station Precipitation Resulting "Effective" Precipitation (P)	100% of official station, based on PGG linear regression analysis.
Portion of "P" going to immediate runoff*	37.9 in/yr (annual average)
Rate of Snow Ablation (SA)	0% of effective precipitation, based on high permeability of soils
Snowmelt Rate Coefficient	N/A
Depth to Till (Not Used in Model)	N/A
Till Thickness (Not Used in Model)	100
Vertical Hydraulic Conductivity of Till	10
Specific Yield of Perched Aquifer	N/A
Darcy Flow Coefficient for Perched Aquifer	N/A

Method of Estimating Potential Evapotranspiration:

Blaney Criddle (BC)

Priestly Taylor Canopy Interception:

Snowpack:

Till Perching:

**RECHARGE CALCULATOR:**

**Evaporation Estimates**

Monthly Temp (T, °F)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	Avg. T, °F
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	51.8	11.0
Blaney Criddle Crop Factor (k)	0.49	0.57	0.73	0.85	0.92	0.92	0.92	0.92	0.87	0.79	0.87	0.55	0.77	(Avg k)
Blaney Criddle % of Annual Light (d)	0.064	0.065	0.082	0.091	0.103	0.105	0.106	0.097	0.084	0.076	0.064	0.061	1.00	(Avg d)
Priestly Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(RN)
Potential Evapotranspiration (PET)	0.46	0.68	1.27	2.04	3.29	4.20	5.02	4.63	3.21	1.85	0.90	0.53	28.07	(PET)

**Water Balance**

Effective Precipitation (P)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	(P)
Interception Loss (IL)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(IL)
Average Snowpack Storage (SS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SS)
Snowpack Ablation (SA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SA)
Snowmelt (SM)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	(SM)
Available Throughfall (ATF)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(ATF)
Runoff (RO)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	(RO)
Infiltration (I)	2.01	2.00	1.98	1.95	1.36	0.82	0.38	0.17	0.56	1.65	1.99	2.00	1.40	(I)
Average Soil Moisture in Soil Profile (SW)	0.00	0.00	0.00	0.00	1.66	2.76	4.26	3.53	1.43	0.00	0.00	0.00	13.63	(SW)
Soil Moisture Deficit (PET-P)	0.46	0.68	1.27	2.04	2.44	1.89	1.28	1.13	1.18	1.58	0.90	0.53	15.35	(PET-P)
Actual Evapotranspiration (AET)	5.17	3.49	2.44	0.52	0.00	0.00	0.00	0.00	0.00	0.63	4.95	5.30	22.50	(AET)
Shallow Recharge (RS)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(RS)
Perched Subflow (PS)***	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(PS)
Deep Recharge (RD)***	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(RD)

ANNUAL SUMMARY	P	IL	SM	ATF	RO	I	PET	AET	RS	PS	RD
	37.86	N/A	N/A	37.86	0.00	37.86	28.07	15.35	22.50	N/A	N/A

**NOTES:**  
 All values used in the Evaporation Estimates, Water Balance, and Annual Summary are in inches unless otherwise noted.  
 Abbreviations used in the annual summary are defined in the Evaporation Estimates and Water Balance.  
 \* Modeled runoff consists of the sum of the fixed percentage of effective precipitation going to runoff and any infiltration rejected when saturation reaches the land surface.  
 \*\* For the non-perched condition, shallow recharge is the water that exits the bottom of the root zone. For the perched condition, it is the water added to the shallow, perched aquifer.  
 \*\*\* Shallow recharge can be negative if perched conditions extend up into the root zone and plant transpiration removes significant amounts of water from the shallow aquifer.

**Table B-12 - Recharge / Water Balance for the SeaTac Project Area - Deciduous Forest on Outwash**

Vegetation Data	
Type of Land Cover	deciduous forest
Rooting Depth	60 in
Priestly Taylor "Alpha"	N/A
Average Annual Fractional Foliar Cover	N/A
Average Annual Foliar Interception Capacity	N/A

Weather Station Data	
Nearest Weather Station	Seatac Airport
Average Precipitation	37.9 in/yr
Avg Annual Temperature	59.3 °F
Latitude	47.45 °N
Longitude	-121.72 °W
Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.06 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site Weather-Station Precipitation Resulting "Effective" Precipitation (P)	100% of official station, based on PGG linear regression analysis.
Portion of "P" going to immediate runoff*	37.9 in/yr (annual average)
Rate of Snow Ablation (SA)	0% of effective precipitation, based on high permeability of soils
Snowmelt Rate Coefficient	N/A
Depth to Till (Not Used in Model)	N/A
Till Thickness (Not Used in Model)	100
Vertical Hydraulic Conductivity of Till	10
Specific Yield of Perched Aquifer	N/A
Darcy Flow Coefficient for Perched Aquifer	N/A

Method of Estimating Potential Evapotranspiration:

Blaney Criddle (BC) ▼

Priestly Taylor Canopy Interception: ▼

Not Modeled ▼

Snowpack: Not Modeled ▼

Till Perching: ▼

Not Modeled ▼

**RECHARGE CALCULATOR:**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
<b>Evaporation Estimates</b>													
Monthly Temp (T, °F)	39.6	42.9	45.2	49.3	55.4	60.4	64.8	64.8	60.4	52.4	45.0	40.6	51.8
Monthly Temp (T, °C)	4.2	6.0	7.3	9.6	13.0	15.8	18.2	18.2	15.8	11.3	7.2	4.8	11.0
Blaney Criddle Crop Factor (K)	0.17	0.25	0.40	0.63	0.86	0.96	0.95	0.82	0.54	0.30	0.19	0.15	0.52
Blaney Criddle % of Annual Light (d)	0.064	0.065	0.082	0.091	0.103	0.105	0.106	0.087	0.084	0.076	0.064	0.061	0.081
Priestly Taylor Net Radiation (RN)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potential Evapotranspiration (PET)	0.16	0.30	0.89	1.51	3.21	4.38	5.19	4.12	1.99	0.70	0.25	0.15	22.86
<b>Water Balance</b>													
Effective Precipitation (P)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Interception Loss (IL)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average Snowpack Storage (SS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Snowpack Ablation (SA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Snowmelt (SM)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Available Throughfall (ATF)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Runoff (RO)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Infiltration (I)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86
Average Soil Moisture in Soil Profile (SW)	3.41	3.41	3.40	3.37	2.76	2.12	1.36	1.14	1.80	3.19	3.41	3.42	2.73
Soil Moisture Deficit (PET-P)	0.00	0.00	0.00	0.00	1.58	2.94	4.42	3.03	0.22	0.00	0.00	0.00	12.18
Actual Evapotranspiration (AET)	0.16	0.30	0.89	1.51	2.46	2.16	1.54	0.91	0.76	0.63	0.25	0.15	11.52
Shallow Recharge (RS)**	5.48	3.86	3.01	1.05	0.00	0.00	0.00	0.00	0.00	1.64	5.60	5.70	26.34
Perched Subflow (PS)***	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Deep Recharge (RD)****	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ANNUAL SUMMARY	P	IL	SM	ATF	RO	I	PET	AET	RS	PS	RD
	37.86	N/A	N/A	37.86	0.00	37.86	22.66	11.52	26.34	N/A	N/A

**NOTES:**

All values used in the Evaporation Estimates, Water Balance, and Annual Summary are in inches unless otherwise noted.  
 Abbreviations used in the annual summary are defined in the Evaporation Estimates and Water Balance.  
 \* Modeled runoff consists of the sum of the fixed percentage of effective precipitation going to runoff and any infiltration rejected when saturation reaches the land surface.  
 \*\* For the non-perched condition, shallow recharge is the water that exits the bottom of the root zone. For the perched condition, it is the water added to the shallow, perched aquifer.  
 \*\*\* Shallow recharge can be negative if perched conditions extend up into the root zone and plant transpiration removes significant amounts of water from the shallow aquifer.

**Table B-13 - Recharge / Water Balance for the SeaTac Project Area - Barren Outwash**

Vegetation Data	
Type of Land Cover	barren
Rooting Depth	12 in
Priestly Taylor "Alpha"	1
Average Annual Fractional Foliar Cover	N/A
Average Annual Foliar Interception Capacity	N/A

Weather Station Data	
Nearest Weather Station	SeaTac Airport
Average Precipitation	37.9 in/yr
Avg Annual Temperature	59.3 °F
Latitude	47.45 °N
Longitude	-121.72 °W
Elevation	300 feet msl

Soil and Water Data	
Avg. Soil Available Water Capacity (AWC)	0.08 inch/inch within root zone, based on SCS soil descriptions.
Ratio of Site Weather-Station Precipitation Resulting "Effective" Precipitation (P)	100% of official station, based on PGG linear regression analysis.
Portion of "P" going to immediate runoff*	37.9 in/yr (annual average)
Rate of Snow Ablation (SA)	0% of effective precipitation, based on high permeability of soils
Snowmelt Rate Coefficient	N/A
Depth to Till (Not Used in Model)	N/A
Till Thickness (Not Used in Model)	100
Vertical Hydraulic Conductivity of Till	20
Specific Yield of Perched Aquifer	N/A
Darcy Flow Coefficient for Perched Aquifer	N/A

Method of Estimating Potential Evapotranspiration:

Priestly Taylor (PT)

Priestly Taylor Canopy Interception:

Snowpack:  Not Modeled

Till Perching:  Not Modeled

**RECHARGE CALCULATOR:**

**Evaporation Estimates**

Monthly Temp (T, °F)	39.6
Monthly Temp (T, °C)	4.2
Blaney Criddle Crop Factor (k)	N/A
Blaney Criddle % of Annual Light (d)	N/A
Priestly Taylor Net Radiation (RN)	0.23
Potential Evapotranspiration (PET)	0.06

**Water Balance**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	
Effective Precipitation (P)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	(P)
Interception Loss (IL)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(IL)
Snowpack Storage (SS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SS)
Snowpack Ablation (SA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SA)
Snowmelt (SM)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(SM)
Available Throughfall (ATF)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	(ATF)
Runoff (RO)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(RO)
Infiltration (I)	5.64	4.16	3.69	2.53	1.63	1.44	0.77	1.10	1.77	3.41	5.87	5.85	37.86	(I)
Soil Moisture in Root Zone (SW)	0.96	0.94	0.92	0.88	0.40	0.29	0.28	0.29	0.43	0.89	0.95	0.96	0.88	(SW)
Soil Moisture Deficit (PET-P)	0.00	0.00	0.00	0.00	1.97	2.73	3.96	2.71	0.47	0.00	0.00	0.00	11.84	(PET-P)
Actual Evapotranspiration (AET)	0.06	0.42	1.27	2.27	2.20	1.47	0.80	1.07	1.62	0.89	0.17	0.00	12.22	(AET)
Shallow Recharge (RS)**	5.58	3.75	2.45	0.30	0.00	0.00	0.00	0.00	0.00	2.03	5.68	5.84	25.64	(RS)
Perched Subflow (PS)*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(PS)
Deep Recharge (RD)*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(RD)

ANNUAL SUMMARY																					
P	37.86	IL	N/A	SM	N/A	ATF	37.86	RO	0.00	I	37.86	PET	23.61	AET	12.22	RS	25.64	PS	N/A	RD	N/A

**NOTES:**

All values used in the Evaporation Estimates, Water Balance, and Annual Summary are in inches unless otherwise noted. Abbreviations used in the annual summary are defined in the Evaporation Estimates and Water Balance.  
 \* Modeled runoff consists of the sum of the fixed percentage of effective precipitation going to runoff and any infiltration rejected when saturation reaches the land surface.  
 \*\* Shallow recharge is water that flows either to the shallow water table or through the bottom of the root zone (infiltration minus actual evapotranspiration from soil).  
 Deep recharge is water that flows through the till layer. Perched subflow is lateral, saturated flow above the till layer to adjacent discharge points.

## Appendix C

### Proposed Third Runway Fill Vadose Zone Modeling with Hydrus-2D

The following three computer-based groundwater models were used for this project:

- Pacific Groundwater Group Recharge Model
- Hydrus-2D by Simunek and others (1999)
- Finite Difference slice model (slice model)

The recharge model was used to calculate recharge for the current and post construction conditions at the proposed third runway fill and borrow sources south of the runways. Hydrus was used to model the movement of water between the root zone and the water table assuming construction of the runway fill. The slice model was used to accumulate recharge in the shallow water table aquifer and move it downgradient under current and built conditions to the Miller Creek riparian wetlands. This appendix describes the input and functions of the Hydrus model. The main text presents basic characterization data, model results, and interpretation.

#### 1 Method Overview

Eight independent models of variably saturated flow within the proposed fill were used to simulate water movement between the root zone and water table below the fill. One of these models was conceptual only: where the fill was less than 20 feet thick, and where it is proposed to be composed entirely of Type 1 fill (adjacent to the proposed wall), the model consisted of assuming that recharge below the root zone was immediately present at the water table or top of glacial till. The other seven models used the computer code Hydrus-2D, and varied only in the assumed thickness of fill (150, 130, 110, 90, 70, 50, and 30 feet). **Figure 3-5** of the main text shows an idealized cross section of the fill through the proposed west wall area, and the thickness variations that would be present. The Hydrus-2D model scenarios were used to analyze lagging and dampening of the recharge pulse between the land surface and a water table assumed to occur on top of a shallow till aquitard (perching layer). A shallow glacial till aquitard is generally present throughout the modeled section and areas north and south. At best, however, the model cross section is a simplification of actual conditions; and in some areas the actual stratigraphy, slopes, and permeabilities are different than modeled.

#### 2 Characterization of Fill Texture

The characteristics of the fill modeled in Hydrus were selected based primarily on the specifications for a small section of fill placed in 1998 and 1999 (Phase I fill - Port of Seattle Commission, 1998). Field data from analysis of Phase I soil samples (Terra Associates, 1998) and samples of the possible Maury Island fill source (Pacific Groundwater Group, 2000) were also examined.

The Port of Seattle Commission specified the particle size ranges shown in **Table C-1** for three fill groups that comprised the Phase I fill. Italicized bold values were calculated for this project based on the specifications. The values for the No 10 sieve were calculated for this project based on interpolations between the No 4 and 40 sieves, and the central values of the ranges were also interpolated and are therefore represented in bold italics. The requirement for modeling with Hydrus-2D was to identify the percentages of gravel, sand, and silt according to the US Department of Agriculture system.

Central values of the ranges passing the sieves were selected to represent the Groups' textures. Groups 1 and 2 were combined to represent "Type 1" fill described by Hart Crowser (1999) in designing the embankment where the Hydrus model was applied. "Type 2" fill of Hart Crowser was assumed to have the texture of Group 3 fill in **Table C-1**. Type 1 soils have few fines, whereas Type 2 soils are siltier. Passing ranges for sieve numbers 10 and 200 were interpolated from the combined textures of Groups 1 and 2 to supply the modeling requirement for percent gravel (USDA - retained by U.S. No 10 sieve) and percent silt and clay (passing U.S. No 200 sieve).

Hart Crowser (1999) reports that only Type 1 fill would be used near the west wall (main text **Figure 3-5**). The remainder of the embankment (called "general embankment" in this report) would be comprised of Type 1 and 2 fills, with Type 1 required below pavement and in certain other areas. Overall, Hart Crowser reports that the relative proportions of Type 1 and 2 fills is 40% and 60%, respectively. Considering the contribution of the volume of the Type 1 fill area near the west wall, we estimated that the general embankment would have 30% Type 1 and 70% Type 2 fills. The calculations are summarized in the **Table C-2**.

Using the percentages of Type 1 and 2 fills in the general embankment; and the percentages of fines, sand, and gravel calculated for Type 1 and 2 fills; we calculated the following average bulk texture for the general embankment:

- General Embankment Percent Gravel 56%
- General Embankment Percent Sand 28%
- General Embankment Percent Silt and Clay 16%

These texture groups were further considered to form two media:

1. an inactive gravel fraction through which water typically does not move, surrounded by
2. an active matrix of sand and fines through which most unsaturated flow occurs.

The gravel fraction was rounded to 55 percent of the bulk general embankment volume from the 56 percent calculated above. The sand-plus-fines matrix was considered to be the remaining 45 percent. The sand-plus-fines matrix was calculated to be composed of an average of 63 percent sand and 37 percent silt; clay was assumed to be absent.

Hydrus-2D supports the U. S. Soil Salinity Laboratory's "neural network" computer program "Rosetta" to estimate soil-moisture characteristic curves and hydraulic conductivity distributions based on grain-size distributions. Rosetta draws upon the USDA's "UNSODA" soil property

database<sup>1</sup> to derive relationships between easily measured grain-size fractions, bulk density, and other information and the key parameters required to approximate soil-moisture characteristic curves and unsaturated hydraulic conductivity distributions using the methods of van Genuchten (1980) and Mualem (1976). The maximum allowable bulk density of 2.0 grams per cubic centimeter (UNSODA 2.0) was used to represent the sand-plus-silt matrix. Appendix **Figures C-1 and C-2** show the predicted soil-moisture characteristic curve and unsaturated hydraulic conductivity distribution for the model of the general embankment fill matrix.

Appendix **Figures C-3 and C-4** present plots of texture for soil samples collected from the Phase I fill and the Maury Island gravel deposit. **Figure C-3** presents analyses of *whole samples from the Phase I fill only* and shows that the 55 percent gravel fraction and 16 percent fines fraction calculated for the general embankment by this method is near the middle of the range observed. However, most samples were observed to be coarser than the modeled fill. **Figure C-4** presents analysis of *the sand and fines fractions from Phase I and Maury Island samples*, and shows that the fraction of silt-plus-clay, as a percentage of the matrix, varied widely in the samples. The value of 36 percent ( $16/(16+28)$ ) calculated for the general embankment by this method is near the middle of the range observed in Phase I soils, and falls between the values for "type 1" and "type 2" fills as it should. However, most field samples were measured to have a lower silt content than the modeled fill.

### 3 Modeling of Active and Inactive Fill Portions

The sand and silt matrix was modeled as an evenly distributed 45 percent of the general fill and all water flow was assumed to occur within this *active* matrix. To maintain a water balance while modeling water flow only through the active matrix, recharge values for grass on outwash (from the Hydrus model) were divided by 0.45 and used as the upper boundary condition flux in Hydrus. This can be viewed as forcing any precipitation percolating into clusters of gravel particles to be absorbed by the surrounding sand-and-silt matrix somewhere within the embankment. The output at the bottom of the Hydrus model was then multiplied by 0.45 to maintain a long-term water flux equal to grass-on-outwash recharge.

The gravel fraction was modeled as inactive because:

- the fill should remain unsaturated except in extreme conditions, and therefore unsaturated flow should predominate,
- large diameter pores associated with gravels will be the first to desaturate as drying occurs,
- over the course of the flow path, water in saturated pores will be absorbed into the finer pores,
- percolation theory (Silliman and Wright, 1988) suggests that continuous paths of finer pores will exist throughout the embankment at the modeled texture (it also predicts continuous course pore paths which would be predominant in saturated flow),
- it was not feasible for this project to characterize soil moisture retention characteristics of gravels

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<sup>1</sup> The UNSODA database catalogs soil properties based upon textural and hydraulic property testing from 790 soil samples.



Our method of characterization should be accurate for classical unsaturated flow modeling used by Hydrus and nearly all other unsaturated flow prediction methods. However, it does not account for the observation that "fingering" of flow can occur in coarse soils under very wet conditions. Fingering occurs when saturation builds-up at one location and then rapidly drains downward through large connected pores in a saturated finger. Such fingering flow will only occur during recharge events when the ground surface, or a subsurface soil zone, becomes saturated. If fingering flow occurs in the fill, the Hydrus model will overestimate groundwater travel times between ground surface and the water table.

In a related model limitation, recharge is simulated as a constant for a given month. Recharge actually occurs as discrete precipitation events. The Hydrus model developed for the embankment fill does not predict saturation of the fill, whereas at least surface saturation could occur during intense precipitation events.

#### 4 Design of Hydrus-2D Model

The Hydrus-2D model was setup to simulate seven portions of the proposed fill that differ in thickness only (see **Figure 3-5** of the main text for thickness variation). The analyses required only a one-dimensional simulation, and Hydrus-2D's finite element grid was set up to most closely approximate a purely 1-D solution. Two columns of nodes were specified with a horizontal separation of 15 cm (6 inches). The upper and lower 150 cm (6 feet) of the profile were assigned relatively detailed nodal definition, with vertical nodal spacings gradually increasing from 1 cm (0.4 inches) at the land surface and water table to 5 cm (2 inches). Between these high-definition top and bottom zones, vertical spacings transitioned to a maximum value of 15 cm (6 inches). Nodes representing the land surface were specified flux boundaries. The bottom two nodes were assigned the "water table" boundary condition, which is a constant head boundary equal to elevation head. "Observation nodes" were specified every 50 feet in the vertical profile, from which hydrographs of water content (or head) vs. time were extracted. Time-series data for volumetric flow rates exiting the bottom of the model domain at the water table boundary nodes could also be extracted.

Modeled hydraulic properties for the fill matrix were generated with Rosetta, based on the percentages of sand, silt and clay discussed in Section 2 of this appendix. Rosetta provides estimates of five parameters used to generate the soil moisture characteristic curve of **Figure C-1**: saturated water content, residual water content, "alpha", "N", and "M" (van Genuchten, 1980). Rosetta also provides an estimate of saturated hydraulic conductivity and a factor "L" used to relate the characteristic curve to the unsaturated hydraulic conductivity curve (Mualem, 1976). A default "L" value of 0.5 was assigned by Rosetta in Hydrus-2D, and was used in this analysis. **Table C-3** presents the hydraulic parameters generated by Rosetta for the general fill matrix. The saturated hydraulic conductivity calculated by Rosetta was  $1.35 \times 10^{-4}$  cm/sec. This value is near the middle of the range presented in Freeze and Cherry (1979) for silty sand. It is near the high end of the reported glacial till range and lower than the clean sand and gravel ranges reported by Freeze and Cherry (1979).

Although the actual value(s) of hydraulic conductivity are not known for this proposed future condition, the value calculated by Rosetta is reasonable for the anticipated texture and density of the general embankment matrix, and is consistent with the two-matrix method of modeling unsaturated

flow in the embankment. Experience with testing saturated hydraulic conductivity of soils similar in texture to the modeled fill suggests that the Rosetta-calculated value is too low for the general embankment fill; however, the reason for this discrepancy is the presence of large pores associated with gravels. Large pores associated with gravel deposits dominate saturated flow but are the first to become inactive as drainage occurs.

## **5 Modeling Approach**

A transient simulation was performed in order to reach a “cyclic steady state” of annual water-content fluctuation within the fill. Cyclic steady state means that seasonal variations are the same for each successive year. Monthly stress periods were used, and monthly recharge estimates were applied to the top of the model. For each modeled fill thickness, hydrographs of water flux at the water table were used to identify that recurrent fluctuations occurred and therefore that a cyclic steady state had been reached (**Figure 3-12** of the main text). The cyclic fluxes at the water tables were multiplied by 0.45 to maintain mass balance (see Section 3 above), and exported to the Finite Difference Slice Model (**Appendix E**).

## **6 References**

Freeze R. A. and J.A. Cherry, 1979, Groundwater, Prentice-Hall, Englewood Cliffs, New Jersey

Mualem, Y. 1976. A new model for predicting the hydraulic conductivity of unsaturated porous media, *Water Resources Research*, 12(3), 513-522.

Silliman S.E., and A.L. Wright, 1988, Stochastic Analysis of Paths of High Hydraulic Conductivity in Porous Media, *Water Resources Research*, Vol. 24, No. 11

Simunek, J., Senjna, M., van Genuchten, M. Th., 1999. Hydrus-2D/Meshgen-2D - Simulating Water Flow and Solute Transport in Two-Dimensional Variably Saturated Media, Version 2.0 dated April 1999, U.S. Salinity Laboratory, USDA/ARS. Distributed by International Groundwater Modeling Center

van Genuchten, M. Th. 1980. A closed form equation for predicting the hydraulic conductivity of unsaturated soils, *Soil Science Society of America Journal*, 44, 892

**Table C-1  
Particle Size Distributions Specified for Phase I Fill**

	Sieve Size	Percent Passing		Central Value of Range
		Lower Limit	Upper Limit	
Group 1	6-inch	100		
	3-inch	70	97	<b>83.5</b>
	3/4-inch	50	77	<b>63.5</b>
	U.S. No 4	30	50	<b>40</b>
	<b>U.S. No 10 (sand)</b>	<b>13</b>	<b>28</b>	<b>20.5</b>
	U.S. No 40	3	15	<b>9</b>
	U.S. No 200 (silt and clay)	0	5	<b>2.5</b>
Group 2	6-inch	100		
	3-inch	70	97	<b>83.5</b>
	3/4-inch	50	85	<b>67.5</b>
	U.S. No 4	30	65	<b>47.5</b>
	<b>U.S. No 10 (USDA sand)</b>	<b>14</b>	<b>43</b>	<b>28.5</b>
	U.S. No 40	5	30	<b>17.5</b>
	U.S. No 200 (silt and clay)	0	12	<b>6</b>
Group 3 <sup>2</sup>	6-inch	100		
	U.S. No 4	50	95	<b>72.5</b>
	<b>U.S. No 10 (USDA sand)</b>	<b>31</b>	<b>73</b>	<b>52</b>
	U.S. No 40	20	60	<b>40</b>
	U.S. No 200 (silt and clay)	12	35	<b>23.5</b>
<b>Combined Groups 1 and 2<sup>3</sup></b>	<b>U.S. No 10 (USDA sand)</b>			<b>24.5</b>
	<b>U.S. No 200 (silt and clay)</b>			<b>4.25</b>

<sup>2</sup> Soil Group 3 is "Type 2" fill as defined in Appendix B to the Wetland Functional Assessment and Impact Analysis by Parametrix in 1999 (Geotechnical Engineering Report, 404 Permit Support, Third Runway Embankment Sea-Tac International Airport, Hart Crowser 1999).

<sup>3</sup> Soil Groups 1 and 2 comprise "Type 1" soils as defined in Appendix B to the Wetland Functional Assessment and Impact Analysis by Parametrix, 1999 (Geotechnical Engineering Report, 404 Permit Support, Third Runway Embankment Sea-Tac International Airport, Hart Crowser 1999).

**Table C-2  
Calculations on Embankment Composition**

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Cross Sectional Area of Type 1 fill Zone Near West Wall	~18,000	sq ft (in section)
Cross Sectional Area of General Embankment	~85,000	sq ft (in section)
Total Embankment Type 1 fill	40%	Hart Crowser, 1999
Total Embankment Type 2 fill	60%	Hart Crowser, 1999
West Wall Zone Type 1 fill content	100%	Hart Crowser, 1999
West Wall Zone Type 2 fill content	0%	Hart Crowser, 1999
General Embankment Type 1 Fill Content	~30%	Calculated
General Embankment Type 2 Fill Content	~70%	Calculated

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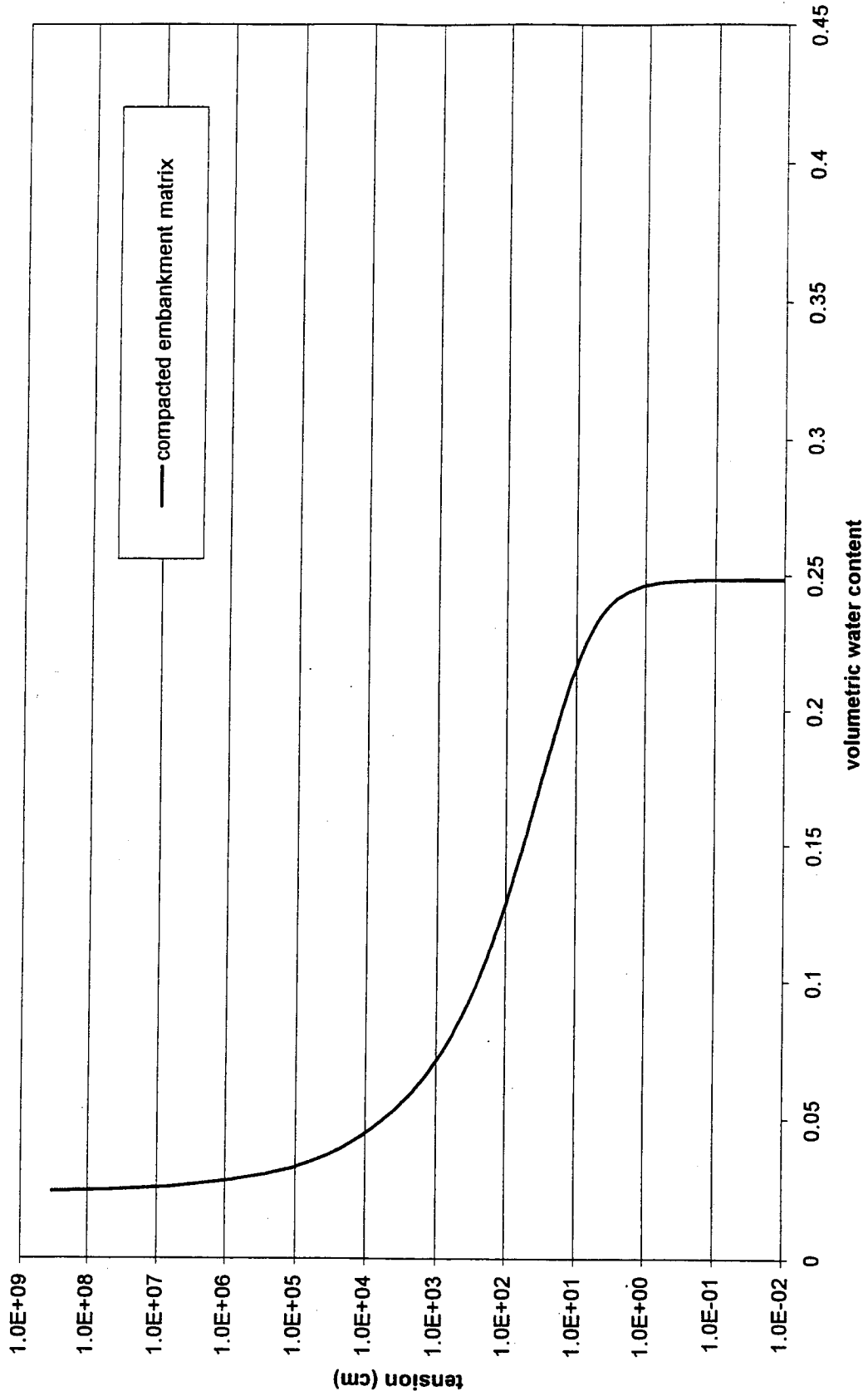
**Table C-3 Summary of Hydraulic Parameters Used for Fill Matrix  
in the Hydrus-2D Model**

