

Miller and Walker Creeks Basin Plan Appendices



Executive Proposed – February 2006



Port of Seattle



Washington State
Department of Transportation



King County

Appendix A

**Miller and Walker Creeks
Basin Plan**



**MILLER & SALMON CREEK BASIN PLAN DEVELOPMENT
INTERLOCAL AGREEMENT**

1 This Agreement is entered into by King County, Washington (hereinafter "King County"),
2 the City of Burien (hereinafter "Burien"), the City of SeaTac (hereinafter "SeaTac"), the Port of
3 Seattle (hereinafter the "Port"), and the State of Washington, Department of Transportation
4 (hereinafter "WSDOT"), collectively referred to as the "Parties," for the purpose of preparing a
5 basin plan for the Miller and Salmon Creek Basins, hereinafter referred to singularly as the
6 "Basin."

7 WHEREAS, the Parties share jurisdiction in or have other interests in the Basin and
8 recognize that it contains important natural resources, including streams, lakes, and wetlands that
9 are vital to promote water quality, fish habitat, recreation, and flood storage, and

10 WHEREAS, the stability and function of the Basin's natural resources are threatened by
11 existing and proposed development within the Basin, and

12 WHEREAS, the Parties manage stormwater within the basin and desire to cooperate to
13 develop cost-effective solutions for stormwater management, and

14 WHEREAS, the Parties agree on the importance of resolving existing drainage, flooding,
15 erosion and sedimentation, and water quality problems in the Basin that cross jurisdictional
16 boundaries, and

17 WHEREAS, the parties recognize that a cooperative effort to identify and address
18 problems in the Basin will promote cost savings to the public and the most effective protection of
19 the natural resource system, and wish to jointly develop a cooperative interjurisdictional Basin
20 Plan, and

21 WHEREAS, the Parties have each previously conducted stream gauging, resource
22 inventory, engineering, hydrologic modeling and water sampling activities in the Basin, all of
23 which they wish to contribute to a basin planning effort, and

24 WHEREAS, the Parties desire to have the King County Water and Land Resources
25 Division assist in preparing a basin plan by providing staff and expertise under the direction of a
26 management team composed of representatives of the Parties, and

27 WHEREAS, pursuant to RCW 39.34, the Interlocal Cooperation Act, the Parties are each
28 authorized to enter into an agreement for cooperative action;



1 NOW THEREFORE, the Parties agree as follows:

2

3 **I. Purpose**

4 The purpose of this Agreement is to provide the means by which the Parties will jointly
5 prepare a basin plan for addressing surface water and fish habitat issues within the Basin,
6 and to develop implementation recommendations for consideration by the implementing
7 agencies, which may or may not include the Parties to this Agreement.

8

9 **II. Basin Plan Description**

10 A. The Miller & Salmon Creek Basin Plan (hereinafter "Basin Plan") will consider the
11 effects of existing development and future land use (using adopted zoning,
12 comprehensive and other land use plans and studies for the area) on the aquatic
13 resources of the entire Basin regardless of jurisdiction.

14 B. The Basin Plan will: gather and analyze existing information; collect information on
15 selected watershed and infrastructure conditions within the Basin; develop a
16 hydrologic model for analyzing identified problems; identify current and anticipated
17 problems relating to stormwater conveyance, water quality, fish habitat, stream
18 stability, and infrastructure operation; prioritize identified problems; identify
19 possible solutions for the highest priority problems of a regional nature; examine
20 potential problems for implementing solution alternatives; develop specific solution
21 recommendations for the highest priority problems; estimate costs for recommended
22 solutions; and develop implementation recommendations.

23 C. When completed, the Basin Plan will be presented to the legislative authorities of
24 King County, Burien, SeaTac and the Port for adoption. Upon adoption, the Basin
25 Plan will serve as a policy framework for the adopting entities to guide decisions and
26 appropriations regarding surface water capital improvements, fish habitat
27 improvements, drainage regulations, enforcement and maintenance, land use,
28 zoning, and/or other related actions identified by the Basin Plan as contributing
29 significantly to existing and future problems. WSDOT will not conduct a formal
30 Basin Plan adoption process, which is not required for WSDOT to consider and
31 participate in the Basin Plan implementation strategies.



1 D. It is intended that implementation of the Basin Plan recommendations will be
2 accomplished by a series of separate implementation interlocal agreements
3 addressing specific projects, policy and programmatic measures.
4

5 **IV. Project Management**

6 A. Development of the Basin Plan (referred to hereinafter as the "Project") shall be
7 managed by a Project Management Team (PMT). The PMT shall review Project
8 work products and approve any necessary changes to the Project, including the
9 amendment of the Project Scope of Work, attached to this Agreement as Exhibit One
10 and incorporated herein and made a part hereof.

11 B. One representative to the PMT will be appointed by each of the Parties, as follows:
12 for King County, by the Manager of King County's Water and Land Resources
13 Division; for Burien, by the Director of the Public Works Department; for SeaTac,
14 by the City Manager; for the Port, by the Director of Aviation Facilities; and for
15 WSDOT, by the Administrator of the Office of Urban Corridors. Involvement of
16 additional staff from any of the Parties in support of the PMT is welcome.
17 Participation in the PMT is the responsibility of each party and is not included in
18 total Project costs.

19 C. King County shall serve as facilitator for the PMT and shall schedule, facilitate, and
20 provide summaries of PMT meetings. PMT facilitation shall be performed by a King
21 County staff person separate from the King County representative to the PMT. The
22 PMT will reach its decisions by consensus. Issues that cannot be resolved by the
23 PMT will be referred for resolution to the appointing authorities for the PMT, as
24 identified in Section IV.B. of this Agreement.

25 D. The PMT shall coordinate public outreach and involvement for the Project.
26 Individual PMT members shall have lead responsibility for public outreach and
27 involvement within their jurisdictions.

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V. Responsibilities

- A. King County shall: 1) provide a representative to serve on the PMT and staff to support and facilitate the PMT; 2) provide staff to perform Project management and coordination duties; and 3) complete the work activities described in Exhibit One and/or hire and manage any consultants necessary to complete work activities.
- B. Burien, SeaTac, the Port and WSDOT shall each provide: 1) a representative to serve on the PMT and staff to support the PMT member; and 2) water quality, fisheries, and stream flow data previously collected; complaint and problem identification information; and land use and zoning maps and other information needed for modeling and analysis.

VI. Costs

A. Agreement cost shares: The Parties agree to pay the following percentages of the cost-shared budget of the Project:

Burien	50%
SeaTac	5%
Port	10%
King County	25%
WSDOT	10%

- C. The cost-shared budget for the Project is identified in Exhibit One and includes costs for staff, overhead, supplies, consultants, and equipment, and costs incurred prior to the execution of this Agreement to initiate the Scope of Work.
- D. The cost-shared budget for the Project is estimated at \$353,178 and shall not exceed \$404,486 without further written agreement of the Parties.

VII. Billing and Payment

- A. King County shall bill the other Parties quarterly on itemized invoices for their shares of the reimbursable Project costs.
- B. The Parties shall review and approve the invoices and forward payment to King County within 60 days of receipt of invoice.

1 C. Nothing herein shall be construed as obligating the Parties to expend money in excess
2 of appropriations authorized by law and administratively allocated for this work.

3 **VIII. Effectiveness, Duration, Termination, and Amendment**

4 A. This Agreement is effective upon signature by the Parties and remains in effect until
5 December 31, 2004.

6 B. A Party may end its participation in the Project and withdraw from this Agreement
7 by providing 30-day written notification to all other Parties and by paying its share
8 of costs for the Project to the end of the quarter in which the Party's participation
9 ends.

10 C. This Agreement may be amended, altered, clarified, or extended only by the written
11 agreement of the Parties hereto, except that changes to the Scope of Work may be
12 made by consensus agreement of the PMT. An equitable adjustment in cost or
13 period of performance or both may be made if required by such change except that
14 maximum allowed Project costs may not be exceeded.

15 D. This Agreement is not assignable by any Party, either in whole or in part.

16 E. This Agreement may be amended to admit additional parties as "latecomers".
17 Participation of additional parties in this Agreement will require the payment of a
18 "latecomer fee" to cover a portion of the cost-shared budget of the Project, as agreed
19 to by the Parties.

20 F. This Agreement is a complete expression of the intent of the Parties and any oral or
21 written representations or understandings not incorporated herein are excluded. The
22 parties recognize that time is of the essence in the performance of the provisions of
23 this Agreement. Waiver of any default shall not be deemed to be waiver of any
24 subsequent default. Waiver of breach of any provision of this Agreement shall not
25 be deemed to be a waiver of any other or subsequent breach and shall not be
26 construed to be a modification of the terms of the Agreement unless stated to be such
27 through written approval by the Parties which shall be attached to the original
28 Agreement.

29
30 **IX. Counterparts**

31 This Agreement may be executed in counterparts.

APPROVED

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X. Indemnification and Hold Harmless

The Parties agree to the following:

Each Party shall protect, defend, indemnify, and save harmless the other Parties, their officers, officials, employees, and agents, while acting within the scope of their employment as such, from any and all costs, claims, judgments, and/or awards of damages, arising out of, or in any way resulting from, each Party's own negligent acts or omissions. Each Party agrees that its obligations under this subparagraph extend to any claim, demand, and/or cause of action brought by, or on behalf of, any of its employees or agents. For this purpose, each Party, by mutual negotiation, hereby waives, with respect to the other Parties only, any immunity that would otherwise be available against such claims under the Industrial Insurance provisions of Title 51 RCW. In the event that any Party incurs any judgment, award, and/or cost arising therefrom, including attorneys' fees, to enforce the provisions of this Article, all such fees, expenses, and costs shall be recoverable from the responsible Party to the extent of that Party's culpability.

IN WITNESS WHEREOF, the Parties hereto have executed this Agreement on the ____ day of _____, 200__.

Approved as to Form

King County:

By: _____

By: _____

Title: Deputy Prosecuting Attorney

Title: King County Executive

Approved as to Form

City of Burien: 11-07-02

By: 

By: 

Title: CITY ATTORNEY
LISA M. MARSHALL

Title: City Manager



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Approved as to Form

City of SeaTac:

By: Mary Elizabeth Mindell
Title: Cr. Asst. City Attorney

By: Bruce A. Rayburn
Title: City manager

Approved as to Form

Port of Seattle:

By: _____
Title: _____

By: _____
Title: _____

Approved as to Form

WSDOT:

By: _____
Title: _____

By: _____
Title: _____

APPROVED

1 Approved as to Form

City of SeaTac:

2

3 By: _____

By: _____

4 Title: _____

Title: _____

5

6 Approved as to Form

Port of Seattle:

7
8 By: Linda J. Street
9 Title: General Counsel

By: M. R. Dinsmore
Title: M. R. Dinsmore
Chief Executive Officer

10

11 Approved as to Form

WSDOT:

12

13 By: _____

By: _____

14 Title: _____

Title: _____

15



1 Approved as to Form

City of SeaTac:

2

3 By: _____

By: _____

4 Title: _____

Title: _____

5

6 Approved as to Form

Port of Seattle:

7

8 By: _____

By: _____

9 Title: _____

Title: _____

10

11 Approved as to Form

WSDOT:

12

13 By: _____

By: *Craig Staro*

14 Title: _____

Title: *Urban Projects Director*

15

**Miller & Salmon Creek Basin Plan Interlocal Agreement
Exhibit One**

Goal: To complete a multi-disciplined assessment (i.e. engineering, hydrology, water quality, geology and ecology disciplines) of the physical, chemical and biological conditions of the Miller and Salmon Creek stream systems; to identify existing and predicted problems regarding the quantity and quality of surface water, particularly those adversely affecting properties and aquatic resources; and to cooperatively assess problems and recommend solutions to the highest priority problems of regional importance to ecological health and public safety.

Tasks and Associated Products and Cost Estimates

Task	Description	Products	Cost Estimate
Contract Management and Facilitation	Manage consultant contracts; facilitate project management team meetings; prepare minutes.	Consultant RFPs and contracts; PMT meeting agendas and minutes.	\$28,532
Data Review/Startup	Review existing data to establish baseline conditions through information searches, interviews, review of complaint records.	Memorandum listing existing information and it's location.	\$47,332
Data Collection	Conduct stream habitat surveys, juvenile fish and spawner spot checks, field investigations to fill data gaps; collect stream flow data to fill data gaps; conduct water quality sampling and temperature monitoring; survey key features of infrastructure; collect data on stream geomorphology; compile and organize data.	Technical memorandum presenting information on existing stream habitat, water quality, salmon use, geomorphology, and key watershed and infrastructure features.	\$139,039
Conditions Analysis	Hydrologic analysis and setup and calibration of model; analysis of hydraulic capacity of major infrastructure; analysis of closed depression hydraulic analysis of fish passage for 3-5 culverts; analysis of water quality data and future trends; analyze factors adversely affecting properties, salmon habitat quality, identify existing and predicted problems.	Hydrologic model; technical memorandum of watershed conditions and existing and predicted problems.	\$114,798

APPROVED

Conditions Summary	Summarize conditions for basin plan; develop initial ranking criteria for identifying regional problems.	Report summarizing the basin's current conditions; memorandum summarizing ranking criteria.	\$50,610
Preliminary Prioritization	Develop preliminary problem list; sort problem list into regional and local problems; apply ranking criteria to regional problems, determine problems/issues for solutions development; develop scope for solutions development for regional problems.	Technical memorandum outlining priority problems and issues; draft scope for regional solutions development.	\$20,534
Solutions Development	Develop, analyze and assess pros and cons of alternatives for addressing selected regional problems; develop conceptual sketches and preliminary cost estimates; evaluate options and develop recommendations.	Written summary of alternatives for addressing selected regional problems.	\$101,205
Report Preparation	Draft and finalize report.	Final Basin Plan (100 copies).	\$26,527
Subtotal Estimate			\$528,577
Contingency	Note: Contingency is based on 10% of project cost, minus printing and lab analysis.		\$51,308
Not-To-Exceed Subtotal			\$579,885

Reductions to Cost-Share:

King Conservation District grant	(\$50,000)
King County White Center project	(\$50,000)
Total King County contribution for project management and facilitation	(\$75,401)
Subtotal, Reductions to cost-share	(\$175,401)
Total Estimated Cost-Shared Budget for Plan Development	\$ 353,178
Not-To-Exceed Cost-Shared Budget (with contingency)	\$ 404,486

First Amendment to the Interlocal Agreement

FIRST AMENDMENT TO THE MILLER AND SALMON CREEK BASIN PLAN Appendix A
Miller and Walker Creeks Basin Plan Development Interlocal Agreement and Amendment
DEVELOPMENT INTERLOCAL AGREEMENT

APPROVED

This First Amendment to the Miller and Salmon Creek Basin Plan Development Interlocal Agreement ("First Amendment") amends that certain Miller and Salmon Creek Basin Plan Development Interlocal Agreement ("Agreement"), entered into on December 15, 2002, by King County, the City of Burien, the City of SeaTac, the Port of Seattle, and the State of Washington, as represented by its Department of Transportation ("WSDOT") (collectively the "Parties"). The Parties now desire to amend the Agreement to provide for an additional party, the City of Normandy Park, to take part in the development of the Miller and Salmon Creek Basin Plan ("Basin Plan"), and to provide for reduced participation by the State of Washington.

WHEREAS, the Parties entered into the Agreement in order to jointly prepare and share costs in the development of the Basin Plan, including those costs incurred prior to execution of the Agreement, and have conducted initial work on the Basin Plan since early in the year 2002; and

WHEREAS, the Agreement provides that additional parties may be added under the Agreement through written amendment of the Agreement; and

WHEREAS, the Parties and Normandy Park desire to now include Normandy Park as a party to the Agreement, and;

WHEREAS, WSDOT desires to reduce its role as a participant in the development of the Basin Plan; and

WHEREAS, the Parties are in agreement that WSDOT may have a reduced role in the development of the Basin Plan as more fully set forth in this First Amendment; and

WHEREAS, the parties have authority to enter into and to amend interlocal agreements under RCW 39.34, the Interlocal Cooperation Act;

NOW, THEREFORE, the Parties mutually agree that the Agreement shall be amended as set forth in Paragraphs 1 through 7 below. Words to be deleted from the Agreement by this First Amendment are indicated below as a strikethrough; words to be added to the Agreement by this First Amendment are indicated below as underlined text.

1. The First Paragraph of the Agreement (Agreement Preamble) is amended to read as follows:

This Agreement is entered into by King County, Washington (hereinafter "King County"), the City of Burien (hereinafter "Burien"), the City of SeaTac (hereinafter "SeaTac"), the Port of

Seattle (hereinafter the "Port"), the City of Normandy Park, and the State of Washington, Department of Transportation (hereinafter "WSDOT"), collectively referred to as the "Parties," for the purpose of preparing a basin plan for the Miller and Salmon Creek Basins, hereinafter referred to singularly as the "Basin."

2. Article II. (Basin Plan Description), Section C. is amended to read as follows:

C. When completed, the Basin Plan will be presented to the legislative authorities of King County, Burien, SeaTac, Normandy Park, and the Port for adoption. Upon adoption, the Basin Plan will serve as a policy framework for the adopting entities to guide decisions and appropriations regarding surface water capital improvements, fish habitat improvements, drainage regulations, enforcement and maintenance, land use, zoning, and/or other related actions identified by the Basin Plan as contributing significantly to existing and future problems. WSDOT will not conduct a formal Basin Plan adoption process, which is not required for WSDOT to consider and participate in the Basin Plan implementation strategies.

3. Article IV. (Project Management), Section B. is amended to read as follows:

B. One representative to the PMT will be appointed by each of the Parties, as follows: for King County, by the Manager of King County's Water and Land Resources Division; for Burien, by the Director of the Public Works Department; for SeaTac, by the City Manager; for the Port, by the Director of Aviation Facilities; for Normandy Park, by the City Manager; and for WSDOT, by the Administrator of the Office of Urban Corridors. Involvement of additional staff from any of the Parties in support of the PMT is welcome. Participation in the PMT is the responsibility of each party and is not included in total Project costs.

4. Article V (Responsibilities), Section B. is amended to read as follows:

B. Burien, SeaTac, the Port, Normandy Park, and WSDOT shall each provide: 1) a representative to serve on the PMT and staff to support the PMT member; and 2) water quality, fisheries, and stream flow data previously collected; complaint and problem identification information; and land use and zoning maps and other information needed for modeling and analysis.