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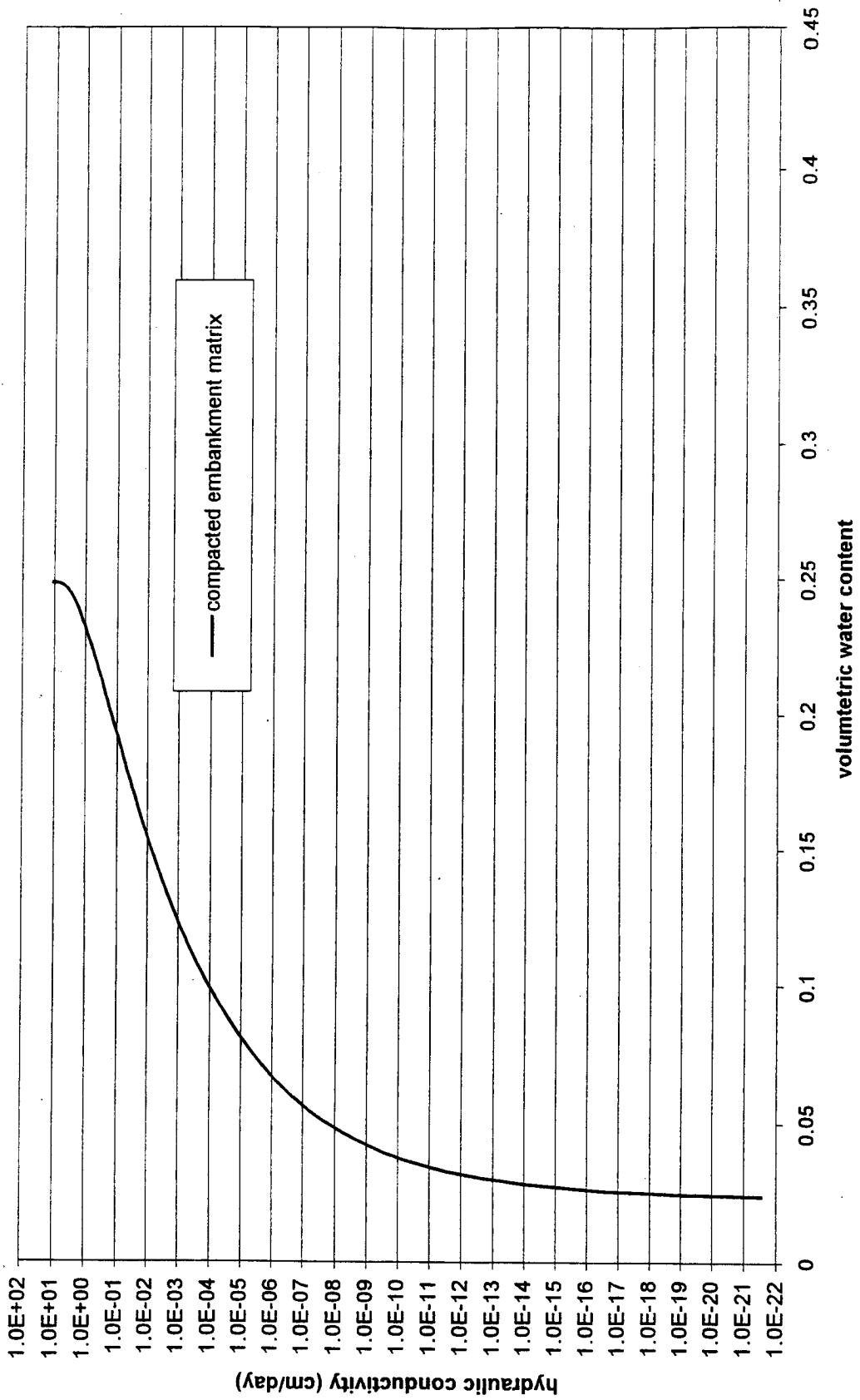
Sand Fraction of matrix	0.63
Silt Fraction of matrix	0.37
Clay Fraction of matrix	0
Saturated Volumetric Water Content of matrix	0.25
Residual Volumetric Water Content of matrix	0.02
"alpha" (1/cm)	0.088
"N"	1.35
Saturated Hydraulic Conductivity (cm/sec) of matrix	$1.35 \times 10^{-4}$

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**Figure C-1**  
**Soil Moisture Characteristic Curve for General Embankment Matrix**

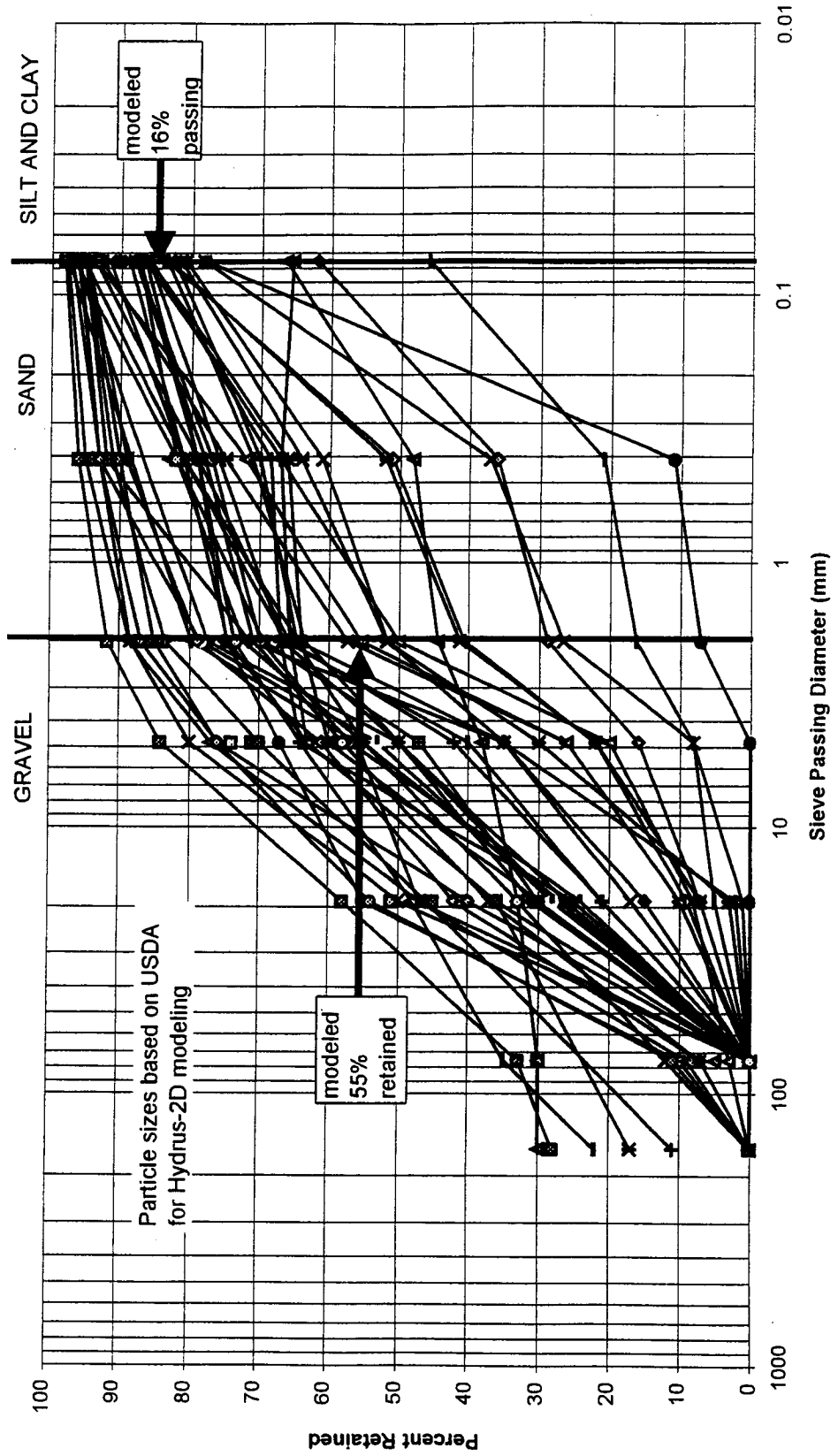


**Figure C-2**  
**Soil Moisture vs Hydraulic Conductivity for General Embankment Matrix**

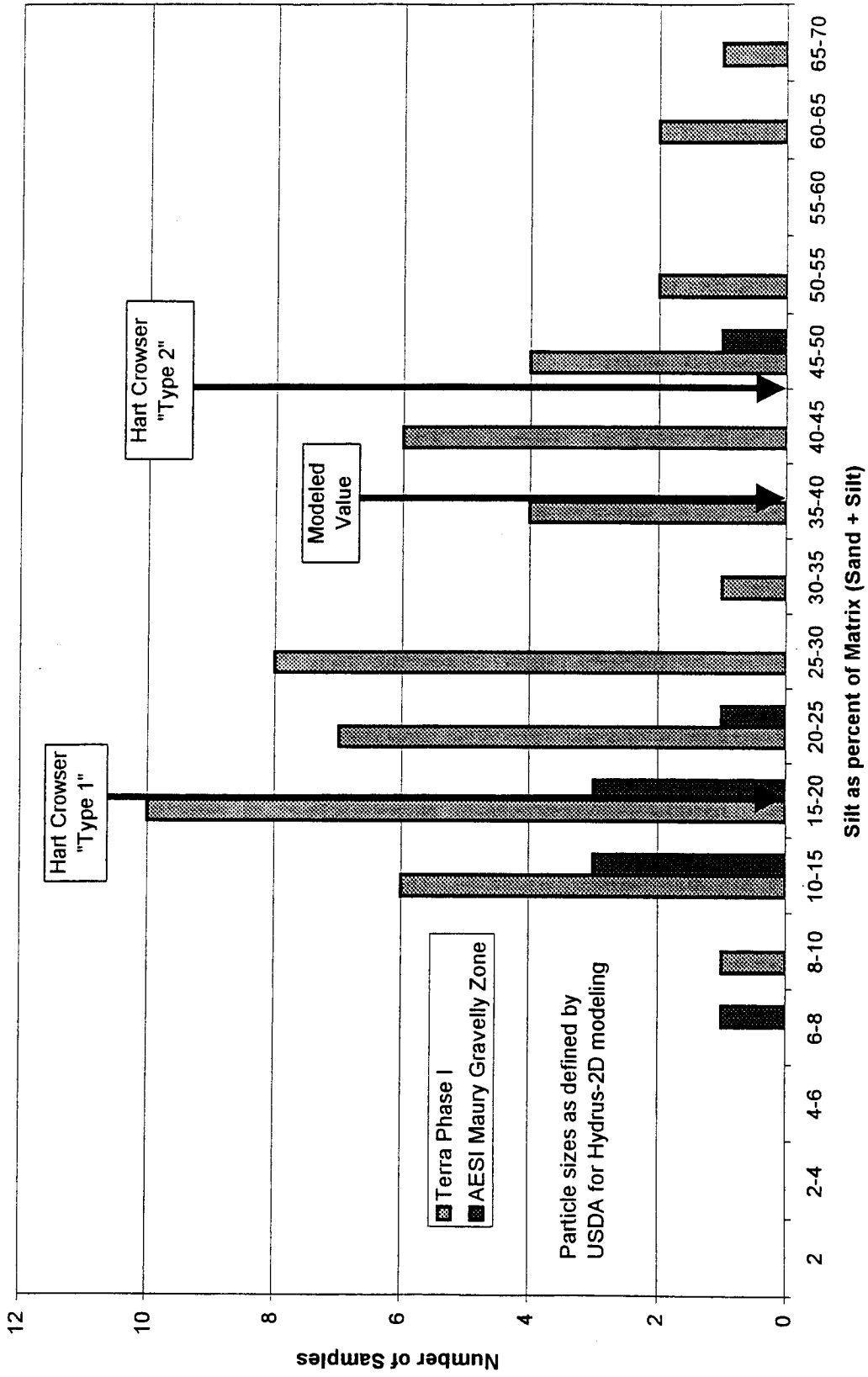




**Figure C-3**  
**Grain Size Analyses of Whole Samples from Phase 1 Fill**



**Figure C-4**  
**Comparison of Silt vs Sand Fractions**



## MEMORADUM

**TO:** File  
**FROM:** Russ Prior  
**DATE:** 4-12-00  
**RE:** Geologic Interpretations by AESI

The purpose of this memorandum is to document a review of the SeaTac area geologic interpretation by AESI. Their interpretation provides the conceptual model, which is the basis for a proposed multi-layered groundwater model.

Russell Prior of Pacific Groundwater Group reviewed the following documents:

- STIA Ground Water Study, Model Boundary Presentation, (No Date), Associated Earth Sciences, Inc. and S.S. Papadopoulos and Assoc., Inc (figures only)
- Map of buyout area showing water supply wells
- 1999 Hydrogeologic Characterization Report, City of Auburn, by Pacific Groundwater Group, Cross-section A-A' (based on USGS interpretation)
- Geologic Map by Booth and Waldron (in press), digitized by AESI

### General Comments

In general, the geologic interpretation is made difficult because maps do not have labeled wells. This is true for the contour maps showing the elevations and thicknesses of the various units and also for the map (Figure 4) showing the location of the cross-section lines. At the very least the maps should be presented with section lines for easier location of wells used in the interpretation. Figure 4 should present topography rather than streets.

In several cases the contouring of the top of the hydrostratigraphic layers does not coincide with the cross sections. It is not known how the contours were generated for each layer. Were they generated based on top elevations picked off of the cross-sections or were they generated directly from point data?

There are many instances where the cross-sections and the contour maps are not consistent. Many of the inconsistencies exist near the ends of the cross-sections. Some of these inconsistencies are indicated below but there is no attempt to document all of them herein.

### Specific Comments on Cross-Sections

#### *Cross-Section B-B'*

At the Des Moines Creek crossing, cross-section B-B' indicates that layer C2 crops out. This is consistent with recent mapping completed by Booth and Waldron (in press).

AR 011793

However, it is not consistent with USGS mapping and cross-sections (Woodward, et al) where Vashon Advance is mapped.

Cross-section B-B' shows a general pinching-out of the upper horizons to the south. Most notably, horizon C1 is shown to pinch-out completely at KCWD75 Well #1. In general, this pinching-out of horizon C1 is understood to be based on the Booth interpretation. However, this interpretation presents some difficulties. For instance it requires interpreting blue clay encountered in wells 23N4E22N1 and 22N4E09P1 differently. Both wells encountered blue clay at elevation 200 feet. In well 22N1, this blue clay is interpreted to be F2 yet in 09P1 this blue clay is interpreted to be F3. Not only are these two units encountered at the same elevation, they are also approximately the same thickness.

There is also a problem with consistency between the southern portion of cross-section B-B' and the contour map showing the thickness and top of Layer C1. Why do any contours exist for unit C1 thickness in an area that is interpreted to have none on the cross-section?

#### *Cross-Section C-C'*

On the west end of this section a deep boring log exists that has Layer C2 labeled on the east side and Layer F2 labeled on the west. This is assumed to be a typographical error.

#### *Cross-Section D-D'*

On the Duwamish River bluff (middle to southern portion of the section) there must be a typo. It indicates Layer C1 overlaying Layer F1. It is assumed that this is intended to be Layer C0.

#### *Cross-Section E-E'*

The southern end of this cross-section indicates that layer C1 does not exist. This interpretation is inconsistent with Booth and Waldron's mapping, which indicates the presence of Qva underneath Vashon Till. If correctly interpreted to be Layer C1, then the next layer down (Well 22N4E20L1) would be Layer C2 to be consistent with the mapping.

#### *Cross-Section F-F'*

On the eastern end of this section, the top of Layer C2 reaches an elevation of over 400 feet. However, the contouring of the top of Layer C2 does not show this. The same location in Figure 12 shows a maximum elevation of C2 at around 300 to 320 feet. It is not clear if the contouring depicts the top of the water table in this vicinity.

#### *Cross-Section H-H'*

The western portion of cross-section H-H' does not appear to be consistent with the geologic mapping of Booth and Waldron. On the bluff west of Miller Creek, the geologic map indicates that the Pre-Fraser fine-grained deposit crops out. The cross-section depicts this bluff as underlain by Layer F2, which correlates with Transitional Beds.

The implication of the geologic mapping is that the Vashon Advance (C1) does not exist in the eastern portion of the upland west of Miller Creek. However, AESI's Figure 7 indicates a thickness on the order of 50 feet here.

### **Structure Contour Maps**

The contour maps that depict the thickness and top elevation for the hydrostratigraphic units appear to have been generated by computer and are based on limited point data. The contours are characterized by many closed contours (highs and lows) around specific data points. The effect is one of many independent "hills" and "holes" which are likely not real. If the pre-Vashon topography looked similar to today then there should be a general north-south system of ridges. Such is not the case with the contour maps. Use of a purely digital process to generate the maps contributes to a non-geologic interpretation.

There appears to be an area where the contours are wrong. This area is in the southern portion of cross-section B-B'. In comparing the contour maps for the top elevations of units C1 and C2, the top of unit C1 is indicated as lower than that of C2. This relationship is not possible and is likely a relict of the contouring technique.

### **Map Showing Location of Domestic Wells**

A map provided by AESI shows the location of several domestic water supply wells in the vicinity immediately west of the airport. Several of the wells shown are either incorrectly located or incorrectly labeled. Two wells in Section 31 (T23NR4E) provide examples. Well 23N4E31H1 is located in the NE  $\frac{1}{4}$  of the NE  $\frac{1}{4}$  of the section. This well should either be relabeled or relocated to the SE  $\frac{1}{4}$  of the NE  $\frac{1}{4}$ . A well, labeled 23N4E32F2, is in the SE  $\frac{1}{4}$  of the NE  $\frac{1}{4}$  of section 31. This well should be relabeled or belongs in the SE  $\frac{1}{4}$  of the NW  $\frac{1}{4}$  of section 32.

This map was apparently generated from wells that have well logs on file with the Department of Ecology. It is clear that AESI's map does not include all of the domestic water supply wells. This finding is based on a one day field visit, which traversed about half of the buyout area. During this visit, two drilled wells and eight dug wells were located. The map provided by AESI indicates only two wells in the buyout area, one of which is either mis-located or mislabeled.

This map shows only a small area of the total model domain. If a similar number of mis-located or mislabeled wells exist in other parts of the model domain, then there could be some problems with the geologic interpretation.

## Appendix E

### Finite Difference Models of Proposed Third Runway Fill Area

The following three computer-based groundwater models were used for this project:

- Pacific Groundwater Group Recharge Model
- Hydrus-2D
- Finite Difference slice model (slice model)

The recharge model was used to calculate recharge for the current and post construction conditions at the proposed third runway fill and borrow sources south of the runways. Hydrus was used to model the movement of water between the root zone and the water table beneath the runway fill. The slice model was used to accumulate and move recharge downgradient under current and built conditions, to the Miller Creek riparian wetlands. This appendix describes the input and functions of the slice model. The main text presents basic characterization data, model results, and interpretation.

#### 1 Method Overview

The slice model was used to simulate groundwater flow for both the current and built conditions. Two versions of the model were constructed to represent expected differences in flow system geometry and hydraulic properties. The slice model is based on a quasi-two-dimensional finite-difference formulation of the partial differential equation describing transient groundwater flow through a saturated medium. Model cells were only connected to laterally adjacent neighbors as opposed to overlying or underlying cells – thus the quasi-two-dimensional nature of the model. Each model cell can contain up to three different “soil layers”, differing in thickness and hydraulic conductivity. The bottom elevation of each cell is defined by the top of the till layer, and downward flow through the till can be simulated. For each cell, the model also specifies storage coefficient and recharge per time-step. The model assumes unconfined flow (variable transmissivity) under horizontal gradients defined by head differences between adjacent cells. The model was implemented in Microsoft Excel, using direct (explicit) methods to solve the finite-difference equation.

Recharge inflow to the slice model was estimated with the recharge and Hydrus models. The recharge model calculates the amount and timing of shallow groundwater recharge percolating through the root zone based on a daily soil moisture budget. Estimates of recharge from the recharge model are appropriate to describe water-table inflows where the depths to water are relatively shallow. This was the case for the current condition, where shallow till is modeled to occur within 10 feet of the land surface, and wetlands (where present) maintain saturation at near the land surface year-round. Monthly recharge estimates from the recharge model were used as input to the slice model under the current condition. For the built condition, Hydrus-2D was used to predict changes in the timing of recharge from the land surface as it moves downward through the

embankment vadose zone. Hydrus is a finite-element, variably saturated flow model which uses Richard's Equation to simulate unsaturated flow. Output from the recharge model was used as input to the Hydrus model, and output from Hydrus was used as input to the slice model.

## **2 Slice Model Geometry**

Figures 3-5a and b of the main text show the geometry and simplified geology of the modeled cross sections (slices). The bottom axis of that figure shows the model cell numbers. The current condition geology has been simplified into the following layers and materials. The till and subsoil layers are shown on main text Figure 3.5a.

- surface soils (2.5 feet thick everywhere)
- wetland and outwash subsoils (7.5 feet thick, not present on the east)
- glacial till (10 feet thick everywhere)

For estimating lateral flow and accumulation of recharge, the model explicitly simulated both soil layers present above the till. The surface soil layers are derived from wetland conditions on the west, outwash sediments in the center, and very shallow glacial till on the east. Subsoil materials were not present in the eastern model domain, due to the shallow presence of till. The layers were divided into model cells with a horizontal dimension of 25 feet.

To model the built condition, the surficial soils were removed and a 4-foot drain layer was added above the scraped land surface as designed by Hart Crowser (1999). The drain was modeled as a third soil layer present within each model cell. In the eastern model domain, only the drain layer and the till was assumed present due to removal of surficial soils.

## **3 Material Properties**

Material properties were assigned in accordance with the conceptual model presented in Section 3.2.2 of the main text.

Under the current condition, surficial soils derived from wetland conditions were assigned a hydraulic conductivity of 1 ft/day, whereas soils derived from till and outwash were assigned hydraulic conductivities of 4 ft/day. These values are near the low end of permeability ranges reported for Snohomish (wetland), Alderwood (till), and Everett (outwash) soils by the SCS for King County (Soil Conservation Service, 1973). Outwash subsoils were modeled with a hydraulic conductivity of 6 feet per day. Wetland subsoils were assumed to consist of 33 percent sandy outwash and 67 percent fine-grained and peaty soils with a resulting hydraulic conductivity of 2.65 ft/day. Glacial till was modeled with a vertical hydraulic conductivity of 0.004 ft/day, except below the wetlands where it was artificially set to zero to prevent deep percolation in that area where groundwater discharges. The drain layer added for the built condition was modeled with a hydraulic conductivity of 300 ft/day. The embankment fill properties are not explicitly modeled in the slice model because they are modeled in Hydrus-2D. Specific yield was equal to 0.3 everywhere.

#### 4 Inflow and Outflow

The explicit formulation of the finite difference equation calculates inflows and outflow to each model cell for each time-step of the transient simulation. Under the current condition, the following inflows and outflow were simulated for each model cell:

**Inflows:**

- recharge to the water table
- groundwater flow from adjacent (upgradient) model cell
- infiltration of surface flow from adjacent (upgradient) model cell

**Outflows:**

- downward seepage through underlying till
- groundwater flow to adjacent (downgradient) model cell
- surface flow to downgradient model cell

The slice model simulated the occurrence of surface flow when inflows to a cell during any time-step were greater than maximum outflows plus available storage. The portion of available inflows that could not be accommodated in the subsurface was passed on to the next downgradient cell as surface flow. Because there was no term for surface storage, any surface flows generated were assumed to pass through the model domain during a single time-step. Under the built condition, the surface flow terms were removed because the drain layer could accommodate all predicted inflows. Because the drain layer is buried beneath the embankment, all flow remains in the subsurface.

Recharge inflow to the water table was specified on a cell-by-cell basis based on the results of the recharge model (for the current condition) and the results of the Hydrus model (for the built condition). **Table E-1** shows the recharge conditions assigned to the classes of model cells used for the current condition simulation. Also for the current condition, **Table E-2** shows the classes assigned to each model cell and **Table E-3** shows the monthly recharge values assigned to each class.

For the built condition, recharge inflows to the water table were based on Hydrus model output for various embankment thicknesses. Each model cell was assigned to one of eight recharge schedules depending on whether the overlying embankment thickness was closest to 0, 30, 50, 70, 90, 110, 130, or 150 feet. **Table E-4** presents a summary of cell type information for the built simulation, **Table E-5** shows variables for individual model cells for the built condition including embankment modeled thickness, and **Table E-6** presents the monthly values of recharge for each generalized category of embankment thickness. It should be noted that all model cells beneath the 225-foot wide runway (cells 26 through 34) received zero recharge, and cells within the western retaining wall of the embankment were assigned a recharge schedule consistent with zero time-lag through the vadose zone. Recharge is assumed to pass quickly through the western Type-1 fill section due to its low fines content. It should also be noted that the recharge schedule for each model cell is independent of its neighbor. Modeling in Hydrus did not include simulation of lateral interaction between different portions of the fill.

Groundwater inflows and outflows were calculated based on effective transmissivities and gradients between adjacent cells. Transmissivity was calculated for each cell by summing the product of the saturated thickness and hydraulic conductivity of each soil layer. The transmissivity of a given cell was used to calculate the groundwater outflow from that cell. Gradient was defined as the head difference divided by the spacing between cells. More detailed explanation of calculation of



groundwater flow is provided in Section 5 of this appendix. No groundwater inflow was assumed into the eastern edge of the model.

Outflow via downward seepage through underlying till was based on the till hydraulic conductivity and variable heads below and above the till. Head at the top of the till was equal to the value calculated for each model cell. Head at the bottom of the till was assumed equal to bottom elevation of the till layer in the eastern upland portion of the model (cells 1-24) and the mid-point of the till layer in the middle of the model slice (cells 25-33). These assignments lead to vertical hydraulic gradients of about 1.0 and 0.5, respectively, with the saturated thickness of each model cell effecting the vertical gradient through the till. Instead of assigning a vertical gradient of zero in the wetland, the hydraulic conductivity was set equal to zero.

Surface flow was calculated in the current condition simulation to accommodate the portion of accumulated recharge that the groundwater system could not conduct. Each model cell has a maximum flow capacity, based on its maximum hydraulic gradient (i.e. the gradient of the land surface) and its maximum transmissivity. When the cell is fully saturated (i.e. to the land surface) conditions may occur where the combined recharge and groundwater inflow estimated for that cell cannot be accommodated or passed on to the next cell within the subsurface. In this case, the model routes the excess portion of inflow to a surficial flow term and passes it on to the next downgradient cell as surface outflow. If the downgradient cell can accommodate the surface flow along with recharge and groundwater inflows, then the surface flow is allowed to infiltrate. The surface inflow for a particular time-step is limited by either the volume of surface flow available from the upgradient cell, the excess storage capacity of the downgradient cell, or the infiltration capacity of that cell (as defined by the permeability of the surficial soil). If a portion of upgradient surface flow does not infiltrate to a cell, it is passed on to the next downgradient cell. In this manner, surface flow can accumulate over the length of the model.

## **5 Modeling Approach**

The explicit formulation of the transient finite difference equation for groundwater flow calculates the various inflows and outflows for a model cell at a given time-step ( $t$ ) based on conditions defined in the prior time-step ( $t-1$ ). The explicit finite difference equation can be viewed as a mass balance, where inflows minus outflows equal the change in storage for the model cell. The following mass balance represents the terms included in the finite difference equation:

$$\text{Rech} + \text{GW}_{\text{in}} + \text{SW}_{\text{in}} - \text{Till} - \text{GW}_{\text{out}} - \text{SW}_{\text{out}} = \Delta S \quad (1)$$

Recharge input (Rech) is calculated for each model cell by multiplying the recharge rate (applicable to the time of year) by the length of the time-step and top area of the cell. Lookup tables, presented in **Tables E-3** and **E-6**, were used to determine recharge rates for each time-step. The top area of the cell is the product of its length (25 feet) and the width of the slice model (1foot). By multiplying the recharge rate by a time interval and area, a volume is calculated for the time-step in question.

Groundwater inflows and outflows ( $\text{GW}_{\text{in}}$  and  $\text{GW}_{\text{out}}$ ) were calculated using the same approach. Inflow and outflow volumes were calculated by multiplying the length of the time-step by the rate of groundwater flow between adjacent cells. Groundwater outflow was calculated by multiplying

the cell's transmissivity by the hydraulic gradient between the cell and its downgradient neighbor. For each cell, transmissivity is calculated by summing products of saturated thickness and hydraulic conductivity for each of the soil layers included. Saturated thickness is determined from the head values calculated in the previous time-step (t-1). Groundwater inflow is defined as the outflow from the cell's upgradient neighbor.

The volume of downward seepage through the till layer (Till) is equal to the product of the time-step interval, the top area of the model cell, and the calculated flow rate through the till. This flow rate is the product of the hydraulic conductivity of the till and the hydraulic gradient across the till, where the hydraulic gradient defined as:

$$(h_{\text{cell}} - h_{\text{tb}})/b \quad (2)$$

where:  $h_{\text{cell}}$  = the head value of the model cell from the previous time-step  
 $h_{\text{tb}}$  = the head value of the bottom of the till (assumed constant)  
 $b$  = the thickness of the till (10 feet).

The mass balance, defined above in equation 1, is performed for every cell for every time-step of the model simulation. For each time-step, mass balance proceeds in consecutive order from upgradient to downgradient cells. In certain instances, when recharge and/or available storage are low, adjustments were required to the till outflow term for the groundwater flow system to ensure that predicted outflows did not exceed available inflows and storage. When such instances occurred, till seepage was scaled back so as not to exceed available volumes.

For the current condition simulation, surface inflows and outflows were defined based on the following set-up rules:

1. Surface flow is accumulated from cell to cell in a downgradient direction. Losses and gains to surface flow calculated for a given cell are applied to the accumulated flow volume from the adjacent, upgradient cell.
2. Surface inflow to a cell ( $SW_{\text{in}}$ ) can only occur when cumulative surface flow exists from upgradient, and when storage capacity still exists in the cell after all groundwater system inflows ( $Rech$  and  $GW_{\text{in}}$ ) and outflows ( $Till$  and  $GW_{\text{out}}$ ) are applied.
3. The portion of the cumulative surface-flow volume allowed to infiltrate from upgradient is equal to the minimum value among the cumulative surface-flow volume, the maximum infiltration volume allowable over the time-step, and the available cell storage after all the groundwater inflows and outflows are accounted for. The maximum allowable infiltration volume is equal to the product of the top area of the cell, the length of the time-step, and the hydraulic conductivity of the surficial soils.
4. Surface outflow from a cell ( $SW_{\text{out}}$ ) can only occur when there is no surface inflow, and the groundwater terms in the mass balance (inflows minus outflows) exceed the available storage of the cell.
5. Surface outflow is calculated as the groundwater system inflows minus the groundwater system outflows minus the change in storage ( $\Delta S$ ) required to bring the model cell to full-thickness saturation.

## 6 Time Steps, Initial Conditions, and Length of Simulation

Time stepping within the model was designed to maintain numerical stability of the explicit finite difference formulation, in accordance with recommendations by Anderson and Woessner, 1982). A critical (maximum) time-step can be estimated based on the following formula:

$$dt = 0.5 * S * a^2 / T \quad (3)$$

where: dt = critical time-step length  
S = storage coefficient  
a = length of model cell (25 ft)  
T = transmissivity

For the current condition, the critical time-step was estimated to be 1.7 days, and a value of 1 day was used. For the built simulation, the critical time-step was estimated to be 0.4 days; however a value of 0.1 day was required for stability. In the built case, it was necessary to rigorously define a plausible initial condition before the time-step value of 0.1 day provided stable results. This was performed by running the model over a long time period with a fixed recharge input and a time-step of 0.1 days.

The model was run for a single year, over and over again, until a repeating cyclic pattern was achieved. Repetition was confirmed by comparing the results of one year with the results of the following year. Model simulations were initiated on the first day of February. This date was chosen because it follows the three months of highest shallow recharge (December through January). For the current condition, a fully saturated initial condition was estimated at the onset of model simulation and several years were required to achieve a repeating cyclic pattern. For the built condition, zero saturation was assumed at the onset of simulation, using a time-step of 0.1 and recharge rates for February. The stable head distribution calculated for February recharge was used as an initial condition for the annual simulations. A minimum of three years was required to achieve a repeating cyclic pattern for the built condition.

## **7 References**

Hart Crowser Inc., 1999, Geotechnical Engineering Report, 404 Permit Supprt, Third Runway Embankment, Sea-Tac International Airport

McDonald , M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-differences groundwater flow model; U.S. Geological Survey Techniques of Water Resources Investigations, Book 6, Chapter A1

United States Department of Agriculture Soil Conservation Service, 1973, Soil Survey, King County Area Washington

**Table E-1  
Model Parameters for the Current Condition Simulation**

Model Parameters for Cells Types

	Cell Type 1	Cell Type 2	Cell Type 3	Cell Type 4	Cell Type 5
Surficial Soil	Alderwood	Everett	Everett	Everett	peaty
Aquifer Materials	till derived soil	outwash stringers	outwash stringers	outwash stringers	peat & outwash
Land Cover	forest	forest	impermeable	grass	grass/forest
Wetland/Upland	upland	upland	upland	upland	wetland
Bottom Layer Hydraulic Conductivity (ft/d)	4	6	6	6	2.7
Top of Bottom Layer (ft above till)	2.5	7.5	7.5	7.5	7.5
Middle Layer Hydraulic Conductivity (ft/d)		4	4	4	1
Top of Middle Layer (ft above till)		10	10	10	10
Upper Layer Hydraulic Conductivity (ft/d)					
Top of Upper Layer (ft above till)					
Maximum Saturated Thickness (ft)	2.5	10	10	10	10
Gradient of Top of Till (ft/ft)	18.8%	18.8%	18.8%	18.8%	3.6%
Full Thickness Hydraulic Conductivity (ft/d)	4	5.5	5.5	5.5	2.2
Maximum Subsurface Flow (cfd)	1.9	10.3	10.3	10.3	0.8
Maximum Downgradient Flow (cfd)	10.3	10.3	10.3	0.8	0.0
Cell Length (ft)	25	25	25	25	25
Specific Yield	30%	30%	30%	30%	30%
Maximum Storage (cubic ft)	18.75	75	75	75	75

NOTE: All values are for a vertical slice of 1-foot width.

Model Constants

Till Thickness (ft)	10
Till Permeability Beneath Uplands (ft/d)	0.004
Till Permeability Beneath Wetlands (ft/d)	0
Outwash Permeability (ft/d)	6
Peat Permeability (ft/d)	1
Percent Outwash in Peaty Aquifer	33%
Peaty Aquifer Permeability (ft/d)	2.65
Drain Material Permeability (ft/d)	
Till Derived Soil Permeability (ft/d)	4
Outwash Derived Soil Permeability (ft/d)	4
Wetland Surficial Soil Permeability (ft/d)	1

Time Stepping

"delta X" (ft)	25
maximum transmissivity (ft <sup>2</sup> /d)	55
minimum storage coefficient	30%
maximum time step (d)*	1.70
user defined model timestep (d)	1.00

(from Anderson & Woessner, 1982:  $dt \leq 0.5 * S^{**} \text{delta } X^{**2} / T$ )

**Table E-2**  
**Model Parameters for Individual Cells in the Current Condition Simulation**

Cell ID	Distance from Outlet	Top of Till Elevation	Cell Length (ft)	Cell Type	Recharge Class	Head at Bottom of Till	Maximum Subsurface Outflow (cfd)	Maximum Runoff Infiltration (cfd)	Specific Yield	Maximum Storage (cf)	Land Surface Elevation
1	1137.5	385.0	25	1	A	375.0	1.9	100	30%	18.8	387.5
2	1112.5	380.4	25	1	A	370.4	1.9	100	30%	18.8	382.9
3	1087.5	375.7	25	1	A	365.7	1.9	100	30%	18.8	378.2
4	1062.5	371.0	25	1	A	361.0	1.9	100	30%	18.8	373.5
5	1037.5	366.3	25	1	A	356.3	1.9	100	30%	18.8	368.8
6	1012.5	361.6	25	1	A	351.6	1.9	100	30%	18.8	364.1
7	987.5	356.9	25	1	A	346.9	1.9	100	30%	18.8	359.4
8	962.5	352.2	25	1	A	342.2	1.9	100	30%	18.8	354.7
9	937.5	347.5	25	1	A	337.5	1.9	100	30%	18.8	350.0
10	912.5	342.9	25	1	A	332.9	1.9	100	30%	18.8	345.4
11	887.5	338.2	25	1	A	328.2	1.9	100	30%	18.8	340.7
12	862.5	333.5	25	1	A	323.5	1.9	100	30%	18.8	336.0
13	837.5	328.8	25	1	A	318.8	1.9	100	30%	18.8	331.3
14	812.5	324.1	25	1	A	314.1	1.9	100	30%	18.8	326.6
15	787.5	319.4	25	1	A	309.4	10.3	100	30%	18.8	321.9
16	762.5	314.7	25	2	B	304.7	10.3	100	30%	75.0	324.7
17	737.5	310.0	25	2	B	300.0	10.3	100	30%	75.0	320.0
18	712.5	305.4	25	2	B	295.4	10.3	100	30%	75.0	315.4
19	687.5	300.7	25	2	B	290.7	10.3	100	30%	75.0	310.7
20	662.5	296.0	25	2	B	286.0	10.3	100	30%	75.0	306.0
21	637.5	291.3	25	2	B	281.3	10.3	100	30%	75.0	301.3
22	612.5	286.6	25	2	B	276.6	10.3	100	30%	75.0	296.6
23	587.5	281.9	25	2	B	271.9	10.3	100	30%	75.0	291.9
24	562.5	277.2	25	2	B	267.2	10.3	100	30%	75.0	287.2
25	537.5	272.5	25	2	B	262.5	10.3	100	30%	75.0	282.5
26	512.5	267.9	25	2	B	257.9	10.3	100	30%	75.0	277.9
27	487.5	263.2	25	2	B	253.2	10.3	100	30%	75.0	273.2
28	462.5	258.5	25	2	B	248.5	10.3	100	30%	75.0	268.5
29	437.5	253.8	25	2	B	243.8	10.3	100	30%	75.0	263.8
30	412.5	249.1	25	3	Z	244.1	10.3	100	30%	75.0	259.1
31	387.5	244.4	25	4	C	239.4	10.3	100	30%	75.0	254.4
32	362.5	239.7	25	4	C	234.7	10.3	100	30%	75.0	249.7
33	337.5	235.0	25	4	C	230.0	0.8	100	30%	75.0	245.0
34	312.5	232.3	25	5	D	222.3	0.8	25	30%	75.0	242.3
35	287.5	231.4	25	5	D	221.4	0.8	25	30%	75.0	241.4
36	262.5	230.5	25	5	D	220.5	0.8	25	30%	75.0	240.5
37	237.5	229.6	25	5	D	219.6	0.8	25	30%	75.0	239.6
38	212.5	228.7	25	5	D	218.7	0.8	25	30%	75.0	238.7
39	187.5	227.8	25	5	D	217.8	0.8	25	30%	75.0	237.8
40	162.5	226.9	25	5	D	216.9	0.8	25	30%	75.0	236.9
41	137.5	226.0	25	5	D	216.0	0.8	25	30%	75.0	236.0
42	112.5	225.1	25	5	D	215.1	0.8	25	30%	75.0	235.1
43	87.5	224.2	25	5	D	214.2	0.8	25	30%	75.0	234.2
44	62.5	223.3	25	5	D	213.3	0.8	25	30%	75.0	233.3
45	37.5	222.4	25	5	D	212.4	0.8	25	30%	75.0	232.4
46	12.5	221.5	25	5	D	211.5	99999.0	25	30%	75.0	231.5

**Table E-3  
Specified Rates of Recharge for Different Recharge Classes in the Current Condition Simulation**

Daily Recharge Rates (ft/d)		Monthly Recharge Volumes (inches)															
Month	Days	Cum Days	forest-til				forest-				grass						
			A	B	C	Z	A	B	C	Z	A	B	C	Z			
Feb-1	28	0	0.010	0.011	0.010	0.011	0.010	0.011	0.000	0.000	0.000	0.000	3.40	3.58	3.49	3.55	0
Mar-1	31	28	0.007	0.007	0.007	0.007	0.007	0.007	0.000	0.000	0.000	0.000	2.60	2.62	2.44	2.55	0
Apr-1	30	59	0.002	0.002	0.001	0.002	0.001	0.002	0.000	0.000	0.000	0.000	0.78	0.78	0.52	0.68	0
May-1	31	89	-0.002	0.000	0.000	0.000	0.000	-0.003	0.000	0.000	0.000	0.000	-0.58	0.00	0.00	-1.14	0
Jun-1	30	120	0.000	0.000	0.000	0.000	0.000	-0.006	0.000	0.000	0.000	0.000	-0.02	0.00	0.00	-2.19	0
Jul-1	31	150	0.000	0.000	0.000	0.000	0.000	-0.010	0.000	0.000	0.000	0.000	0.00	0.00	0.00	-3.56	0
Aug-1	31	181	0.000	0.000	0.000	0.000	0.000	-0.007	0.000	0.000	0.000	0.000	0.00	0.00	0.00	-2.67	0
Sep-1	30	212	0.000	0.000	0.000	0.000	0.000	-0.002	0.000	0.000	0.000	0.000	0.00	0.00	0.00	-0.55	0
Oct-1	31	242	0.003	0.003	0.002	0.003	0.002	0.005	0.000	0.000	0.000	0.000	0.97	1.29	0.63	1.95	0
Nov-1	30	273	0.014	0.014	0.014	0.014	0.014	0.014	0.000	0.000	0.000	0.000	5.20	5.20	4.95	5.15	0
Dec-1	31	303	0.015	0.015	0.014	0.015	0.014	0.015	0.000	0.000	0.000	0.000	5.46	5.46	5.30	5.42	0
Jan-1	31	334	0.014	0.014	0.014	0.014	0.014	0.014	0.000	0.000	0.000	0.000	5.26	5.26	5.17	5.23	0
TOTAL			23.04	24.19	22.50	24.19	22.50	14.43	0.00	0.00	0.00	0.00	23.04	24.19	22.50	14.43	0.00

**Table E-4**  
**Model Parameters for the Built Simulation**

Model Parameters for Cells Types

	Cell Type 1 removed fill embankment upland	Cell Type 2 removed outwash stringers embankment upland	Cell Type 5 removed peat & outwash embankment wetland
Surficial Soil			
Aquifer Materials			
Land Cover			
Wetland/Upland			
Bottom Layer Hydraulic Conductivity (ft/d)	300	6	2.65
Top of Bottom Layer (ft above till)	4	7.5	7.5
Middle Layer Hydraulic Conductivity (ft/d)		300	300
Top of Middle Layer (ft above till)		11.5	11.5
Upper Layer Hydraulic Conductivity (ft/d)			
Top of Upper Layer (ft above till)			
Maximum Saturated Thickness (ft)	4	11.5	11.5
Gradient of Top of Till (ft/ft)	18.8%	18.8%	3.6%
Full Thickness Hydraulic Conductivity (ft/d)	300	108.2608696	106.076087
Maximum Subsurface Flow (cfd)	225.0	233.4	43.9
Maximum Downgradient Flow (cfd)	233.4	43.9	124.2
Cell Length (ft)	25	25	25
Specific Yield	30%	30%	30%
Maximum Storage (cubic ft)	30	86.25	86.25
Bottom Layer Storage (cubic ft)	30	56.25	56.25

NOTE: All values are for a vertical slice of 1-foot width.

Model Constants

Till Thickness (ft)	10
Till Permeability Beneath Uplands (ft/d)	0.004
Till Permeability Beneath Wetlands (ft/d)	0
Outwash Permeability (ft/d)	6
Peat Permeability (ft/d)	1
Percent Outwash in Peaty Aquifer	33%
Peaty Aquifer Permeability (ft/d)	2.65
Drain Material Permeability (ft/d)	300
Till Derived Soil Permeability (ft/d)	4
Outwash Derived Soil Permeability (ft/d)	4
Wetland Surficial Soil Permeability (ft/d)	1

Time Stepping

"delta X" (ft)	25
maximum transmissivity (ft <sup>2</sup> /d)	236
minimum storage coefficient	30%
maximum time step (d)*	0.40
user defined model timestep (d)	0.10

(from Anderson & Woessner, 1982:  $dt \leq 0.5 * S^{***} \text{delta X}^{**2} / T$ )



**Table E-5  
Model Parameters for Individual Cells in the Built Simulation**

Cell ID	Distance from Outlet	Top of Till Elevation	Cell Length (ft)	Cell Type	Till Permeability	Head at Bottom of Till	Maximum Subsurface Outflow (cfd)	Specific Yield	Maximum Storage (cf)	Fill Material	Actual Embankment Thickness (ft)	Modeled Embankment Thickness for Recharge(ft)
1	1137.5	386.0	25	1	0.004	375.0	225.00	30%	30.0	Type 2	3	0
2	1112.5	380.4	25	1	0.004	370.4	225.00	30%	30.0	Type 2	7	0
3	1087.5	375.7	25	1	0.004	365.7	225.00	30%	30.0	Type 2	11	0
4	1062.5	371.0	25	1	0.004	361.0	225.00	30%	30.0	Type 2	14	0
5	1037.5	366.3	25	1	0.004	356.3	225.00	30%	30.0	Type 2	19	0
6	1012.5	361.6	25	1	0.004	351.6	225.00	30%	30.0	Type 2	24	30
7	987.5	356.9	25	1	0.004	346.9	225.00	30%	30.0	Type 2	27	30
8	962.5	352.2	25	1	0.004	342.2	225.00	30%	30.0	Type 2	32	30
9	937.5	347.5	25	1	0.004	337.5	225.00	30%	30.0	Type 2	35	30
10	912.5	342.9	25	1	0.004	332.9	225.00	30%	30.0	Type 2	40	30
11	887.5	338.2	25	1	0.004	328.2	225.00	30%	30.0	Type 2	44	50
12	862.5	333.5	25	1	0.004	323.5	225.00	30%	30.0	Type 2	49	50
13	837.5	328.8	25	1	0.004	318.8	225.00	30%	30.0	Type 2	54	50
14	812.5	324.1	25	1	0.004	314.1	225.00	30%	30.0	Type 2	57	50
15	787.5	319.4	25	1	0.004	309.4	225.00	30%	30.0	Type 2	60	50
16	762.5	314.7	25	2	0.004	304.7	233.44	30%	86.3	Type 2	64	70
17	737.5	310.0	25	2	0.004	300.0	233.44	30%	86.3	Type 2	69	70
18	712.5	305.4	25	2	0.004	295.4	233.44	30%	86.3	Type 2	74	70
19	687.5	300.7	25	2	0.004	290.7	233.44	30%	86.3	Type 2	78	70
20	662.5	296.0	25	2	0.004	286.0	233.44	30%	86.3	Type 2	84	90
21	637.5	291.3	25	2	0.004	281.3	233.44	30%	86.3	Type 2	90	90
22	612.5	286.6	25	2	0.004	276.6	233.44	30%	86.3	Type 2	96	90
23	587.5	281.9	25	2	0.004	271.9	233.44	30%	86.3	Type 2	101	110
24	562.5	277.2	25	2	0.004	267.2	233.44	30%	86.3	Type 2	105	110
25	537.5	272.5	25	2	0.004	262.5	233.44	30%	86.3	Type 2	111	110
26	512.5	267.9	25	2	0.004	257.9	233.44	30%	86.3	Type 2	116	no recharge
27	487.5	263.2	25	2	0.004	253.2	233.44	30%	86.3	Type 2	120	no recharge
28	462.5	258.5	25	2	0.004	248.5	233.44	30%	86.3	Type 2	125	no recharge
29	437.5	253.8	25	2	0.004	243.8	233.44	30%	86.3	Type 2	129	no recharge
30	412.5	249.1	25	2	0.004	239.1	233.44	30%	86.3	Type 2	132	no recharge
31	387.5	244.4	25	2	0.004	234.4	233.44	30%	86.3	Type 2	138	no recharge
32	362.5	239.7	25	2	0.004	229.7	233.44	30%	86.3	Type 2	142	no recharge
33	337.5	235.0	25	2	0.004	225.0	43.92	30%	86.3	Type 2	147	no recharge
34	312.5	230.3	25	5	0	220.3	43.92	30%	86.3	Type 2	149	no recharge
35	287.5	231.4	25	5	0	221.4	43.92	30%	86.3	Type 2	148	150
36	262.5	230.5	25	5	0	220.5	43.92	30%	86.3	Type 2	148	150
37	237.5	229.6	25	5	0	219.6	43.92	30%	86.3	Type 2	148	150
38	212.5	228.7	25	5	0	218.7	43.92	30%	86.3	Type 2	148	150
39	187.5	227.8	25	5	0	217.8	43.92	30%	86.3	Type 2	148	150
40	162.5	226.9	25	5	0	216.9	43.92	30%	86.3	Type 1	148	0
41	137.5	226.0	25	5	0	216.0	43.92	30%	86.3	Type 1	146	0
42	112.5	225.1	25	5	0	215.1	43.92	30%	86.3	Type 1	145	0
43	87.5	224.2	25	5	0	214.2	43.92	30%	86.3	Type 1	115	0
44	62.5	223.3	25	5	0	213.3	43.92	30%	86.3	Type 1	35	0
45	37.5	222.4	25	5	0	212.4	43.92	30%	86.3	Type 1	7	0
46	12.5	221.5	25	5	0	211.5	9999.00	30%	86.3	Type 1	0	0

**Table E-6  
Specified Rates of Recharge for Different Embankment Thicknesses in the Built Simulation**

Daily Recharge Rates (ft/d)		Monthly Recharge Rates (cm/d)																				
Month	Days	Cum Days	150 ft	130 ft	110 ft	90 ft	70 ft	50 ft	30 ft	0 ft	Month											
			150 ft	130 ft	110 ft	90 ft	70 ft	50 ft	30 ft	0 ft	Feb-1	Mar-1	Apr-1	May-1	Jun-1	Jul-1	Aug-1	Sep-1	Oct-1	Nov-1	Dec-1	Jan-1
Feb-1	28	0	0.004	0.003	0.003	0.002	0.005	0.014	0.013	0.010	0.113	0.098	0.084	0.069	0.146	0.416	0.393					
Mar-1	31	28	0.003	0.003	0.003	0.006	0.012	0.011	0.010	0.007	0.105	0.091	0.077	0.178	0.356	0.322	0.292					
Apr-1	30	59	0.003	0.003	0.006	0.011	0.010	0.008	0.007	0.001	0.095	0.083	0.196	0.321	0.300	0.254	0.206					
May-1	31	89	0.003	0.007	0.010	0.009	0.007	0.006	0.005	0.000	0.090	0.210	0.296	0.262	0.222	0.195	0.150					
Jun-1	30	120	0.007	0.009	0.008	0.007	0.006	0.005	0.003	0.000	0.224	0.273	0.240	0.213	0.193	0.154	0.097					
Jul-1	31	150	0.008	0.007	0.007	0.006	0.005	0.004	0.002	0.000	0.249	0.221	0.203	0.184	0.153	0.113	0.070					
Aug-1	31	181	0.007	0.007	0.006	0.005	0.004	0.003	0.002	0.000	0.210	0.201	0.182	0.153	0.122	0.088	0.055					
Sep-1	30	212	0.006	0.006	0.005	0.004	0.003	0.002	0.002	0.000	0.196	0.177	0.154	0.130	0.103	0.074	0.046					
Oct-1	31	242	0.006	0.005	0.004	0.004	0.003	0.002	0.001	0.002	0.178	0.156	0.134	0.111	0.087	0.063	0.039					
Nov-1	30	273	0.005	0.004	0.004	0.003	0.002	0.002	0.001	0.014	0.156	0.136	0.116	0.096	0.076	0.055	0.034					
Dec-1	31	303	0.004	0.004	0.003	0.003	0.002	0.002	0.003	0.014	0.137	0.121	0.103	0.085	0.066	0.049	0.093					
Jan-1	31	334	0.004	0.004	0.003	0.002	0.002	0.004	0.014	0.014	0.125	0.109	0.092	0.076	0.060	0.118	0.423					

NOTE: Values for 0 feet embankness thickness taken directly from estimates for recharge to grass on outwash (see Table E-3).  
All other values taken from Hydrus model (grass-outwash input).



**Analytical Resources, Incorporated**  
Analytical Chemists and Consultants

November 10, 1999

Inger Jackson  
Pacific Groundwater Group  
2377 Eastlake Ave. East, Suite 200  
Seattle, WA 98102

**RE: Project No. JE9907**  
**ARI Job No. AX18**

Dear Leslie:

Please find enclosed original Chain of Custody (COC) and analytical results for the above-referenced project. Analytical Resources, Inc. (ARI) accepted four water samples in good condition on October 25, 1999.

The samples were analyzed for total metals and hardness by EPA methods 6010/200.8, total suspended solids by EPA method 160.2, ammonia by EPA method 350.1, nitrate plus nitrite by EPA method 353.2, total phosphorus and ortho-phosphorus by EPA method 365.2, biological oxygen demand by EPA method 405.1, and total oil and grease by EPA method 413.1 as requested on the COC. Quality control analysis results are included for your review.

Lead was detected in the total metals method blank at .002 mg/L. Lead was undetected in three of the samples and detected at .001 mg/L in the fourth. Lead is a common contaminant at this low level and no corrective action was taken.

No other analytical complications were encountered. A copy of this report and all associated raw data will remain on file with ARI. If you have any questions or require additional information, please contact me at your convenience.

Sincerely,

ANALYTICAL RESOURCES, INC.

Mary Lou Fox  
Project Manager  
206-389-6155

MLF/mlf  
Enclosure

# Chain of Custody Record & Laboratory Analysis Request

**Analytical Resources, Incorporated**  
 Analytical Chemist and Consultants  
 400 Ninth Avenue North  
 Seattle, WA 98109-4708  
 (206) 621-6490  
 (206) 621-7523 (Fax)



Date: 10/25/99 of 1  
 Page  
 Number of coolers: 2  
 Cooler Temp: \_\_\_\_\_

ARI Client: <u>Pacific Groundwater Group</u> Phone#: <u>339-0141</u>					
Client Contact: <u>Myer Jackson</u>					
Client Project ID: <u>JE9907</u>					
Samplers: <u>RS/CTE</u>					
Sample ID	Date	Time	Matx	No Cont	Lab ID
1	<u>Muller Creek at Kuevins</u>	<u>10/23/99 17:20</u>	<u>W</u>	<u>6</u>	
2	<u>Muller Creek at 3156<sup>th</sup></u>	<u>10/23/99 15:30</u>	<u>W</u>	<u>6</u>	
3	<u>Des Moines Cr at South 14<sup>th</sup></u>	<u>10/23/99 12:00</u>	<u>W</u>	<u>6</u>	
4	<u>Des Moines at Tree</u>	<u>10/23/99 12:40</u>	<u>W</u>	<u>6</u>	
5					
6					
7					
ARI Project No: _____					
T.A.T. Requested: _____					
Comments/Special Instructions: <u>Do not perform metals analyses until contacted by PGG.</u>					
Relinquished by: <u>Myer Jackson</u> (Signature) Printed Name: <u>Myer Jackson</u> Company: <u>ARI</u> Date: <u>10/25/99</u> Time: <u>11:53</u>					
Received by: <u>Mary Lou Fox</u> (Signature) Printed Name: <u>Mary Lou Fox</u> Company: <u>ARI</u> Date: <u>10/25/99</u> Time: <u>11:53</u>					

Analysis Required				Notes/Comments	
FG	BOD	TSS	SRP	Total P, N, & NH <sub>3</sub> Nitrogen	Total Metals: As, Cd, Pb, Cu, Zn
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X

Limits of Liability: ARI will perform all requested services in accordance with appropriate methodology following Standard Operating Procedures and our Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the invoiced amount for said services. The acceptance by the client of a proposal for services by ARI releases ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the client.


INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: AX18MB  
LIMS ID: 99-16119  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: NA  
Date Received: NA

Data Release Authorized:   
Reported: 11/08/99

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	10/26/99	6010	11/04/99	7440-38-2	Arsenic	0.05	0.05 U
200.8	10/27/99	200.8	11/01/99	7440-43-9	Cadmium	0.0002	0.0002 U
3010	10/26/99	6010	11/04/99	7440-70-2	Calcium	0.05	0.05 U
3010	10/26/99	6010	11/04/99	7440-50-8	Copper	0.002	0.002 U
200.8	10/27/99	200.8	11/01/99	7439-92-1	Lead	0.001	0.002
3010	10/26/99	6010	11/04/99	7439-95-4	Magnesium	0.02	0.02 U
3010	10/26/99	6010	11/04/99	7440-66-6	Zinc	0.006	0.006 U

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

AR 011811


**INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS**

Sample No: Miller Creek at Kiwanis

Lab Sample ID: AX18A  
LIMS ID: 99-16119  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 10/22/99  
Date Received: 10/25/99

Data Release Authorized:   
Reported: 11/08/99

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	10/26/99	6010	11/04/99	7440-38-2	Arsenic	0.05	0.05 U
200.8	10/27/99	200.8	11/01/99	7440-43-9	Cadmium	0.0002	0.0002 U
3010	10/26/99	6010	11/04/99	7440-70-2	Calcium	0.05	24.8
3010	10/26/99	6010	11/04/99	7440-50-8	Copper	0.002	0.002 U
200.8	10/27/99	200.8	11/01/99	7439-92-1	Lead	0.001	0.001 U
3010	10/26/99	6010	11/04/99	7439-95-4	Magnesium	0.02	15.6
3010	10/26/99	6010	11/04/99	7440-66-6	Zinc	0.006	0.007

Calculated Hardness (mg-CaCO3/L): 130

U Analyte undetected at given RL  
RL Reporting Limit


**INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS**

Sample No: Miller Creek at S 156th

Lab Sample ID: AX18B  
LIMS ID: 99-16120  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 10/22/99  
Date Received: 10/25/99

Data Release Authorized:   
Reported: 11/08/99

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	10/26/99	6010	11/04/99	7440-38-2	Arsenic	0.05	0.05 U
200.8	10/27/99	200.8	11/01/99	7440-43-9	Cadmium	0.0002	0.0002 U
3010	10/26/99	6010	11/04/99	7440-70-2	Calcium	0.05	27.8
3010	10/26/99	6010	11/04/99	7440-50-8	Copper	0.002	0.002 U
200.8	10/27/99	200.8	11/01/99	7439-92-1	Lead	0.001	0.001
3010	10/26/99	6010	11/04/99	7439-95-4	Magnesium	0.02	18.6
3010	10/26/99	6010	11/04/99	7440-66-6	Zinc	0.006	0.008

Calculated Hardness (mg-CaCO<sub>3</sub>/L): 150

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**AR 011813**

**INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS**

Sample No: Des Moines at Tyee

Lab Sample ID: AX18D  
LIMS ID: 99-16122  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 10/23/99  
Date Received: 10/25/99

Data Release Authorized:  
Reported: 11/08/99



Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	10/26/99	6010	11/04/99	7440-38-2	Arsenic	0.05	0.05 U
200.8	10/27/99	200.8	11/01/99	7440-43-9	Cadmium	0.0002	0.0002 U
3010	10/26/99	6010	11/04/99	7440-70-2	Calcium	0.05	21.8
3010	10/26/99	6010	11/04/99	7440-50-8	Copper	0.002	0.004
200.8	10/27/99	200.8	11/01/99	7439-92-1	Lead	0.001	0.001 U
3010	10/26/99	6010	11/04/99	7439-95-4	Magnesium	0.02	12.2
3010	10/26/99	6010	11/04/99	7440-66-6	Zinc	0.006	0.010

Calculated Hardness (mg-CaCO<sub>3</sub>/L): 100

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**AR 011814**



**INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS**

Sample No: Des Moines Cr at S 18th

Lab Sample ID: AX18C  
LIMS ID: 99-16121  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 10/22/99  
Date Received: 10/25/99

Data Release Authorized  
Reported: 11/08/99

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	10/26/99	6010	11/04/99	7440-38-2	Arsenic	0.05	0.05 U
200.8	10/27/99	200.8	11/01/99	7440-43-9	Cadmium	0.0002	0.0002 U
3010	10/26/99	6010	11/04/99	7440-70-2	Calcium	0.05	20.7
3010	10/26/99	6010	11/04/99	7440-50-8	Copper	0.002	0.003
200.8	10/27/99	200.8	11/01/99	7439-92-1	Lead	0.001	0.001 U
3010	10/26/99	6010	11/04/99	7439-95-4	Magnesium	0.02	11.7
3010	10/26/99	6010	11/04/99	7440-66-6	Zinc	0.006	0.010

Calculated Hardness (mg-CaCO3/L): 100

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

**AR 011815**

INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS



Lab Sample ID: AX18LCS  
LIMS ID: 99-16119  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Data Release Authorized  
Reported: 11/08/99

A handwritten signature in black ink, appearing to be 'B. J.', written over the 'Data Release Authorized' text.