5. Article VI.(Costs), Section A. is amended to read as follows:

A. Agreement cost shares: The Parties agree to pay the following percentages of the cost-shared budget of the Project:

Burien	50%
SeaTac	5%
Port	10%
King County	25%
WSDOT	10% 1%
<u>Normandy Park</u>	<u>9%</u>

6. Article VI. (Costs), is amended by adding a new section E. as follows:

E. In addition to the amounts provided for in Section A of this Article VI, Normandy Park shall pay a latecomer fee of \$4,000 to cover additional administrative costs.


7. Article VII. (Billing and Payment), Section A. is amended to read as follows:

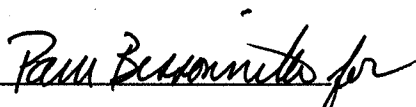
A. King County shall bill the other Parties quarterly on itemized invoices for their shares of the reimbursable Project costs. King County shall bill Normandy Park for the \$4,000 latecomer fee on the first invoice issued to Normandy Park.

All other terms of the Agreement are unaffected by this First Amendment and shall remain in full force and effect. This First Amendment shall be effective upon signature of all of the Parties and by the City of Normandy Park, and may be executed in multiple counterparts, each of which shall constitute an original.

Approved as to Form

King County:

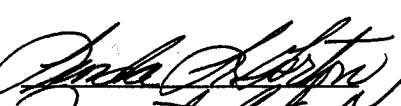
By: 
Title: Deputy Prosecuting Attorney

By: 
Title: King County Executive

Approved as to Form

City of Burien:

By: _____
Title: _____

By: 
Title: Deputy City Manager

APPROVED

Approved as to Form

By: Robert L McAdam
Title: CITY ATTORNEY

City of SeaTac:

By: Bruce Rayburn
Title: Bruce Rayburn, City Manager

Approved as to Form

By: _____
Title: _____

Port of Seattle:

By: _____
Title: _____

Approved as to Form

By: _____
Title: _____

WSDOT:

By: _____
Title: _____

Approved as to Form

By: _____
Title: _____

City of Normandy Park:

By: _____
Title: _____

APPROVED

Approved as to Form

City of Burien:

By: _____
Title: _____

By: _____
Title: _____

Approved as to Form

City of SeaTac:

By: _____
Title: _____

By: _____
Title: _____

Approved as to Form

Port of Seattle:

By: Israel M Lopez
Title: Senior Port Counsel

By: Michael Altman
Title: Deputy Managing Director

Approved as to Form

WSDOT:

By: _____
Title: _____

By: _____
Title: _____

Approved as to Form

City of Normandy Park:

By: _____
Title: _____

By: _____
Title: _____

APPROVED

Approved as to Form

City of SeaTac:

By: _____

By: _____

Title: _____

Title: _____

Approved as to Form

Port of Seattle:

By: _____

By: _____

Title: _____

Title: _____

Approved as to Form

WSDOT:

By: Bruce Brown
Title: Asst Atty General

By: Craig Stone
Title: Urban Corridor Project Director

Approved as to Form

City of Normandy Park:

By: _____

By: _____

Title: _____

Title: _____

APPROVED

Approved as to Form

City of SeaTac:

By: _____

By: _____

Title: _____

Title: _____

Approved as to Form

Port of Seattle:

By: _____

By: _____

Title: _____

Title: _____

Approved as to Form

WSDOT:

By: _____

By: _____

Title: _____

Title: _____

Approved as to Form

City of Normandy Park:

By: Susan Rae Sampson

By: [Signature]

Title: City attorney

Title: City Manager

Appendix B

**Miller and Walker Creeks
Basin Plan**

Appendix B: Past Studies of Miller and Walker Creeks

Over the past several decades there have been a number of studies that have made recommendations for improvements to Miller Creek and Walker Creek. Although this current planning effort did not conduct an exhaustive search of all past studies, several key studies were identified:

► **Miller Creek Watershed.**
University of Washington, 1973.

This report included both the Miller and Walker basins. The report recognized that uncontrolled stormwater runoff and the introduction of large amounts of fine sediments to the stream were harming it. The report suggested that detention of stormwater and implementation of erosion control measures were critical to recovery of the basin. Interestingly, two other proposals favored at the time, as cited in the report, were creating a storm sewer system and turning the stream into a concrete channel to accommodate the uncontrolled stormwater runoff. Creation of a concrete channel involved enlarging the existing 72-inch culvert pipe that conveys Miller Creek under 1st Avenue South and building a fifty- to 65-foot wide channel in Miller Creek all the way to the mouth. The channel was to carry stormwater from Sea-Tac Airport, SR 509, and other development in the basin. The King County proposal was the subject of a lawsuit brought by a resident in the area. Neither the storm sewer system project nor the concrete channel project was built. The recommendations in the University of Washington report were largely ignored.

► **Correspondence, James Ames.**
Washington Department of Fisheries, 1973.

James Ames, a fisheries biologist with the Washington Department of Fisheries, summarized the basin's problems in a 1973 letter to a consulting engineer. It is probable that his observations applied to both Miller Creek and Walker Creek. He identified excess fine-grained sediment as a particular problem.

He also made the following comment:

“Anadromous fish are now virtually extinct in upper Miller Creek due almost entirely to lack of total planning for man’s activities in the watershed. With proper direction, this would not have happened. Perhaps the greatest value of Miller Creek as it now exists, is as an example of what not to do. It may well remind us that the restrictions that we place on hydraulic projects are not unreasonably founded, but are mandatory to maintain the resource.”

► **Miller and Walker Basin Reconnaissance Survey.**
King County, 1987.

Subsequently, as part of a basin reconnaissance survey, King County identified erosion, flooding, and habitat loss as problems in the Miller and Walker basins, and recommended that several actions be taken. The recommendations included reducing peak flows, decreasing the introduction of fine sediments to the stream, and completing a basin plan. The report also proposed a prioritized list of capital projects, primarily designed to increase stormwater detention in the basin.

Appendix C

**Miller and Walker Creeks
Basin Plan**

Appendix C: Habitat Characteristics and Identified Problems of Miller and Walker Creeks

Miller Creek Characteristics

The natural habitat of the Miller Creek basin has changed dramatically over the past 100 years. Under a fully forested land cover, it is likely that there were many more fish, amphibians, birds, and mammals present. Annual spawning returns of one to two thousand chum, coho, steelhead, and cut-throat are estimated to have occurred before the effects of urbanization, an approximate ten-fold difference over recent returns.

How was this estimate developed?

Miller Creek and Walker Creek include a variety of seasonal and permanent fish passage barriers as well as degraded habitat conditions. These include a degraded estuary due to recreational development; pre-spawn mortality; seasonal, species-specific, and permanent fish passage barriers; and degraded in-stream habitat due to siltation and elimination of gravels and large woody debris recruitment. Provisional estimates of lost fish production suggest that as many as 1,500 fish per year are being lost as a result of the passage barriers and degraded habitat conditions. **Exhibit C-1** on the following page calculates lost fish productivity calculated by species.

What type of habitat exists in the Miller Creek basin today?

With development in the basin came filling of wetlands, straightening and channeling of the stream through the addition of rip-rap, loss of forest cover, introduction of water pollutants, and changes in hydrology leading to more erosion and higher peak flows. The habitat that is currently available is limited and somewhat degraded, although some areas of relatively good habitat still exist.

How was existing habitat identified in the Miller Creek Basin?

Stream habitat characteristics and conditions were examined and evaluated within Miller Creek in order to identify and rank current problems for future engineering and environmental analysis. King County staff requested permission to access the stream from many riparian property owners in the basin; approximately one-third of those property owners that were contacted allowed access. Additional information on stream habitat conditions was obtained from a variety of sources including the following:

**Exhibit C-1
Lost Fish Productivity**

<u>SPECIES</u>	<u>CALCULATION</u>
<i>Chum</i>	<p>Assuming a run size of 1.25 adults per 10.8 square feet (i.e., one square meter) of habitat, an average channel width of six feet, an estimate of 1141 feet of available spawning habitat, and ten percent survival:</p> $(6846 \text{ square feet of available spawning habitat}) \times (1.25 \text{ adults}/10.8 \text{ square feet}) \times (0.25 \text{ survival})$ $= 198 \text{ returning adults/year}$
<i>Coho</i>	<p>Based on assumptions of 0.5 smolts produced per 10.8 square feet (i.e., one square meter) of habitat, an average channel width of six feet, an estimate of 28,720 feet of available habitat, and ten percent survival:</p> $(172,320 \text{ square feet of available habitat}) \times (0.5 \text{ smolts}/10.8 \text{ square feet}) \times (0.10 \text{ survival})$ $= 798 \text{ returning adults/year}$
<i>Cutthroat Trout</i>	<p>Assuming cutthroat trout production is typically 0.25 to 0.5 times that of coho salmon for similar stream reaches, seven miles (36,960 lineal feet) of habitat, an average channel width of six feet, and ten percent survival:</p> $(221,760 \text{ square feet of available habitat}) \times (0.25 \text{ adults}/10.8 \text{ square feet}) \times (0.10 \text{ survival})$ $= 513 \text{ returning adults/year}$

Assumptions:

Historic conditions within the Miller Creek and Walker Creek basins are the same as other watersheds and "typical" production rates are adequate to define historic production without additional analysis.

Restoration of salmon habitat within the Miller Creek and Walker Creek basins to historic conditions does not require restoration of the entire watershed to historic or near historic conditions.

Fish production is determined only by the condition of the freshwater watershed and other ecosystem factors are not substantive in determining production with current conditions.

Natural salmon production is relatively constant.

- ▶ **Miller Basin Reconnaissance (King County Surface Water Management Division, 1987)**
- ▶ **Level 1 Stream Survey (Trout Unlimited, 1993)**
- ▶ **Stream Survey Report for Miller Creek (Luchessa, 1995)**

- ▶ Assessment of Spawning and Habitat in Three Puget Sound Streams, Washington (Hillman, 1999)
- ▶ Water Type Survey Results, South King County, May/June 2003 (Washington Trout, 2004)

To organize and evaluate habitat characteristics, Miller Creek was divided into eleven reaches. Within each reach, channel habitat types were classified using the Oregon Watershed Assessment Manual (Network, 1999). During stream surveys conducted by King County staff, channel habitat characteristics were noted, including reach length, gradient, valley shape, channel pattern, and confinement. Additional habitat variables were evaluated, based on available data, including channel width, substrate size and distribution, aquatic habitat characteristics, riparian cover composition and abundance, fish passage barriers, large woody debris characteristics and abundance, fish species, and habitat utilization.

a. Habitat Characteristics

Riparian habitats (includes streamside native vegetation) have been mostly lost to urbanization within the Miller Creek basin. Riparian buffers (i.e., preservation of streamside native vegetated areas) are one of the most significant measures for mitigating the impacts of urbanization and helping to restore habitat for salmon, steelhead and coastal cut-throat trout. Optimally, riparian buffers should be 100 to 200 feet wide. This corresponds to one to two site potential tree heights based on the site potential tree height, which is the expected height of coniferous trees upon maturity (200 years). This averages 170 feet in much of the Pacific Northwest, but may exceed 200 feet in areas such as the Olympic Peninsula or the redwood zone in California (Spence et al., 1996). Most of the riparian habitat in Miller Creek is much less than 100 feet in width.

Riparian buffers can moderate downstream flood peaks by temporarily storing stormwater. Streamside vegetation provides shade and maintains cool water temperatures. Vegetation roots contribute to soil cohesion that stabilizes banks and filters sediment chemicals and nutrients from upstream sources. Trees supply large wood to the channel that maintains channel form and improves in-stream habitat complexity. Trees and shrubs contribute leaves, branches, and terrestrial insects that sustain aquatic invertebrates upon which salmonids feed.

Large woody debris (LWD) from riparian buffers is critical to Pacific Northwest streams and plays a dominant role in forming pools, trapping spawning gravels, providing habitat for aquatic organisms and creating a more complex stream environment. LWD forms dammed and scour pools that create slow water habitats and provide refuge for fish during high- and low- flow events. Pools provide holding areas for spawning salmon, and pool tailouts are important spawning areas. Miller Creek is lacking in both large woody debris and pool habitat.

Studies (Roni, 2001; Roni, 2002) of stream restoration projects involving the placement of LWD and boulders indicated that salmonids responded positively

to wood placement. These studies showed that the largest fish population increases were seen in those streams that had the largest increase in pool area and wood loading, suggesting that large changes in physical habitat are needed to detect a significant fish response.

Lack of nutrients has been shown responsible for depressed productivity in many watersheds in the Pacific Northwest (Gregory, 1987). Salmon carcasses have been shown to elevate stream productivity (Levy, 1997) both indirectly and directly. As carcasses decay they release nutrients that enrich the nutrient food base and contribute to the production of aquatic invertebrates which salmon feed on. Juvenile salmon have also been observed directly feeding on carcasses (Bilby, 1996). The direct addition of nutrients has been shown (Slaney, 2003) to increase the production of salmonids in small streams and has become a common practice in nutrient-limited streams in British Columbia. Salmon returns in Miller Creek are currently relatively low (a few hundred adults per year) and occur in relatively limited areas of the stream system. It is possible that nutrient limitation is a problem in Miller Creek, although no studies documenting this have been completed at this time.

b. Fish Populations

There are no reliable estimates of historical fish usage within Miller Creek, although volunteer spawner surveys conducted in recent years has provided useful information. Recent stream surveys indicate that Miller Creek supports spawning habitat for four species of anadromous salmonids, including chum and coho salmon, sea-run cut-throat, and steelhead trout. Two fish propagation programs are underway that may be directly and indirectly affecting Miller Creek. The Des Moines Chapter of Trout Unlimited (TU) runs a small coho hatchery located in a building on the grounds of the SW Suburban Sewer District (Batcho, 2004). Approximately 120,000 coho eggs are provided by another hatchery (the Soos Creek hatchery) and raised at the Miller Creek hatchery to fry stage. In the past, the fry planted throughout Miller, Walker, Des Moines, and Massy Creeks were fed over a three to five month period.

Based on observations of natural spawning and fry production in the lower parts of these streams, TU has discontinued feeding fry. Fry are scatter-planted into the upper reaches of these streams where natural spawning and fry utilization has not been observed. In addition to the TU propagation program, the Des Moines Chapter of the Northwest Steelhead and Salmon Council rears coho fry in a saltwater net pen located at the Des Moines marina. The Soos Creek hatchery provides 30,000 fry to the net pen, which are then released to the saltwater as smolts in June. Even though the number of fry released to the system is very large, recent surveys indicate that only approximately 200 adult salmon have returned to spawn in the past several years.

Pre-spawn mortality has emerged as a significant concern in several Puget Sound streams. Inspections of salmon carcasses in Miller Creek indicated that coho females voided 28% (arithmetic mean) of their eggs; in Walker Creek coho females voided 37 percent of their eggs (Hillman, 1999). One steelhead carcass found in Walker Creek voided no eggs. Chum carcasses in both creeks were

completely voided of eggs. In order to study this issue the Northwest Fisheries Science Center conducted a series of studies in fall/winter 2002 and documented a very high rate of acute mortality (>90%) in adult coho (Coordinated Research on Coho Pre-Spawn Mortality in the Puget Sound Basin, National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center). Before they died, these adult coho showed common symptoms (e.g., loss of orientation and equilibrium). Stormwater quality has been identified as a concern in these studies, although there is not yet a definitive link between water quality and pre-spawn mortality. This study suggests, however, that it may not be sufficient to restore habitat structure without addressing water quality if self-sustaining salmon populations are to be re-established.

In 1997 biological monitoring was performed using the benthic index of biological integrity (B-IBI). The benthic index of biological integrity (B-IBI) is a multimetric index based on the attributes of the benthic invertebrate community (Kleindl, 1995). Benthic invertebrates are critical food sources for salmonids. They can also function as indicators of biological health in streams (Karr, 1998). The basic principle behind the study of macroinvertebrates is that some are more sensitive to pollution than others. Therefore, if a stream site is inhabited by organisms that can tolerate pollution - and the more pollution-sensitive organisms are missing - a pollution problem is likely.

The B-IBI score examines the human impact on a sample stream compared to a minimally-degraded "reference" stream. As basins become more urban the number of aquatic invertebrate taxa (richness) declines and the proportional richness and abundance of (urban) tolerant taxa increases. Therefore, a minimally-degraded "reference" stream with excellent biological conditions will have the highest B-IBI score of 46 to fifty. At the opposite end of the scale, streams with very poor biological conditions B-IBI scores will be ten to 16. B-IBI assessments of streams (Ecology, 1999 and May, 1997) found that coho salmon populations diminish where B-IBI scores are 33 or lower. In such instances resident cutthroat, which are more resilient to urbanization, predominated.

Two B-IBI scores for Miller Creek are available, one was 12 (Morley, 2000) and one was 10 (Parametrix, 2000). Both studies found total species richness (taxa) was 9.3 compared to 33.3 at Rock Creek, a reference stream, with no long-lived or (urban) intolerant taxa found in the sample. In the earlier study, the B-IBI results indicated that out of a sample of 45 streams in King County, Miller Creek had the most degraded habitat conditions relative to reference streams.

c. Stream Reach Analysis

The estuary extends from the mouth of Miller Creek on Puget Sound to SW 175th Place. Land use in this sub-area is residential and recreational. The Normandy Park Community Club is the majority landowner and manages the two estuary reaches of Miller and Walker creeks. Geologically this is a delta estuary consisting of outwash alluvium. Almost all of the estuary area, except for the Community Club buildings, is occupied by the 100-year combined floodplains of Miller and Walker creeks. Walker Creek is located to the south of

Miller Creek and extends in two areas of the estuary – into a wetland area (the Beaver Pond, located on the south of the property) and along the south side of the Community Club. The stream has been channelized throughout this reach and discharges into Miller Creek at two points – at approximately 420 feet from the mouth (near the Community Club building) and approximately 30 feet from the mouth (this is the outlet from the Beaver Pond). Puget Sound tidally influences the streams in this sub-area for several hundred feet and historically this area was a salt marsh. Dredging, filling and diking have limited the salt marsh to a few acres located east of the shoreline dike.