BLANK SPIKE QUALITY CONTROL REPORT

Analyte	Spike mg/L	Spike Added	% Recovery	Q
Arsenic	2.60	2.50	104%	
Cadmium	0.0241	0.0250	96.4%	
Calcium	10.5	10.0	105%	
Copper	0.106	0.100	106%	
Lead	0.025	0.025	100%	
Magnesium	10.4	10.0	104%	
Zinc	0.515	0.500	103%	

'Q' codes: N = control limit not met

Control Limits: 80-120%

FORM-VII

AR 011816

QA Report - Method Blank Analysis

Matrix: Water  
 QC Report No: AX18-Pacific Groundwater Group  
 Project: JE9907  
 Date Received: NA  
 Data Release Authorized: *mf*  
 Reported: 11/09/99 Dr. M.A. Perkins

METHOD BLANK RESULTS  
CONVENTIONALS

Analysis Date & Batch	Constituent	Units	Result
10/27/99 102799#1	Total Suspended Solids	mg/L	< 1.0 U
11/02/99 110299#1	N-Ammonia	mg-N/L	< 0.010 U
11/02/99 110299#1	Total Phosphorous	mg-P/L	< 0.008 U
10/25/99 102599#1	Ortho-Phosphorous	mg-P/L	< 0.004 U
11/03/99 110399#1	Total Oil & Grease	mg/L	< 1.0 U
10/29/99 102999#2	Nitrate + Nitrite (NO <sub>2</sub> +NO <sub>3</sub> )	mg-N/L	< 0.010 U
10/25/99 102599#1	Biological Oxygen Demand	mg/L	< 1 U

**Final Report  
Laboratory Analysis of Conventional Parameters**

Sample No: Miller Creek at Kiwanis

Lab Sample ID: AX18A

QC Report No: AX18-Pacific Groundwater Group

LIMS ID: 99-16119

Project: JE9907

Matrix: Water

Date Sampled: 10/22/99

Data Release Authorized: *mo*

Date Received: 10/25/99

Reported: 11/09/99 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	10/27/99 102799#1	EPA 160.2	1.8	mg/L	< 1.8 U
N-Ammonia	11/02/99 110299#1	EPA 350.1	0.010	mg-N/L	0.013
Nitrate + Nitrite (NO <sub>2</sub> +NO <sub>3</sub> )	10/29/99 102999#2	EPA 353.2	0.020	mg-N/L	1.3
Total Phosphorous	11/02/99 110299#1	EPA 365.2	0.016	mg-P/L	0.071
Ortho-Phosphorous	10/25/99 102599#1	EPA 365.2	0.004	mg-P/L	0.038
Biological Oxygen Demand	10/25/99 102599#1	EPA 405.1	3	mg/L	< 3 U
Total Oil & Grease	11/03/99 110399#1	EPA 413.1	1.0	mg/L	1.2

RL Analytical reporting limit  
U Undetected at reported detection limit

Report for AX18 received 10/25/99

**AR 011818**

**Final Report  
Laboratory Analysis of Conventional Parameters**

Sample No: Miller Creek at S 156th

Lab Sample ID: AX18B  
LIMS ID: 99-16120  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 10/22/99  
Date Received: 10/25/99  
Data Release Authorized: *MP*  
Reported: 11/09/99 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	10/27/99 102799#1	EPA 160.2	1.1	mg/L	5.0
N-Ammonia	11/02/99 110299#1	EPA 350.1	0.010	mg-N/L	0.058
Nitrate + Nitrite (NO2+NO3)	10/29/99 102999#2	EPA 353.2	0.020	mg-N/L	1.3
Total Phosphorous	11/02/99 110299#1	EPA 365.2	0.016	mg-P/L	0.080
Ortho-Phosphorous	10/25/99 102599#1	EPA 365.2	0.004	mg-P/L	0.033
Biological Oxygen Demand	10/25/99 102599#1	EPA 405.1	2	mg/L	2
Total Oil & Grease	11/03/99 110399#1	EPA 413.1	0.9	mg/L	< 1.0 U

RL Analytical reporting limit  
U Undetected at reported detection limit

Report for AX18 received 10/25/99

**Final Report  
Laboratory Analysis of Conventional Parameters**

Sample No: Des Moines Cr at S 18th

Lab Sample ID: AX18C

QC Report No: AX18-Pacific Groundwater Group

LIMS ID: 99-16121

Project: JE9907

Matrix: Water

Date Sampled: 10/22/99

Data Release Authorized *MS*

Date Received: 10/25/99

Reported: 11/09/99 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	10/27/99 102799#1	EPA 160.2	1.1	mg/L	1.2
N-Ammonia	11/02/99 110299#1	EPA 350.1	0.010	mg-N/L	< 0.010 U
Nitrate + Nitrite (NO <sub>2</sub> +NO <sub>3</sub> )	10/29/99 102999#2	EPA 353.2	0.010	mg-N/L	0.69
Total Phosphorous	11/02/99 110299#1	EPA 365.2	0.016	mg-P/L	0.043
Ortho-Phosphorous	10/25/99 102599#1	EPA 365.2	0.004	mg-P/L	0.025
Biological Oxygen Demand	10/25/99 102599#1	EPA 405.1	2	mg/L	< 2 U
Total Oil & Grease	11/03/99 110399#1	EPA 413.1	1.0	mg/L	< 1.0 U

RL Analytical reporting limit  
U Undetected at reported detection limit

Report for AX18 received 10/25/99

**AR 011820**

Final Report  
Laboratory Analysis of Conventional Parameters

Sample No: Des Moines at Tyee

Lab Sample ID: AX18D  
LIMS ID: 99-16122  
Matrix: Water

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 10/23/99  
Date Release Authorized: *MS* Date Received: 10/25/99  
Reported: 11/09/99 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	10/27/99 102799#1	EPA 160.2	1.1	mg/L	< 1.1 U
N-Ammonia	11/02/99 110299#1	EPA 350.1	0.010	mg-N/L	0.017
Nitrate + Nitrite (NO2+NO3)	10/29/99 102999#2	EPA 353.2	0.010	mg-N/L	0.86
Total Phosphorous	11/02/99 110299#1	EPA 365.2	0.016	mg-P/L	0.040
Ortho-Phosphorous	10/25/99 102599#1	EPA 365.2	0.004	mg-P/L	0.017
Biological Oxygen Demand	10/25/99 102599#1	EPA 405.1	2	mg/L	2
Total Oil & Grease	11/03/99 110399#1	EPA 413.1	1.0	mg/L	< 1.0 U

RL Analytical reporting limit  
U Undetected at reported detection limit


Report for AX18 received 10/25/99

**QA Report - Laboratory Control Samples**

QC Report No: AX18-Pacific Groundwater Group

Project: JE9907

Date Received: NA

Data Release Authorized: 

Reported: 11/09/99 Dr. M.A. Perkins


**LABORATORY CONTROL SAMPLES  
CONVENTIONALS**

<u>Constituent</u>	<u>Units</u>	<u>Measured Value</u>	<u>True Value</u>	<u>Recovery</u>
<b>Laboratory Control Sample</b>				
Total Oil & Grease	mg/L	45.2	57.0	79.3%
Date analyzed: 11/03/99 Batch ID: 110399#1				
<b>Laboratory Control Sample</b>				
Biological Oxygen Demand	mg/L	178	200	89.0%
Date analyzed: 10/25/99 Batch ID: 102599#1				



QA Report - Standard Reference Material Analysis

QC Report No: AX18-Pacific Groundwater Group  
Project: JE9907  
Date Received: NA

Data Release Authorized   
Reported: 11/09/99 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS  
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
<b>IV #1035</b>				
N-Ammonia	mg-N/L	0.815	0.800	102%
Date analyzed: 11/02/99 Batch ID: 110299#1				
<b>SPEX #6-26</b>				
Total Phosphorous	mg-P/L	5.14	5.00	103%
Date analyzed: 11/02/99 Batch ID: 110299#1				
<b>IV #1032</b>				
Ortho-Phosphorous	mg-P/L	0.132	0.129	102%
Date analyzed: 10/25/99 Batch ID: 102599#1				
<b>IV #1084</b>				
Nitrate + Nitrite (NO <sub>2</sub> +NO <sub>3</sub> )	mg-N/L	0.407	0.400	102%
Date analyzed: 10/29/99 Batch ID: 102999#2				

QA Report - Replicate Analysis

Matrix: Water  
 QC Report No: AX18-Pacific Groundwater Group  
 Project: JE9907  
 Date Received: 10/25/99  
 Data Release Authorized: *MP*  
 Reported: 11/09/99 Dr. M.A. Perkins

DUPLICATE ANALYSIS RESULTS  
CONVENTIONALS

Constituent	Units	Sample Value	Duplicate Value	RPD
ARI ID: 99-16119, AX18 A Client Sample ID: Miller Creek at Kiwanis				
N-Ammonia	mg-N/L	0.013	0.014	7.4%
Total Phosphorous	mg-P/L	0.071	0.068	4.3%
Ortho-Phosphorous	mg-P/L	0.038	0.038	0.0%
ARI ID: 99-16122, AX18 D Client Sample ID: Des Moines at Tyee				
Nitrate + Nitrite (NO2+NO3)	mg-N/L	0.86	0.89	3.4%
Biological Oxygen Demand	mg/L	2	2	0.0%

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

Matrix: Water  
 Data Release Authorized *MS*  
 Reported: 11/09/99 Dr. M.A. Perkins

QC Report No: AX18-Pacific Groundwater Group  
 Project: JE9907  
 Date Received: 10/25/99

MATRIX SPIKE QA/QC REPORT  
 CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 99-16119, AX18 A Client Sample ID: Miller Creek at Kiwanis					
N-Ammonia	mg-N/L	0.013	0.447	0.400	108%
Total Phosphorous	mg-P/L	0.071	0.469	0.400	99.5%
Ortho-Phosphorous	mg-P/L	0.038	0.138	0.100	100%
ARI ID: 99-16122, AX18 D Client Sample ID: Des Moines at Tyee					
Nitrate + Nitrite (NO2+NO3)	mg-N/L	0.857	1.23	0.400	93.2%

MS/MSD Recovery Limits: 75 - 125 %

Water MS/MSD QA Report Page 1 for AX18 received 10/25/99



**Analytical Resources, Incorporated**  
Analytical Chemists and Consultants

February 14, 2000

Inger Jackson  
Pacific Groundwater Group  
2377 Eastlake Ave. East, Suite 200  
Seattle, WA 98102

**RE: Project No. JE9907**  
**ARI Job No. BF85**

Dear Inger:

Please find enclosed original Chain of Custody (COC) and analytical results for the above-referenced project. Analytical Resources, Inc. (ARI) accepted four water samples in good condition on January 28, 2000.

The samples were analyzed for total metals and hardness by EPA methods 6010/200.8, total suspended solids by EPA method 160.2, ammonia by EPA method 350.1, nitrate plus nitrite by EPA method 353.2, total phosphorus and ortho-phosphorus by EPA method 365.2, biological oxygen demand by EPA method 405.1, and total oil and grease by EPA method 413.1 as requested on the COC. Quality control analysis results are included for your review.

Magnesium was detected in the total metals method blank at .03 mg/L. Magnesium was detected in all of the samples at levels greater than ten times the level in the method blank and no corrective action was taken.

No further analytical complications were encountered. A copy of this report and all associated raw data will remain on file with ARI. If you have any questions or require additional information, please contact me at your convenience.

Sincerely,

ANALYTICAL RESOURCES, INC.

A handwritten signature in cursive script that reads "Mary Lou Fox".

Mary Lou Fox  
Project Manager  
206-389-6155  
marylou@arilabs.com

MLF/mlf  
Enclosure

# Chain of Custody Record & Laboratory Analysis Request

Analytical Resources, Incorporated  
 Analytical Chemist and Consultants  
 400 Ninth Avenue North  
 Seattle, WA 98109-4708  
 (206) 621-6490  
 (206) 621-7523 (Fax)



Date: 1/27/00  
 Page 1 of 1  
 Number of coolers: 2  
 Cooler temp: 3.55, 5.5

ARI Client: <u>REG</u>		Phone#: <u>329-0141</u>			
Client Contact: <u>Inger Jackson/Charles Ellingson</u>					
Client Project ID: <u>JEG007</u>					
Samplers: <u>IRJ/LAM</u>					
Sample ID	Date	Time	Matx	No Cont	Lab ID
1 <u>Muller at Kivanis</u>	<u>1/27/00</u>	<u>13:45</u>	<u>W</u>	<u>6</u>	
2 <u>Des Moines at 518th</u>	<u>1/27/00</u>	<u>15:30</u>	<u>W</u>	<u>6</u>	
3 <u>Muller at 5156th</u>	<u>1/27/00</u>	<u>10:45</u>	<u>W</u>	<u>6</u>	
4 <u>Des Moines at Tyee</u>	<u>1/27/00</u>	<u>16:50</u>	<u>W</u>	<u>6</u>	
5					
6					
7					

ARI Project No:	
T.A.T. Requested:	
Comments/Special Instructions:	<u>Refer to Mary Lou Fox (ARI) or Inger Jackson (REG) for Metals Method.</u>

Relinquished by: (Signature)	<u>[Signature]</u>
Printed Name:	<u>Mary R Jackson</u>
Company:	<u>REG</u>
Date:	<u>1/27/00</u>
Time:	<u>18:40</u>
Relinquished by: (Signature)	<u>[Signature]</u>
Printed Name:	<u>[Signature]</u>
Company:	<u>[Signature]</u>
Date:	<u>1/27/00</u>
Time:	<u>7:30</u>

Analysis Required		Notes/Comments	
BOD	SRP (NO <sub>3</sub> <sup>-</sup> )	Total Metals:	AS (Al, Cu, Pb, Zn)
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1

Relinquished by: (Signature)	
Printed Name:	
Company:	
Date:	
Time:	
Received by: (Signature)	
Printed Name:	
Company:	
Date:	
Time:	

Limits of Liability: ARI will perform all requested services in accordance with appropriate methodology following Standard Operating Procedures and our Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the invoiced amount for said services. The acceptance by the client of a proposal for services by ARI releases ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the client.

1/27/00 HJL

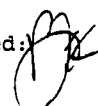
INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS

Sample No: Method Blank

Lab Sample ID: BF85MB  
LIMS ID: 00-877  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: NA  
Date Received: NA

Data Release Authorized:   
Reported: 02/08/00

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	01/31/00	6010	02/03/00	7440-38-2	Arsenic	0.05	0.05 U
200.8	01/31/00	200.8	02/04/00	7440-43-9	Cadmium	0.0002	0.0002 U
3010	01/31/00	6010	02/03/00	7440-70-2	Calcium	0.05	0.05 U
3010	01/31/00	6010	02/03/00	7440-50-8	Copper	0.002	0.002 U
200.8	01/31/00	200.8	02/04/00	7439-92-1	Lead	0.001	0.001 U
3010	01/31/00	6010	02/03/00	7439-95-4	Magnesium	0.02	0.03
3010	01/31/00	6010	02/03/00	7440-66-6	Zinc	0.006	0.006 U

U Analyte undetected at given RL  
RL Reporting Limit

FORM-I


INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS

Sample No: Miller At Kiwanis

Lab Sample ID: BF85A  
LIMS ID: 00-876  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00  
Date Received: 01/28/00

Data Release Authorized:   
Reported: 02/08/00

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	01/31/00	6010	02/03/00	7440-38-2	Arsenic	0.05	0.05 U
200.8	01/31/00	200.8	02/04/00	7440-43-9	Cadmium	0.0002	0.0002 U
3010	01/31/00	6010	02/03/00	7440-70-2	Calcium	0.05	21.0
3010	01/31/00	6010	02/03/00	7440-50-8	Copper	0.002	0.004
200.8	01/31/00	200.8	02/04/00	7439-92-1	Lead	0.001	0.001
3010	01/31/00	6010	02/03/00	7439-95-4	Magnesium	0.02	10.4
3010	01/31/00	6010	02/03/00	7440-66-6	Zinc	0.006	0.014

Calculated Hardness (mg-CaCO3/L): 95

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

AR 011829

INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS



Sample No: Miller At Kiwanis  
Lab Sample ID: BF85A      QC Report No: BF85-Pacific Groundwater Group  
LIMS ID: 00-876      Project: JE9907  
Matrix: Water

Date Received: 01/28/00

Data Release Authorized  
Reported: 02/08/00

MATRIX SPIKE QUALITY CONTROL REPORT

Analyte	Sample mg/L	Spike mg/L	Spike Added	% Recovery	Q
Arsenic	0.05 U	2.49	2.50	99.6%	
Cadmium	0.0002 U	0.0244	0.0250	97.6%	
Calcium	21.0	30.8	10.0	98.0%	
Copper	0.004	0.104	0.100	100%	
Lead	0.001	0.027	0.025	104%	
Magnesium	10.4	20.2	10.0	98.0%	
Zinc	0.014	0.504	0.500	98.0%	

'Q' codes:      N = control limit not met  
                  H = %R not applicable, sample concentration too high  
                  \* = RPD control limit not met  
                  NA = Not applicable - analyte not spiked

Control Limits:      Percent Recovery: 75-125%  
                          RPD:                    +/-20%

FORM-V

AR 011830




**INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS**

Sample No: Des Moines at S 18th

Lab Sample ID: BF85E  
LIMS ID: 00-877  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00  
Date Received: 01/28/00

Data Release Authorized:   
Reported: 02/08/00

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	01/31/00	6010	02/03/00	7440-38-2	Arsenic	0.05	0.05 U
200.8	01/31/00	200.8	02/04/00	7440-43-9	Cadmium	0.0002	0.0002 U
3010	01/31/00	6010	02/03/00	7440-70-2	Calcium	0.05	19.1
3010	01/31/00	6010	02/03/00	7440-50-8	Copper	0.002	0.005
200.8	01/31/00	200.8	02/04/00	7439-92-1	Lead	0.001	0.001 U
3010	01/31/00	6010	02/03/00	7439-95-4	Magnesium	0.02	8.75
3010	01/31/00	6010	02/03/00	7440-66-6	Zinc	0.006	0.012

Calculated Hardness (mg-CaCO3/L): 84

U Analyte undetected at given RL

RL Reporting Limit

FORM-I


AR 011831

INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS



Lab Sample ID: BF85B                      Sample No: Des Moines at S 18th  
LIMS ID: 00-877                            QC Report No: BF85-Pacific Groundwater Group  
Matrix: Water                                Project: JE9907

Date Received: 01/28/00

Data Release Authorized:   
Reported: 02/08/00

MATRIX DUPLICATE QUALITY CONTROL REPORT

Analyte	Sample mg/L	Duplicate mg/L	RPD	Control Limit	Q
Arsenic	0.05 U	0.05 U	0.0%	+/- 0.05	L
Cadmium	0.0002 U	0.0002 U	0.0%	+/- 0.0002	L
Calcium	19.1	19.1	0.0%	+/- 20 %	
Copper	0.005	0.005	0.0%	+/- 0.002	L
Lead	0.001 U	0.001 U	0.0%	+/- 0.001	L
Magnesium	8.75	8.71	0.5%	+/- 20 %	
Zinc	0.012	0.012	0.0%	+/- 0.006	L

'Q' codes:                      \* = control limit not met  
                                      L = RPD not valid, alternate limit = detection limit

FORM-VI

AR 011832

INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS


Sample No: Miller at S 156th

Lab Sample ID: BF85C  
LIMS ID: 00-878  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00

Date Received: 01/28/00

Data Release Authorized:   
Reported: 02/08/00

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	01/31/00	6010	02/03/00	7440-38-2	Arsenic	0.05	0.05 U
200.8	01/31/00	200.8	02/04/00	7440-43-9	Cadmium	0.0002	0.0002 U
3010	01/31/00	6010	02/03/00	7440-70-2	Calcium	0.05	21.0
3010	01/31/00	6010	02/03/00	7440-50-8	Copper	0.002	0.005
200.8	01/31/00	200.8	02/04/00	7439-92-1	Lead	0.001	0.004
3010	01/31/00	6010	02/03/00	7439-95-4	Magnesium	0.02	10.2
3010	01/31/00	6010	02/03/00	7440-66-6	Zinc	0.006	0.022

Calculated Hardness (mg-CaCO3/L): 95

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

AR 011833

INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS

Sample No: Des Moines at Tye

Lab Sample ID: BF85D  
LIMS ID: 00-879  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00  
Date Received: 01/28/00

Data Release Authorized *[Signature]*  
Reported: 02/08/00

Prep Meth	Prep Date	Analysis Method	Analysis Date	CAS Number	Analyte	RL	mg/L
3010	01/31/00	6010	02/03/00	7440-38-2	Arsenic	0.05	0.05 U
200.8	01/31/00	200.8	02/04/00	7440-43-9	Cadmium	0.0002	0.0002 U
3010	01/31/00	6010	02/03/00	7440-70-2	Calcium	0.05	19.3
3010	01/31/00	6010	02/03/00	7440-50-8	Copper	0.002	0.007
200.8	01/31/00	200.8	02/04/00	7439-92-1	Lead	0.001	0.001 U
3010	01/31/00	6010	02/03/00	7439-95-4	Magnesium	0.02	8.54
3010	01/31/00	6010	02/03/00	7440-66-6	Zinc	0.006	0.014

Calculated Hardness (mg-CaCO3/L): 83

U Analyte undetected at given RL

RL Reporting Limit

FORM-I

INORGANICS ANALYSIS DATA SHEET  
TOTAL METALS



Lab Sample ID: BF85LCS  
LIMS ID: 00-877  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Data Release Authorized  
Reported: 02/08/00

A handwritten signature in black ink, appearing to be a stylized name, located to the right of the 'Data Release Authorized' text.

BLANK SPIKE QUALITY CONTROL REPORT

Analyte	Spike mg/L	Spike Added	% Recovery	Q
Arsenic	2.47	2.50	98.8%	
Cadmium	0.0232	0.0250	92.8%	
Calcium	10.3	10.0	103%	
Copper	0.102	0.100	102%	
Lead	0.024	0.025	96.0%	
Magnesium	10.0	10.0	100%	
Zinc	0.486	0.500	97.2%	

'Q' codes: N = control limit not met

Control Limits: 80-120%

FORM-VII

AR 011835

QA Report - Method Blank Analysis

QC Report No: BF85-Pacific Groundwater Group  
 Matrix: Water Project: JE9907  
 Date Received: NA  
 Data Release Authorized: *MP*  
 Reported: 02/10/00 Dr. M.A. Perkins

METHOD BLANK RESULTS  
CONVENTIONALS


Analysis Date & Batch	Constituent	Units	Result
01/28/00 01280#1	Total Suspended Solids	mg/L	< 1.0 U
01/28/00 01280#2	Nitrate + Nitrite (NO <sub>2</sub> +NO <sub>3</sub> )	mg-N/L	< 0.010 U
01/31/00 01310#1	Total Phosphorous	mg-P/L	< 0.008 U
01/28/00 01280#1	Ortho-Phosphorous	mg-P/L	< 0.004 U
02/03/00 02030#1	Total Oil & Grease	mg/L	< 1.0 U
01/28/00 01280#1	Biological Oxygen Demand	mg/L	< 1 U
01/31/00 01310#3	N-Ammonia	mg-N/L	< 0.010 U

Final Report  
Laboratory Analysis of Conventional Parameters

Sample No: Miller At Kiwanis

Lab Sample ID: BF85A  
LIMS ID: 00-876  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00  
Date Release Authorized:  Date Received: 01/28/00  
Reported: 02/10/00 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	01/28/00 01280#1	EPA 160.2	1.1	mg/L	4.1
N-Ammonia	01/31/00 01310#3	EPA 350.1	0.010	mg-N/L	0.013
Nitrate + Nitrite (NO <sub>2</sub> +NO <sub>3</sub> )	01/28/00 01280#2	EPA 353.2	0.10	mg-N/L	1.3
Total Phosphorous	01/31/00 01310#1	EPA 365.2	0.016	mg-P/L	0.060
Ortho-Phosphorous	01/28/00 01280#1	EPA 365.2	0.004	mg-P/L	0.029
Biological Oxygen Demand	01/28/00 01280#1	EPA 405.1	2	mg/L	< 2 U
Total Oil & Grease	02/03/00 02030#1	EPA 413.1	0.9	mg/L	1.8

RL Analytical reporting limit  
U Undetected at reported detection limit

Report for BF85 received 01/28/00

AR 011837



Final Report  
 Laboratory Analysis of Conventional Parameters

Sample No: Des Moines at S 18th

Lab Sample ID: BF85B  
 LIMS ID: 00-877  
 Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
 Project: JE9907

Date Sampled: 01/27/00  
 Date Received: 01/28/00  
 Data Release Authorized: *MB*  
 Reported: 02/10/00 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	01/28/00 01280#1	EPA 160.2	1.1	mg/L	1.7
N-Ammonia	01/31/00 01310#3	EPA 350.1	0.010	mg-N/L	< 0.010 U
Nitrate + Nitrite (NO2+NO3)	01/28/00 01280#1	EPA 353.2	0.010	mg-N/L	0.54
Total Phosphorous	01/31/00 01310#1	EPA 365.2	0.016	mg-P/L	0.051
Ortho-Phosphorous	01/28/00 01280#1	EPA 365.2	0.004	mg-P/L	0.013
Biological Oxygen Demand	01/28/00 01280#1	EPA 405.1	2	mg/L	2
Total Oil & Grease	02/03/00 02030#1	EPA 413.1	0.9	mg/L	1.5

RL Analytical reporting limit  
 U Undetected at reported detection limit

Report for BF85 received 01/28/00

AR 011838



Final Report  
Laboratory Analysis of Conventional Parameters

Sample No: Miller at S 156th

Lab Sample ID: BF85C  
LIMS ID: 00-878  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00  
Date Received: 01/28/00  
Data Release Authorized: *MB*  
Reported: 02/10/00 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	01/28/00 01280#1	EPA 160.2	1.8	mg/L	17
N-Ammonia	01/31/00 01310#3	EPA 350.1	0.010	mg-N/L	0.066
Nitrate + Nitrite (NO2+NO3)	01/28/00 01280#2	EPA 353.2	0.10	mg-N/L	1.3
Total Phosphorous	01/31/00 01310#1	EPA 365.2	0.016	mg-P/L	0.098
Ortho-Phosphorous	01/28/00 01280#1	EPA 365.2	0.004	mg-P/L	0.026
Biological Oxygen Demand	01/28/00 01280#1	EPA 405.1	2	mg/L	2
Total Oil & Grease	02/03/00 02030#1	EPA 413.1	1.0	mg/L	1.6

RL Analytical reporting limit  
U Undetected at reported detection limit

Report for BF85 received 01/28/00

AR 011839

**Final Report  
Laboratory Analysis of Conventional Parameters**

**Sample No: Des Moines at Tye**

Lab Sample ID: BF85D  
LIMS ID: 00-879  
Matrix: Water

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Sampled: 01/27/00  
Date Received: 01/28/00  
Data Release Authorized: *MB*  
Reported: 02/10/00 Dr. M.A. Perkins

Analyte	Analysis			Units	Result
	Date & Batch	Method	RL		
Total Suspended Solids	01/28/00 01280#1	EPA 160.2	2.0	mg/L	3.8
N-Ammonia	01/31/00 01310#3	EPA 350.1	0.010	mg-N/L	< 0.010 U
Nitrate + Nitrite (NO2+NO3)	01/28/00 01280#2	EPA 353.2	0.010	mg-N/L	0.56
Total Phosphorous	01/31/00 01310#1	EPA 365.2	0.016	mg-P/L	0.060
Ortho-Phosphorous	01/28/00 01280#1	EPA 365.2	0.004	mg-P/L	0.005
Biological Oxygen Demand	01/28/00 01280#1	EPA 405.1	2	mg/L	2
Total Oil & Grease	02/03/00 02030#1	EPA 413.1	0.9	mg/L	1.4

RL Analytical reporting limit  
U Undetected at reported detection limit

Report for BF85 received 01/28/00

**AR 011840**

**QA Report - Laboratory Control Samples**

QC Report No: BF85-Pacific Groundwater Group  
 Project: JE9907  
 Date Received: NA

Data Release Authorized: *MB*  
 Reported: 02/10/00 Dr. M.A. Perkins

**LABORATORY CONTROL SAMPLES  
CONVENTIONALS**

<u>Constituent</u>	<u>Units</u>	<u>Measured Value</u>	<u>True Value</u>	<u>Recovery</u>
<b>Laboratory Control Sample</b>				
Total Oil & Grease	mg/L	51.6	66.7	77.4%
Date analyzed: 02/03/00 Batch ID: 02030#1				
<b>Laboratory Control Sample</b>				
Biological Oxygen Demand	mg/L	163	200	81.5%
Date analyzed: 01/28/00 Batch ID: 01280#1				

QA Report - Standard Reference Material Analysis

QC Report No: BF85-Pacific Groundwater Group  
Project: JE9907

Date Received: NA

Data Release Authorized: *MB*  
Reported: 02/10/00 Dr. M.A. Perkins

STANDARD REFERENCE MATERIAL ANALYSIS  
CONVENTIONALS

Constituent	Units	Value	True Value	Recovery
<b>SPEX #15-121</b>				
Nitrate + Nitrite (NO2+NO3)	mg-N/L	0.429	0.400	107%
Date analyzed: 01/28/00 Batch ID: 01280#2				
<b>SPEX #6-26</b>				
Total Phosphorous	mg-P/L	5.17	5.00	103%
Date analyzed: 01/31/00 Batch ID: 01310#1				
<b>SPEX #17-17</b>				
Ortho-Phosphorous	mg-P/L	0.122	0.120	102%
Date analyzed: 01/28/00 Batch ID: 01280#1				
<b>SPEX #16-50</b>				
N-Ammonia	mg-N/L	0.794	0.800	99.2%
Date analyzed: 01/31/00 Batch ID: 01310#3				

QA Report - Replicate Analysis

Matrix: Water  
 Data Release Authorized: *MS*  
 Reported: 02/10/00 Dr. M.A. Perkins  
 QC Report No: BF85-Pacific Groundwater Group  
 Project: JE9907  
 Date Received: 01/28/00

DUPLICATE ANALYSIS RESULTS  
CONVENTIONALS

Constituent	Units	Sample Value	Duplicate Value	RPD
ARI ID: 00-876, BF85 A Client Sample ID: Miller At Kiwanis				
Nitrate + Nitrite (NO2+NO3)	mg-N/L	1.3	1.3	0.0%
Total Phosphorous	mg-P/L	0.060	0.060	0.0%
Ortho-Phosphorous	mg-P/L	0.029	0.029	0.0%
ARI ID: 00-877, BF85 B Client Sample ID: Des Moines at S 18th				
Biological Oxygen Demand	mg/L	2	2	0.0%
ARI ID: 00-879, BF85 D Client Sample ID: Des Moines at Tyee				
N-Ammonia	mg-N/L	< 0.010 U	< 0.010 U	NA

QA Report - Matrix Spike/Matrix Spike Duplicate Analysis

Matrix: Water  
 QC Report No: BF85-Pacific Groundwater Group  
 Project: JE9907  
 Date Received: 01/28/00  
 Data Release Authorized: *MB*  
 Reported: 02/10/00 Dr. M.A. Perkins

MATRIX SPIKE QA/QC REPORT  
CONVENTIONALS

Constituent	Units	Sample Value	Spike Value	Spike Added	Recovery
ARI ID: 00-876, BF85 A Client Sample ID: Miller At Kiwanis					
Nitrate + Nitrite (NO2+NO3)	mg-N/L	1.31	5.10	4.00	94.8%
Total Phosphorous	mg-P/L	0.060	0.461	0.400	100%
Ortho-Phosphorous	mg-P/L	0.029	0.128	0.100	99.0%
ARI ID: 00-879, BF85 D Client Sample ID: Des Moines at Tye					
N-Ammonia	mg-N/L	< 0.010	0.383	0.400	95.8%

MS/MSD Recovery Limits: 75 - 125 %

Water MS/MSD QA Report Page 1 for BF85 received 01/28/00

AR 011844

## Appendix G

### Ecological Evaluation of Maury Island Soil as Potential Fill

Gravel from a mine on Maury Island is being considered as fill for the proposed runway expansion. The top eighteen inches of gravel at Maury Island contain high levels of arsenic, cadmium, and lead originating from the former ASARCO smelter in Tacoma. The top 18 inches of soil at Maury Island are proposed to be contained at the island mine prior to aggregate extraction. Ecology must have assurance that the fill used for the airport project will not result in exceedances of state water quality criteria. The Port and Ecology are working to determine what screening methods and contingencies are necessary to ensure that water quality criteria are met.

This project analyzed the potential effects to ecological receptors, such as the benthic community and wildlife-consuming benthic organisms, if contaminants in the Maury Island fill were to migrate from soils to nearby sediments. Surface and subsurface soil data of the potential Maury Island fill were compared to ecological benchmarks to assess whether unacceptable ecological risks may occur.

For screening purposes, concentrations of arsenic, cadmium, and lead in soil were compared directly to Ecology's proposed Lowest Adverse Effects Thresholds (LAETs) for sediment (Cabbage, 1997). Sediment concentrations would be expected to be much lower than soil concentrations since contamination would need to leach or migrate from soil to sediment. Therefore, this comparison represents a conservative initial screening step, and exceedence of benchmarks does not imply that unacceptable ecological risks would occur.

A summary of the benchmarks used for comparison is presented in **Table G-1**. In addition to the LAETs, background concentrations for Washington State and MTCA Method A, industrial and residential concentrations are included for comparison. In each case, the ecological benchmarks are lower than the industrial human health MTCA levels and above background concentrations. The ecological benchmarks are similar to the residential human health MTCA Level A values.

Surface and subsurface soil data are presented in **Tables G-2 and G-3**, respectively. For the purpose of this evaluation, surface soil was defined as samples collected less than 2 feet below ground surface (BGS); subsurface soil was defined as samples collected from 2 or more feet BGS. These data are as presented in *Draft Environmental Impact Statement for Lone Star Maury Island Mining Operation, Final Sampling Results NW Aggregates Maury Island Gravel Mine, and the Technical Memorandum on Environmental Soil Sampling, Arsenic, Cadmium, and Lead, Lone Star Maury Island Site, King County, Washington*.

As shown in **Table G-2**, surface soil samples frequently exceed ecological benchmarks, particularly for arsenic and lead. Concentrations of these contaminants are highest in the more shallow soils, although many samples from nine inches BGS exceeded the LAET screening level for arsenic and a few samples from 18 inches BGS also marginally exceeded the LAET screening level for arsenic.

Contamination in surface soils could pose an unacceptable risk if this contamination migrates to sediments. If surface soils are to be used as fill, more comprehensive modeling of contamination leaching and migration should be performed to estimate potential sediment concentrations.

**Table G-3** presents the available subsurface soil data. As indicated in this table, all subsurface soil results are below ecological screening levels for all three analytes. Cadmium and lead generally were not detected in subsurface soil, and arsenic concentrations were generally an order of magnitude below the LAET screening level and the MTCA Level A Residential level.

Based on the above analysis, use of subsurface soils as fill should not pose an unacceptable risk to ecological receptors.



**Table G-1  
Summary of Benchmarks and Screening Levels**

	Ecology LAETs	Background Concentrations	MTCA Method A Industrial	MTCA Method A Residential
Arsenic	40	7	200	20
Cadmium	7.6	1	10	2
Lead	260	24	1000	250

*All values expressed in mg/kg.*

**Table G-2  
Comparison of Surface Soil Samples to Ecotoxicological Benchmarks**

Sample Number	Surface				9-Inch Depth				18-Inch Depth			
	Arsenic	Cadmium	Lead		Arsenic	Cadmium	Lead		Arsenic	Cadmium	Lead	
1	330	2	830		37	0.84	27		43	0.66	19	
2	120	2.3	390		25	1.2	10		8.7	0.56 U	5.6 U	
3	150	0.79 U	280		110	0.91	81		10	0.62	8.6	
4	160	1.5	450		19	0.72	25		4.2	0.53 U	5.3 U	
5	47	0.92	54		47	0.84	59		43	0.63 U	51	
6	100	9.3	470		270	2.9	120		64	1.1	30	
7	17	0.58 U	13		19	0.56 U	18		13	0.53 U	11	
8	190	3	550		67	0.94	41		10	0.58 U	7.6	
9	98	1.6	510		110	0.95	30		9.2	0.77	7.1	
10	4.3	0.53 U	5.3 U		1.6 U	0.53 U	5.3 U		1.6 U	0.52 U	5.2 U	
11	1.9	0.53 U	5.3 U		1.6 U	0.55 U	5.3 U		1.6 U	0.53 U	5.3 U	
12	6.1	0.54 U	5.8		6.2	0.54 U	5.4 U		5.7	0.55 U	6	
13	220	1.2 U	470		130	0.82	45		8.2	1.5	8.3	
14	18	0.91	70		130	1.2	37		2.0 U	0.92	36	
15	1.6 U	0.53 U	5.3 U		1.6 U	0.53 U	5.3 U		1.6 U	0.53 U	5.3 U	
16	280	1.6	730		39	0.84	17		40	0.89	23	
17	61	6	240		260	1.2	35		11	0.52 U	5.2 U	
18	11	0.59 U	7.1		8.2	0.57 U	5.7 U		5.9	0.57 U	6.1	
19	100	6	470		270	1.4	67		3.8	0.59 U	5.9 U	
20	140	5.4	710		11	0.59 U	11		7.6	0.59	6.6	

Values expressed in mg/kg.

U = undetected

Bold values exceed proposed Ecology LAETs for freshwater sediment.

**Table G-3**  
**Comparison of Subsurface Soil Samples to Ecotoxicological Benchmarks**

Depth (bgs)	Arsenic	Cadmium	Lead
9	4.3	0.58 U	5.8 U
10	4.5	0.54 U	5.4 U
8.5	2.7	0.61 U	6.1 U
10	2.4	0.53 U	5.3 U
10	3.9	0.54 U	5.4 U
10	2.4	0.54 U	5.4 U
10	3.5	0.54 U	5.4 U
10	3.1	0.54 U	5.4 U
10	4.6	0.54 U	5.4 U
10	6.9	0.58 U	5.8 U
10	3.1	0.54 U	5.4 U
10	3.3	0.54 U	5.4 U
10	4	0.56 U	5.6 U
10	2.2	0.52 U	5.2 U
NL	1.6 U	0.53 U	5.3 U
NL	2.2	0.53 U	5.3 U
NL	1.6	0.53 U	5.3 U
NL	1.8	0.54 U	5.4 U
95	1.9 U	0.63 U	6.3 U
270	2.4	0.67 U	6.7 U
55	3 U	NA	7.7
190	1.7 U	NA	6
140	3 U	NA	8.9
220	3 U	NA	5.3
2	8 U	1 U	10 U
2	8 U	1 U	10 U
2	8 U	1 U	10 U
2	8 U	1 U	10 U

*Values expressed in mg/kg*

*U = Undetected*

*NA = Not analyzed.*

*NL = Not listed.*

*All samples are below proposed Ecology LAETs for freshwater sediment and background concentrations.*

**G**

**AR 011850**

Page 1 of 52  
Permit No. WA-002465-1  
Issuance Date: February 20, 1998  
Effective Date: March 1, 1998  
Expiration Date: June 30, 2002  
Modification Date: May 29, 2001

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM  
WASTE DISCHARGE PERMIT No. WA-002465-1

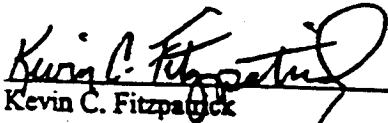
State of Washington  
DEPARTMENT OF ECOLOGY  
Northwest Regional Office  
3190 - 160<sup>th</sup> Avenue SE  
Bellevue, WA 98008-5452

In compliance with the provisions of  
The State of Washington Water Pollution Control Law  
Chapter 90.48 Revised Code of Washington  
and  
The Federal Water Pollution Control Act  
(The Clean Water Act)  
Title 33 United States Code, Section 1251 et seq.

PORT OF SEATTLE  
SEATTLE-TACOMA INTERNATIONAL AIRPORT  
P.O. Box 68727  
Seattle, Washington 98168

<u>Facility Location</u>	<u>Industry Type</u>
Sea-Tac International Airport Seattle, Washington King County	Airport
<u>Water Body I.D. No.</u>	<u>Receiving Water</u>
(i) WA-PS-0270	(i) Puget Sound (Industrial Wastewater)
(ii) WA-09-2000	(ii) Des Moines Creek, (Stormwater)
(iii) WA-09-2005	(iii) Miller Creek (Stormwater)
(iv) WA-09-1020	(iv) City of SeaTac Storm Sewer, tributary to Gilliam Creek and the Green River (Stormwater)
(vi) 1223370474523	(v) Midway Sewer District Sanitary Sewer (Miscellaneous Blowdown)
(vii) 1222552474518	(vi) Walker Creek and tributaries (Construction Stormwater)
	(vii) Gilliam Creek and tributaries (Construction Stormwater)

is authorized to discharge in accordance with the special and general conditions which follow.

  
Kevin C. Fitzpatrick  
Water Quality Section Manager  
Northwest Regional Office  
Washington State Department of Ecology

Discharge Location:

(i) Puget Sound

Outfall 001      Latitude: 47° 24' 07" N  
                         Longitude: 122° 20' 07" W

(ii) Des Moines Creek

Outfall 002      Latitude: 47° 26' 13" N  
(SDE4)            Longitude: 122° 17' 38" W

Outfall 003      Latitude: 47° 26' 00" N  
(SDS1)            Longitude: 122° 18' 01" W

Outfall 004      Latitude: 47° 25' 50" N  
(SDS2)            Longitude: 122° 18' 42" W

Outfall 005      Latitude: 47° 25' 58" N  
(SDS3)            Longitude: 122° 18' 30" W

Outfall 009      Latitude: 47° 25' 33" N  
(SDS4)            Longitude: 122° 18' 15" W

Outfall 010      Latitude: 47° 26' 09" N  
(SDW3)            Longitude: 122° 18' 53" W

Outfall 014      Latitude: 47° 26' 07" N  
(Sub-basin B)    Longitude: 122° 18' 48" W

Outfall 015      Latitude: 47° 26' 06" N  
(Sub-basin D)    Longitude: 122° 18' 46" W

(iii) Miller Creek

Outfall 006      Latitude: 47° 27' 56" N  
(SDN1)            Longitude: 122° 18' 09" W

Outfall 007      Latitude: 47° 28' 00" N  
(SDN2)            Longitude: 122° 18' 28" W

Outfall 008      Latitude: 47° 27' 59" N  
(SDN3)            Longitude: 122° 18' 45" W

Outfall 011      Latitude: 47° 28' 00" N  
(SDN4)            Longitude: 122° 18' 38" W

(iv) City of SeaTac Storm Sewer

Outfall 012      Latitude: 47° 27' 34" N  
(Engineering Yard) Longitude: 122° 17' 50" W

Outfall 013      Latitude: 47° 27' 37" N  
(Taxi Yard)        Longitude: 122° 17' 43" W

Modification Date: May 29, 2001

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**SUMMARY OF SCHEDULED PERMIT REPORT SUBMITTALS**

<b>Permit Section</b>	<b>Submittal</b>	<b>Frequency</b>	<b>First Submittal Date</b>
S1.F	IWS Collection System Integrity Scope of Work	Once/permit cycle	June 30, 1999
S1.F	IWS Collection System Integrity Investigation Report	Once/permit cycle	December 31, 2001
S2.B	Procedures Manual for Stormwater Sampling	Once/permit cycle	Within three (3) months of effective date
S2.C	Construction Stormwater/Dewatering Monitoring Plan	As necessary	Thirty (30) days prior to start of construction
S2.D	Glycol Usage Summary Report	Annually	June 1, 1998
S2.E	Annual Stormwater Monitoring Summary Report	Annually	October 1, 1998
S2.F	Annual Sanitary Sewer Discharge Summary Report	Annually	January 15, 2000
S3.A	Discharge Monitoring Report (Industrial Wastewater)	Monthly	April 1, 1998
S3.B	Discharge Monitoring Report (Stormwater)	Monthly, Quarterly, Semi-annually, and Annually	April 1, 1998
<del>S3.C</del>	<del>Discharge Monitoring Report (Construction Stormwater)</del>	<del>Every other Month</del>	<del>June 1, 2001</del>
S4	IWS Engineering Report	Once/permit cycle	Within two (2) months of effective date
S5.A	Operations and Maintenance Manual Update or Review Confirmation Letter	Annually	Within one (1) year of effective date
S7	Spill Plan	Once /permit cycle	Within one (1) year of effective date
S8.A	IWS Acute Toxicity Characterization Data	Quarterly for one (1) year	Within sixty (60) days of sample date
S8.A	IWS Acute Toxicity Tests Characterization Summary Report	Once/permit cycle	Within ninety (90) days of last test
S9.A	IWS Chronic Toxicity Characterization Data	Quarterly for one (1) year	Within sixty (60) days of sample date
S9.A	IWS Chronic Toxicity Characterization Summary Report	Once/permit cycle	Within ninety (90) days of last test

Permit Section	Submittal	Frequency	First Submittal Date
S10.A	Stormwater Acute Toxicity Characterization Data	10/permit cycle	Within sixty (60) days of sample date
S10.A	Stormwater Acute Toxicity Tests Characterization Summary Report	1/permit cycle	Within ninety (90) days of last test
S11.A	Sediment Baseline Sampling and Analysis Plan	1/permit cycle	Within one (1) year of effective date
S11.B	Sediment Data Report	1/permit cycle	Within three (3) years of effective date
S12.B	Stormwater Pollution Prevention Plan for Airport Operations	2/permit cycle	November 30, 1998
S14	Lake Reba Operations and Maintenance Plan	Once/permit cycle	Within three (3) months of effective date
S15	IWS Hydrogeologic Study Scope of Work	Once/permit cycle	Within six (6) months of effective date
S15	IWS Hydrogeologic Study Final Report	Once/permit cycle	June 30, 2000
G1	Notice of Change in Authorization	As necessary	
G7	Application for Permit Renewal	1/permit cycle	One hundred and eighty (180) days before permit expiration

### SPECIAL CONDITIONS

#### S1. DISCHARGE LIMITATIONS

All discharges and activities authorized by this permit shall be consistent with the terms and conditions of this permit. The discharge of any of the following pollutants more frequently than, or at a concentration in excess of, that authorized by this permit shall constitute a violation of the terms and conditions of this permit. Compliance with this permit is deemed compliance with the Federal Water Pollution Control Act, also known as the Clean Water Act (33 U.S.C. § 1251, et seq.) and the Water Pollution Control Act (RCW 90.48). ~~This permit regulates the discharges at Seattle Tacoma International Airport identified in paragraphs S1, A-F. This permit also covers the discharge of construction stormwater related to the construction of temporary interchanges for SR 509 and SR 518.~~

#### A. Interim Effluent Limitations - Industrial Wastewater

Beginning on the effective date of this permit and lasting to the effective date of the final effluent limitations, the Permittee is authorized to discharge treated industrial wastewater<sup>a</sup> to Puget Sound subject to meeting the following limitations:

INTERIM EFFLUENT LIMITATIONS: OUTFALL 001		
Parameter	Average Monthly <sup>b</sup>	Maximum Daily <sup>c</sup>
Flow	---	4,800 gpm <sup>d</sup>
pH	---	Within the range of 6.0 to 9.0 Std. Units
Oil and Grease	8 mg/L <sup>e</sup>	15 mg/L <sup>e</sup>
Total Suspended Solids (TSS)	21 mg/L	33 mg/L

<sup>a</sup> Industrial wastewater is water or liquid-carried waste from industrial or commercial processes, as distinct from domestic wastewater, non-contact cooling water, or stormwater associated with industrial activity. Industrial wastewater may result from any process or activity of industry, manufacture, trade or business, and includes, but is not limited to: water used for industrial processes such as pipe integrity pressure testing and vehicle and aircraft wash water; stormwater contaminated with fuel, oil, fire foam, cleaning agents and aircraft deicing/anti-icing agents; contaminated construction dewatering waters; excess water from ground water well construction and monitoring; and leachate from solid waste facilities. Industrial wastewater does not include stormwater runoff that contains deicing/anti-icing agents that shear or drip from aircraft in the storm drainage system.

**S1. DISCHARGE LIMITATIONS (CONTINUED)**

<p><sup>b</sup> The average monthly effluent limitation is defined as the highest allowable average of daily discharges over a calendar month, calculated as the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during that month.</p>
<p><sup>c</sup> The highest allowable daily discharge of a pollutant (or flow) measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. The daily discharge is calculated as the average measurement of the pollutant (or flow) over the day.</p>
<p><sup>d</sup> Flow shall not exceed the discharge rate specified in the Midway Sewer District discharge agreement. See Footnote S1.B<sup>d</sup>.</p>
<p><sup>e</sup> These oil and grease effluent limitations are based on Method 413.1, and are subject to modification based on the outcome of monitoring with Method 1664. The permit may be modified to establish equivalent effluent limitations after the side-by-side monitoring outlined in Special Condition S2.A, footnote c, is concluded.</p>

**B. Final Effluent Limitations - Industrial Wastewater**

Beginning on the date of completion of start up of the Permittee's approved treatment system as required under Special Condition S4 and lasting through the expiration date of this permit, the Permittee is authorized to discharge treated industrial wastewater\* to Puget Sound subject to meeting the following limitations:

<b>FINAL EFFLUENT LIMITATIONS: OUTFALL 001</b>		
<b>Parameter</b>	<b>Average Monthly<sup>b</sup></b>	<b>Maximum Daily<sup>c</sup></b>
Flow		2,500 gpm <sup>d</sup>
pH		Within the range of 6.0 to 9.0 Std. Units
Oil and Grease	TBD <sup>e</sup>	TBD <sup>e</sup>
TSS	TBD <sup>e</sup>	TBD <sup>e</sup>
Biochemical Oxygen Demand (BOD <sub>5</sub> )	TBD <sup>e</sup>	TBD <sup>e</sup>

**S1. DISCHARGE LIMITATIONS (CONTINUED)**

<p><sup>a</sup> Industrial wastewater is water or liquid-carried waste from industrial or commercial processes, as distinct from domestic wastewater, non-contact cooling water, or stormwater associated with industrial activity. Industrial wastewater may result from any process or activity of industry, manufacture, trade or business, and includes, but is not limited to: water used for industrial processes such as pipe integrity pressure testing and vehicle and aircraft wash water; stormwater contaminated with fuel, oil, fire foam, cleaning agents and aircraft deicing/anti-icing agents; contaminated construction dewatering waters; excess water from ground water well construction and monitoring; and leachate from solid waste facilities. Industrial wastewater does not include stormwater runoff that contains deicing/anti-icing agents that shear or drip from aircraft in the storm drainage system.</p>
<p><sup>b</sup> The average monthly effluent limitation is defined as the highest allowable average of daily discharges over a calendar month, calculated as the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during that month.</p>
<p><sup>c</sup> The highest allowable daily discharge of a pollutant (or flow) measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. The daily discharge is calculated as the average measurement of the pollutant (or flow) over the day.</p>
<p><sup>d</sup> Flow shall not exceed 2,500 gpm whenever the combined flow from the IWS and Midway Sewer District exceeds ninety percent (90%) of the outfall's present capacity of twelve thousand five hundred (12,500) gpm. The 2,500 gpm limitation may be increased if the outfall capacity is increased.</p>
<p><sup>e</sup> Effluent limitations shall be determined by the Department after approval of the AKART Engineering Report required in Special Condition S4. Final effluent limitations will be set through a major modification of the permit and will be subject to public comment.</p>

**C. Mixing Zone Description - Outfall 001**

The boundaries of the mixing zone for Outfall 001 shall be defined by the Department through a major permit modification after the AKART determination required by Special Condition S4.

**D. Non-Contact Cooling Water**

Discharge of non-contact cooling water to waters of the State is prohibited. Cooling tower blowdown may be discharged to the sanitary sewer with permission from the Midway Sewer District.

S1. DISCHARGE LIMITATIONS (CONTINUED)

E. Stormwater Drainage System

Discharge of industrial wastewater to the Storm Drain System is prohibited. Stormwater associated with industrial activity and construction activity may be discharged to the storm drainage system in accordance with the terms and conditions of this permit. Overflows of untreated industrial wastewater from the IWS collection systems or lagoons due to stormwater flows in excess of the design criteria are authorized bypasses that are not subject to this condition.

F. Ground Water Discharges

The Permittee shall apply the following known, available, and reasonable methods to prevent the unintentional release of industrial wastewater to groundwater:

- 1) The Permittee shall clean and line Lagoon No. 3 as part of the Compliance Schedule set forth in Special Condition S4; and
- 2) On or before June 30, 1999, the Permittee shall submit a scope of work to Ecology to investigate the integrity of the IWS collection system by assessing the structural integrity of a representative portion of the IWS piping system. The assessment shall provide an overview of the entire IWS Collection System including the IWTP interconnecting piping, and shall explain how the "representative portion" of the system was selected. The assessment shall be completed prior to December 31, 2001.

If the assessment detects significant leaks, the Permittee shall assess the remaining portions of the represented system in the shortest practicable time and, in consultation with the Department, shall assess whether any of the leaks show a reasonable potential to violate ground water quality standards. If a reasonable potential to violate ground water standards is shown, the Permittee shall, in consultation with the Department and within six (6) months of such a showing, develop a schedule to repair, if feasible, the leaking portion of the collection system. If it is not feasible to repair the leaking portion, the Permittee shall propose an alternative. The Permittee may, at its discretion, forego the reasonable potential analysis and elect to develop, within six (6) months of detection of the leaks, a schedule to repair the pipeline. Cleanups of residual contamination due to releases of industrial wastewater or contaminants are regulated under the Model Toxics Control Act ("MTCA") and are not regulated under this permit. Ongoing discharges of industrial wastewater or contaminants are regulated under this permit.

Discharge of stormwater to ground water is permitted.

Modification Date: May 29, 2001

S1. DISCHARGE LIMITATIONS (CONTINUED)

G. Construction Related Discharges

This permit authorizes the discharge of stormwater associated with construction and uncontaminated construction dewatering to waters of the state of Washington and/or to municipal storm drains from airport construction sites. ~~Stormwater and uncontaminated construction dewatering water may be discharged through temporary construction outfalls to Miller Creek, Des Moines Creek, the City of Seattle Storm Sewer tributary to Gilliam Creek and the Green River to the S. Gilliam Creek and tributaries, and Walker Creek and tributaries.~~ A SWPPP for construction activity, including construction dewatering, shall be prepared and implemented prior to the commencement of any construction activity which disturbs five (5) or more acres of total land area (or other minimum land area to be determined by federal regulation), as required in Special Condition S13.

H. Municipal Sewer System Discharges

During the period beginning on the date of issuance and lasting through the expiration date of this permit, the Permittee is authorized to discharge boiler blowdown, cooling tower blowdown, rental car wash blowdown, and equipment wash rack blowdown to the Midway Sewer District sewer system subject to the following limitations:

FINAL EFFLUENT LIMITATIONS: Sanitary Sewer Discharge		
Parameter	Average Monthly <sup>a</sup>	Maximum Daily <sup>b</sup>
Flow (Boiler Blowdown)	125 gpd	500 gpd
Flow (Cooling Tower Blowdown)	7,200 gpd	200,000 gpd
Flow (Rental Car Wash Blowdown)	15,250 gpd	15,250 gpd
Flow (Equipment Wash Rack Blowdown)	1,000 gpd	1,000 gpd
Oil and Grease <sup>c</sup>	-	100 mg/L
<sup>a</sup> The average monthly effluent limitation is defined as the highest allowable average of daily discharges over a calendar month, calculated as the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during that month.		
<sup>b</sup> The highest allowable daily discharge of a pollutant (or flow) measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. The daily discharge is calculated as the average measurement of the pollutant (or flow) over the day.		
<sup>c</sup> The oil and grease effluent limitation applies to the rental car wash and equipment wash rack blowdown waste streams.		



S2. MONITORING REQUIREMENTS

A. Industrial Wastewater

The Permittee shall monitor the effluent from the Industrial Wastewater System (IWS) prior to mixing with the Midway Wastewater Treatment Plant effluent according to the following schedule:

Parameter	Units	Minimum Sampling Frequency <sup>a</sup>	Sample Type
Maximum Daily Flow	gpm	Daily	continuous
pH	Standard Units	1/week	grab
TSS	mg/L	1/week	composite <sup>b</sup>
Oil and Grease <sup>c</sup>	mg/L	1/week	grab
BOD <sub>5</sub>	mg/L	1/month	composite <sup>b</sup>
Total Glycols <sup>d</sup>	mg/L	1/month <sup>e</sup>	composite <sup>b</sup>
Total Petroleum Hydrocarbon (TPH) <sup>f</sup>	mg/L	1/month	grab
Fecal Coliform	#/100 mls	1/month <sup>g</sup>	grab
Priority Pollutants <sup>h</sup>	mg/L	annually	grab/ composite

<sup>a</sup> If no discharge occurs in a given month, sampling is not required. "No Discharge" shall be clearly stated on that month's discharge monitoring report. A day shall be a calendar day and a month shall be a calendar month. A week shall be a period of time lasting seven consecutive days, beginning at 12:00 am on the first day of operation and ending at 11:59 PM on the seventh day of operation when the treatment plant is operated intermittently. Intermittent operation includes start up and shut down.

<sup>b</sup> Composite samples shall be a combination of at least four representative grab samples of a fixed volume collected at equal time intervals throughout the normal working day. Automatically timed composited samples are preferred over manually collected samples.

<sup>c</sup> The IWS effluent shall be monitored for oil and grease using Method 413.1. When a laboratory in the greater Seattle area is certified for Method 1664, the IWS effluent shall be monitored for oil and grease using both Method 413.1 and Method 1664 for a period of one (1) year or for as long as Method 413.1 is available but no longer than one year. During the one-year period of side-by-side monitoring, compliance with the effluent limits for oil and grease shall be based on Method 413.1.

<sup>d</sup> Total glycols equals the sum of ethylene glycol and propylene glycol.

<sup>e</sup> The IWS effluent shall be monitored for both ethylene and propylene glycol once per month upon being notified by the airlines that aircraft deicing or anti-icing has occurred. BOD<sub>5</sub> shall be sampled concurrently with glycols in those months deicing occurs.

<sup>f</sup> Total Petroleum Hydrocarbons shall be measured using the NWTPH-D<sub>x</sub> method or an equivalent method approved by the Department.

<sup>g</sup> This monitoring requirement may be eliminated with Department approval if the Permittee can show that fecal coliform from human sources are not present.

<sup>h</sup> Priority pollutant monitoring shall include: semivolatiles (organic acid extractables and organic base-neutral extractables), volatile organic analysis, and total recoverable copper, lead, and zinc.

## S2. MONITORING REQUIREMENTS (CONTINUED)

B. Non-construction Stormwater

The Permittee shall monitor stormwater discharges according to the following monitoring schedule. No monitoring is necessary for reporting periods in which there are no storm events that meet the criteria set forth in the Procedures Manual for Stormwater Sampling. All samples shall be collected according to the procedures outlined in a Procedures Manual for Stormwater Sampling. The Permittee shall submit an updated Procedures Manual to the Department for review and approval within three (3) months of the effective date of this permit. The Permittee shall include the following data for each sampled storm event in the Annual Stormwater Monitoring Summary Report required in Special Condition S2.E: date, duration, the number of dry hours preceding the storm event, total rainfall during the storm event (inches), maximum flow rate during the rain event (gallons per minute), and the total flow from the rain event (gallons). The Permittee shall also include a monthly summary of daily rainfall in the Annual Stormwater Monitoring Summary Report.

1. The Permittee shall monitor the stormwater discharges at Outfalls 002, 005, 006<sup>a</sup>, and 011 according to the following schedule:

Parameter	Units	Minimum Sampling Frequency	Sample Type
TPH <sup>b</sup>	mg/L	eight/year <sup>c</sup>	grab
TSS	mg/L	eight/year <sup>c</sup>	composite
Turbidity	NTU	eight/year <sup>c</sup>	composite
Fecal Coliform	#/100 mL	eight/year <sup>c</sup>	grab
BOD <sub>5</sub>	mg/L	eight/year <sup>c,d</sup>	composite
Ethylene Glycol and Propylene Glycol <sup>e</sup>	mg/L	eight/year <sup>c</sup>	composite
Total Recoverable Copper	mg/L	eight/year <sup>c</sup>	composite
Total Recoverable Lead	mg/L	eight/year <sup>c</sup>	composite
Total Recoverable Zinc	mg/L	eight/year <sup>c</sup>	composite

<sup>a</sup> The Permittee may request a reduction in monitoring frequency for Outfall 006 after one year of monitoring. The Department may reduce the frequency to quarterly, semi-annually, or annually.

<sup>b</sup> Total Petroleum Hydrocarbons shall be measured using the NWTPH-D<sub>x</sub> method or an equivalent method approved by the Department.

<sup>c</sup> The Permittee shall collect eight samples per year in the following manner: One sample shall be collected during the months of June-August. The remaining seven samples shall be collected during the remainder of the year with a minimum of one per quarter. One year from the permit modification effective date, stormwater Discharge Monitoring Reports for Outfalls 002, 005, 006 and 011 shall be submitted quarterly.

<sup>d</sup> BOD<sub>5</sub> monitoring at Outfall 005 shall occur, to the extent practicable, during a precipitation event that coincides with a runway deicing event in those months in which a runway deicing event occurs.

<sup>e</sup> Ethylene glycol and propylene glycol shall be measured monthly at Outfalls 002, 005, and 011 except for the months of June, July, and August. Glycol monitoring is not required at Outfall 006. Sampling shall occur, to the extent practicable, during a precipitation event that coincides with a deicing or anti-icing event.

## S2. MONITORING REQUIREMENTS (CONTINUED)

2. The Permittee shall monitor the stormwater discharges at Outfalls 003, 004, 008, 009, 010, 014, and 015 according to the following schedule:

Parameter	Units	Minimum Sampling Frequency	Sample Type
TPH <sup>a</sup>	mg/L	annually	grab
TSS	mg/L	annually	composite
Turbidity	NTU	annually	composite
Fecal Coliform <sup>b</sup>	#/100 mL	annually	grab
Total Recoverable Copper	mg/L	annually	composite
Total Recoverable Lead	mg/L	annually	composite
Total Recoverable Zinc	mg/L	annually	composite
<sup>a</sup> Total Petroleum Hydrocarbons shall be measured using the NWTPH-D <sub>x</sub> method or an equivalent method approved by the Department.			
<sup>b</sup> This monitoring requirement may be eliminated with Department approval if the Permittee can show that fecal coliform from human sources are not present.			

3. The Permittee shall monitor the stormwater discharges from Outfall 007, the Port Engineering Yard (Outfall 012) and the Taxi Yard (Outfall 013), according to the following schedule:

Parameter	Units	Minimum Sampling Frequency	Sample Type
TPH <sup>a</sup>	mg/L	semi-annually	grab
TSS	mg/L	semi-annually	composite
<sup>a</sup> Total Petroleum Hydrocarbons shall be measured using the NWTPH-D <sub>x</sub> method or an equivalent method approved by the Department.			

4. The Permittee shall monitor the stormwater discharges from Outfall 003 and Outfall 007 according to the following schedule:

Parameter	Units	Minimum Sampling Frequency	Sample Type
Ethylene Glycol and Propylene Glycol	mg/L	Quarterly <sup>a</sup>	Grab <sup>b</sup>
Flow (Outfall 007)		Each bypass event	Report <sup>c</sup>
<sup>a</sup> Ethylene glycol and propylene glycol shall be measured at Outfalls 003 and 007 in the three quarters December – February, March – May, and September – November. Sampling shall occur during a precipitation event that coincides with a deicing/anti-icing event. For Outfall 003, samples may be taken during base-flow, snowmelt, or any precipitation event that coincides with a deicing/anti-icing event. This monitoring requirement may be eliminated after four sampling events at each outfall with Department approval.			
<sup>b</sup> Samples shall be collected during the first sixty (60) minutes of each discharge event. The Permittee shall request permission to use data gathered after the first sixty (60) minutes of the discharge if it is not possible to grab a sample in the first sixty (60) minutes.			
<sup>c</sup> The Permittee shall report when a bypass from the SDN-2 IWS pump station occurs at Outfall 007 by indicating "yes" on the Discharge Monitoring Report.			

S2. MONITORING REQUIREMENTS (CONTINUED)

C. Construction Stormwater/Dewatering Monitoring

1. The Permittee shall submit a monitoring plan for stormwater and construction dewatering discharges from construction projects required to have a Stormwater Pollution Prevention Plan in Special Condition S13 of this permit. The monitoring plan shall be submitted to the Department for review and approval at least thirty (30) days prior to the start of construction. The plan shall be deemed approved if Ecology does not respond to the plan at least five (5) days prior to the scheduled date of construction.

Monitoring Schedule for Construction Stormwater Discharges to Walker Creek and tributaries and Gilman Creek and tributaries.

Special Condition S13.C.1.b requires inspection of all on-site erosion and sediment control measures within 24 hours after any storm event of greater than 1.5 inches of precipitation per 24-hour period. In addition, the Permittee shall monitor turbidity and pH in any surface water discharge from construction sites within 24 hours after any storm event of greater than 1.5 inches of precipitation per 24-hour period. The storm event shall be measured by an on-site rain gauge. The monitoring meter shall be a portable turbidimeter and a pH meter following the prescribed maintenance, operating, and calibration procedures in the instrument's instruction manuals. Alternatively, a grab sample can be analyzed by a laboratory accredited under the provisions of accreditation of Environmental Laboratories, Chemical Analysis, WA0.