Reach 1

Reach one extends 1,800-feet from the mouth of Miller Creek upstream to river mile (RM) 0.3 at Southwest 175th Street. It is a small estuarine channel with a stream gradient of 1% and a sinuosity of 1.1. It is situated within a broad alluvial floodplain valley with terraces. It has a single, meandering pool-riffle channel pattern. Very little LWD was observed; the channel is unconfined and the dominant substrate consists of small gravels and sand.

Reach 2

Reach 2 forms the beginning of the ravine sub-area and extends from RM 0.3 at SW 175th Place to RM 0.64. This reach is 1,795-foot long, low-gradient medium floodplain channel that is situated in an alluvial floodplain valley. The stream channel has a gradient of 1.9 percent with a single channel that is unconfined that has a high sinuosity of 2.24. This reach of Miller Creek has good quality gravel substrates for coho and steelhead spawning and is dominated by riffles with frequently spaced pools. It appears to be stable in plan and profile. There is a high quality riparian corridor with overhanging cover including abundant mature deciduous trees and less abundant coniferous trees shading over eighty percent of the channel. There are no barriers to fish migration in this reach. LWD was moderately abundant. Washington Trout found substantial use of this reach by coho, resident and searun cut-throat trout (Washington Trout, 2004). This is the highest quality reach for spawning and rearing in Miller Creek. In 1997 biological monitoring was performed at RM 0.54 using the benthic index of biological integrity (B-IBI). The B-IBI scores from this site (Morley, 2000) was twelve. Total species richness (taxa) was 9.3 compared to 33.3 taxa at Rock Creek, with no long-lived or (urban) intolerant taxa found in the sample. These B-IBI results indicate that Miller Creek is greatly degraded. Although the exact causes of the decline in the B-IBI scores is unknown, it is reasonable to conclude that a combination of factors is responsible, including changes in flow regime, habitat structure, and water quality.

Reach 3

Reach 3 extends from RM 0.64 near 8th Avenue SW to RM 0.77 below the mouth of tributary 09.0353. This reach is a 686-foot long, moderate-gradient confined channel that is situated in a narrow valley with little river terrace development. The valley has moderate to steep side slopes (thirty to sixty percent) that average close to sixty percent and the bottom width is narrow (ten to thirty meters) with an average width of fifty feet. The stream channel has a

gradient of 3.6 percent and a low sinuosity of 0.72. The first 528 feet of this reach consists of a cast in place concrete channel with gate baffles for fish passage (Washington Trout, 2004). This highly confined and entrenched channel feature extends through the grounds of the Southwest Suburban Sewer District (SWSSD). The channel has no riparian cover, no LWD, and no pools or riffles. The channel does not appear to be a velocity barrier to fish migration. The upper end of the reach consists of rip-rapped banks and substrate with moderate riparian cover. Washington Trout noted steep gradients of greater than three percent in the reach; sampling found coho, and resident and searun cut-throat trout (Washington Trout, 2004). This reach is the lowest quality reach in the ravine sub-area due to the degraded aquatic habitat including lack of riparian cover and channel substrate and steep gradients.

Reach 4

Reach 4 extends 3,250 feet from RM 0.77 below the mouth of tributary 09.0353 to RM 1.56 at the confluence of tributary 0354 on the right (north) bank. This is a moderate-gradient moderately confined channel reach. It is situated in a narrow valley with moderate channel confinement due to hill-slopes and valley terraces that limit channel migration and floodplain development. The stream channel has a moderately steep gradient of 2.9 percent with a moderate sinuosity of 1.7. Aquatic habitat includes small cascades and good spawning riffles with frequently spaced pools. There was a moderate abundance of coarse sediments and a low abundance of fine sediments. Aquatic habitat consisted of eighty percent fast water, with twenty percent slow water with scour pools formed by boulders and LWD. Overall LWD abundance is low. Riparian conditions included abundant mature deciduous tree cover and sparse conifers shading over eighty percent of the channel. No barriers to fish migration were observed. Washington Trout found substantial use of this reach by coho, resident and searun cut-throat trout. This is one of the highest quality reaches in Miller Creek.

Tributary stream 0353

This tributary mouth is located at the bottom of the reach. There is a ten-inch culvert perched greater than one foot above a riprap bank that is impassible to fish. Washington Trout (Washington Trout, 2004) observed another fish-impassible culvert barrier located 75 feet upstream. This tributary is a source of high quality spawning gravels; however, the numerous culverts have constrained the channel and are preventing downstream gravel migration where they would provide excellent spawning substrate.

Reach 5

Reach 5 extends 1,100 feet from RM 1.56, below the mouth of tributary 0354, to RM 1.8 below the 1st Avenue South culvert. This is the upper end of the ravine sub-area and transitional to the upland sub-area. This is a moderately-steep narrow valley channel reach and is situated in a narrow valley and is confined by adjacent steep hill-slopes. The stream channel has an average gradient of 1.8 percent and a moderate sinuosity of 1.26. Aquatic habitat consists of abundant fast water and moderate slow water. Aquatic habitat in the lower section of the

reach includes slow water formed by two dammed pools formed by LWD debris jams. The channel substrate includes gravels that are suitable for coho spawning. The middle section of this reach consists of a series of three cascade step-pools formed by concrete step weirs. These protect a sewer pipe and control bed scour. The right bank is armored with large riprap to protect a sewer pipeline. High flows appear to have scoured away gravels and the entrenched and confined stream channel cannot meander and recruit gravels from lateral scour. As a result of these features this section of the reach is highly constrained and functionally non-alluvial. The weirs probably present a barrier to juvenile migration. The upper section of the reach parallels 1st Avenue South. This is a fast water riffle and the channel substrate consists of abundant gravels that are moderately embedded with sands and silts. A sewer manhole is submerged in the stream channel. Riparian shade and cover were good throughout this reach with mixed deciduous and sparse coniferous cover. LWD quality and abundance was high at the lower end, but low in the middle and upper sections.

Tributary 0354

This is a perennial tributary that drains Lake Burien. The mouth of this tributary has good pools, excellent spawning gravels and abundant LWD providing instream cover. Washington Trout reported a fish passage barrier approximately 600 ft from the mouth consisting of a thirty inch corrugated metal pipe culvert (Washington Trout, 2004). Numerous other fish passage barriers were reported upstream as well. Washington Trout observed coho fry.

Tributary 0371F

This tributary drains an area of commercial and light industrial development including auto repair shops and car dealerships. The Ambaum Pond in-stream Regional Detention Facility is located on the east side of 1st Avenue South. Washington Trout noted that upstream of Ambaum Pond the stream has a gradient of 1.3 percent with suitable spawning gravels consisting of forty percent gravel, forty percent cobble and ten percent mud. Riparian conditions included sparse conifer and deciduous tree cover. No LWD was present and no fish were observed (Washington Trout, 2004).

Reach 6

Reach 6 extends 1,600 feet from RM 1.8, at the outlet below the 1st Avenue South culvert to RM 2.2 below SR 509. This reach is a low-gradient, moderately-confined channel that is moderately confined by low terraces, landscaping, riprap bank hardening, weirs and culverts. The 1st Ave South culvert is a 108-inch, bolted culvert that extends 320 feet and is bowed (Washington Trout, 2004). The culvert is not countersunk in gravel, there are no baffles, and it presents at least a seasonal (summer low-flow) barrier to both adult and juvenile fish. At the upstream end of the reach there are four weirs constructed of concrete or concrete-filled sandbags (Washington Trout, 2004). These weirs may be passage barriers to juvenile fish. Miller Creek passes under SR 509 through a 150-foot long, 72-inch culvert that is 50% filled with sediment (Washington Trout, 2004). Aquatic habitat consists of fast bed-form of this reach and is predominantly plan-bed. Substrate consists of large rip-rap and high

amounts of sands, silts, and mud. Riparian cover consists of moderate deciduous cover, shrubs, and grasses associated with urban landscaping, and invasive blackberries and grasses. LWD is very low, with some patchy accumulations of limbs, brush, and urban trash. There are no known fish barriers in this reach. The stream has an average gradient of less than one percent and a low sinuosity of 1.2. Washington Trout found juvenile coho and coastal cut-throat.

Tributary 0317S

This tributary extends from the confluence with Miller Creek approximately 350 feet to a perched concrete culvert located that appears to discharge from a curtain drain somewhere under or east of SR 509. Riparian conditions consisted of moderate deciduous shrubs providing approximately sixty percent cover and invasive blackberries. Aquatic habitat consisted of slack water glides. Substrate consisted of high amounts of sands, silts and mud. Washington Trout reported cold water (54 degrees F) and both coho fry and adult coastal cut-throat trout (Washington Trout, 2004).

Reach 7

Reach 7 extends from RM 2.2 below SR 509 to South 160th Street at RM 3.1. The stream crosses under Des Moines Memorial Drive through twin six foot CMP culverts. Evidence of herbicide use to control blackberries was observed by Washington Trout. This reach is a 4292-foot long low-gradient, medium floodplain channel with a moderate sinuosity of 1.2 and an average gradient of one percent. The channel is predominantly unconfined except where bank armoring, culverts, or dredging have occurred. Aquatic habitat consists of alternating slow water pools and fast water riffles. The channel substrate consists of moderate amounts of gravel and gravel embedded with high amounts of sands and silts. Riparian cover consists of abundant deciduous tree and shrub cover and invasive blackberries. Washington Trout (Washington Trout, 2004) observed a cut-throat redd and numerous cut-throat fry, as well as coho fry. No fish barriers exist, although there are three concrete bag weirs located east of Des Moines Memorial Drive South that are probable barriers to juvenile migration.

Wetlands

Approximately 34 wetlands totaling 53.74 acres have been delineated (Parametrix < 2001) within the subbasin boundaries of Reach 7. These include forest, scrub-shrub, and emergent classes (Cowardin, 1979) of wetlands.

Tributary 0317G

This tributary is entirely located on the right bank of Miller Creek. It extends 1600 at a less than one percent gradient, terminating at a culvert located at 160th Street. Washington Trout (Washington Trout, 2004) found sea-run cut-throat using the lower part of this tributary and related that local neighbors had historically observed salmon farther upstream until the headwater wetlands were filled. Observations indicate the localized use herbicide use on riparian blackberries.

This stream had cold water (9.5 C) indicating that groundwater is discharging into it. Riparian cover consists of patchy deciduous and conifer trees, with abundant wetland shrubs and grasses, and invasive blackberries and grasses. This tributary is fringed by 2.8 acres of palustrine forest/scrub-shrub/emergent wetlands including wetlands A17b, A17c, and D (Parametrix, 2001).

Tributary 03171K

This tributary drains wetland R15a, a 0.79 acre forested/scrub-shrub/ emergent wetland (Parametrix, 2001).

Tributary 03171U

This perennial tributary drains through a series of wetlands approximately 600 feet upstream of the mouth. Substrate consists of sands, silt, and mud. Riparian cover is poor, consisting of invasive shrubs and grasses; much of the channel is choked with vegetation. No LWD is present. Washington Trout found coho and cut-throat (Washington Trout, 2004).

Tributary 03171L

This is a perennial tributary located on the left bank. It drains STIA wetland 37a, a 5.7 acre palustrine forested/emergent wetland (Parametrix, 2001 #31). Riparian cover consists of moderate deciduous, invasive blackberries and grasses. No LWD is present. No fish barriers were observed.

Tributary 03171M

This is a tributary to 03171L that drains STIA wetland 37a (Parametrix, 2001 #28).

Tributary 03171N

This tributary drains STIA wetlands 18, a 3.44 acre palustrine forested/scrub-shrub/emergent wetland and wetland 37a, a 5.7 acre palustrine forested/emergent wetland (Parametrix, 2001 #28). Riparian conditions consist of moderate deciduous and abundant invasive blackberries (Washington Trout, 2004).

Reach 8

Reach 8 is located entirely on STIA property and extends from RM 3.1, south of South 160th Street, to RM 3.4, south of South 156th Way. This reach is a 1,300-foot long low-gradient confined channel with an average gradient of 1.9 percent. Aquatic habitat consists of fast water, with some large scour pools. Channel confinement is high due to incision, bank hardening, and road crossings. The channel substrate consists of moderate amounts of gravels that are embedded with sand and silts, and moderate amounts of sands and silts.

Riparian cover consists of patchy deciduous shrub and tree cover and a moderate abundance of invasive blackberry and grasses. Near the head of this reach there is a 5.4 foot nick point waterfall that is passable to adult sea-run cut-throat (Bowles, 2003) but a barrier to juvenile fish. Washington Trout found abundant

cut-throat and coho (Washington Trout, 2004) in the plunge pool below this waterfall.

Wetlands

Approximately 11 wetlands totaling 1.27 acres have been delineated (Parametrix, 2001) within the sub-basin boundaries of Reach 8, including forest, scrub-shrub, and emergent classes (Cowardin, 1979) of wetlands.

Reach 9

Reach 9 extends 3,250 feet from RM 3.4, south of South 156th Way, to RM 4.2 north of SR 518, where Miller Creek forks. Although the east fork (0371) is typed as the Miller Creek mainstem (Williams et al., 1975) it drains a smaller contributing basin and is not perennial. The western fork (0376) drains a larger contributing basin and is perennial and therefore is the mainstem of Miller Creek. In this basin plan, however, we have maintained the original Fisheries stream designations. Reach 9 is a low-gradient, medium floodplain channel that has an average gradient of less than 0.66 percent and is moderately confined by road crossings. Aquatic habitat consists of a few fast-water riffles but is predominantly slow-water glide habitat. The channel substrate consists of sands and silts. Riparian cover consists of patchy deciduous shrub and tree cover and a high abundance of invasive blackberry and grasses. No fish barriers exist. Washington Trout found both cut-throat and coho (Washington Trout, 2004). The upper section of this reach supports a mosaic of wetlands, including wetlands 4,5,6,7,8 and 9 that comprise over 25 acres of forested/scrub-shrub/emergent habitats.

Tributary 03171P

This is a low-gradient tributary that provides rearing habitat. It is fringed by wetland A1, a 5.59-acre forested/scrub-shrub/emergent wetland that includes Lora Lake. Washington Trout found coho and cut-throat (Washington Trout, 2004). Riparian cover is low, consisting of patchy shrubs, invasive blackberry, and grasses.

Lora Lake

Lora Lake is a 3.06-acre lake on STIA property. Washington Trout noted elevated temperatures and low-flow fish passage barriers at the lake outlet (Washington Trout, 2004).

Lake Reba Stormwater Facility

Lake Reba Stormwater Facility functions as a stormwater detention facility for STIA. It is a fish passage barrier.

Reach 10

Reach 10 (WRIA 08.0376) is the west fork of Miller Creek. This reach extends 4,550 feet from RM 4.2 north of SR 518 to RM 5.1 east of SR 509. The downstream 150 feet of this reach is piped underneath a storage business. This is probably a permanent year-round barrier to anadromous fish passage

(Washington Trout, 2004). The inlet to the underground pipe is located on the west side of Des Moines Memorial Drive South. Between South 144th Street and South 140th Street there is a 2-3 acre palustrine/scrub-shrub/ emergent wetland that is moderately well connected to approximately 1,250 feet of Miller Creek. This reach is low-gradient, moderately-confined channel with an average gradient of less than 1.3 percent. The channel is moderately entrenched due to downcutting. Urbanization has confined the channel through ditching and bank hardening. There are few pools in this reach; aquatic habitat consists of fast-water runs. The channel substrate consists of small amounts of gravels found primarily at culvert outlets, and high amounts of sands and silts. Riparian cover consists of patchy deciduous shrub and tree cover, landscaping, and a high abundance of invasive blackberry. This reach is the uppermost limits of fish; Washington Trout found a resident cut-throat at the culvert crossing of South 140th Street.

Tributary 0371

Tributary 0371 is the east fork of Miller Creek. It extends approximately 2,259 feet to Tub Lake.

Tub Lake

Tub Lake is a 0.9 acre, palustrine unconsolidated bottom wetland.

Reach 11

Reach 11 (0376) extends approximately 3,600 feet from the north side of SR 509 to Arbor Lake. This reach includes one tributary (03719) that drains the Hermes depression. Aquatic habitat in reach 11 is severely degraded; many sections of this reach are culverted and alongside SR 509. The reach functions primarily as a drainage ditch with bed and banks lined in asphalt. For most of this reach there is little or no riparian shade or cover; what exists consists of blackberries or grass. This reach is probably a significant source of stormwater and pollutants to Miller Creek.

Tributary 03719

This tributary extends 3600 feet from the confluence with Miller Creek at the South 136th Street crossing to the Hermes Depression, located north of SW 130th Street and east of 4th Avenue SW. Hermes Depression is a 1.5-acre palustrine/scrub-shrub/open water wetland that is a closed depression. Drainage from the depression occurs via pumps and a combination of an open-channel and piped system.

Arbor Lake

Arbor Lake is a 4.5-acre palustrine open water/aquatic bed wetland. It is a King County park that is primarily managed for passive recreation.

Miller Creek Identified Problems

Streams within the Miller Creek basin, including the mainstem of Miller Creek, have been affected by development and have lost stream structure and function. Stream structure plays a significant role in providing habitat for salmonids and other organisms and is the product of interactions between stream channel geomorphology, hydrology, sediment load, and riparian vegetation. Hydrologic and geomorphic impacts are closely associated with an increase of impervious area resulting from development (Hammer, 1972; Booth, 1994; Booth, 2000; Booth, 2002). Miller Creek has been affected by development through changes in hydrology that have increased the frequency and duration of peak flow volumes; decreased summer base flow; increased fine sediment loading; increased the frequency of occurrence, concentration, and loading of organic and inorganic chemicals; increased stream temperatures; decreased connectivity between streams, wetlands and floodplains; and decreased riparian buffers. All of these changes have resulted in an overall loss of salmon habitat, species diversity, and productivity.

In order to more effectively characterize Miller Creek, sub-areas were delineated by examining patterns of hydrology, land use, road crossings, habitat characteristics, and species distributions. The five sub-areas delineated include headwater, plateau, urban, ravine, and estuary sub-areas. The headwater sub-area includes the headwater lakes and wetlands of Arbor Lake, Tub Lake, Lake Burien, and Hermes Depression, and the Miller Creek forks and tributaries to the mainstem. The plateau sub-area includes the mainstem of Miller Creek between SR 518 and SR 509. The urban sub-area extends from SR 509 to 1st Ave South, below which the ravine sub-area extends to SW 175th Street. Below this the estuary sub-area reaches to Puget Sound.

The **headwater sub-area** consists of residential land uses and an extensive road network. Miller Creek has been ditched, piped, straightened, and simplified, with stretches alongside SR 509 consisting of asphalt-lined channel. Riparian buffers are lacking or diminished in structure and function; wetlands are few, small, and poorly connected to the stream corridor. There is no evidence that anadromous salmon use this area, although one resident cut-throat trout was located at South 140th Street. Historically, this area probably supported a mosaic of small seasonal streams and wetlands. This area may have been more important as a source of summer base-flow than as habitat for resident or anadromous salmon.

A review of aerial photos showed that the **plateau sub-area** is in transition from historic recreational and agricultural uses. This area, aside from the ravine sub-area, contains the best habitat in the basin. It includes the largest contiguous area of wetlands and open water lakes in the basin. Sea-run cut-throat trout utilize small gravel patches for spawning and, along with coho salmon, rearing. Historically this area was probably a broad mosaic of braided stream channels, beaver ponds, and willows and cedar that would have provided high quality rearing habitat for coho salmon. Some wetland areas are degraded and there is a lack of riparian cover in some areas. The Port of Seattle has acquired the properties within this area to expand the airport and implement associated stream

and wetland mitigation activities. The proposed mitigation projects will include relocating reaches of Miller Creek, enhancing and creating wetlands, and restoring riparian buffers.

Intermediate between the plateau and ravine landscapes is the **urban sub-area** consisting of numerous road crossings, and residential and commercial land uses. The road crossings here present seasonal barriers to salmon migration and a source of untreated stormwater runoff into Miller Creek. Riparian buffers are small and patchy; aquatic habitat is degraded with high amounts of sediment, likely due to erosion of unconsolidated sediments caused by high flows. Invasive weeds, including policeman's helmet, hogweed, and purple loosestrife, have been noted in this area. This area provides limited rearing habitat for coho and cut-throat trout. Suitably-sized gravels for spawning are few, with coho observed spawning in the lower ravine reaches and sea-run cut-throat redds observed in random gravel patches located above Des Moines Memorial Drive. Historically this landscape was probably part of the plateau, consisting of scrub-shrub and forested wetlands.

The **ravine sub-area** is predominantly undeveloped with large parcels in public ownership. The steep valley walls have limited stream-side development, and most residences are located at the top of the valley, along the edge of the plateau. Only two road crossings exist, located at the bottom of the ravine, where they have not interrupted the downstream movement of LWD, water, and gravel. High-quality riparian conditions exist, with over eighty percent canopy cover dominated by mature deciduous red alder, big leafed maple, and black cottonwood. Coniferous trees, including western red cedar and Douglas fir, are less abundant and immature. Unfortunately, invasive weeds, including policeman's helmet, hogweed, and purple loosestrife, have also been noted in this area.

Substrate conditions include high-quality spawning gravels suitable for coho. Other areas, however, contain localized channel-bed and bank hardening. For example, in order to protect sewer trunk lines and treatment facilities, large rocks, concrete step-weirs, and concrete channel sections have been constructed. These features have constrained the stream channel and prevented the normal recruitment and trapping of stream-bed gravel. Those reaches where the channel is unconstrained include riffles and pools that provide spawning and rearing habitat for coho salmon and steelhead trout.

Aquatic habitat types consist of approximately eighty percent fast-water habitats and twenty percent slow-water habitats. LWD abundance and distribution is low, accounting for the low distribution of scour pools. Fish surveys of Miller Creek performed in 1999 (Hillman, 1999) and in 2003 (Washington Trout, 2004) revealed that the ravine sub-area supported sea-run cut-throat, steelhead, and coho salmon. Hillman (Hillman, 1999) observed both coho and chum redds in this reach. Coho salmon were predominantly hatchery stock and most abundant, with many females found to have low egg voidance.

The **estuary sub-area** is where Miller and Walker Creeks join and drain into Puget Sound. These streams have been straightened and channelized, and some areas of the historic salt-water and fresh-water marsh have been filled to create

recreational space. Riparian habitat is limited, LWD is absent, and the channel substrate is dominated by fine sediments. Invasive weeds, including policeman's helmet, hogweed, and purple loosestrife, have been noted in this area. Despite these conditions, restoration of areas of the estuary can benefit both local and regional fish and wildlife populations; chum salmon, coho salmon, and steelhead trout migrate through this area. An improvement project recently completed by the Normandy Park Community Club enhances a portion of the habitat in the estuary sub-area by removing invasive weeds, planting native vegetation, meandering the streams, adding large woody debris, and restoring salt-water and fresh-water wetland areas.

Walker Creek Characteristics

The natural habitat of the Walker Creek basin has changed dramatically over the past 100 years. The habitat that is currently available is limited and somewhat degraded, although, in general, in better condition than habitat in Miller Creek.

Estuary Subarea

There is only one reach within the Estuary Subarea, so a description of that reach (below) will serve to describe the subarea as well.

Reach One

Reach one extends from the mouth of Walker Creek upstream to river mile (RM) 0.35 at Southwest 175th Street. This reach is approximately 2050 feet long with a low average gradient of one percent. It is slightly entrenched in a broad floodplain valley with a pool-riffle bed morphology. The sinuosity of the reach is about 1.3, though this has little to do with hydrologic influence as the channel course has been manipulated extensively. The lowermost reach of Walker Creek has been manipulated such that it flows northward from its natural mouth, parallel to the beach, to intersect Miller Creek just above its mouth at Puget Sound.

This change in the stream's course adds approximately 450 feet to its length, effectively lowering the average gradient of the lower reach of Walker Creek from approximately 1.25 percent to one percent. This lengthening of the natural channel course and lowering of the effective gradient also lowers the ability of the channel to transport sediment. This contributes, along with other factors such as increased sediment supply caused by development of the watershed, to sediment deposition problems in the lower reaches of Walker Creek.

There is also a short channel connecting Walker Creek with Miller about 900 feet upstream of the Miller/Walker Creek confluence, just downstream of the Normandy Park community Center building. This connection may further dilute the sediment transport capacity of lower Walker Creek, but may also be the last remnant of the complex intertwining of the two channels that probably existed before the estuary was filled and developed.

The lower reach of Walker Creek probably has little in common with its predevelopment character. It is likely that the lower reaches of both Miller and Walker Creeks commingled extensively through their lowermost reaches prior to filling and development of their shared estuary. Analysis of historical aerial

photos suggests that most of the area west of the present site of the Normandy Park Community Center building was estuarine and that therefore both Miller and Walker Creeks reached sea level with effectively shorter channels than present.

The channel form of Walker Creek throughout the Estuary Subarea and Reach 1 is consistent with those of artificially dug or dredged channels. The channel banks are frequently vertical, the bed is relatively flat and the channel's course does not reflect hydrological influences. Lawn and landscaping is maintained to the channel's edges through much of the reach. There is little or no large woody debris and few hydraulically maintained pools.

The confluence of Walker Creek with Tributary 09.0371i is immediately downstream of 13th Avenue SW/SW 175th Street, where the culverts conveying the two streams empty into a large pool. This pool, however, like most of the reach downstream, is almost completely lacking in cover and complexity.

Ravine Subarea

The Ravine Subarea of Walker Creek encompasses four reaches (2, 3, 4 and 5). The ravine descends from the plateau, at an elevation of around 200 feet, down to the estuarine area beginning at an elevation of about twenty feet. The average gradient of the subarea is about 3.1 percent, though this is not consistent throughout the subarea; the channel "stairsteps" down through the ravine, losing elevation rapidly and then flattening out, then repeating. Most of the Ravine Subarea of Walker Creek is well forested.

Reach Two

Reach two extends upstream from the crossing beneath 13th Avenue SW/SW 175th Street. at RM 0.38 to RM 0.6. The sinuosity of the reach is just slightly over one and the average gradient is approximately 1.6 percent. Access to this reach for purposes of habitat and channel assessment was very limited by property owners. However, observations that were permitted revealed a fairly wide and shallow channel showing signs of gravel deposition and good spawning potential. The riparian areas are well vegetated with mature and semi-mature trees, though mostly deciduous. LWD is sparse. The reach is somewhat buffered from the adjacent residences, though the ravine walls are not nearly as steep as above.

Reach Three

Reach three extends approximately 2,000 feet upstream and is characterized by the depth of the ravine that buffers it from the neighboring residences and the sewage treatment plant. The average gradient is approximately 4.25 percent and the sinuosity is very low, as would be expected in a confined ravine reach. Reach Three contains perhaps the highest quality habitat in Walker Creek. The riparian areas are well vegetated with a mix of mature deciduous and coniferous trees; moderate to high quantities of large woody debris that is integrated into the streambed and forms pools and traps sediment. In places the streambed has been scoured down to a layer of till. However, this is accompanied by only minor bank erosion or failure. Numerous adult coho salmon were observed spawning

and holding in this reach. A small slope failure is located on the right bank near the upper end of this reach, opposite the lowermost of several residences that encroach on the left bank buffer, mostly in Reach Four (see below). The slope failure is a minor source of sediment, but probably not significant in the overall sediment budget of the system.

Reach Four

Reach Four is characterized geomorphically by an easing of the slopes of the ravine, accompanied by increased residential encroachment into the left bank buffer. The reach is about 1,325 feet in length, has an average gradient of 3.4 percent and little sinuosity (1.02). Instream habitat is less complex than in the reaches upstream or downstream, with less woody debris and fewer pools. The left bank buffer is less vegetated, with residential yards and landscaping occasionally reaching the streambanks. Invasive plant species such as blackberry and Japanese knotweed are pervasive, especially near the lower end of the reach. The reach appears to be something of a geomorphic anomaly in that the channel is almost perched on the wall of the much larger and deeper Miller Creek ravine just to the north. A small rise of perhaps ten vertical feet separates the two drainages here.

Reach Five

Reach Five is located at the top of the ravine and is approximately 1,200 feet in length. At its head, the channel plunges steeply into the ravine and then swinging in a wide arc to the left of almost 180 degrees. Most of the elevation loss in the reach occurs at the head; the channel then proceeds at a fairly flat gradient (about one percent) for the remainder of the reach. The upper portion of the reach abuts the embankment below 1st Ave South on its right bank. Much of the channel in this reach is scoured to the till layer and has very steep banks. Riparian vegetation is mostly deciduous with some invasive blackberry. Few pieces of LWD are in the channel.

Upland Subarea

The Upland Subarea of Walker Creek is characterized by its urbanized surroundings, low gradient and two wetlands, one of which is quite large and of notably high quality, considering its urban location. The Subarea is divided into two reaches: the first, Reach 6, extends from the top of the ravine upstream to the outlet of the fen wetland and the second, Reach 7, includes the fen and the short reach to the headwaters.

Reach Six

Reach Six encompasses approximately 4,100 linear feet of low-gradient (0.7 percent) channel that meanders through backyards, along road shoulders, through several road culverts and numerous driveway culverts as well as the occasional forested patch and a relatively large wetland complex (King County Wetland #16, class 2). Several of the road and driveway culverts are obviously undersized and have sand and silt deposits upstream of their inlets. Riparian vegetation is predominantly immature and deciduous and often exotic;

landscaping frequently extends to the streambanks. In many areas, the channel has obviously been channelized or manipulated, including the short stretch through Wetland #16. The substrate is predominantly sand or silt, and occasionally gravels, usually “cemented” or embedded in smaller-sized. There is very little LWD in this reach, though there are some large pools, mostly associated with culverts

Reach Seven

Reach Seven encompasses the large (19 acre) wetland (King County Wetland #19, class 1) just east of Des Moines Memorial Way, the culvert beneath Highway 509 that drains into the wetland, and the short channel reach on Port of Seattle property to the east of Highway 509. The reach is about 2,750 feet long and of low gradient (one percent). The wetland probably has a moderating effect upon the hydrology of the system, attenuating peak storm flows and providing significant detention. Some portions of the reach, especially the upstream sections near Highway 509, have excellent riparian cover. The culverts beneath Highway 509 are probably barriers to upstream migration; however, no substantial fish habitat is present upstream of the headwater wetland due to channel slopes and water depths. The stream sections upstream of Highway 509 flow through abandoned homesites with the remnants of landscaping slowly being overgrown in their riparian areas.

Walker Creek Tributaries

Walker Creek has two principal tributaries (0371H and 0371E) and two seasonal tributaries (0371B and 0371C), as well as three much smaller headwater reaches whose confluence just above and below Highway 509 forms the mainstem of Walker Creek (and which will not be treated separately here).

Tributary 0371H

Tributary 0371H was observed by Washington Trout in May, 2003. The stream is described as, “a very nice stream with fairly good fish habitat.” Gradients are less than five percent, substrate is mostly gravel suitable for spawning and 35 to forty percent of the instream habitat is pool. Riparian cover is estimated at seventy percent and composed of a mixed deciduous and coniferous composition. Coho salmon fry and trout were observed almost up to the SW 174th Street culvert, approximately 950 feet upstream of its confluence with the mainstem of Walker Creek at the culverts beneath 12th Avenue SW. This reach of the tributary flows through a small ravine that buffers it from the residential development on either bank. The culvert beneath SW 174th Street is probably a barrier to upstream fish migration (1.1-foot perch at the outfall and 28 percent gradient). Electrofisher sampling upstream of the culvert yielded no fish. A small tributary about 400 feet in length joins the stream from the east (right bank) just upstream of the SW 174th Street culvert. This tributary passes through landscaped yards and driveway culverts and leads to the City Hall Park ballfields. Upstream of the SW 174th Street culvert, Tributary 0371H shows signs of incision and downcutting as it flows between residences and City Hall Park. A six-inch pipe—possibly a sewer line—crosses the channel about 150 feet upstream of SW 174th Street and collects debris, forming a dam with a 2.8-

foot drop. The stream's origin appears to be about 700 feet upstream of the SW 174th Street culvert.

Tributary 0371E

Tributary 0371E joins the mainstem of Walker Creek from the south within Wetland #16, just east of 1st Avenue South. Access to this stream was limited. The reach within Wetland 16 was well vegetated, though mostly with deciduous trees. Substrate is primarily sand and silt, with some small woody debris. Gradient is low, around one percent. The stream enters the wetland via a 48-inch culvert beneath South 174th Street. This culvert appears to be quite long and probably a barrier to fish migration upstream. The stream was not observed upstream of the culvert.

Tributary 0371B

Tributary 0371B is a very short, steep, swale-like tributary flowing down the south wall of the Walker Creek ravine and joining the mainstem on the left bank. Its gradient prevents it from being fish-accessible. It has sparse riparian vegetation, mostly grass, and a mud substrate. This tributary could possibly turn into a sediment source to Walker Creek during a flood event or if excess drainage were directed down its course.

Tributary 0371C

Tributary 0371C rises very steeply (thirty percent) from its confluence with Walker Creek for at least 150 feet, making fish access from Walker Creek unlikely. The stream is probably seasonal in flow. Slope failure in the lower reaches appears to have eliminated any stream structure (Washington Trout). The total length of the stream is undetermined, though it does reach a culvert crossing at 4th Avenue SW.

Walker Creek Identified Problems

Walker Creek and its tributaries have lost habitat due to agricultural and urban development (Parametrix, 2001), although the degree of impact is less than in Miller Creek. The effects of development on habitat are discussed more fully in the Miller Creek Habitat section of this report.

Three Walker Creek sub-areas were delineated: upland, ravine, and estuary. The upland sub-area includes the headwater wetland and other areas contributing to flows in Walker Creek prior to its entrance into the ravine sub-area at 2nd Avenue SW and SW 168th Street. Downstream of this, the ravine sub-area extends to 12th Avenue SW. The estuary sub-area then extends to Puget Sound and is the site of Walker Creek's two points of confluence with Miller Creek. A full description of the Walker Creek wetlands and their function can be found in Parametrix (2000) and Parametrix (2001.)

The **upland sub-area** is characterized by its urbanized surroundings. The culverts beneath Highway 509 that drain into the headwater wetland are probably barriers to upstream fish passage; however due to the limited size and depth of the channel it is unlikely that this is suitable fish habitat (Parametrix,

2000, 2001, 2004). After exiting the headwater wetland, the stream meanders through backyards, along road shoulders, and through numerous road and driveway culverts, several of which were observed during field surveys to be undersized and to have sand and silt deposits upstream of their inlets. Riparian vegetation is predominantly immature and deciduous, and often exotic; landscaping frequently extends to the stream banks. In many areas, the channel has obviously been channelized or otherwise altered by homeowners (Parametrix, 2001b). The substrate is predominantly sand or silt, and occasionally gravels, usually “cemented” or embedded in smaller-sized sediments. There is very little LWD in this reach.

The **ravine sub-area** contains the best habitat in Walker Creek, but also has several problem areas. They include areas of limited LWD, erosion of the streambed down to till, and minor bank erosion or failure. Some encroachment of urban landscaping into the stream buffer is also evident. Invasive plant species such as blackberry and Japanese knotweed are pervasive.

Within the **estuary sub-area**, the channel course has been manipulated extensively. The channel form is consistent with those of artificially dug or dredged channels. The channel banks are frequently vertical, the bed is relatively flat, and the channel’s course does not reflect hydrological influences. Lawn and landscaping is maintained to the channel’s edges through much of the reach. There is little or no large woody debris and few hydraulically maintained pools. Changes to the stream have increased its length, effectively lowering its average gradient and decreasing the ability of the channel to transport sediment. This contributes, along with other factors such as increased sediment supply caused by development of the watershed, to sediment deposition problems in the lower reaches of Walker Creek.

Appendix D

**Miller and Walker Creeks
Basin Plan**

Appendix D: Summary of Hydrologic Modeling

A hydrologic model was developed as part of the analysis for the Miller and Walker Creek basin plan. The model allowed stream flows to be predicted given assumptions about land cover and rainfall. It allowed the project team to answer "what if" questions - such questions as "What would stream flows be like if this were all forest?" or "How would the stream behave if the cities and the county required a certain uniform level of detention?"