During each rain event the turbidimeter and pH meter shall also be used for the measurement of turbidity and pH at an agreed point upstream of the point of discharge to the receiving water and an agreed downstream point of the thorough mixing of the discharge and the receiving water.

If a visual sheen is observed, the Permittee shall sample for oil and grease.

Parameter	Units	Sample Point <sup>1</sup>	Minimum Sampling Frequency	Sample Type
Oil and Grease	mg/L	Point of Discharge	Each rain event	Grab
<sup>1</sup> Samples shall be collected from the outfall or an on-line stormwater drain access point nearest the outfall terminus.				

S2. MONITORING REQUIREMENTS (CONTINUED)

The MDL for oil and grease is 0.2 mg/L using trichlorotrifluoroethane extraction and gravimetric analysis using EPA Method 413.1. The quantitation level (QL) for oil and grease is 1.0 mg/L (5x MDL). An equivalent method is Method 1664 using normal hexane (n-hexane) as the extraction solvent in place of 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113, Freon-113). An equivalent method is total petroleum hydrocarbons with a MDL of 0.1 mg/L using Gas Chromatography and Flame Ionization Detector (FID) and Method WHPH-D, Disc 4 (WHPH-D) from the Washington State Department of Ecology Method WHPH-D. The quantitation level (QL) for TPH-D is 0.5 mg/L (5x MDL).

b. Compliance Evaluation

Monitoring will be reviewed for compliance with WAC 173-2014. The Department will exercise its enforcement discretion in the event of noncompliance with these standards.

D. Deicing/Anti-icing Fluids Usage

All deicing and anti-icing events of either aircraft or runways shall be reported no later than June 1 of each year, and shall include the volumes of each type of deicing and anti-icing material used each day by each airline and the Permittee. Anti-icing means measures taken to prevent ice accumulation on the surface of the aircraft, airfield, or runway. Deicing means removing ice from the surface of the aircraft, airfield, or runway.

E. Annual Stormwater Monitoring Summary Report

On or before October 1 of each year, the Permittee shall submit a report to the Department summarizing the results of the stormwater monitoring conducted pursuant to Special Condition S2.B or S3.E of this permit during the preceding twelve (12) month period from July 1 through June 30.

The report shall present the analytical data, the Port's conclusions as to what is being learned from the data, and any new initiatives to be undertaken as part of the Stormwater Pollution Prevention Plan for Airport Operations required in Special Condition S12.

F. Annual Sanitary Sewer Discharge Summary Report

On or before January 15<sup>th</sup> of each year, the Permittee shall submit a report to the Department summarizing the following data for the previous calendar year:

S2. MONITORING REQUIREMENTS (CONTINUED)

1. Monthly average and maximum daily discharge flow rates for each waste stream; and
2. Quarterly oil and grease monitoring results for the rental car wash blowdown and equipment wash rack blowdown.

G. Sampling and Analytical Procedures

Samples and measurements taken to meet the requirements of this permit shall be representative of the volume and nature of the monitored parameters, including representative sampling of any unusual discharge or discharge condition, including bypasses, upsets, and maintenance-related conditions affecting effluent quality.

Sampling and analytical methods used to meet the water and wastewater monitoring requirements specified in this permit shall conform to the latest revision of the *Guidelines Establishing Test Procedures for the Analysis of Pollutants* contained in 40 CFR Part 136 or to the latest revision of *Standard Methods for the Examination of Water and Wastewater* (APHA), unless otherwise specified in this permit or approved in writing by the Department.

Ground water sampling shall conform to the latest protocols in the *Implementation Guidance for the Ground Water Quality Standards* (Ecology 1996).

H. Flow Measurement

Appropriate flow measurement devices and/or methods consistent with accepted scientific practices shall be selected and used to ensure the accuracy and reliability of measurements of the quantity of monitored flows. The devices shall be installed, calibrated, and maintained to ensure that the accuracy of the measurements are consistent with the accepted industry standard for that type of device. Frequency of calibration shall be in conformance with manufacturer's recommendations and at a minimum frequency of at least one (1) calibration per year. Calibration records shall be maintained for at least three (3) years.

I. Laboratory Accreditation

All monitoring data required by the Department shall be prepared by a laboratory registered or accredited under the provisions of *Accreditation of Environmental Laboratories*, Chapter 173-50 WAC. Flow, temperature, settleable solids, conductivity, pH, and internal process control parameters are exempt from this requirement. Conductivity and pH shall be accredited if the laboratory must otherwise be registered or accredited.

~~Modification Date: May 29, 2001~~

S3. **REPORTING AND RECORDKEEPING REQUIREMENTS**

The Permittee shall monitor and report in accordance with the following conditions. The falsification of information submitted to the Department shall constitute a violation of the terms and conditions of this permit.

A. Reporting - Industrial Wastewater

The first monitoring period begins on the effective date of the permit. Monitoring results shall be submitted monthly. Monitoring data obtained during the previous month shall be summarized and reported on a form provided, or otherwise approved, by the Department, and be received no later than the 30th day of the month following the completed reporting period, unless otherwise specified in this permit. The report(s) shall be sent to the Department of Ecology, Northwest Regional Office, 3190 160th Avenue SE, Bellevue, Washington 98008-5452.

B. Reporting - Stormwater

The first monitoring period begins on the effective date of the permit. Monitoring results shall be submitted monthly, quarterly, semi-annually, or annually as required in Special Condition S2.B. Quarters shall be defined as: December - February, March - May, June - August, and September - November. Monitoring results obtained during the previous reporting period shall be reported on the forms provided, or otherwise approved, by the Department, and be received no later than the 30th day of the month following the completed reporting period, unless otherwise specified in this permit. The report(s) shall be sent to the Department of Ecology, Northwest Regional Office, 3190 160th Avenue SE, Bellevue, Washington 98008-5452.

All lab reports for metal parameters shall be submitted with the Discharge Monitoring Report. The following information shall be provided: sampling date, sample location, date of analysis, parameter name, CAS number, analytical method/number, method detection limit (MDL), lab practical quantitation limit (PQL), reporting units, and concentration detected.

~~C. Reporting - Construction Stormwater~~

~~Monitoring results for construction stormwater discharges to Walker Creek and tributaries and Gilliam Creek and tributaries shall be submitted every other month beginning July 1, 2001.~~

D. Records Retention

The Permittee shall retain records of all monitoring information for a minimum of three (3) years. Such information shall include all calibration and maintenance records and all original recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for this permit. This period of retention shall be extended during the course of any unresolved litigation regarding the discharge of pollutants by the Permittee or when requested by the Director.

S3. **REPORTING AND RECORDKEEPING REQUIREMENTS (CONTINUED)**

E. Recording of Results

For each measurement or sample taken, the Permittee shall record the following information: (1) the date, exact place, method, and time of sampling; (2) the individual who performed the sampling or measurement; (3) the dates the analyses were performed; (4) who performed the analyses; (5) the analytical techniques or methods used; and (6) the results of all analyses.

F. Additional Monitoring by the Permittee

If the Permittee monitors any pollutant more frequently than required by this permit using the test procedures and the locations specified by Special Condition S2 of this permit, then the results of this monitoring shall be included in the calculation and reporting of the data submitted in the Permittee's self-monitoring reports.

If the Permittee performs validated water quality monitoring or sediment monitoring using methods and/or locations other than those specified in Special Condition S2, the Permittee shall include notice of this monitoring with the Discharge Monitoring Report for the month in which the monitoring data is received and must provide the data to the Department upon request. MTCA monitoring is excluded from reporting requirements under this permit. For purposes of this condition, the term "sediment" means settled particulate matter located in the predominantly biologically active aquatic zone, or exposed to the water column. Sediment does not include vector waste solids or street sweepings.

G. Noncompliance Notification

In the event the Permittee is unable to comply with any of the permit terms and conditions due to any cause, the Permittee shall:

1. Immediately take action to stop, contain, and cleanup unauthorized discharges or otherwise stop the violation, and correct the problem;
2. Repeat sampling and analysis of any violation and submit the results to the Department within thirty (30) days after becoming aware of the violation. Repeat sampling and analysis is not required for any parameter that will be sampled within thirty (30) days to satisfy the requirements of Special Condition S2;



**S3. REPORTING AND RECORDKEEPING REQUIREMENTS (CONTINUED)**

3. Notify the Department of the failure to comply. Spill events to waters of the state shall be reported immediately to the Department's 24-Hour Spill Response Team at (425) 649-7000 and to the NPDES permit manager within 24 hours of becoming aware of the spill. Spills of less than or equal to 20 gallons of petroleum products that are contained by the IWS do not need to be reported. All other spills of substances not permitted to be discharged to the IWS, which are contained by the IWS, shall be reported monthly to the NPDES permit manager, but not the Spill Response Team. All other noncompliance shall be reported to the NPDES permit manager within 24 hours upon becoming aware of the noncompliance; and
4. Except as specified in subparagraph S3.F(3) above, submit a detailed, written report to the Department within thirty (30) days (five [5] days for spills, upsets, and bypasses) unless requested earlier by the Department. The report should describe the nature of the violation, corrective action taken and/or planned, steps to be taken to prevent a recurrence, results of the resampling, and any other pertinent information.

Compliance with these requirements does not relieve the Permittee from responsibility to maintain continuous compliance with the terms and conditions of this permit or the resulting liability for failure to comply.

**S4. COMPLIANCE SCHEDULE**

The Permittee shall submit an addendum to the Industrial Wastewater Treatment AKART Engineering Report to the Department within two (2) months of the permit effective date for review and approval.

The engineering report shall be consistent with all the requirements of chapter 173-240 WAC. The AKART engineering report shall review all known, available, and reasonable methods of prevention and treatment, shall quantify the expected concentration of pollutants from each identified treatment, and shall detail the cost of each identified option. Fire control foam disposal shall be considered in the analysis. The engineering report shall also include a schedule for project design, construction, and startup.

The Permittee shall then submit a preliminary design report, plans and specifications to the Department for review and approval, as required by chapter 173-240 WAC.

The Permittee shall take all available and reasonable means to implement the AKART determination in the shortest practicable time, but no later than June 30, 2004.

S5. **OPERATION AND MAINTENANCE**

The Permittee shall at all times be responsible for the proper operation and maintenance of any facilities or systems of control installed to achieve compliance with the terms and conditions of the permit.

A. Industrial Wastewater System (IWS) Operations and Maintenance Manual

The existing IWS O&M Manual shall be reviewed by the Permittee at least annually and the Permittee shall confirm this review by letter to the Department. Substantial changes or updates to the O&M Manual shall be submitted to the Department whenever they are incorporated into the Manual.

The O&M Manual shall be kept available at the permitted facility and all operators are responsible for being familiar with and using this manual.

The O&M Manual shall include, but is not limited to, the following:

1. A baseline operating condition which describes the operating parameters and procedures used to meet the effluent limitations of Special Condition S1.
2. In the event of flow rates which are below the baseline levels used to establish these limitations, the plan shall describe the operating procedures and conditions needed to maintain design treatment efficiency. The monitoring and reporting shall be described in the manual.
3. In the event of an upset due to plant maintenance activities, severe stormwater events, cold weather operation (below 35 °F), summer algae blooms, start ups or shut downs, or other causes, the plan shall describe the operating procedures and conditions employed to mitigate the upset. The monitoring and reporting shall be described in the manual.
4. A description of any regularly scheduled maintenance or repair activities at the IWTP which would affect the volume or character of the wastes discharged from the wastewater treatment system and a plan for monitoring and treating/controlling the discharge of maintenance-related materials (such as cleaners, degreasers, solvents, etc.).
5. A description of the regularly scheduled inspection and maintenance program for the IWS conveyance system, including provisions for handling of solids or wastewater removed during maintenance activities.

B. Bypass Procedures

The Permittee shall notify the Department of any spill, overflow, or bypass from any portion of the collection or treatment system immediately at the time the Permittee becomes aware of the spill, overflow, or bypass.

**S5. OPERATION AND MAINTENANCE (CONTINUED)**

The bypass of wastes from any portion of the treatment system to surface water is prohibited unless one of the following conditions (1, 2, or 3) applies:

1. Unavoidable Bypass -- Bypass is unavoidable to prevent loss of life, personal injury, or severe property damage. "Severe property damage" means substantial physical damage to property, damage to the treatment facilities which would cause them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass.

If the resulting bypass from any portion of the treatment system results in noncompliance with this permit, the Permittee shall notify the Department in accordance with Special Condition S3.F "Noncompliance Notification."

2. Anticipated Bypass that has the Potential to Violate Permit Limits or Conditions -- Bypass is authorized by an administrative order issued by the Department. The Permittee shall apply to the Department for the administrative order at least thirty (30) days before the planned date of bypass. The written submission shall contain: (1) a description of the bypass and its cause; (2) an analysis of all known alternatives which would eliminate, reduce, or mitigate the need for bypassing; (3) a cost-effectiveness analysis of alternatives including comparative resource damage assessment; (4) the minimum and maximum duration of bypass under each alternative; (5) a recommendation as to the preferred alternative for conducting the bypass; (6) the projected date of bypass initiation; (7) a statement of compliance with SEPA; (8) a request for a water quality modification, as provided for in WAC 173-201A-110, and (9) steps taken or planned to reduce, eliminate, and prevent reoccurrence of the bypass.

For probable construction bypasses, the need to bypass is to be identified as early in the planning process as possible. The analysis required above shall be considered during preparation of the engineering report or plans and specifications and shall be included to the extent practical. In cases where the probable need to bypass is determined early, continued analysis is necessary up to and including the construction period in an effort to minimize or eliminate the bypass.

The Department will consider the following prior to issuing an administrative order:

- a. If the bypass is necessary to perform construction or maintenance-related activities essential to meet the requirements of the permit.

55. OPERATION AND MAINTENANCE (CONTINUED)

- b. If there are feasible alternatives to bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, stopping production, maintenance during normal periods of equipment down time, or transport of untreated wastes to another treatment facility.
- c. If the bypass is planned and scheduled to minimize adverse effects on the public and the environment.

After consideration of the above and the adverse effects of the proposed bypass and any other relevant factors, the Department will approve or deny the request. The public shall be notified and given an opportunity to comment on bypass incidents of significant duration, to the extent feasible. Approval of a request to bypass will be by administrative order issued by the Department under RCW 90.48.120.

- 3. Bypass for Essential Maintenance Without the Potential to Cause Violation of Permit Limits or Conditions – Bypass is authorized if it is for essential maintenance and does not have the potential to cause violations of limitations or other conditions of the permit, or adversely impact public health as determined by the Department prior to the bypass.

An overflow of untreated industrial wastewater from the Industrial Wastewater System collection system or lagoons due to stormwater flows in excess of the design criteria will not be considered a bypass and will not constitute a violation of this permit if the Department determines that at the time the overflow occurred the Industrial Wastewater Facility was operated in compliance with the approved Operations and Maintenance Manual. The Industrial Wastewater Facility includes the Industrial Wastewater Treatment Plant (IWTP), the Industrial Wastewater System Lagoons, and the equipment used to collect, treat, and dispose of industrial wastewater.

56. SOLID WASTE DISPOSAL

A. Solid Waste Handling

The Permittee shall handle and dispose of all solid waste material in such a manner as to prevent its entry into state ground or surface water.

B. Leachate

The Permittee shall not allow leachate from its solid waste material to enter state waters without providing all known, available, and reasonable methods of prevention and treatment, nor allow such leachate to cause violations of the State Surface Water Quality Standards, Chapter 173-201A WAC, or the State Ground Water Quality Standards, Chapter 173-200 WAC.

**S7. SPILL PLAN**

The Permittee shall submit to the Department an update to the existing Spill Control Plan within twelve (12) months of the effective date of this permit.

The updated spill control plan shall include the following:

- A description of the reporting system which will be used to alert responsible managers and legal authorities in the event of a spill.
- A description of preventive measures and facilities (including an overall facility plot showing drainage patterns) which prevent, contain, or treat spills of these materials.
- A list of all oil, chemicals, and hazardous wastes used, processed, or stored by the Permittee which may be spilled into state waters.

For the purpose of meeting this requirement, plans and manuals required by 40 CFR Part 112 and contingency plans required by Chapter 173-303 WAC may be submitted.

**S8. ACUTE TOXICITY - INDUSTRIAL WASTEWATER**

**A. Effluent Characterization**

The Permittee shall conduct acute toxicity testing on the IWS final effluent to determine the presence and amount of acute (lethal) toxicity. The three acute toxicity tests listed below shall be conducted on each sample taken for effluent characterization.

Effluent characterization for acute toxicity shall be quarterly for one (1) year. Acute-toxicity testing shall follow protocols, monitoring requirements, and quality assurance/quality control procedures specified in this section. A dilution series consisting of a minimum of five concentrations and a control shall be used to estimate the concentration lethal to 50% of the organisms ( $LC_{50}$ ). The percent survival in 100% effluent shall also be reported.

Testing shall begin within sixty (60) days after the startup date of the new IWS Waste Treatment System required in Special Condition S4. A written report shall be submitted to the Department within sixty (60) days after the sample date. A final effluent characterization summary report shall be submitted to the Department within ninety (90) days after the last monitoring test results are final. This summary report shall include a tabulated summary of the individual test results and any information on sources of toxicity, toxicity source control, correlation with effluent data, and toxicity treatability which is developed during the period of testing.

Acute toxicity tests shall be conducted with the following species and protocols:

- 1) Topsmelt or Silverside minnow, *Atherinops affinis* or *Menidia beryllina* (96-hour static-renewal test, method: EPA/600/4-90/027F)

S8. ACUTE TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)

- 2) Mysid shrimp, *Holmesimysis costata* or *Mysidopsis bahia* (48-hour static test, method: EPA/600/4-90/027F).

B. Effluent Limit for Acute Toxicity

The Permittee has an effluent limit for acute toxicity if, after completing one year of effluent characterization, either:

- 1) The median survival of any species in 100% effluent is below 80%, or
- 2) Any one test of any species exhibits less than 65% survival in 100% effluent, and the test meets the Department's criteria for test acceptability and is not considered anomalous by the Department.

If an effluent limit for acute toxicity is required by subsection B at the end of one year of effluent characterization, the Permittee shall immediately complete all applicable requirements in subsections C, D, and F.

If no effluent limit is required by subsection B at the end of one year of effluent characterization, then the Permittee shall complete all applicable requirements in subsections E and F.

**The effluent limit for acute toxicity is no acute toxicity detected in a test concentration representing the acute critical effluent concentration (ACEC).**

The ACEC means the maximum concentration of effluent during critical conditions at the boundary of the zone of acute criteria exceedance assigned pursuant to WAC 173-201A-100. The zone of acute criteria exceedance will be established per Special Condition S1.C of this permit. The ACEC shall be defined by the Department through a major permit modification.

If the Permittee has an effluent limit for acute toxicity and the ACEC is not known, then effluent characterization for acute toxicity shall continue until the time an ACEC is known. Effluent characterization shall be continued until an ACEC has been determined and shall be performed using each one of the tests listed in subsection A on a rotating basis. When an ACEC has been determined, the Permittee shall immediately complete all applicable requirements in subsections C, D, and F.

If no effluent limit is required by subsection B at the end of one year of effluent characterization, then the Permittee shall stop effluent characterization and begin to conduct the activities in subsection E even if the ACEC is unknown.

In the event of failure to pass the test described in subsection C of this section for compliance with the effluent limit for acute toxicity, the Permittee is considered to be in compliance with all permit requirements for acute whole effluent toxicity as long as the requirements in subsection D are being met to the satisfaction of the Department.

S8. ACUTE TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)

C. Monitoring for Compliance With an Effluent Limit for Acute Toxicity

Monitoring to determine compliance with the effluent limit shall be conducted monthly for the remainder of the permit term using each of the species listed in subsection A above on a rotating basis and performed using at a minimum 100% effluent, the ACEC, and a control. The Permittee shall schedule the toxicity tests in the order listed in the permit unless the Department notifies the Permittee in writing of another species rotation schedule. The percent survival in 100% effluent shall be reported for all compliance monitoring.

The Permittee may petition for less frequent testing if both species demonstrate low sensitivity. If one species demonstrates more sensitivity, the Permittee may petition to limit testing to this species and discontinue the rotational testing schedule between species.

Compliance with the effluent limit for acute toxicity means no statistically significant difference in survival between the control and the test concentration representing the ACEC. The Permittee shall immediately implement subsection D if any acute toxicity test conducted for compliance monitoring determines a statistically significant difference in survival between the control and the ACEC using hypothesis testing at the 0.05 level of significance (Appendix H, EPA/600/4-89/001). If the difference in survival between the control and the ACEC is less than 10%, the hypothesis test shall be conducted at the 0.01 level of significance.

D. Response to Noncompliance With an Effluent Limit for Acute Toxicity

If the Permittee violates the acute toxicity limit in subsection B, the Permittee shall begin additional compliance monitoring within one week from the time of receiving the test results. This additional monitoring shall be conducted weekly for four consecutive weeks using the same test and species as the failed compliance test. For intermittent discharges, testing shall be conducted on the next four discharge events using the same test and species as the failed compliance test. Testing shall determine the LC<sub>50</sub> and effluent limit compliance. The discharger shall return to the original monitoring frequency in subsection C after completion of the additional compliance monitoring.

If the Permittee believes that a test indicating noncompliance will be identified by the Department as an anomalous test result, the Permittee may notify the Department that the compliance test result might be anomalous and that the Permittee intends to take only one additional sample for toxicity testing and wait for notification from the Department before completing the additional monitoring required in this subsection. The notification to the Department shall accompany the report of the compliance test result and identify the reason for considering the compliance test result to be anomalous. The Permittee shall complete all of the additional monitoring required in this subsection as soon as possible after

S8. ACUTE TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)

notification by the Department that the compliance test result was not anomalous. If the one additional sample fails to comply with the effluent limit for acute toxicity, then the Permittee shall proceed without delay to complete all of the additional monitoring required in this subsection. The one additional test result shall replace the compliance test result upon determination by the Department that the compliance test result was anomalous.

If all of the additional compliance monitoring conducted in accordance with this subsection complies with the permit limit, the Permittee shall search all pertinent and recent facility records (operating records, monitoring results, inspection records, spill reports, weather records, production records, raw material purchases, pretreatment records, etc.) and submit a report to the Department on possible causes and preventive measures for the transient toxicity event which triggered the additional compliance monitoring.

If toxicity occurs in violation of the acute toxicity limit during the additional compliance monitoring, the Permittee shall submit a Toxicity Identification/Reduction Evaluation (TI/RE) plan to the Department within sixty (60) days after test results are final. The TI/RE plan shall be based on WAC 173-205-100(2) and shall be implemented in accordance with WAC 173-205-100(3).

E. Monitoring When There Is No Permit Limit for Acute Toxicity

If the IWS effluent has been characterized as specified in subsection A and no permit limit for acute toxicity is required, then the Permittee shall test final effluent once in the last summer and once in the last winter prior to submission of the application for permit renewal. All species used in the initial acute effluent characterization or substitutes approved by the Department shall be used and results submitted to the Department as a part of the permit renewal application process. If less than one summer and winter are available between final characterization and the due date of the permit renewal application, the Permittee shall contact the Department for clarification of further effluent WET testing.

F. Sampling and Reporting Requirements

1. All reports for effluent characterization or compliance monitoring shall be submitted in accordance with the most recent version of Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* in regards to format and content. Reports shall contain bench sheets and reference toxicant results for test methods. If the lab provides the toxicity test data on floppy disk for electronic entry into the Department's database, then the Permittee shall send the disk to the Department along with the test report, bench sheets, and reference toxicant results.



**S8. ACUTE TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)**

2. Testing shall be conducted on composite effluent samples. Samples taken for toxicity testing shall be cooled to 4 degrees Celsius while being collected and shall be sent to the lab immediately upon completion. The lab shall begin the toxicity testing as soon as possible but no later than 36 hours after sampling was ended.
3. All samples and test solutions for toxicity testing shall have water quality measurements as specified in Department of Ecology's Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* or most recent version thereof.
4. All toxicity tests shall meet quality assurance criteria and test conditions in the most recent versions of the EPA manual listed in subsection A and the Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*. If test results are determined to be invalid or anomalous by the Department, testing shall be repeated with freshly collected effluent.
5. Control water and dilution water shall be laboratory water meeting the requirements of the EPA manual listed in subsection A or pristine natural water of sufficient quality for good control performance.
6. The whole effluent toxicity tests shall be run on an unmodified sample of final effluent, except modifications required by testing protocol.
7. The Permittee may choose to conduct a full dilution series test during compliance monitoring in order to determine dose response. In this case, the series must have a minimum of five effluent concentrations and a control. The series of concentrations must include the ACEC, if known.
8. All whole effluent toxicity tests, effluent screening tests, and rapid screening tests that involve hypothesis testing and do not comply with the acute statistical power standard of 29% as defined in WAC 173-205-020 must be repeated on a fresh sample with an increased number of replicates to increase the power.

**S9. CHRONIC TOXICITY - INDUSTRIAL WASTEWATER****A. Effluent Characterization**

The Permittee shall conduct chronic toxicity testing on the IWS final-effluent. The three chronic toxicity tests listed below shall be conducted on each sample taken for effluent characterization.

Testing shall begin within sixty (60) days after the startup date of the new IWS Waste Treatment System required in Special Condition S4. A written report shall be submitted to the Department within sixty (60) days after the sample date. A

S9. CHRONIC TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)

final effluent characterization summary report shall be submitted to the Department within ninety (90) days after the last monitoring test results are final. This summary report shall include a tabulated summary of the individual test results and any information on sources of toxicity, toxicity source control, correlation with effluent data, and toxicity treatability which is developed during the period of testing.

Effluent testing for chronic toxicity shall be conducted quarterly for one (1) year or until an acute critical effluent concentration (ACEC) is determined, if that determination takes longer than one year (see S8.C, Effluent Limit for Acute Toxicity, for a definition of the ACEC). The Permittee shall conduct chronic toxicity testing during effluent characterization on a series of at least five concentrations of effluent in order to determine appropriate point estimates. The chronic no observed effects concentration (NOEC) will also be determined for comparison to the ACEC when the ACEC is known. If the ACEC is determined before the one year of characterization is over, the Permittee shall include the ACEC in the concentration series of all subsequent tests and compare the ACEC to the control using hypothesis testing at the 0.05 level of significance as described in Appendix H, EPA/600/4-89/001. If the ACEC is unknown at the end of one year of effluent characterization, the Permittee shall continue the effluent characterization until an ACEC has been determined. Toxicity testing conducted during an effluent characterization extended past one year until an ACEC has been determined shall be performed using each one of the tests listed below on a rotating basis.

Chronic toxicity tests shall be conducted with the following three species and the most recent version of the following protocols:

Saltwater Chronic Toxicity Test Species		Method
Topsmelt or Silverside minnow	<i>Atherinops affinis</i> or <i>Menidia beryllina</i>	EPA/600/R-95/136 or EPA/600/4-91/003
Mysid shrimp	<i>Holmesimysis costata</i> or <i>Mysidopsis bahia</i>	EPA/600/R-95/136 or EPA/600/4-91/003
Pacific oyster or Mussel	<i>Crassostrea gigas</i> or <i>Mytilus sp.</i>	EPA/600/R-95/136

The Permittee shall use the West Coast fish (Topsmelt, *Atherinops affinis*) and Mysid (*Holmesimysis costata*) for toxicity testing unless the lab cannot obtain a sufficient quantity of a West Coast species in good condition in which case the East Coast fish (Silverside minnow, *Menidia beryllina*) or Mysid (*Mysidopsis bahia*) may be substituted.

S9. **CHRONIC TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)**

The Pacific oyster and mussel tests shall be run in accordance with EPA/600/R-95/136 and the bivalve development test conditions in the Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* or most recent version thereof.

B. Effluent Limit for Chronic Toxicity

After completion of effluent characterization, the Permittee has an effluent limit for chronic toxicity if any test conducted for effluent characterization shows a significant difference between the control and the ACEC at the 0.05 level of significance using hypothesis testing (Appendix H, EPA/600/4-89/001) and shall complete all applicable requirements in subsections C, D, and F.

If no significant difference is shown between the ACEC and the control in any of the chronic toxicity tests, the Permittee has no effluent limit for chronic toxicity and only subsections E and F apply.

**The effluent limit for chronic toxicity is no toxicity detected in a test concentration representing the chronic critical effluent concentration (CCEC).**

The CCEC means the maximum concentration of effluent allowable at the boundary of the mixing zone assigned in Special Condition S1.C of this permit. The CCEC shall be defined by the Department upon approval of the Engineering Report required in Special Condition S4.

In the event of failure to pass the test described in subsection C of this section for compliance with the effluent limit for chronic toxicity, the Permittee is considered to be in compliance with all permit requirements for chronic whole effluent toxicity as long as the requirements in subsection D are being met to the satisfaction of the Department.

C. Monitoring for Compliance With an Effluent Limit for Chronic Toxicity

Monitoring to determine compliance with the effluent limit shall be conducted monthly for the remainder of the permit term using each of the species listed in subsection A above on a rotating basis and performed using at a minimum the CCEC, the ACEC, and a control. The Permittee shall schedule the toxicity tests in the order listed in the permit unless the Department notifies the Permittee in writing of another species rotation schedule.

The Permittee may petition for less frequent testing if all species demonstrate low sensitivity. If one species demonstrates more sensitivity, the Permittee may petition to limit testing to this species and discontinue the rotational testing schedule between species.

59. **CHRONIC TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)**

Compliance with the effluent limit for chronic toxicity means no statistically significant difference in response between the control and the test concentration representing the CCEC. The Permittee shall immediately implement subsection D if any chronic toxicity test conducted for compliance monitoring determines a statistically significant difference in response between the control and the CCEC using hypothesis testing at the 0.05 level of significance (Appendix H, EPA/600/4-89/001). If the difference in response between the control and the CCEC is less than 20%, the hypothesis test shall be conducted at the 0.01 level of significance.

In order to establish whether the chronic toxicity limit is eligible for removal from future permits, the Permittee shall also conduct this same hypothesis test (Appendix H, EPA/600/4-89/001) to determine if a statistically significant difference in response exists between the ACEC and the control.

D. Response to Noncompliance With an Effluent Limit for Chronic Toxicity

If a toxicity test conducted for compliance monitoring under subsection C determines a statistically significant difference in response between the CCEC and the control, the Permittee shall begin additional compliance monitoring within one week from the time of receiving the test results. This additional monitoring shall be conducted monthly for three (3) consecutive months using the same test and species as the failed compliance test. Testing shall be conducted using a series of at least five effluent concentrations and a control in order to be able to determine appropriate point estimates. One of these effluent concentrations shall equal the CCEC and be compared statistically to the nontoxic control in order to determine compliance with the effluent limit for chronic toxicity as described in subsection C. The discharger shall return to the original monitoring frequency in subsection C after completion of the additional compliance monitoring.

If the Permittee believes that a test indicating noncompliance will be identified by the Department as an anomalous test result, the Permittee may notify the Department that the compliance test result might be anomalous and that the Permittee intends to take only one additional sample for toxicity testing and wait for notification from the Department before completing the additional monitoring required in this subsection. The notification to the Department shall accompany the report of the compliance test result and identify the reason for considering the compliance test result to be anomalous. The Permittee shall complete all of the additional monitoring required in this subsection as soon as possible after notification by the Department that the compliance test result was not anomalous. If the one additional sample fails to comply with the effluent limit for chronic toxicity, then the Permittee shall proceed without delay to complete all of the additional monitoring required in this subsection. The one additional test result shall replace the compliance test result upon determination by the Department that the compliance test result was anomalous.

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S9. **CHRONIC TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)**

If all of the additional compliance monitoring conducted in accordance with this subsection complies with the permit limit, the Permittee shall search all pertinent and recent facility records (operating records, monitoring results, inspection records, spill reports, weather records, production records, raw material purchases, pretreatment records, etc.) and submit a report to the Department on possible causes and preventive measures for the transient toxicity event which triggered the additional compliance monitoring.

If toxicity occurs in violation of the chronic toxicity limit during the additional compliance monitoring, the Permittee shall submit a Toxicity Identification/Reduction Evaluation (TI/RE) plan to the Department within sixty (60) days after test results are final. The TI/RE plan shall be based on WAC 173-205-100(2) and shall be implemented in accordance with WAC 173-205-100(3).

E. Monitoring When There Is No Permit Limit for Chronic Toxicity

If the IWS effluent has been characterized as specified in subsection A and no permit limit for acute toxicity is required, then the Permittee shall test final effluent once in the last summer and once in the last winter prior to submission of the application for permit renewal. All species used in the initial chronic effluent characterization or substitutes approved by the Department shall be used and results submitted to the Department as a part of the permit renewal application process. If less than one summer and winter are available between final characterization and the due date of the permit renewal application, the Permittee shall contact the Department for clarification of further effluent WET testing.

F. Sampling and Reporting Requirements

1. All reports for effluent characterization or compliance monitoring shall be submitted in accordance with the most recent version of Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* in regards to format and content. Reports shall contain bench sheets and reference toxicant results for test methods. If the lab provides the toxicity test data on floppy disk for electronic entry into the Department's database, then the Permittee shall send the disk to the Department along with the test report, bench sheets, and reference toxicant results.
2. Testing shall be conducted on composite effluent samples. Samples taken for toxicity testing shall be cooled to 4 degrees Celsius while being collected and shall be sent to the lab immediately upon completion. The lab shall begin the toxicity testing as soon as possible but no later than 36 hours after sampling was ended.

S9. CHRONIC TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)

3. All samples and test solutions for toxicity testing shall have water quality measurements as specified in Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* or most recent version thereof.
4. All toxicity tests shall meet quality assurance criteria and test conditions in the most recent versions of the EPA manual listed in subsection A. and the Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*. If test results are determined to be invalid or anomalous by the Department, testing shall be repeated with freshly collected effluent.
5. Control water and dilution water shall be laboratory water meeting the requirements of the EPA manual listed in subsection A or pristine natural water of sufficient quality for good control performance.
6. The whole effluent toxicity tests shall be run on an unmodified sample of final effluent, except modifications required by testing protocol.
7. The Permittee may choose to conduct a full dilution series test during compliance monitoring in order to determine dose response. In this case, the series must have a minimum of five effluent concentrations and a control. The series of concentrations must include the ACEC and the CCEC.
8. All whole effluent toxicity tests, effluent screening tests, and rapid screening tests that involve hypothesis testing and do not comply with the chronic statistical power standard of 39% as defined in WAC 173-205-020 must be repeated on a fresh sample with an increased number of replicates to increase the power.

S10. ACUTE TOXICITY - STORMWATER

A. Effluent Characterization

The Permittee shall conduct acute toxicity testing on stormwater to determine the presence and amount of acute (lethal) toxicity. The two acute toxicity tests listed below shall be conducted on each sample taken for effluent characterization.

Effluent characterization for acute toxicity shall be conducted twice at each of the following outfalls: Outfall 002, 005, 006, and 011. Alternative outfalls with similar drainage basin characteristics may be substituted with Department's approval. Acute toxicity testing shall follow protocols, monitoring requirements, and quality assurance/quality control procedures specified in this section. A dilution series consisting of a minimum of five concentrations and a control shall be used to estimate the concentration lethal to 50% of the organisms (LC<sub>50</sub>). The percent survival in 100% effluent shall also be reported.

S9. CHRONIC TOXICITY - INDUSTRIAL WASTEWATER (CONTINUED)

Testing shall be completed within one (1) year of the permit effective date. A written report shall be submitted to the Department within sixty (60) days after each sample date. A final effluent characterization summary report shall be submitted to the Department within ninety (90) days after the last monitoring test results are final. This summary report shall include a tabulated summary of the individual test results and any information on sources of toxicity, toxicity source control, correlation with effluent data, and toxicity treatability which is developed during the period of testing.

Acute toxicity tests shall be conducted with the following species and protocols:

1. Fathead minnow, *Pimephales promelas* (96-hour static-renewal test, method: EPA/600/4-90/027F)
2. Daphnid, *Ceriodaphnia dubia*, *Daphnia pulex*, or *Daphnia magna* (48-hour static test, method: EPA/600/4-90/027F). The Permittee shall choose one of the three species and use it consistently throughout effluent characterization.

B. Sampling and Reporting Requirements

1. All reports for effluent characterization shall be submitted in accordance with the most recent version of Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* in regards to format and content. Reports shall contain bench sheets and reference toxicant results for test methods. If the lab provides the toxicity test data on floppy disk for electronic entry into the Department's database, then the Permittee shall send the disk to the Department along with the test report, bench sheets, and reference toxicant results.
2. Testing shall be conducted on composite stormwater samples. Composite samples shall be taken over the first one-inch of the storm event or the entire storm event if the total rainfall is less than one inch. Samples taken for toxicity testing shall be cooled to 4 degrees Celsius while being collected and shall be sent to the lab immediately upon completion. The lab shall begin the toxicity testing as soon as possible but no later than 36 hours after sampling was ended.
3. All samples and test solutions for toxicity testing shall have water quality measurements as specified in Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* or most recent version thereof.

S10. ACUTE TOXICITY - STORMWATER (CONTINUED)

4. All toxicity tests shall meet quality assurance criteria and test conditions in the most recent versions of the EPA manual listed in subsection A. and the Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*. If test results are determined to be invalid or anomalous by the Department, testing shall be repeated with freshly collected effluent.
5. Control water and dilution water shall be laboratory water meeting the requirements of the EPA manual listed in subsection A or pristine natural water of sufficient quality for good control performance.
6. The whole effluent toxicity tests shall be run on an unmodified sample of final effluent, except modifications required by testing protocol.
7. All whole effluent toxicity tests, effluent screening tests, and rapid screening tests that involve hypothesis testing and do not comply with the acute statistical power standard of 29% as defined in WAC 173-205-020 must be repeated on a fresh sample with an increased number of replicates to increase the power.

S11. SEDIMENT MONITORING (MARINE)

A. Sediment Sampling and Analysis Plan

The Permittee shall submit to the Department for review and approval a Sediment Sampling and Analysis Plan for sediment monitoring no later than one (1) year after permit effective. The purpose of the plan is to re-characterize sediment quality in the vicinity of Outfall 001. The Permittee shall follow the guidance provided in the Department of Ecology's Sediment Source Control Standards User Manual, Appendix B: Sediment Sampling and Analysis Plan (1995).

The Permittee may either cooperate with the Midway Sewer District to perform this baseline study or conduct its own study.

B. Sediment Data Report

Following Department approval of the Sediment Sampling and Analysis Plan, sediments will be collected and analyzed. The Permittee shall submit to the Department a Sediment Data Report containing the results of the sediment sampling and analysis within three (3) years after permit effective. The Sediment Data Report shall conform with the approved Sampling and Analysis Plan.



**S12. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR AIRPORT OPERATIONS**

The Permittee shall continue to maintain the existing SWPPP in accordance with the relevant and appropriate requirements of this special condition, including, but not limited to, maintaining a Pollution Prevention Team, self-inspections, annual review of the SWPPP, and updates as necessary, employee training, and recordkeeping.

**A. Objectives**

1. To eliminate the discharges of unpermitted industrial wastewater, domestic wastewater, non-contact cooling water, or other illicit discharges to the storm drainage system;
2. To implement and maintain Best Management Practices (BMPs) to identify, reduce, eliminate, and/or prevent the discharge of stormwater pollutants;
3. To prevent violations of water quality, ground water quality, or sediment management standards; and
4. To prevent adverse water quality impacts on beneficial uses of the receiving water by controlling peak rates and volumes of stormwater runoff at the Permittee's outfalls and downstream of the outfalls.

**B. General Requirements**

**1. Submission and Retention**

The Permittee shall submit an updated SWPPP to the Department for review and comment at least twice during the term of this permit. An updated SWPPP shall be submitted no later than November 30, 1998, and again with the application for permit renewal required in General Condition G7. The Permittee shall include an evaluation of whether measures to reduce pollutant loadings identified in the SWPPP are adequate and properly implemented in accordance with the terms of the permit or whether additional controls are needed. The evaluation shall specifically include, but is not limited to, fecal coliform, copper, lead, and zinc. The updated SWPPP shall include a summary of the results of the inspections required in subsection C, any incidents of noncompliance, and a certification, in accordance with General Condition G1, that the facility is in compliance with the plan.

The Permittee shall also submit that portion of the SWPPP which addresses the discharge to the City of SeaTac stormwater system to the City of SeaTac if it is modified.

The SWPPP shall be retained on-site or within reasonable access to the site.

**S12. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR AIRPORT OPERATIONS (CONTINUED)**

2. Modifications
  - a. The Permittee shall modify the SWPPP whenever there is an alteration of airfield facilities or their operation or maintenance which causes the SWPPP to be less effective in controlling pollutants.
  - b. Whenever a self-inspection reveals that the description of potential pollutant sources or the pollution prevention measures and controls identified in the SWPPP are inadequate, due to the discharge of, or the potential to discharge, a significant amount of pollutant, the SWPPP shall be modified, as appropriate, within two (2) weeks of such inspection for noncapital BMPs, and within six (6) months of such inspection for capital BMPs. The proposed capital modifications shall be submitted to the Department at least thirty (30) days in advance of implementing the proposed changes in the plan unless the Department approves immediate implementation. The Permittee shall provide for implementation of any modifications to the SWPPP in a timely manner.
3. The Permittee may incorporate applicable portions of plans prepared for other purposes. Plans or portions of plans incorporated into a SWPPP become enforceable requirements of this permit. If other plans are referenced in the SWPPP, they must be made available per the requirements of Special Condition S3.G.
4. The Permittee shall prepare the SWPPP in accordance with the guidance provided in the *Stormwater Pollution Prevention Planning for Industrial Facilities*. The plan shall contain the following elements:
  - a. Assessment and description of existing and potential pollutant sources,
  - b. A description of selected operational BMPs,
  - c. A description of selected source-control BMPs,
  - d. A description of selected erosion and sediment control BMPs,
  - e. A description of selected treatment BMPs, and
  - f. An implementation schedule.
5. Applicability of Current and Future Editions of the Stormwater Management Manual for the Puget Sound Basin (SWMM):

**S12. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR AIRPORT OPERATIONS (CONTINUED)**

BMPs shall be selected from the most recent published edition of the SWMM, or other manuals determined to be equivalent by the Department, available at least one hundred twenty (120) days before the selection of the BMPs. The Permittee may develop site-specific BMPs that are appropriate for airport industrial activities with approval of the Department.

**C. Implementation**

The Permittee shall conduct at least four inspections per year: three during the wet season (October 1 - June 30) and one during the dry season (July 1 - September 30).

1. The wet season inspections shall be conducted during a rainfall event by personnel named in the Stormwater Pollution Prevention Plan (SWPPP) to verify that the description of potential pollutant sources required under this permit is accurate; the site map as required in the SWPPP has been updated or otherwise modified to reflect current conditions; and the controls to reduce pollutants in stormwater discharges associated with industrial activity identified in the SWPPP are being implemented and are adequate. The wet-weather inspections shall include observations of the presence of floating materials, suspended solids, oil and grease, discolorations, turbidity, odor, etc., in the stormwater discharges.
2. The dry season inspection shall be conducted by personnel named in the SWPPP. The dry season inspection shall determine the presence of unpermitted non-stormwater discharges such as domestic wastewater, non-contact cooling water, or industrial wastewater to the stormwater drainage system. If an unpermitted, non-stormwater discharge is discovered, the Permittee shall immediately notify the Department.

**S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR CONSTRUCTION ACTIVITIES**

A SWPPP for construction activity, including construction dewatering, shall be prepared and implemented prior to the commencement of any construction activity which disturbs five (5) or more acres of total land area (or other minimum land area to be determined by federal regulation). Construction activities included in this requirement include clearing, grading, filling, and excavation activities except operations that result in the disturbance of less than five acres of total land area which are not part of a larger common plan of development or sale. For construction projects that discharge solely to ground water, the SWPPP for construction activities shall be protective of ground water quality. With approval of the Department, a SWPPP shall not be required for construction projects that discharge to the IWS.

**S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR CONSTRUCTION ACTIVITIES (CONTINUED)**

**A. Objectives**

1. To implement Best Management Practices (BMPs) to minimize erosion and sediments from rainfall runoff at construction sites, and to identify, reduce, eliminate, or prevent the pollution of stormwater.
2. To prevent violations of surface water quality, ground water quality, or sediment management standards.
3. To prevent, during the construction phase, adverse water quality impacts including impacts on beneficial uses of the receiving water by controlling peak rates and volumes of stormwater runoff at the Permittee's outfalls and downstream of the outfalls.
4. To eliminate the discharges of unpermitted process wastewater, domestic wastewater, illicit discharges, and non-contact cooling water to stormwater drainage systems and surface waters of the state.

**B. General Requirements**

1. The Permittee shall be responsible for the implementation of a SWPPP. The Erosion and Sediment Control Plan shall be attached to bid packages when seeking contractors to allow the contractor sufficient time to plan implementation. At construction sites for which a lease, easement, or other use agreement has been obtained from the Permittee, the Permittee shall be responsible for the implementation of a SWPPP.
2. The Permittee shall implement procedures for reviewing the SWPPP with contractors and subcontractors prior to initiating construction activities. The Permittee shall implement procedures for addressing changes in plans and construction activities and resolving disagreements on the interpretation of the SWPPP.
3. The Permittee shall designate a contact person who will be available 24 hours a day to respond to emergencies, and to inquiries or directives from the Department. The contact person shall have authority over the SWPPP implementation. For construction of projects identified in the Proposed Master Plan Update, the Permittee shall establish and fund an independent qualified construction pollution control officer to advise on and determine compliance with applicable water quality standards. These names shall be listed in the SWPPP.
4. The Permittee shall retain the SWPPP on-site or within reasonable access to the site and make it available per the requirements of Special Condition S3.G.

**S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR  
CONSTRUCTION ACTIVITIES (CONTINUED)**

5. The Permittee shall retain the SWPPP and copies of inspection reports and all other reports required by this permit for at least three (3) years after the date of final stabilization of the construction site. The Permittee shall make these documents available per the requirements of Special Condition S3.G.
6. Reports on incidents, such as discharge of spills and other noncompliance notification, shall be included in the records.
7. **Modifications**
  - a. The Department may notify the Permittee when the SWPPP does not meet one or more of the requirements of this special condition. Upon notification by the Department, the Permittee shall take appropriate action(s) to come into compliance with this special condition.
  - b. The Department may require SWPPP and BMP modifications if compliance with State of Washington Surface Water Quality Standards (chapter 173-201A WAC), Sediment Management Standards (chapter 173-204 WAC), Ground Water Quality Standards (chapter 173-200 WAC), and human health based criteria in the National Toxics Rule (Federal Register, Vol. 57, No. 246, Dec. 22, 1992, pages 60848-60923) is not being achieved.
  - c. The Permittee shall modify the SWPPP whenever there is a change in design, construction, operation, or maintenance of any BMP which cause(s) the SWPPP to be less effective in controlling the pollutants.
  - d. Whenever a self-inspection reveals that the description of pollutant sources or the BMPs identified in the SWPPP are inadequate, due to the actual discharge of or potential to discharge a significant amount of any pollutant, the SWPPP shall be modified, as appropriate. The Permittee shall provide for implementation of any modifications to the SWPPP in a timely manner.
8. BMPs shall be selected from the most recent published edition of the Stormwater Management Manual for the Puget Sound Basin (SWMM), that has been available for at least one hundred twenty (120) days prior to BMP selection, or other equivalent manuals available at the time of BMP selection or when the selection of additional BMPs is necessary.

**S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR  
CONSTRUCTION ACTIVITIES (CONTINUED)**

a. **Stabilization Practices**

The Erosion and Sediment Control Plan shall include a description of stabilization BMPs, including site-specific scheduling of the implementation of the practices. Stabilization practices may include: temporary seeding, permanent seeding, mulching, geotextiles, sod stabilization, vegetative buffer strips, protection of trees, preservation of mature vegetation, commercially available soil stabilization products, and other appropriate measures. A record of the dates when major grading activities occur, when construction activities temporarily or permanently cease on a portion of the site, and when stabilization measures are initiated shall be included in the plan. Stabilization measures shall be initiated as soon as practicable in portions of the site where construction activities have temporarily or permanently ceased.

The plan shall ensure that the following requirements are satisfied:

- i) All exposed and unworked soils shall be stabilized by suitable and timely application of BMPs.
- ii) Existing vegetation should be preserved where attainable. Areas which are not to be disturbed, including setbacks, sensitive/critical areas and their buffers, trees and drainage courses, shall be marked or flagged on site before construction activities are initiated. These areas should not be harmed when measures under the SWPPP and/or construction activities are undertaken.
- iii) Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Slopes shall be stabilized in accordance with the requirements of this subsection.
- iv) Stabilization adequate to prevent erosion of outlets and adjacent stream banks shall be provided at the outlets of all conveyance systems.
- v) All storm drain inlets made operable during construction shall be properly maintained.
- vi) Wherever construction vehicle access routes intersect paved roads, provisions must be made to minimize the transport of sediment (mud) onto the paved road. If sediment is transported onto a road surface, the roads adjacent to the construction site shall be cleaned on a regular basis. Street washing shall be allowed only after other methods to prevent the transport or removal of the sediments are unsuccessful.

**S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR CONSTRUCTION ACTIVITIES (CONTINUED)**

**b. Structural Practices**

In addition to stabilization practices, the Erosion and Sediment Control Plan shall include a description of structural BMPs to divert flows from exposed soils, store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site to the degree attainable. Such practices may include silt fences, earth dikes, drainage swales, sediment traps, check dams, sub-surface drains, pipe slope drains, level spreaders, storm drain inlet protection, rock outlet protection, reinforced soil retaining systems, gabions, and sediment basins. Structural practices should be placed on upland soils to the degree attainable. The installation of these devices may be subject to Section 404 of the Federal Clean Water Act. The plan shall ensure that the following requirements are satisfied:

- i) Prior to leaving the site, stormwater runoff shall pass through a sediment pond or sediment trap, or other appropriate BMPs.
- ii) Properties adjacent to the project site shall be protected from sediment deposition.
- iii) Sediment ponds and traps, perimeter dikes, sediment barriers, and other BMPs intended to trap sediment on-site shall be constructed as a first step in grading. These BMPs shall be functional before land disturbing activities take place. Earthen structures used for sediment control such as dams, dikes, and diversions shall be stabilized as soon as possible.
- iv) Properties and waterways downstream from the construction site shall be protected from erosion due to increases in volume, velocity, and peak flow of stormwater runoff from the project site.
- v) All temporary erosion and sediment control BMPs shall be removed within thirty (30) days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on-site. Disturbed soil areas resulting from removal shall be permanently stabilized.

S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR  
CONSTRUCTION ACTIVITIES (CONTINUED)

c. Inspection and Maintenance

All BMPs shall be inspected, maintained, and repaired as needed to assure continued performance of their intended function. All on-site erosion and sediment control measures shall be inspected at least once every seven days and within 24 hours after any storm event of greater than 0.5 inches of rain per 24 hour period.

d. Recordkeeping

Reports summarizing the scope of inspections, the personnel conducting the inspection, the date(s) of the inspection, major observations relating to the implementation of the SWPPP, and actions taken as a result of these inspections shall be prepared and retained as part of the SWPPP.

e. Format

The Erosion and Sediment Control Plan shall consist of two parts: a narrative and a set of site plans. The Permittee may refer to Chapter II-4 of the Department's SWMM for guidance on the content and format.

2. Control of Pollutants Other Than Sediment on Construction Sites

All pollutants other than sediment that occur on-site during construction shall be handled and disposed of in a manner that does not cause contamination of stormwater. Chapter II-3 of the SWMM can be referenced for guidance in controlling other potential pollutants.

3. Coordination with Local Requirements

This permit does not relieve the Permittee of compliance with any more stringent requirements of local government.

Also, as required by the Puget Sound Water Quality Management Plan, local governments within the Puget Sound Basin are to adopt requirements for construction which are at least equivalent to the requirements listed in Chapter I-2 of the Department's SWMM. Where the Department has determined such requirements to be equivalent, compliance with these requirements meets the SWMM requirements of this permit.



**S13. STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR CONSTRUCTION ACTIVITIES (CONTINUED)**

**4. Construction Stormwater/Dewatering Monitoring**

A monitoring plan for stormwater and construction dewatering discharges shall be submitted to the Department for review and approval at least thirty (30) days prior to the start of construction. The plan shall be deemed approved if Ecology does not respond to the plan at least five (5) days prior to the scheduled date of construction.

**5. ~~SWPPP Contents for Discharges of Construction Stormwater to Gilliam Creek and tributaries and Walker Creek and tributaries~~**

~~a. The SWPPP shall at a minimum incorporate Special Condition S2.C.2.~~

~~b. Stormwater Detention - Unless otherwise authorized in writing by Ecology, any new diversion ditch or channel, pond, trap, impoundment or other detention or retention BMP constructed at the site for treatment of construction stormwater shall be designed, constructed, and maintained to contain and provide treatment for the peak flow for the 10-year, 24-hour precipitation event estimated from data published by the National Oceanic and Atmospheric Administration.~~

~~c. Vehicle Trackout - Vehicles shall be cleaned of mud, rock, and other material before entering a paved public highway to prevent visible tire tracks.~~

**S14. STORMWATER DRAINAGE DETENTION**

All construction actions taken by the Permittee shall provide sufficient detention and/or shall use existing available detention capacity, in accordance with the Stormwater Management Manual for the Puget Sound Basin or its approved equivalent, to prevent an increase in the peak flow rate or flooding frequency of Miller Creek and Des Moines Creek. All detention facilities owned and/or operated by the Permittee shall be inspected, maintained, and repaired as needed to assure continued performance of their intended function.

The Permittee shall submit to the Department within three (3) months of the effective date of this permit an Operations and Maintenance Plan for the Lake Reba Detention Facility.

**S15. IWS HYDROGEOLOGIC STUDY**

The Permittee shall perform a hydrogeologic study in the vicinity of the Industrial Waste Treatment Plant and Lagoons to evaluate the potential for the Industrial Wastewater Facility operations to impact ground water quality. The IWS Hydrogeologic Study shall include an assessment of the current condition of the hydrogeologic environment in the vicinity of the Industrial Waste System Treatment plant and lagoons. The IWS Hydrogeologic Study shall comply with the requirements contained in WAC 173-200 and make appropriate reference to the Implementation Guidance for the Ground Water Quality Standards (Ecology Publication # 96-02).

**S15. IWS HYDROGEOLOGIC STUDY (CONTINUED)**

The Permittee shall submit a scope of work for the IWS Hydrogeologic Study to the Department for review and approval within six (6) months of the effective date of this permit. A report of the study results shall be submitted to the Department no later than twenty-one (21) months from Ecology's approval of the scope of work, but in no event later than September 1, 2001. This condition is not applicable to any cleanup of residual contamination due to releases of industrial wastewater or contaminants, which are regulated under the MTCA and are not regulated under this permit. Ongoing discharges of industrial wastewater or contaminants are regulated under this permit.

**S16. SANITARY SEWER PROHIBITED DISCHARGES**

**A. General Prohibitions**

The Permittee shall not introduce into the POTW pollutant(s) which cause pass through or interference.

**B. Specific Prohibitions**

In addition, the following shall not be introduced into the POTW:

1. Pollutants which create a fire or explosion hazard in the POTW, including, but not limited to, waste streams with a closed cup flashpoint of less than 60° C (140° F) using the test methods specified in 40 CFR 261.21;
2. Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW resulting in interference;
3. Any pollutant, including oxygen-demanding pollutants (BOD, etc.), released in a discharge at a flow rate and/or pollutant concentration which will cause interference with the POTW;
4. Heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature at the POTW treatment plant exceeds 40° C (104° F) unless the approval authority, upon request of the POTW, approves alternative temperature limits;
5. Petroleum oil, non-biodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;
6. Pollutants which result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute worker health and safety problems;
7. Any trucked or hauled pollutants, except at discharge points designated by the POTW;

S16. SANITARY SEWER PROHIBITED DISCHARGES (CONTINUED)

8. Pollutants which will cause corrosive structural damage to the POTW, but in no case discharges with pH lower than 5.0 or greater than 12.0, unless the works is specifically designed to accommodate such discharges.

C. Prohibited Unless Approved

1. Any of the following discharges are prohibited unless approved by the Department under extraordinary circumstances (such as a lack of direct discharge alternatives due to combined sewer service or a need to augment sewage flows due to septic conditions):
  - a. Non-contact cooling water in significant volumes.
  - b. Stormwater and other direct inflow sources.
  - c. Wastewaters significantly affecting system hydraulic loading, which do not require treatment or would not be afforded a significant degree of treatment by the system.
2. Unless specifically authorized in this permit, the discharge of dangerous wastes as defined in Chapter 173-303 WAC, is prohibited.

## GENERAL CONDITIONS

### G1. SIGNATORY REQUIREMENTS

All applications, reports, or information submitted to the Department shall be signed and certified.

- A. All permit applications shall be signed by either a principal executive officer of at least the level of vice president of a corporation, a general partner of a partnership, or the proprietor of a sole proprietorship.
- B. All reports required by this permit and other information requested by the Department shall be signed by a person described above or by a duly authorized representative of that person. A person is a duly authorized representative only if:
  1. The authorization is made in writing by a person described above and submitted to the Department, and
  2. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility, such as the position of plant manager, superintendent, position of equivalent responsibility, or an individual or position having overall responsibility for environmental matters. (A duly authorized representative may thus be either a named individual or any individual occupying a named position.)
- C. Changes to authorization. If an authorization under paragraph B.2. above is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of B.2. must be submitted to the Department prior to or together with any reports, information, or applications to be signed by an authorized representative.
- D. Certification. Any person signing a document under this section shall make the following certification:

*"I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."*

**G2. RIGHTS OF ENTRY**

The permittee shall allow an authorized representative of the Department, upon the presentation of credentials and such other documents as may be required by law:

- A. To enter upon the premises where a discharge is located or where any records must be kept under the terms and conditions of this permit;
- B. To have access to and copy at reasonable times any records that must be kept under the terms of the permit;
- C. To inspect at reasonable times any monitoring equipment or method of monitoring required in the permit;
- D. To inspect at reasonable times any collection, treatment, pollution management, or discharge facilities; and
- E. To sample at reasonable times any discharge of pollutants.

**G3. PERMIT ACTIONS**

This permit shall be subject to modification, suspension, or termination, in whole or in part by the Department for any of the following causes:

- A. Violation of any permit term or condition;
- B. Obtaining a permit by misrepresentation or failure to disclose all relevant facts;
- C. A material change in quantity or type of waste disposal;
- D. A material change in the condition of the waters of the state; or
- E. Nonpayment of fees assessed pursuant to RCW 90.48.465.

The Department may also modify this permit, including the schedule of compliance or conditions, if it determines good and valid cause exists, including promulgation or revision of regulations or new information.

**G4. INITIATING A CAUSE FOR MODIFICATION**

The permittee shall submit a new application, or a supplement to the previous application, along with required engineering plans and reports, whenever a material change in the quantity or type of discharge is anticipated which is not specifically provided for by this permit. This application shall be submitted at least sixty (60) days before any proposed changes. Submission of this application does not relieve the permittee of the duty to comply with the existing permit until it is modified or reissued.

**G5. PLAN REVIEW REQUIRED**

Prior to constructing or modifying any wastewater control facilities, an engineering report and detailed plans and specifications shall be submitted to the Department for approval in accordance with Chapter 173-240 WAC. Engineering reports, plans, and specifications should be submitted at least one hundred and eighty (180) days prior to the planned start of construction. Facilities shall be constructed and operated in accordance with the approved plans.

**G6. COMPLIANCE WITH OTHER LAWS AND STATUTES**

Nothing in the permit shall be construed as excusing the Permittee from compliance with any applicable federal, state, or local statutes, ordinances, or regulations.

**G7. DUTY TO REAPPLY**

The Permittee must apply for permit renewal at least 180 days prior to the specified expiration date of this permit.

**G8. PERMIT TRANSFER**

This permit is automatically transferred to a new owner or operator if:

- A. A written agreement between the old and new owner or operator containing a specific date for transfer of permit responsibility, coverage, and liability is submitted to the Department;
- B. A copy of the permit is provided to the new owner; and
- C. The Department does not notify the Permittee of the need to modify the permit.

Unless this permit is automatically transferred according to section A. above, this permit may be transferred only if it is modified to identify the new Permittee and to incorporate such other requirements as determined necessary by the Department.

**G9. REDUCED PRODUCTION FOR COMPLIANCE**

The Permittee, in order to maintain compliance with its permit, shall control production and/or all discharges upon reduction, loss, failure, or bypass of the treatment facility until the facility is restored or an alternative method of treatment is provided. This requirement applies in the situation where, among other things, the primary source of power of the treatment facility is reduced, lost, or fails.

**G10. REMOVED SUBSTANCES**

Collected screenings, grit, solids, sludges, filter backwash, or other pollutants removed in the course of treatment or control of wastewaters shall not be resuspended or reintroduced to the final effluent stream for discharge to state waters.

**G11. TOXIC POLLUTANTS**

If any applicable toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under Section 307(a) of the Clean Water Act for a toxic pollutant and that standard or prohibition is more stringent than any limitation upon such pollutant in the permit, the Department shall institute proceedings to modify or revoke and reissue the permit to conform to the new toxic effluent standard or prohibition.

**G12. OTHER REQUIREMENTS OF 40 CFR**

All other requirements of 40 CFR 122.41 and 122.42 are incorporated in this permit by reference.

**G13. ADDITIONAL MONITORING**

The Department may establish specific monitoring requirements in addition to those contained in this permit by administrative order or permit modification.

**G14. PAYMENT OF FEES**

The Permittee shall submit payment of fees associated with this permit as assessed by the Department. The Department may revoke this permit if the permit fees established under Chapter 173-224 WAC are not paid.

**G15. PENALTIES FOR VIOLATING PERMIT CONDITIONS**

Any person who is found guilty of willfully violating the terms and conditions of this permit shall be deemed guilty of a crime, and upon conviction thereof shall be punished by a fine of up to ten thousand dollars and costs of prosecution, or by imprisonment in the discretion of the court. Each day upon which a willful violation occurs may be deemed a separate and additional violation.

Any person who violates the terms and conditions of a waste discharge permit shall incur, in addition to any other penalty as provided by law, a civil penalty in the amount of up to ten thousand dollars for every such violation. Each and every such violation shall be a separate and distinct offense, and in case of a continuing violation, every day's continuance shall be and be deemed to be a separate and distinct violation.