The first step in hydrologic modeling was to develop the model using HSPF (Hydrologic Simulation Program - Fortran). HSPF is a continuous time-series model that is frequently used to simulate hydrologic conditions in streams. The relationship between rainfall and stream flow was determined by assuming certain land cover and geology characteristics. In other words, assumptions about what happened to the rain when it landed on the ground were made - how much of it runs off the land and enters the stream and how much of it infiltrates (sinks into the ground). These assumptions were made based on the geology of the basin and the extent and type of development that has occurred.

Assumptions about the geology were based on geology mapping done by the United States Geological Survey (USGS) and other local studies. Assumptions about existing development in the basin were based on 1995 satellite mapping of the basin, and relationships between development type, impervious surface coverage, and runoff based on past modeling efforts. In addition, the comprehensive plans for the cities of Burien, Normandy Park, and SeaTac were examined. The *Comprehensive Stormwater Management Plan for the Port of Seattle* was also consulted. After initial modeling parameters were developed, the model was calibrated using stream flow data collected at flow gauges in the streams and rainfall data collected at precipitation gauges in the watersheds.

In Miller Creek, the model was calibrated with one precipitation gauge (gauge #42U) and two flow gauges, one near the confluence with Walker Creek (42A) and one at the outflow of the Lake Reba regional detention facility (42B). In Walker Creek, records were used from one precipitation gauge (42U) and two flow gauges, one near the confluence with Miller Creek (42E) and one just downstream of the headwater wetland (42C).

The table on the following page summarizes the gauge information.

	MILLER	WALKER
Precipitation Gauges	42U (10/94 - 9/97) At Lake Reba	42U (10/94 - 9/97) At Lake Reba
Flow Gauges	42A (10/94 - 9/97) Just upstream of confluence with Walker 42B (10/94 - 9/97) Miller Creek Regional Detention Facility outflow	42E (10/94 - 9/97) Just upstream of confluence with Miller 42C (10/94 - 9/97) Just downstream of the headwater wetland at Des Moines Memorial Drive

Gauge Records Used for Calibration

The calibration procedure consisted of making adjustments to the variables in the model to match the predicted model flows to recorded stream flows. The degree to which the model agreed with the recorded stream flows was a measure of the ability of the model to successfully predict stream flows based on hypothetical rainfall events. This level of agreement was calculated and assigned a numeric value called a correlation coefficient. For Miller Creek, the correlation coefficient for the mean daily flow was 75 percent (0.75) at the Miller Creek Regional Detention Facility (MCRDF). This means that the model can correctly account for 75 percent of the variability observed at that location. While this may not seem as high as desirable, it is a fairly typical degree of a model's predictive power in the natural environment. In the Miller Creek example, it means that the modeled results for mean daily flow may be inaccurate by approximately 25 percent at the MCRDF. The largest source of error in the model is the assumption that rainfall measured at one location, the rainfall gauge, falls uniformly across the basin. The only way to reduce the error associated with this assumption is to install a greater number of precipitation gauges throughout the basin.

The degree of variability, as represented by their correlation coefficients, is shown in the table on the following page.

	MILLER	WALKER
Mean Daily Flow	75% (MCRDF), 86% (Mouth)*	79% (DMMD), 75% (Mouth)*
Daily Peak-Hour Flow	67% (MCRDF), 75% (Mouth)*	70% (DMMD), 78% (Mouth)*

* Two values are presented because there are 2 stream flow gauges used in the calibration. For Miller Creek the flow gauges are located at the Miller Creek Regional Detention Facility (MCRDF) and at the mouth. For Walker Creek, the flow gauges are located at Des Moines Memorial Drive (DMMD) and at the mouth.

Degree of Variability (based on correlation coefficients)

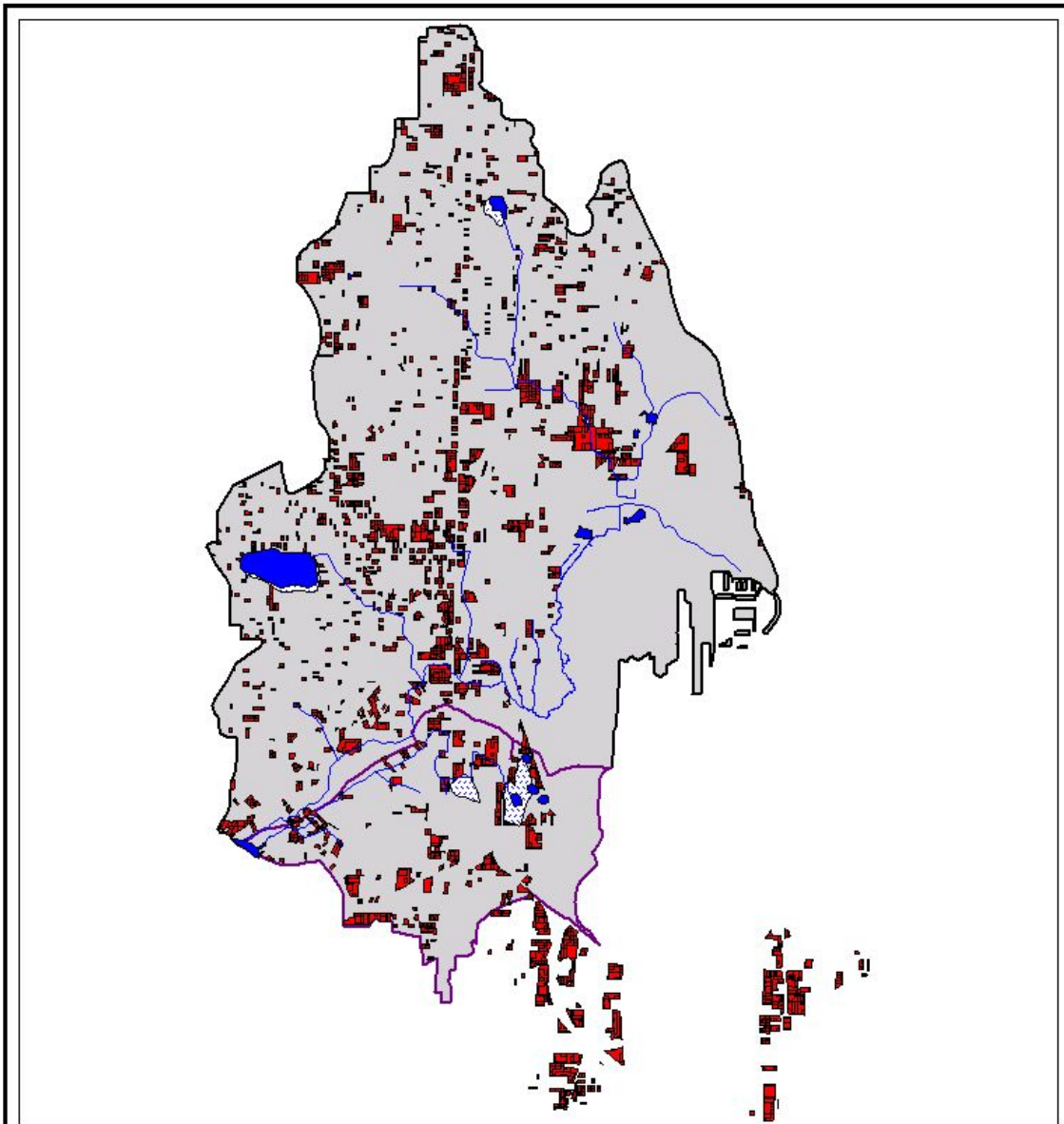
After development and calibration, the program was used to assess the response of the stream to varying amounts of precipitation under various land covers. For each model run, fifty years of rainfall was allowed to "rain" on the basins. The rainfall assumed during model runs was based on precipitation measured at Seattle-Tacoma International Airport from 1949 to 1998. The resulting data were used to generate curves showing peak flows (maximum high flows that occur during storms) and low flows [minimum flows that occur during times of no precipitation when streams rely solely on base flow (i.e., ground water)]. In addition, calculations of erosive work were performed for the Miller Creek Basin, as it has experienced historically high degrees of erosion. The same historic rainfall was used for all model runs so that a consistent, long-term basin response to precipitation could be determined.

To assess the impact of future development on the basin, assumptions were made concerning its likelihood of occurrence. Initially, it was assumed that full development would occur consistent with existing zoning. This assumption, however, led to an enormous increase in impervious surface area that appeared inconsistent with existing development patterns and rates. Instead, an analysis of development potential was done by examining the relationship between land values and improvement values. Parcels for which the improvement value was less than or equal to the land value were identified as being likely to develop in the near future. Those parcels, the "red parcels," were assumed to be developed in subsequent model runs (see **Exhibit D-1**).

Although there is no way to accurately predict exactly which parcels will be developed and when, this designation of red parcels seems to be a much more realistic approach than assuming that complete re-development of the basin under existing zoning will occur in the next twenty years.

Consultants hired by the Airport Communities Coalition reviewed the development, calibration, and early use of the model. They provided a favorable review and saw no barriers to using the model to more fully assess basin responses to potential future scenarios.

Exhibit D-1
Prediction of Parcel Development and Redevelopment in the
Miller and Walker Creek Basins



Miller and Walker Basins

Parcels Likely to Redevelop

The information included on this map has been compiled by King County staff from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or right to the use of such information. King County shall not be liable for any general, special, indirect, incidental, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.



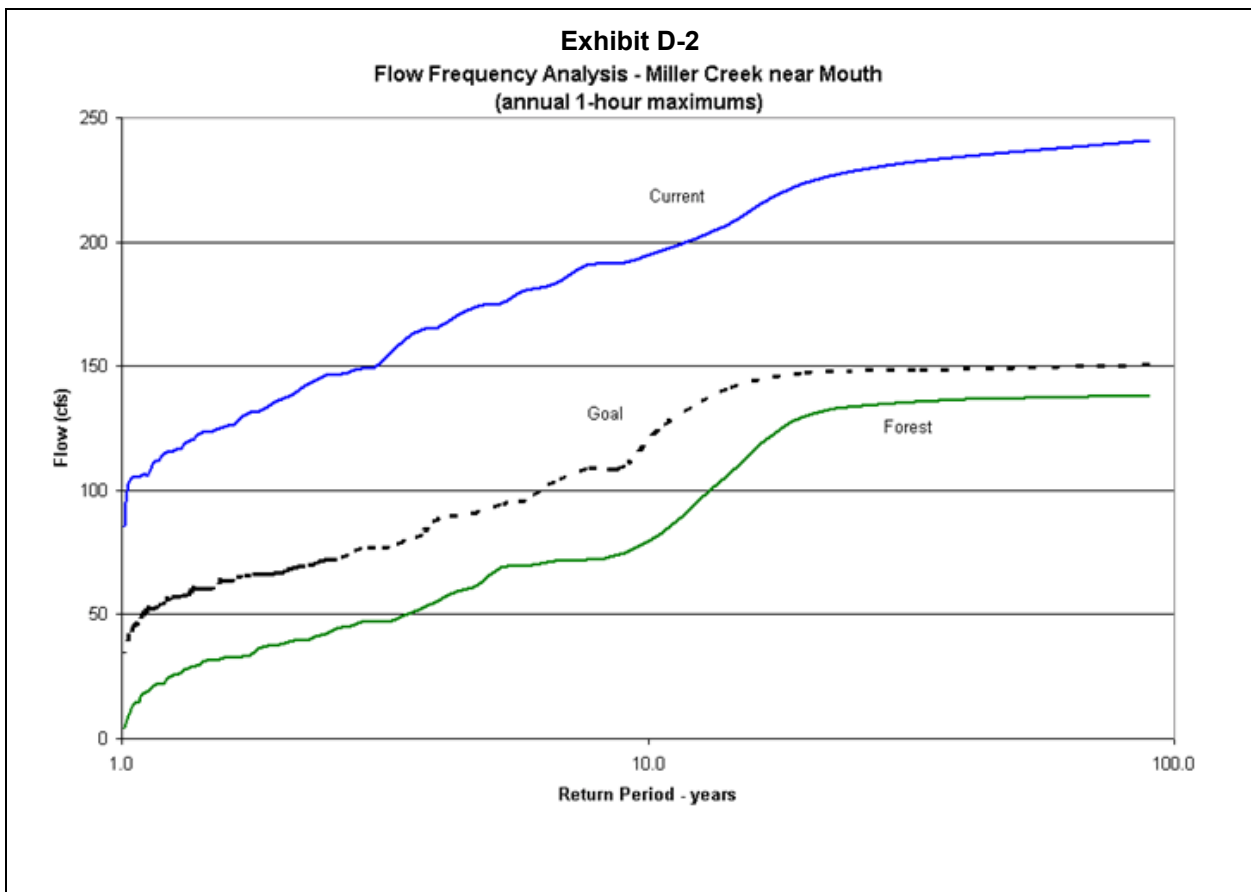
Legend

- Lakes and Ponds
- Rivers and Streams
- Wetlands
- Parcels likely to redevelop based on land and improvement values
- Walker Basin Outline
- Miller Basin Outline

A number of model runs for each of the basins are presented below. Each figure is accompanied by a summary of what the modeling scenario shows. A key describing the assumptions of each run is also included.

Miller Creek: Analysis of Peak Flows

Exhibit D-2 shows peak flows near the mouth of Miller Creek under fully-forested and existing conditions. In addition, a goal flow is shown that represents a basin-wide land cover of 75 percent forest, 15 percent grass, and ten percent impervious surface. The figure shows that peak flows in the basin are much higher now (Current) than they were prior to development (Forest). The increase has ranged from approximately 70 to 1600 percent, with the largest increases occurring with more frequent storms (those with smaller return periods).



Under forested conditions, the range of storm flows expected would be approximately six cubic feet per second (cfs) for a 1-year return period (a storm flow likely to occur on average once every year) to 140 cfs for a 100-year return period (a storm flow likely to occur on average once every one hundred years). Under current conditions, storm flows range from approximately 95 cfs to 240 cfs for the 1-year to 100-year return periods. The goal flows for the 1-year to 100-year return periods of 40 cfs to 150 cfs

represent an approximate reduction of 40 to 60 percent relative to current flows.

Exhibit D-3 shows the same peak flow information for Miller Creek at the Miller Creek Regional Detention Facility (MCRDF). Under forested conditions peak flows would vary from approximately 2.5 cfs to 60 cfs, while under current conditions the peak flows vary from about 30 cfs to 75 cfs. The goal flows represent a 12 to 50 percent reduction relative to current flows.

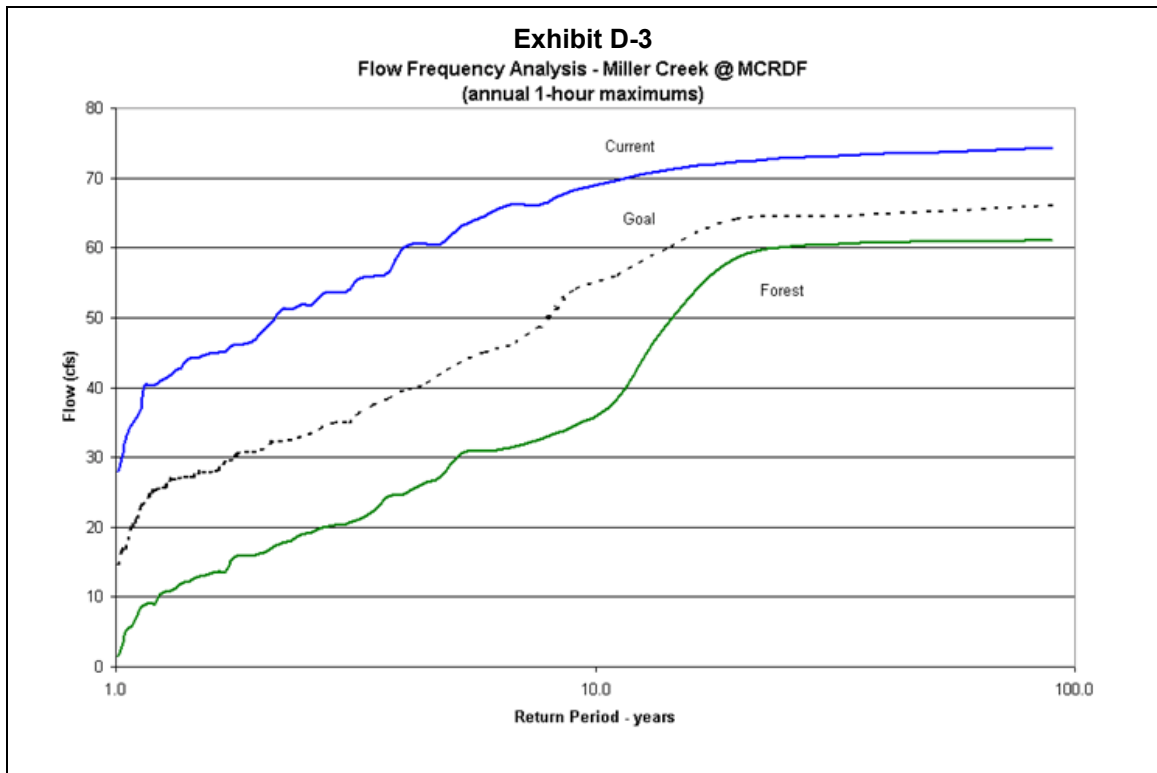


Exhibit D-4 depicts the effect of two different storm water regulations on peak flows near the mouth of Miller Creek. If a Level 1 (maintains the predevelopment peak flow rates for the 2-year and 10-year runoff events) detention standard is used for the red parcels [except for the Port of Seattle that is required to use Level 2 (75/15/10 - maintains the duration of high flows to their predeveloped levels which in this case is 75% forest, 15% grass, and 10% impervious)], it does little to reduce the peak flows below current levels.

A Level 2 (Forest) detention standard for the red parcels [except for the Port of Seattle that is required by DOE to use Level 2 (75/15/10)] does measurably reduce peak flows, but still does not attain the goal flow. This modeling run suggested that a Level 2 detention standard should be used instead of a Level 1 standard.