PORT OF SEATTLE, SEATTLE-TACOMA INTERNATIONAL AIRPORT  
NPDES PERMIT NUMBER WA-002465-1  
ADDENDUM TO FACT SHEET  
MAJOR MODIFICATION  
MAY 29, 2001

This is an addendum to the fact sheet accompanying NPDES Permit No. WA-002465-1 issued to the Port of Seattle for the discharge of treated industrial wastewater and stormwater from Seattle-Tacoma International Airport to waters of the State of Washington.

**MODIFICATIONS IN RESPONSE TO REQUEST FROM THE PORT OF SEATTLE**

On October 20, 2000, the Port of Seattle submitted to the Department of Ecology a request for a major permit modification to NPDES Permit No. WA-002465-1 (Port of Seattle, Seattle-Tacoma International Airport). The Port of Seattle requested the permit modification to extend permit coverage to stormwater and uncontaminated construction dewatering discharges associated with construction projects at Seattle-Tacoma International Airport and the Third Runway and Master Plan Update projects. The modified permit will authorize discharges from construction activities to Walker Creek and its tributaries, Gilliam Creek and its tributaries, Des Moines Creek, the City of SeaTac storm sewer, the IWS and Miller Creek .

The Department modified the NPDES Permit No. WA-002465-1 as follows and as a response to public comment.

**NPDES Permit**

**Page 1, Receiving Water**

The listing of receiving water has been modified to include new water bodies (vi), (vii):

- (i) Puget Sound (Industrial Wastewater)
- (ii) Des Moines Creek, (Stormwater).
- (iii) Miller Creek (Stormwater)
- (iv) City of SeaTac Storm Sewer, tributary to Gilliam Creek and the Green River (Stormwater).
- (v) Midway Sewer District Sanitary Sewer, (Miscellaneous Blowdown)
- (vi) Walker Creek and tributaries (Construction Stormwater)
- (vii) Gilliam Creek and tributaries (Construction Stormwater)



**H**

**AR 011903**

## Watershed Determinants of Ecosystem Functioning

Richard R. Horner<sup>1,2</sup>, M. ASCE; Derek B. Booth<sup>2</sup>; Amanda Azous<sup>3</sup>; and Christopher W. May<sup>2</sup>

### Abstract

By the mid-1980s it was clear that urban stormwater runoff was strongly implicated in the alteration of streams and freshwater wetlands in the Puget Sound Basin of Washington state to ecosystems lower in biological diversity and productivity of the species most valued by society. It was also apparent that the causes of these modifications were rooted in watershed hydrology and sediment transport as well as reduced water quality. Recognition of these connections and the rapid pace of development in the region stimulated research to define the linkages among stream and wetland habitat structure, conditions in the surrounding landscapes, and the associated biological responses. One project monitored watershed and riparian zone conditions, flow, physical habitat characteristics, water quality, benthic macroinvertebrates, and fish in 31 reaches on 19 low-order streams, representing a gradient of urbanization, over a three-year period. A second project followed 19 palustrine wetlands during an eight-year period when urbanization began or increased in the watersheds of about half, while the remainder were essentially unchanged. Overall, the findings of these projects agree that the effects of modified hydrology accompanying urbanization exert the earliest and, at least initially, the strongest deleterious influences on the freshwater ecosystems studied. Furthermore, the results agree that the steepest rates of decline in biological functioning of both streams and wetlands, and the conditions necessary to support that functioning, occur as urbanization increases total impervious land cover from 0 to about 6 percent, unless mitigated by extensive riparian protection, management efforts, or both. Thereafter, the decline proceeds at a slower rate as impervious cover increases further. Functioning at the highest level (e. g., stream benthic index of biotic integrity, B-IBI, > 35) with very low imperviousness drops by roughly half

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In analyses of aquatic ecosystem impacts, watershed urbanization has been expressed most commonly in terms of the proportion of watershed area covered by impervious surface. Some past work has identified impervious cover of 10 +/- several percent as the level at which stream ecosystem impairment becomes evident. For example, Klein (1979) used a variety of hydrologic, water quality, biological information to conclude that serious stream quality impairment can be prevented if watershed imperviousness does not exceed 15 percent, or 10 percent for more sensitive ecosystems with self-sustaining trout populations. Booth and Reinelt (1993) found a very similar relationship for Puget Sound Basin lowland streams. Shaver et al. (1995) found decline in macroinvertebrate community indices in Delaware creeks with 8 percent watershed imperviousness and substantially more decrease above 15 percent. They demonstrated that the impact was linked more to physical habitat than water quality degradation.

#### Toward a Systematic Approach to Managing Watershed and Aquatic Ecosystem Change

With recognition of the web tying together landscapes and aquatic habitats and their inhabitants has come an interest in defining the functional relationships between discharges from watersheds and aquatic resources well enough to avoid or minimize resource losses through management intervention. In this scenario there would be reasonable confidence that a goal to maintain a given organism or community at a specified level could be met by sustaining a certain set of habitat measures, which in turn depend on established values of particular watershed measures. To realize the promise of this approach, of course, it will be necessary to set well conceived goals that set the direction and parameters of the entire management thrust.

Needed for progress in systematically managing watersheds and their aquatic resources are meaningful and convenient measures of watershed conditions, biological "health," and the habitat conditions on which biota depend. Moreover, these measures must be suitable for defining the linkages among these ecosystem components. For expressing watershed conditions, the traditional use of impervious cover must be supplemented by measures that express other facets of the landscape (e. g., riparian zone and drainage system characteristics). Perhaps most critical to progress in describing habitat structure is to identify on an ecoregional scale the variables with the most utility for assessing habitat relationships with watershed circumstances on the one hand and biological responses on the other. The work reported here makes an attempt to advance the measurement and interpretation of both watershed and habitat conditions.

The last 15 years have seen substantial progress in expressing biological community attributes in useful forms for comprehensive watershed studies. Major developments include the index of biotic integrity (IBI; Karr 1981; Karr and Dudley 1981; Karr et al. 1986; Karr 1991; Kerans and Karr 1994; Fore et al. in review) the

## Experimental Designs

### Stream Research

The design of the stream study was to establish attributes of the watersheds contributing to selected stream reaches and then to make a number of measurements of the riparian, habitat, and biological conditions within those reaches. The concept underlying the study, simply illustrated as follows, was that watershed and riparian characteristics determine habitat conditions, which, in relation to evolved organism preferences and tolerances, set the composition of the biological communities:

Watershed and riparian characteristics = Habitat conditions = Biota

Data analysis was directed at establishing the linkages represented by the arrows, as well as the less direct connections between watershed characteristics and biota.

Researchers and governmental participants in the research selected streams and study reaches from over 100 candidates that best met 15 criteria expressing such factors as representativeness of Puget Sound lowland stream conditions and resources, ability to cover a range of watershed urbanization from near zero to more than 50 percent imperviousness, and data availability. All study reaches are of the same general scale, being of first, second, or third order. They have mean annual discharges in the approximate range 0.1-1.7 m<sup>3</sup>/s (3.5-60 ft<sup>3</sup>/second); lie at altitudes of less than 150 meters above sea level; and have average stream gradients under 5 percent.

Site selection emphasized contributing catchments in the early stages of urbanization, when it was hypothesized that the most rapid change in ecological conditions occurs, or with very little to no urbanization. These latter catchments represent what is considered to be the maximum attainable ecological function in Puget Sound lowland streams. Until recently, these "reference" sites have experienced relatively little human activity after being logged approximately 100 years ago. Watersheds contributing to the 31 study reaches monitored since 1994 exhibit the following distributions of TIA: 0-5%--8 sites, 5-10%--7 sites, 10-20%--3 sites, 20-30%--3 sites, 30-50% 6 sites, and > 50%--4 sites.

The study watersheds cover two distinctly different geologic conditions. All but two are underlain by glacial till, in which continental glaciation (15,000 years b. p.) deposited a dense hardpan, now approximately 1 meter beneath the surface and overlain by a loamy soil. The other watersheds are underlain by glacial outwash, with surface coarse material providing direct hydraulic communication between the surface and the regional aquifer. In the undisturbed forested condition glacial till catchments are capable of providing precipitation storage on the order of 15 cm in the overlying soil, and the outwash areas much more (Wigmosta et al. 1994).

Research Results and InterpretationsStream ResearchStream Biology in Relation to Watershed and Riparian Characteristics

This discussion considers observed linkages between the source and response components of the system, letting aside for the moment the intermediate habitat component:

Watershed and riparian characteristics      =      Habitat conditions      =      Biota

Throughout this paper watershed condition is characterized by impervious cover. Analyses demonstrated that the relationships discussed are very similar if watershed condition is alternatively expressed by road density (km/km<sup>2</sup> of watershed area, May 1996).

The ecological condition and functioning of the benthic macroinvertebrate community was expressed in terms of a Benthic Index of Biotic Integrity (B-IBI), which accounts for the relative presence in the respective reaches of certain taxa and trophic groups with varying tolerances to stress (Kleindl 1995). Figure 1 portrays the relationship between B-IBI values computed in 1994 and 1995 and urbanization level, expressed by total impervious area as a percentage of the total watershed (% TIA). Only reaches with TIA < 3.9 percent exhibited an index of 35 or greater. All B-IBI values of at least 25 were associated with watersheds having no more than 11 percent impervious, with eight notable exceptions. These eight points (B-IBI = 25-31) were computed for reaches on two streams having contributing catchments with 25-34 percent TIA. Despite the moderately high level of urbanization in these cases, these streams have more of their riparian areas in intact wetlands (17.2-21.5 percent) than all but one of the 19 streams and have overall wider riparian zones (~ 60 percent > 30 meters wide) than most cases of similar urbanization level. These observations give an indication that maintenance of the adjacent stream buffer zone may help ameliorate the effects of more distant urbanization.

Setting aside these eight points, the general shape of the curve in Figure 1 indicates a relatively rapid rate of decline in biological function as impervious area increase to about 8 percent, following which the rate of decline appears to slow as urbanization increases further. It appears from these data to be probable that Puget Sound lowland streams would have a B-IBI of 15 or less with more than 45 percent imperviousness.

Among the salmonid fish, the research concentrated on the coho salmon (*Oncorhynchus kisutch*), the species arguably most vulnerable to urban runoff

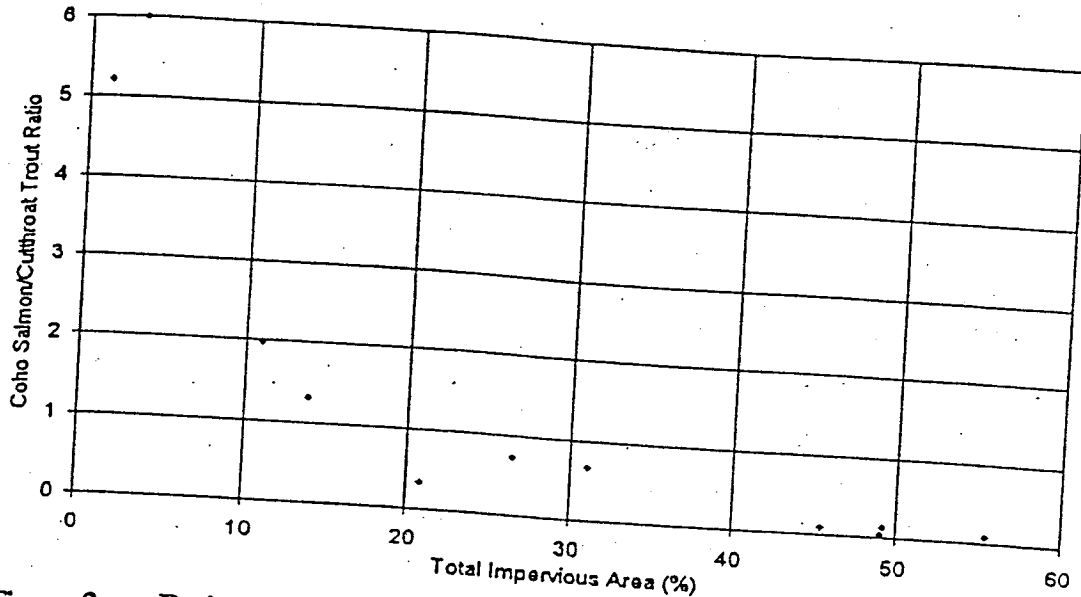


Figure 2. — Ratio of Coho Salmon to Cutthroat Trout in Puget Sound Lowland Streams Over a Gradient of Watershed Impervious Land Cover

Water quality was examined in wet and dry season base flow and during runoff from small (0.6-1.2 cm precipitation), medium (1.2-1.8 cm), and large (> 1.8 cm) rain storms. Figure 3 illustrates a representative result, showing total zinc concentrations versus TIA for all three storm sizes. Also shown are acute and chronic criteria for protection of aquatic life for the hardness prevailing in these streams. The concentration was well below both criteria under all conditions until TIA rose above 40 percent. The gaps between measured concentrations and regulatory criteria were even greater for other metals. The distributions of storm flow concentrations were similar for total suspended solids and other contaminants. Base flow concentrations were generally lower. It does not appear that measured water quality effects are strongly associated with the biological responses seen with rather small impervious proportions in Figures 1 and 2.

Figure 4 plots sediment zinc concentrations over the % TIA gradient. All were below the "lowest effect threshold" of the Washington Department of Ecology (1991) freshwater sediment criteria and far below the "severe effect threshold." The low measured concentrations relative to advisory or regulatory criteria were found with other metals as well. As with water quality, it appears that sediment quality does not change appreciably until urbanization reaches the vicinity of 50 percent impervious. Again, there is no sign of a strong association between sediment quality and the biological changes that occur much earlier during the onset of urbanization.

*See my paper for question.*

In contrast to the absence of associations between water and sediment quality with relatively low and moderate levels of urbanization, increasing hydrologic fluctuation seems to be an early harbinger of rising impervious cover. Discharge

The ratio expresses the relative stream power, and thus physical stress on habitats and biota, exerted by storm runoff in relation to interevent conditions. The ratio is consistently  $< 20$  with TIA  $< 15$  percent, mostly 20-30 with TIA = 20-40 percent, and usually above 40 thereafter.

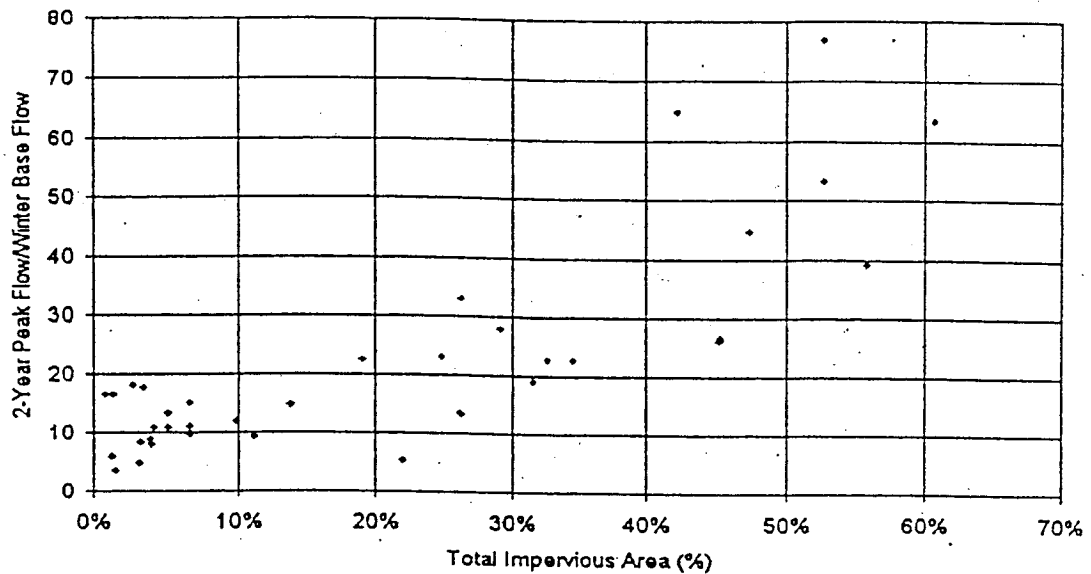


Figure 5. — Ratio of 2-Year Peak Flow to Winter Base Flow in Puget Sound Lowland Stream Sediments Over a Gradient of Watershed Impervious Land Cover

Several other habitat features have been related to urbanization as expressed by impervious cover. Figure 6 shows, for example, the results for large woody debris quantity. This feature is particularly important in Northwest streams, providing roughness that regulates velocities, cover to fish, and aid in forming pools in which fish feed and rest (McMahon and Hartman 1989). LWD more numerous than 300 pieces/km never occurred when TIA was more than 9 percent, with two exceptions where, respectively, wood was added to the channel in a habitat improvement project and a culvert prevents wood movement downstream. Numbers were always below 100/km with TIA  $> 40$  percent. As a second example, not illustrated, the proportion of fines ( $< 0.85$  mm) in the stream bed surface (top 10 cm) did not exceed 16 percent until TIA went above 20 percent. Values were in the range 22-27 percent fines with TIA at 45 percent or above, except where flushed by high flows.

A major reason, probably the leading one, for the death of salmonid embryos in the egg is ineffective dissolved oxygen (DO) interchange through fines that cover the spawning grounds. Measurement of both water column and intragravel DO gave the opportunity to assess this risk in relation to urbanization, as pictured in Figure 7. The ratio of intragravel to water column DO was above 90 percent in about half of the cases where TIA was 5 percent or less and above 80 percent for all but one of the remainder. Values generally fell below 70 percent above 10 percent TIA, but

attributes, it is reasonable to suppose that associations of similar form exist between habitat conditions and biology. This discussion explores those linkages:

Watershed and riparian characteristics → Habitat conditions → Biota

Figure 8 illustrates how B-IBI varies in relation to the ratio of 2-year peak flow to winter base flow. All indices of 35 or above were found in reaches where the hydrologic ratio was below 20. With ratios of 39 and above all but one B-IBI value was less than 20.

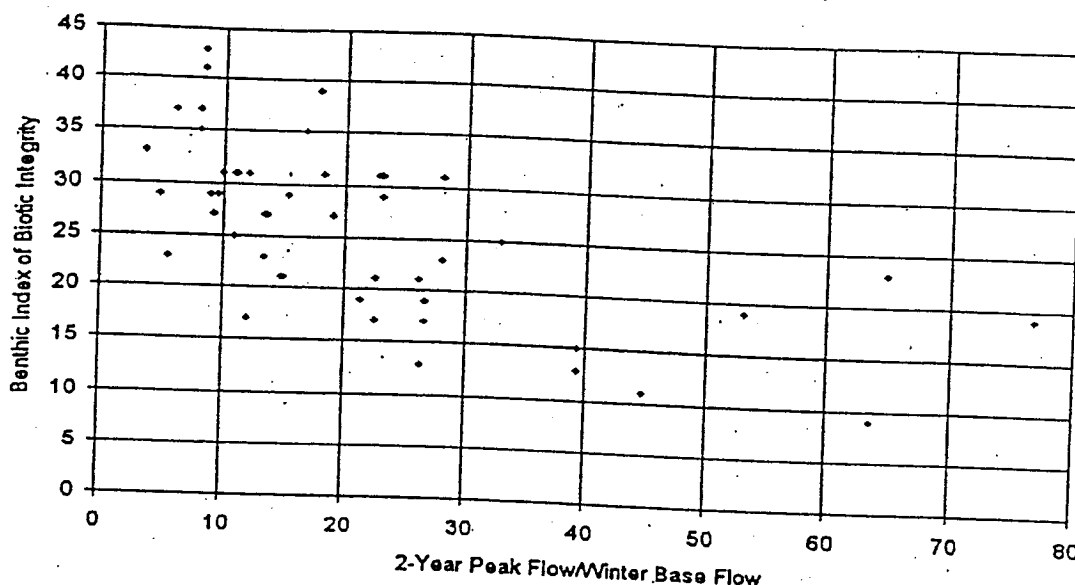


Figure 8. — Benthic Index of Biotic Integrity in Relation to Ratio of 2-Year Peak Flow to Winter Base Flow in Puget Sound Lowland Streams

Figure 9 shows the influence of the riparian zone on the biotic index. The highest indices ( $\geq 35$ ) were all found where at least 60 percent of the riparian buffer zone upstream of the sampling point was at least 30 meters wide, and the lowest ( $< 20$ ) where less than 50 percent of the buffer was that wide.

Also investigated, but not shown, was B-IBI versus percent fines ( $< 0.85$  mm) in the bed substratum. All indices  $\geq 35$  were consistent with no more than 15 percent fines, whereas reaches with 22 percent or more fines all had B-IBI  $< 20$ . The benthos thus appear to be quite sensitive to a relatively small alteration of the substratum.

Finally, Figure 10 shows B-IBI and coho salmon/cutthroat trout ratio in relation to a Qualitative Habitat Index. This index was derived by assigning scores of 1-4 to 15 attributes and summing (May 1996). Coho salmon dominance is consistent with B-IBI  $> 35$  and a habitat index  $> 50$ . At the other extreme, cutthroat trout dominance is absolute with B-IBI under 20 and habitat index less than 40.



of hydrology further (Reinelt and Horner 1990). The widely recognized primacy of hydroperiod (inundation pattern, specifically its depth, frequency, and duration) as a determinant of wetland ecosystem character (Mitsch and Gosselink 1993) produced an interest in finding a convenient means of measuring and expressing hydroperiod and investigating its relationship to biological communities on the one hand and attributes of contributing watersheds on the other. Instantaneous and crest (maximum since preceding measurement) water level readings were taken and used in computing water level fluctuation (WLF) as the difference between the crest and the average instantaneous depth in a time period (Azous 1990, Taylor 1993).

Plant species richness (number of species represented) was found to decline with increased mean annual WLF in the emergent (Figure 11) and scrub-shrub zones (not shown). Richness differed significantly (Mann-Whitney test,  $p < 0.002$ ) between areas with mean annual WLF above and below 22 cm in both zones. No emergent areas had more than 14 species if WLF exceeded 22 cm, whereas 30 percent of the areas with  $WLF < 22$  cm had at least 16 species. In the higher WLF group 33 percent had five or less species, in contrast to only 8 percent in the group subject to less fluctuation. Very similar distinctions pertained to scrub-shrub zones.

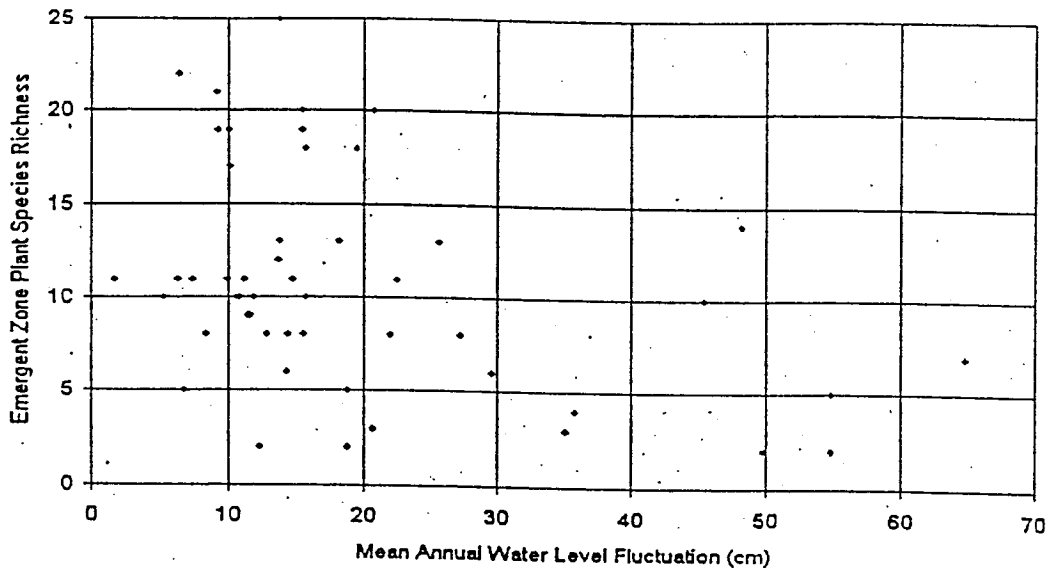


Figure 11. — Emergent Zone Plant Species Richness in Relation to Mean Annual Water Level Fluctuation in Puget Sound Lowland Wetlands

Being restricted to wetlands for reproduction, amphibians represent a biological indicator useful in assessing wetland condition. Figure 12 graphs richness in this community during the baseline years of the study versus mean annual WLF and presents a picture similar to the plant community. Of the wetlands with  $WLF < 22$  cm, 62 percent had five or more species, and all had at least three. Of the wetlands in the group with  $WLF \geq 22$  cm, 83 percent had four or less species. In later years amphibians declined in all wetlands, whether affected by urbanization or not. The reason for this decline is not known but may be the result of natural variation,

Amphibians responded negatively to urbanization in a pattern similar to the variation of WLF with imperviousness (Figure 13). Of the instances of highest amphibian richness (5 or more species), all were in watersheds with 22 percent or less impervious area, and 78 percent had watersheds with TIA < 6 percent. Another observation for this group of wetlands, although not graphed, was that watershed forest cover was at least 35 percent in 88 percent of the cases.

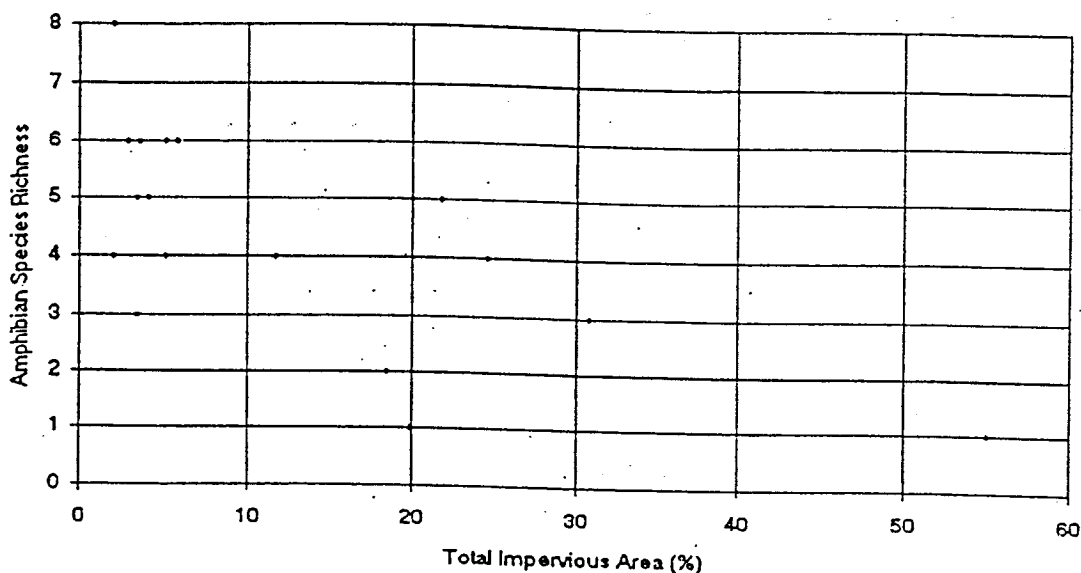


Figure 13. — Amphibian Species Richness in Puget Sound Lowland Wetlands Over a Gradient of Watershed Impervious Land Cover

#### Conclusions and Implications for Watershed Management

Research in representative sets of Puget Sound lowland streams and wetlands has shown that a host of physical habitat and biological characteristics change with increasing urbanization in a continuous rather than threshold fashion. Although the patterns of change differ among the attributes studied and are more strongly evidenced for some than for others, physical and biological measures generally were seen to change most rapidly from levels lightly affected by urbanization as total impervious area increased to 5-8 percent. With greater urbanization, the rate of alteration of habitat and biology usually slowed. There was direct evidence in both stream and wetland cases that altered watershed hydrology was at the source of the overall changes observed.

Water quality measures and concentrations of metals in sediments did not follow this pattern. They did not change much over the urbanization gradient until imperviousness approached 50 percent. Even then water column concentrations did not surpass aquatic life criteria, and sediment concentrations remained far below freshwater sediment criteria.

Thus, physical and biological change were seen to start early, almost immediately, in the urbanization process. Chemical pollutants did not exhibit a role in these

left. Holding the line can be successful if changes with negative tendencies are compensated by actions that maintain the overall status in about the same position. Another management objective should be to use any available opportunities to enhance the ecosystem structure and functioning. One of the leading strategies, on the basis of both its feasibility and probably effectiveness, should be to protect the riparian zone and, whenever possible, acquire riparian property and return it to a natural condition.

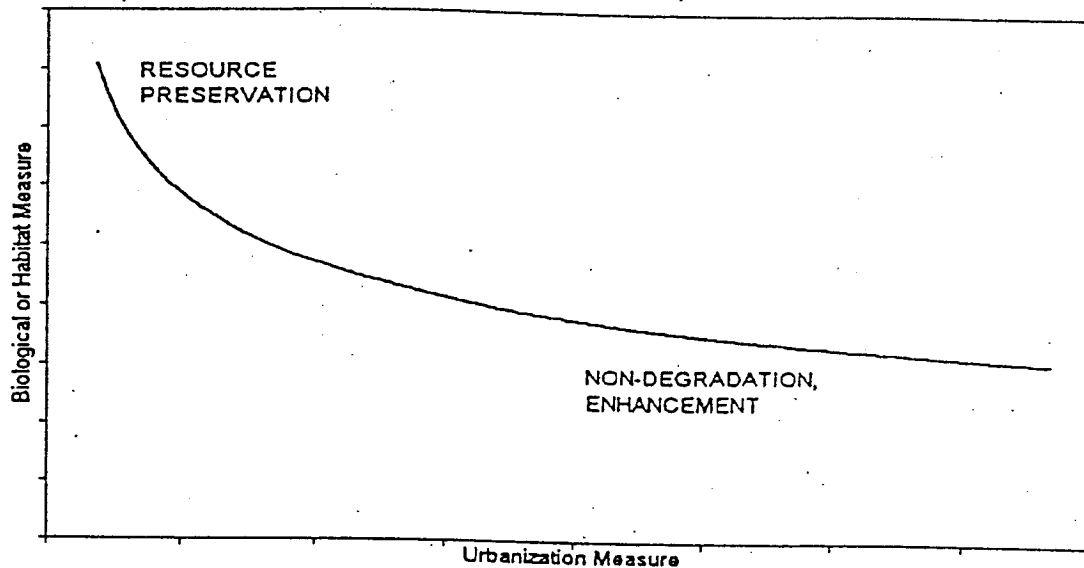


Figure 14. — General Pattern of Physical Habitat Characteristics in Puget Sound Lowland Streams and Wetlands Over a Gradient of Urbanization, with Regions Representing Different Watershed Management Objectives and Challenges

In the region on the left of the graph, resources have not been substantially affected and are likely to be highly valued. Here, a relatively small modification outside of the aquatic system is likely to create a proportionately bigger change within. The management objective would probably be to preserve the resources. Accomplishing this objective would require intense management to control the amount and location of impervious surfaces, maintain existing runoff storage capacity, prevent disruption of riparian areas, and the like, a very difficult challenge technically, and perhaps even more so, politically. The only way to meet such an objective is through strong preservation and regulation that allows very little and only certain types of watershed alteration. Implementing this program may be possible only with extensive property-owner incentives, government purchase of a large portion of the contributing catchment, transfer of development rights to an already highly degraded watershed, or some combination. Obviously, government could not move in such a fashion, nor justify the political and economic costs, without a strong case for the value of the resource thereby saved.

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# EFFECTS OF WATERSHED DEVELOPMENT AND MANAGEMENT ON AQUATIC ECOSYSTEMS

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