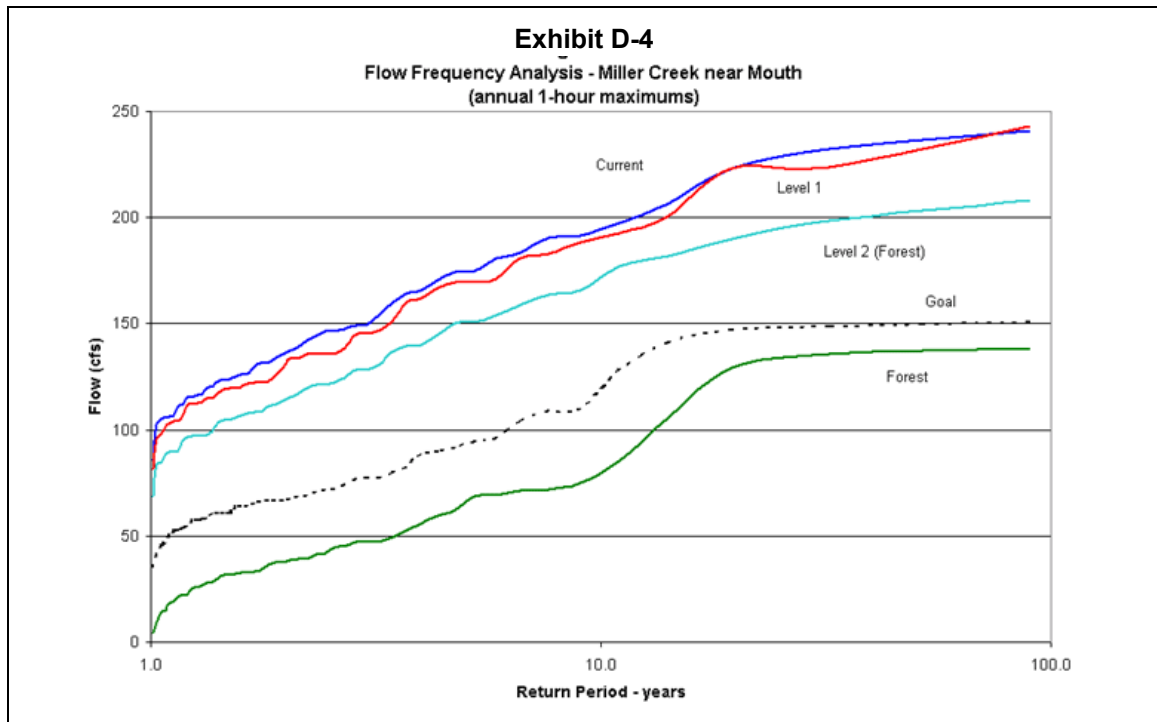
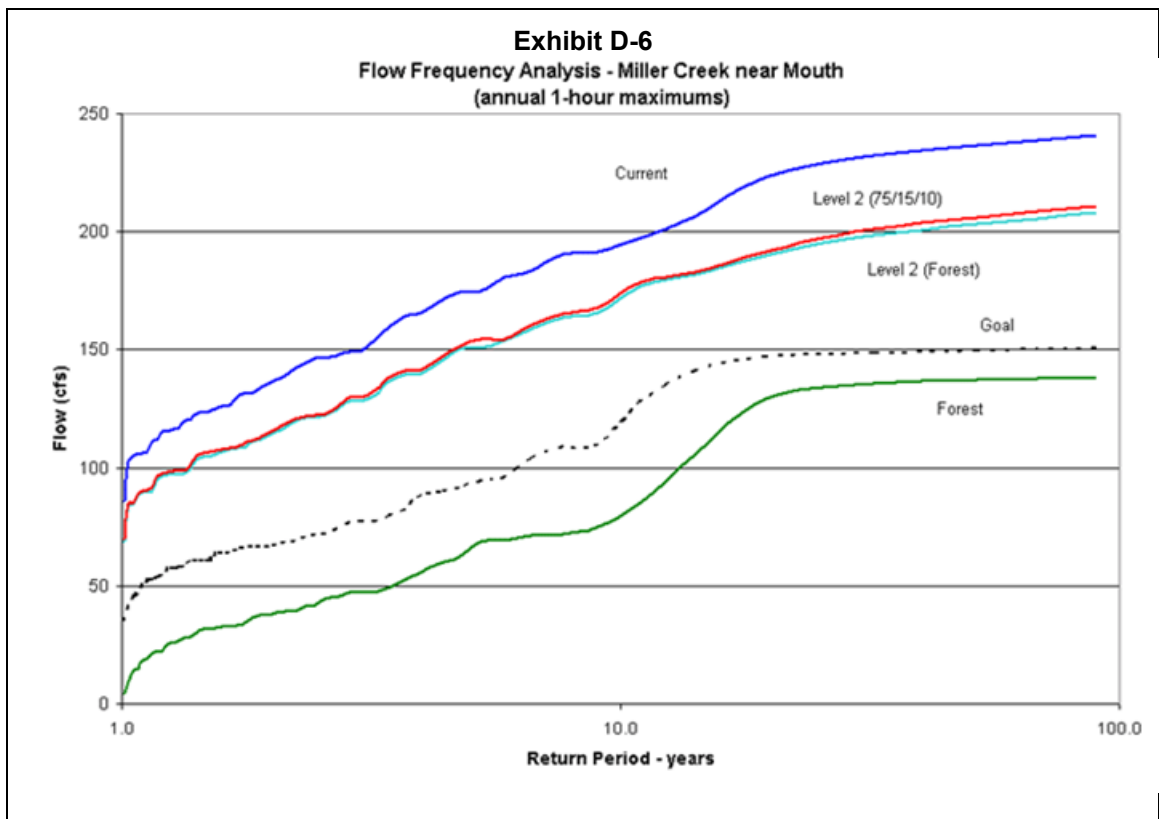
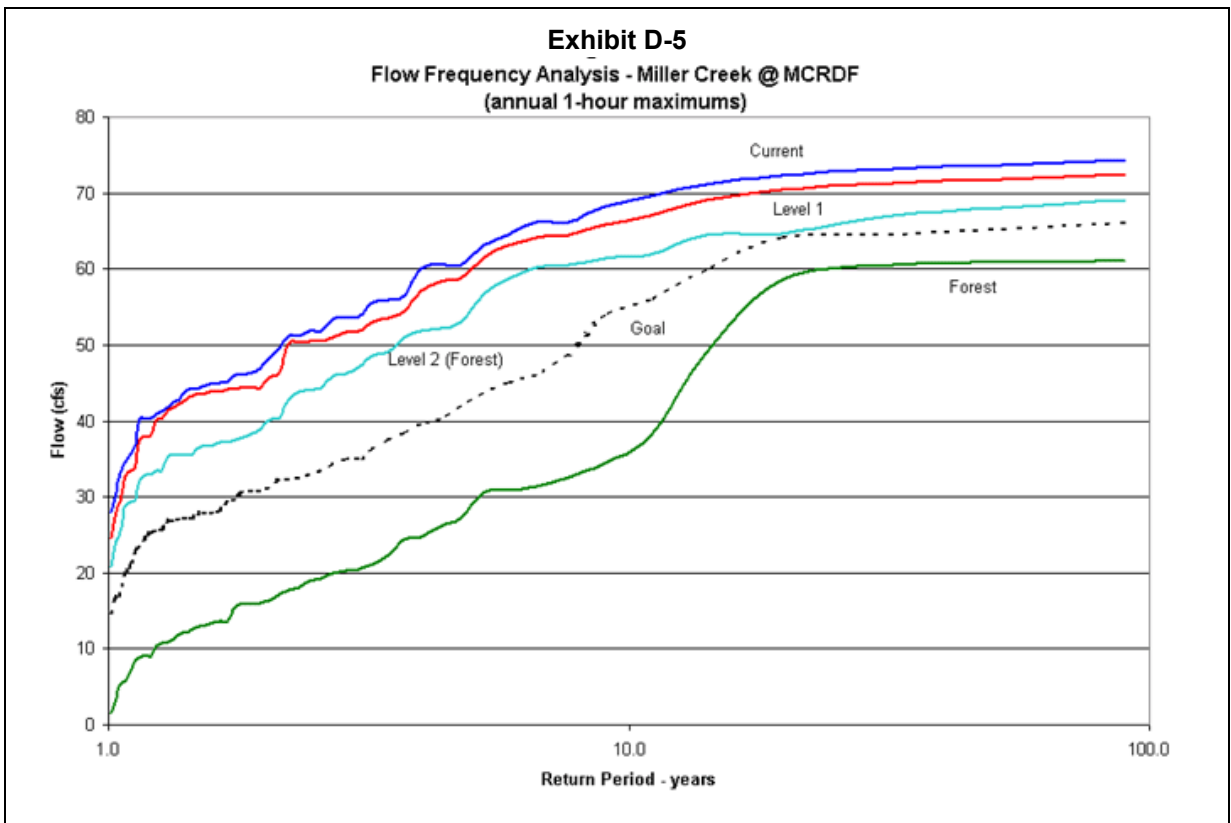
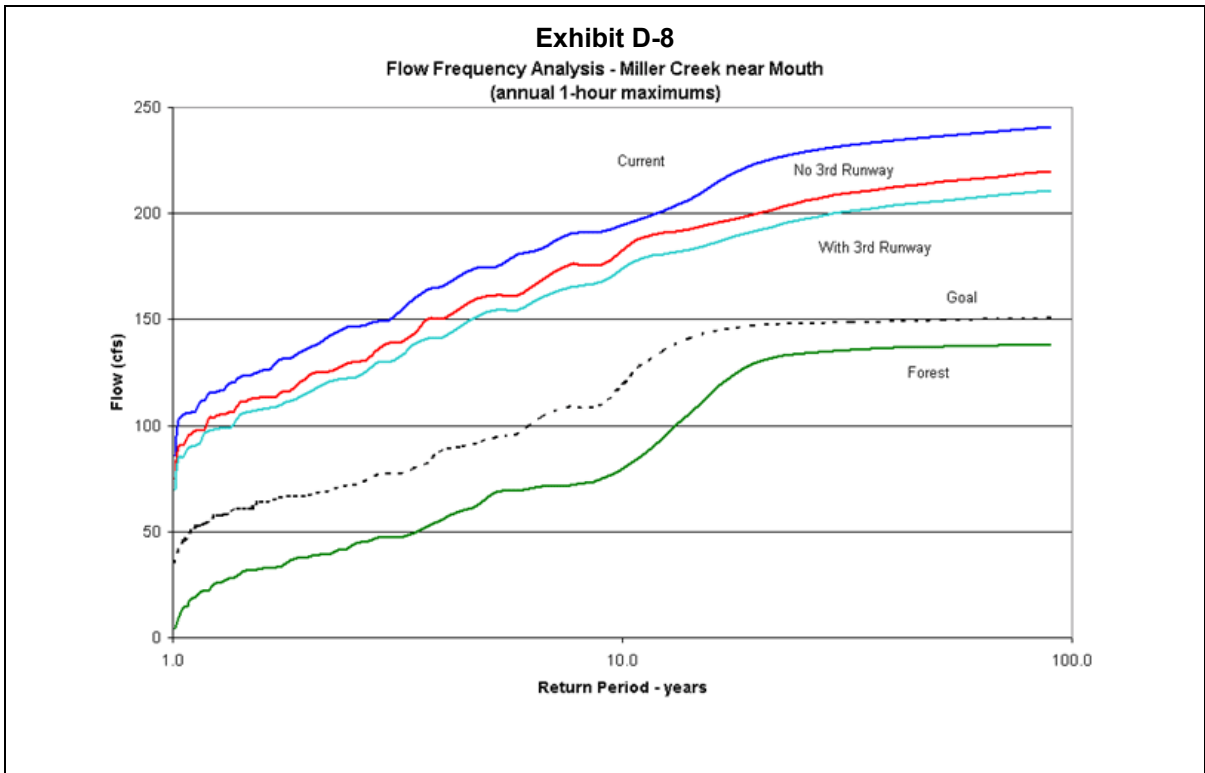
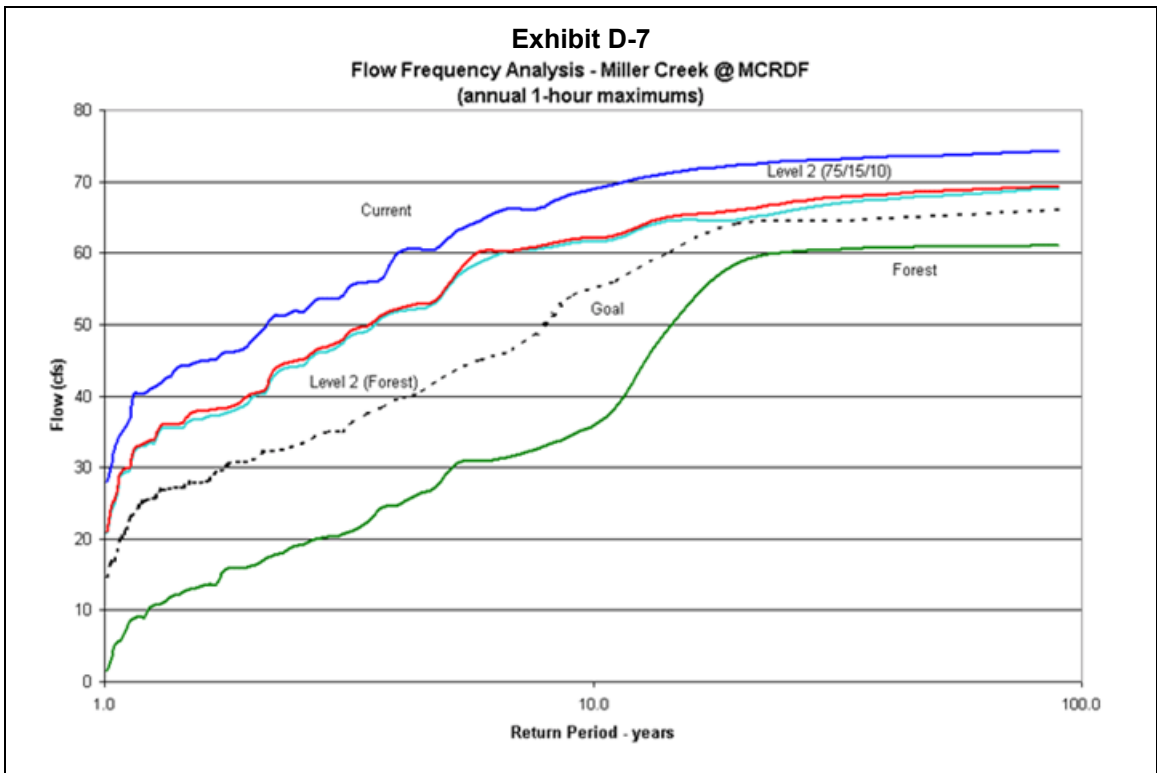


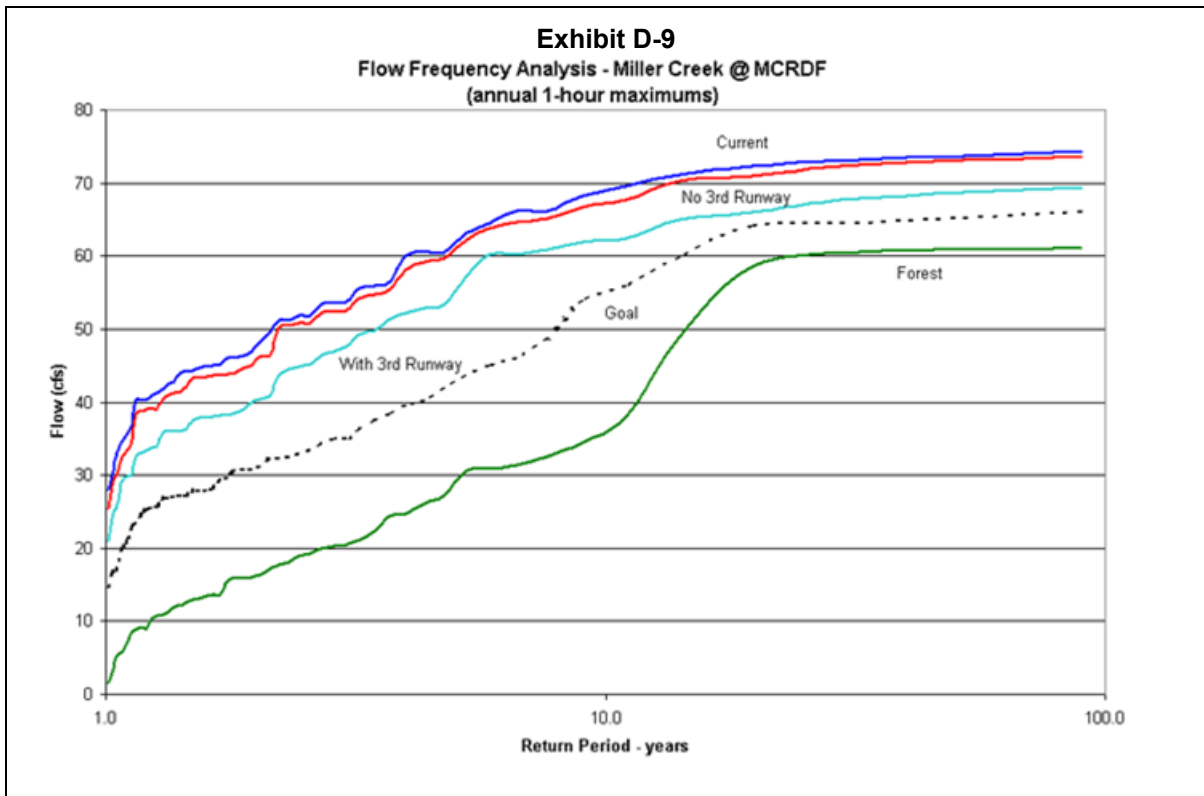
Exhibit D-5 compares Level 1 and Level 2 detention standards for Miller Creek at the MCRDF. Again, this modeling run suggests that Level 2 detention standards are preferable, although unable to achieve the goal flow.

Exhibits D-6 and D-7 compare two different Level 2 detention standards, the typical Department of Ecology Level 2 (Forest) standard versus the Level 2 (75/15/10) standard approved by Ecology for use by the Port of Seattle. The different standards produce nearly identical results. This was an important finding as the Level 2 (75/15/10) standard will be much more affordable for red parcel developers to meet than the Level 2 (Forest) standard. Also, it did not seem equitable to hold differing developments in the basin to differing detention standards. Because Ecology has already approved such a standard for the Port of Seattle, there is precedent to apply it to the basin as a whole, although Ecology would need to approve of such an application.

Exhibits D-8 and D-9 explore the impacts of the proposed third runway and its associated mitigation on the peak flows in Miller Creek. What is found is that the peak flows will actually decrease in Miller Creek due to construction of the third runway and its association mitigation. This is because the detention standard required by Ecology for the Port is a Level 2 (75/15/10) standard. This standard is also being applied to older areas not currently providing detention or treatment of surface runoff. This is a restorative standard that improves hydrologic conditions over those caused by current land use that is more developed than 75 percent forest, 15 percent grass, and ten percent impervious surface. Because the proposed runway is a large red parcel, mitigation of flows from it cause a relatively large positive effect on peak flows. This analysis underscores the importance of the Port fully and effectively implementing its required mitigation.







Exhibits D-10 and D-11 examine the effects of additional storm water detention facilities on peak flows at the mouth and at the MCRDF, respectively. The detention option meets the goal flow at the lower end of the peak curve for the mouth while exceeding the goal flow at the MCRDF where it provides more forest-like flows. **Exhibit D-11** shows that the proposed detention facility expansion at the MCRDF will need to be evaluated over time to ensure that its greatly reduced flows relative to forested conditions do not cause excessive accumulations of fine materials. If necessary, operation of the facility could be modified to more closely match forested flows. While there are other potential detention options in addition to those considered in this modeling run, the important point is that approximately 65 acre-feet of additional storm water detention in the basin can achieve the goal flow at the mouth of Miller Creek.

Analysis of Erosive Work

Field investigations revealed that Miller Creek has experienced severe erosion in many areas. Part of the flow control strategy in this basin plan is to reduce erosion in the stream. To analyze the ability of the various peak flow reduction strategies (discussed above), a measure of mitigation of erosive work was developed. First, the erosive work on the stream was calculated for the range of flows expected under each scenario presented above. Then, the percent of mitigation of erosive work for any particular flow reduction option was expressed as the following ratio:

$$\frac{\text{(Erosive Work for Scenario X)}}{\text{(Erosive Work for Forested Scenario)}}$$

Where Scenario X is one of the peak flow reduction scenarios described above.

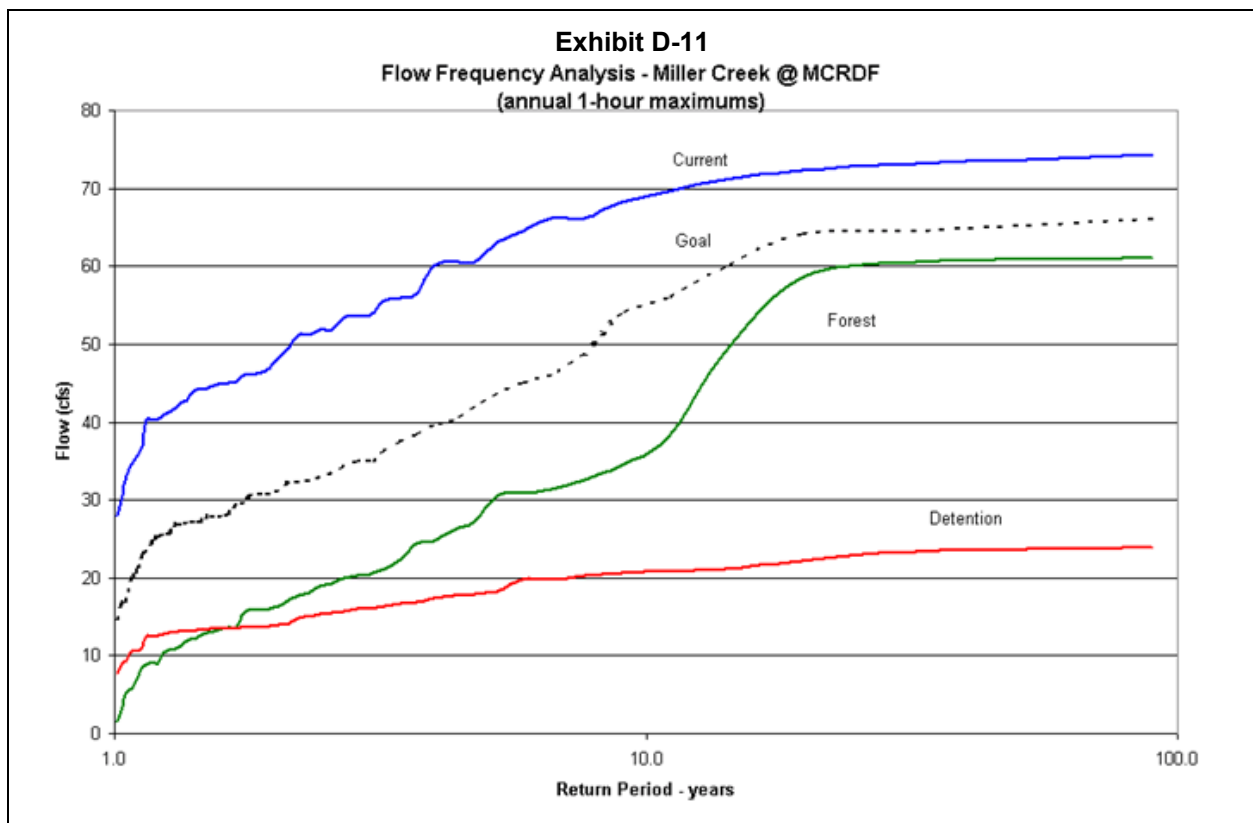
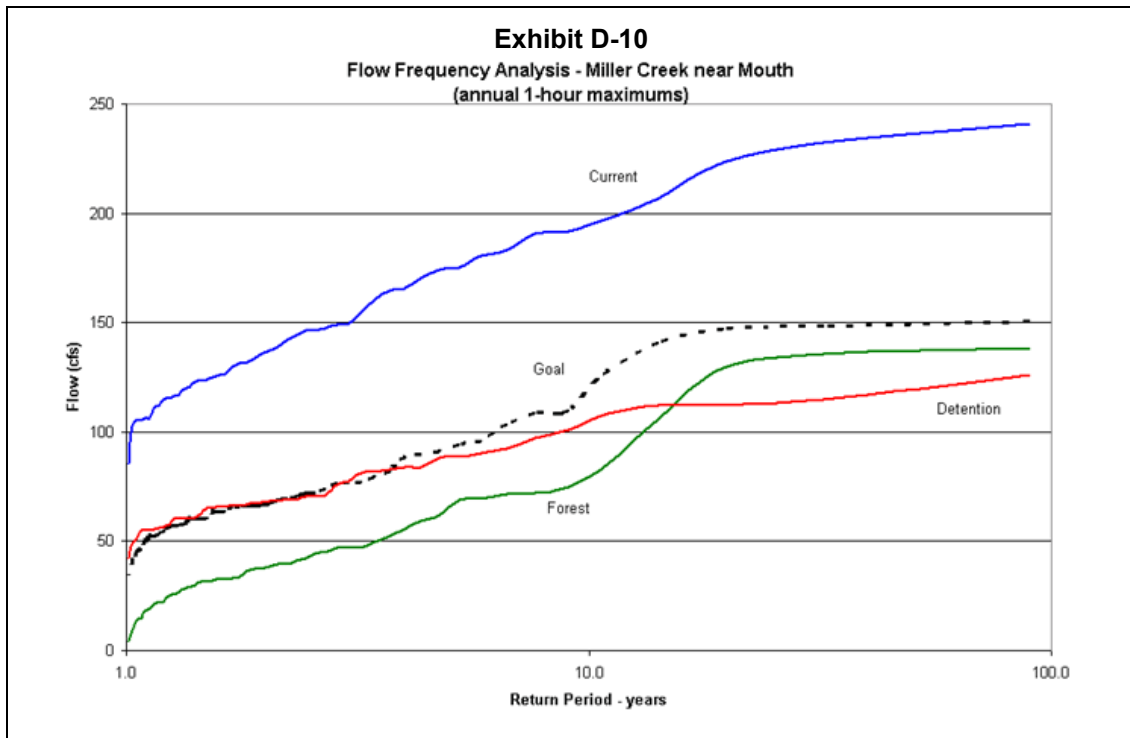
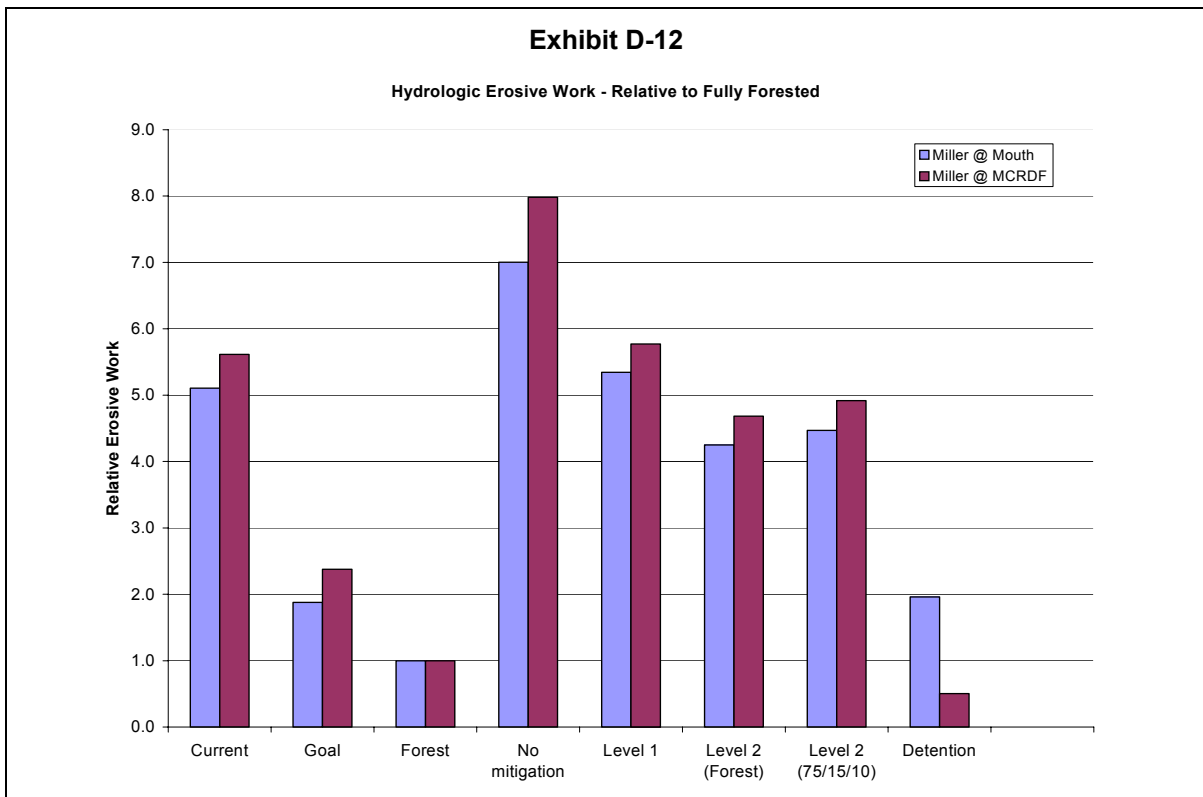


Exhibit D-12 shows the results of the relative erosive work analysis for Miller Creek. With the fully forested condition being the basis for comparison the other scenarios are shown as ratios. The no mitigation scenario sees 600 percent more erosive work than the forested condition at the mouth of Miller and 700 percent more at the MCRDF. Under current conditions the amount of erosive work is approximately 400 and 450 percent greater than the forested condition at the mouth and MCRDF, respectively. Under the goal regime, the amount of erosive work is almost 100 percent greater than the level of the forested scenario at the mouth of Miller Creek and approaches a level of 150 percent that of the forested scenario at the MCRDF. None of the regulatory measures alone will achieve erosive mitigation equivalent to the goal flow. The Level 1 and Level 2 detention regulations will achieve less than half of the erosion mitigation of the goal flow regime. Note that the Level 2 (Forest) and Level 2 (75/15/10) detention standards achieve essentially identical degrees of erosion mitigation, over 300 percent the level of fully forested.. The detention option, however, which includes Level 2 (75/15/10) detention standards and 65 ac-ft of additional detention in the basin, does a good job of approximating the goal. The goal is exceeded for erosive work at the MCRDF by about 50 percent. In fact, the detention option has more erosion mitigation than even the forested option which is necessary to achieve the goals at the mouth. Erosive work at the mouth is greater under the detention option than the goal. While not a perfect match to the goal, the detention option does provide enormous benefits relative to the current degree of erosion.



Analysis of Low Flows

Exhibits D-13 and **D-14** show the results of the low flow analysis. Although no problems relative to low flows have been reported in Miller Creek, there are reductions in low flows due to development. **Exhibit D-13** shows that low flows at the mouth have been reduced by up to about 15 percent relative to fully-forested conditions. There is essentially no difference in the low flows expected under various regulatory scenarios (current, Level 1, and Level 2) - the multiple curves representing these scenarios are shown as one line. Figure **Exhibit D-14** shows a similar situation. Low flows at the MCRDF have been reduced by up to about forty percent. There is essentially no difference in low flows due to regulatory differences; therefore, only a single line is shown to represent current, Level 1, and Level 2.

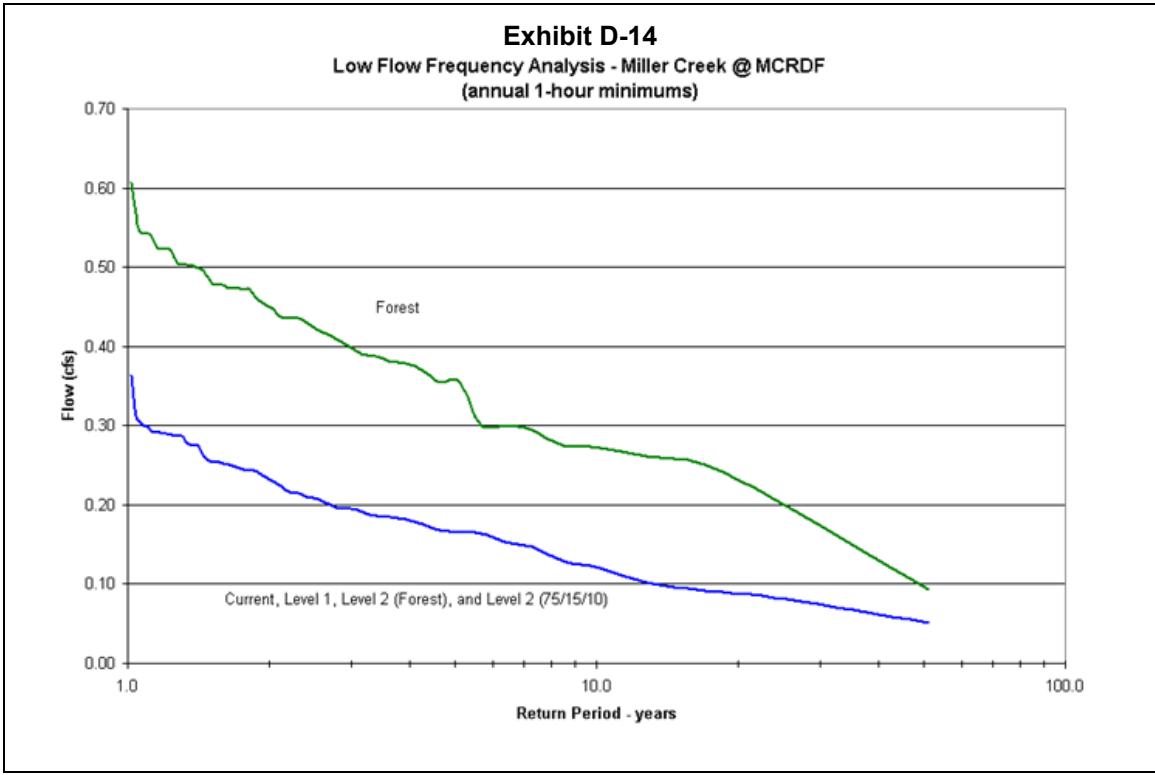
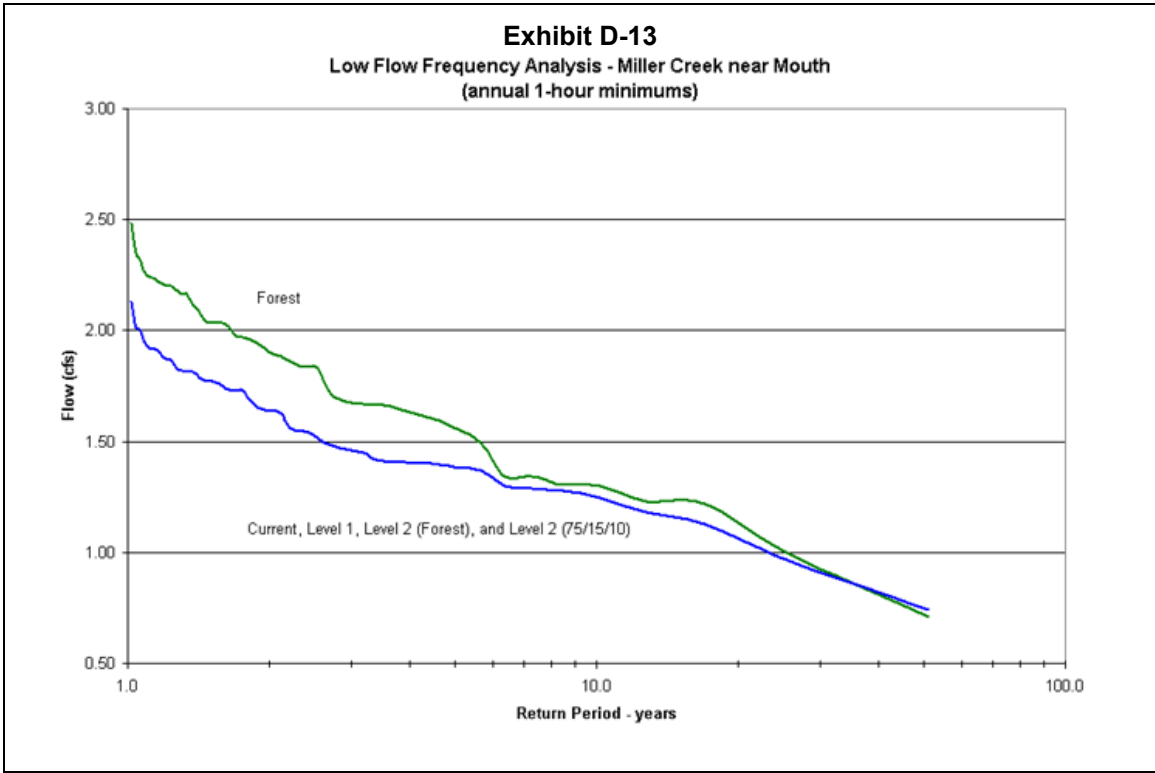
Walker Creek: Analysis of Peak Flows

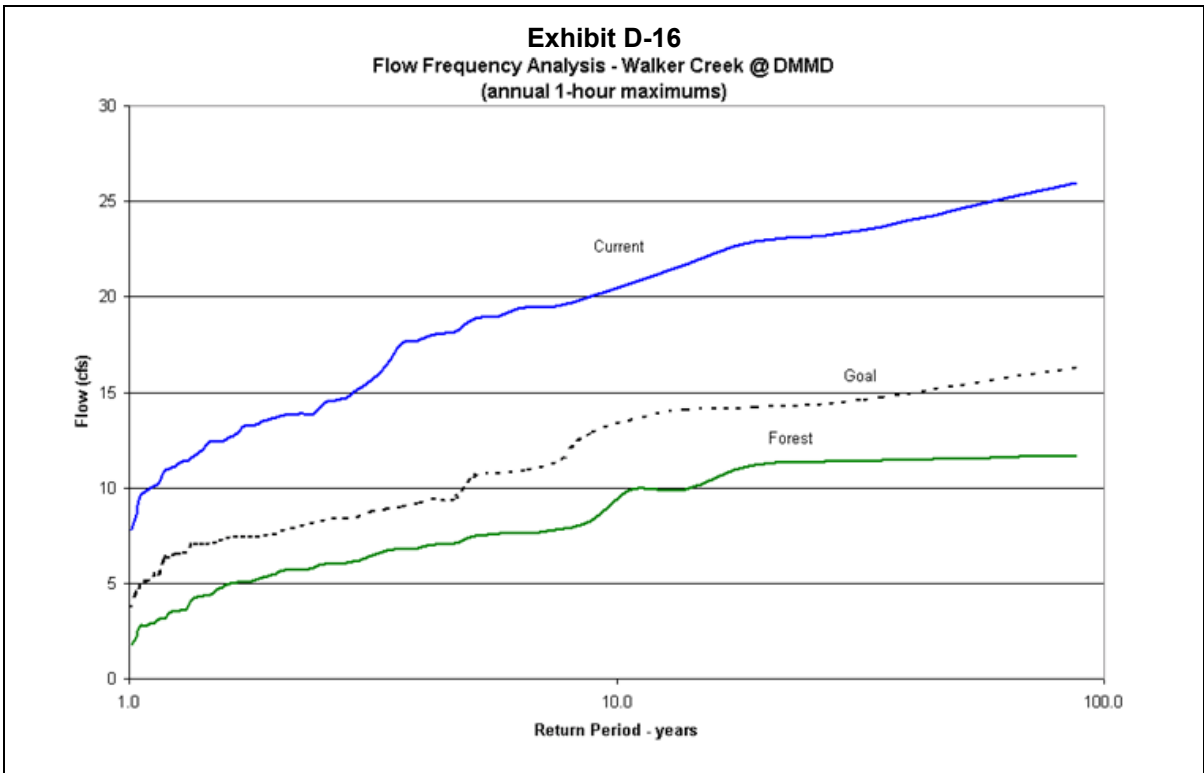
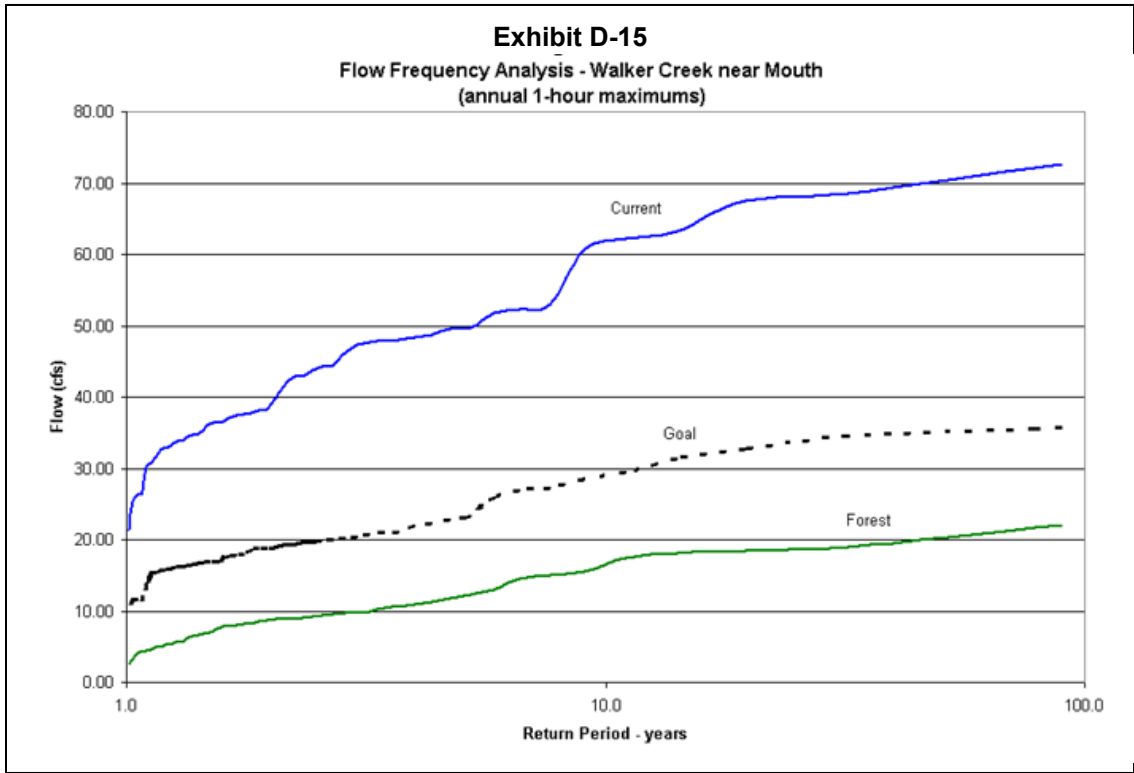
Exhibit D-15 shows peak flows near the mouth of Walker Creek under fully-forested and existing conditions. In addition, a goal flow is shown that represents a basin-wide land cover of 75 percent forest, 15 percent grass, and ten percent impervious surface. The figure shows that peak flows in the basin are three to eight times higher now (Current) than they were prior to development (Forest), with the largest increases occurring with more frequent storms (those with smaller return periods).

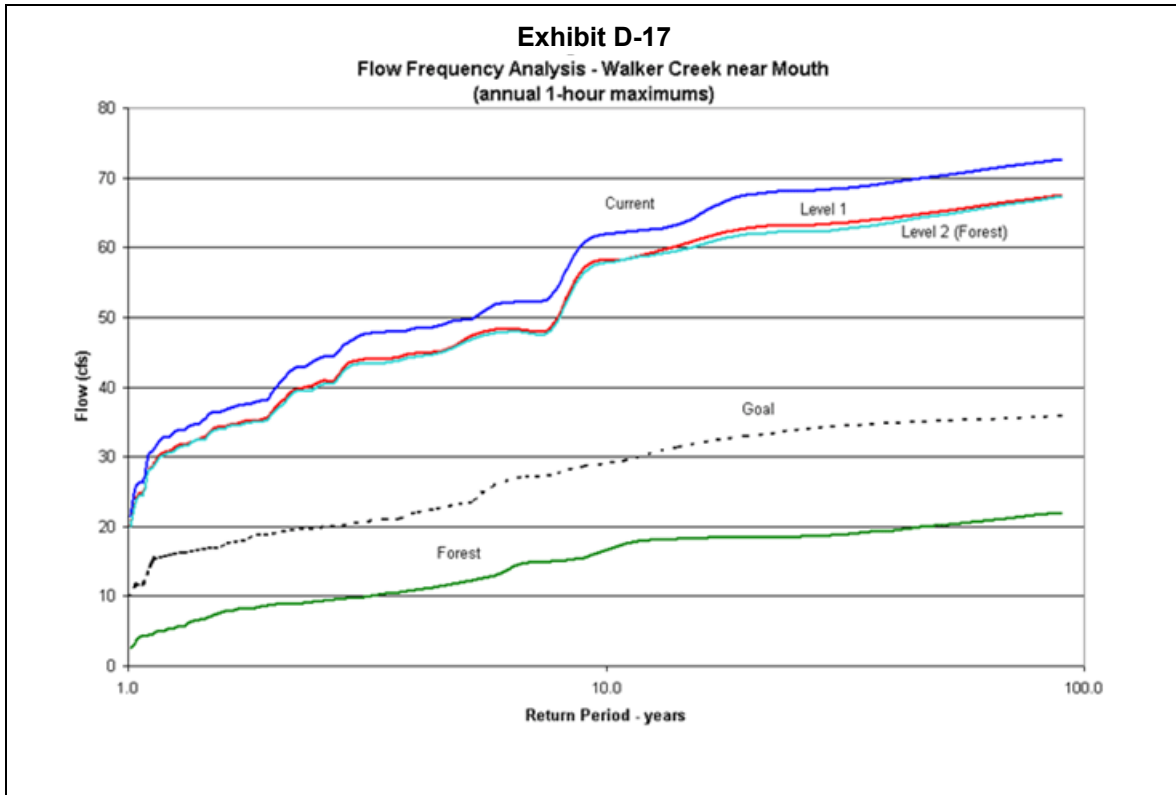
Under forested conditions, the range of storm flows expected would be approximately three cubic feet per second (cfs) for a one-year return period (a storm flow likely to occur on average once every year) to 22 cfs for a 100-year return period (a storm flow likely to occur on average once every 100 years). Under current conditions, storm flows range from approximately 23 cfs to 73 cfs for the one-year to 100-year return periods. In order to meet the goal flows ranging from 11 to 36 cfs for the one-year to 100-year return periods, respectively, a reduction of approximately 50 percent is needed relative to current flows.

Exhibit D-16 shows the same peak flow information for Walker Creek at Des Moines Memorial Drive (DMMD). Under forested conditions peak flows would vary from approximately two cfs to 12 cfs, while under current conditions the peak flows vary from about eight cfs to 26 cfs. The goal flows represent a 40 to 50 percent reduction relative to current flows.

Exhibit D-17 depicts the effect of two different storm water regulations on peak flows near the mouth of Walker Creek. If a Level 1 detention standard is used for the red parcels [except for the Port of Seattle that is required to use Level 2 (75/15/10)], it reduces the peak flows below current levels by several cfs (zero to five). A Level 2 (Forest) detention standard for the red parcels [except for the Port of Seattle that is required to use Level 2 (75/15/10)] achieves nearly identical reductions in peak flows, but still does not attain the goal flow. This modeling run showed that there was little difference between the Level 2 (Forest) and Level 1 standard. In order to protect the higher-quality habitat generally found in Walker Creek, a Level 2 (75/15/10) standard is proposed for the basin. It will be a restorative standard and yet much more



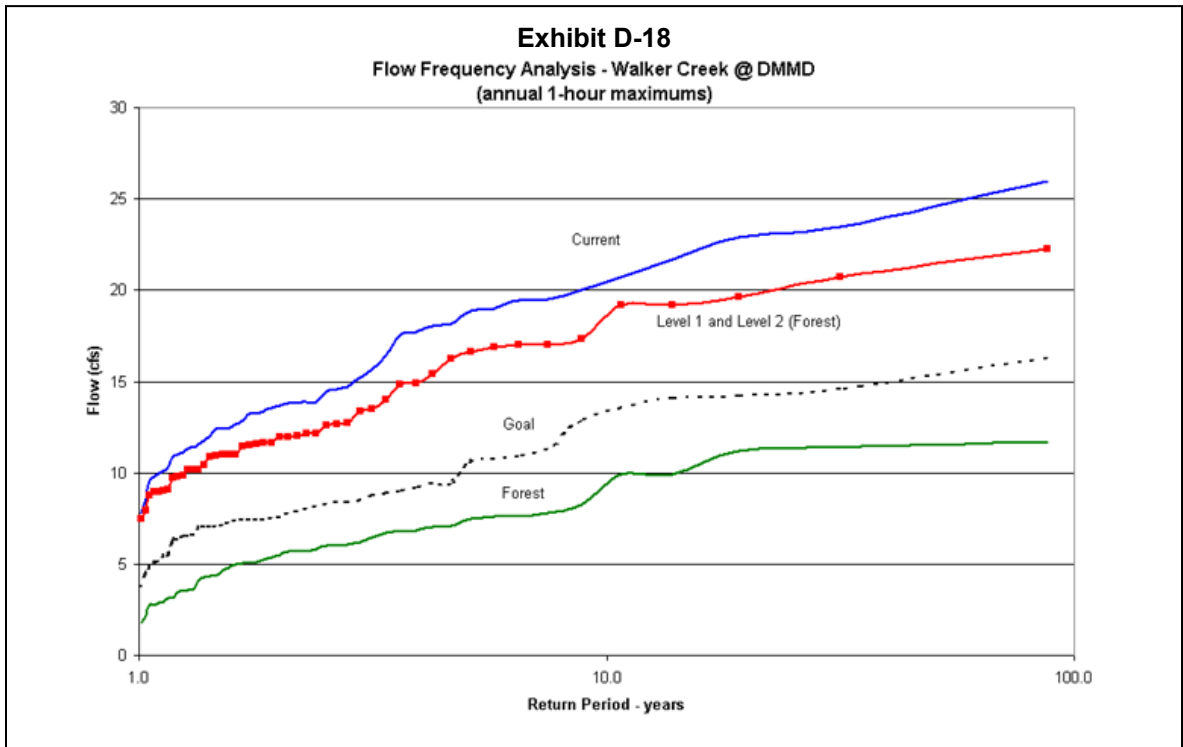




affordable for developers than Level 2 (Forest). In addition, it will be consistent with proposed Miller Creek detention standards and those approved for the Port.

Exhibit D-18 compares Level 1 and Level 2 detention standards for Walker Creek at DMMD. The detention standards achieve identical results for peak flows, a reduction in a few cfs, although neither is able to achieve the goal flow. Again, a Level 2 (75/15/10) detention standard is proposed in order to be conservative.

At this time no additional flow control projects are being suggested for Walker Creek. This decision is made based on field surveys that indicate that, in general, Walker Creek is stable and is in much better condition than Miller Creek. A flow, water quality, and habitat monitoring program is proposed for both Miller and Walker Creek so that any changes, either good or bad, can be observed. If conditions in Walker Creek worsen over time, then additional flow control measures, such as detention or infiltration facilities, can be proposed.



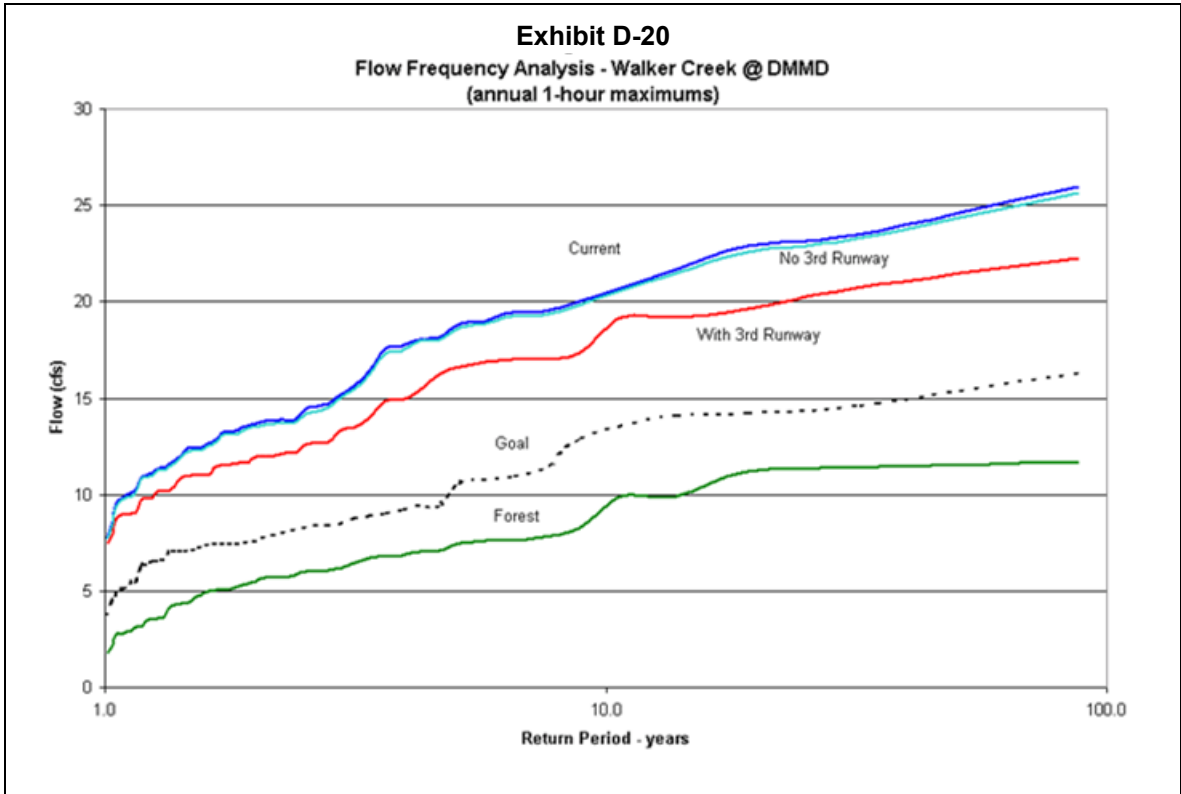
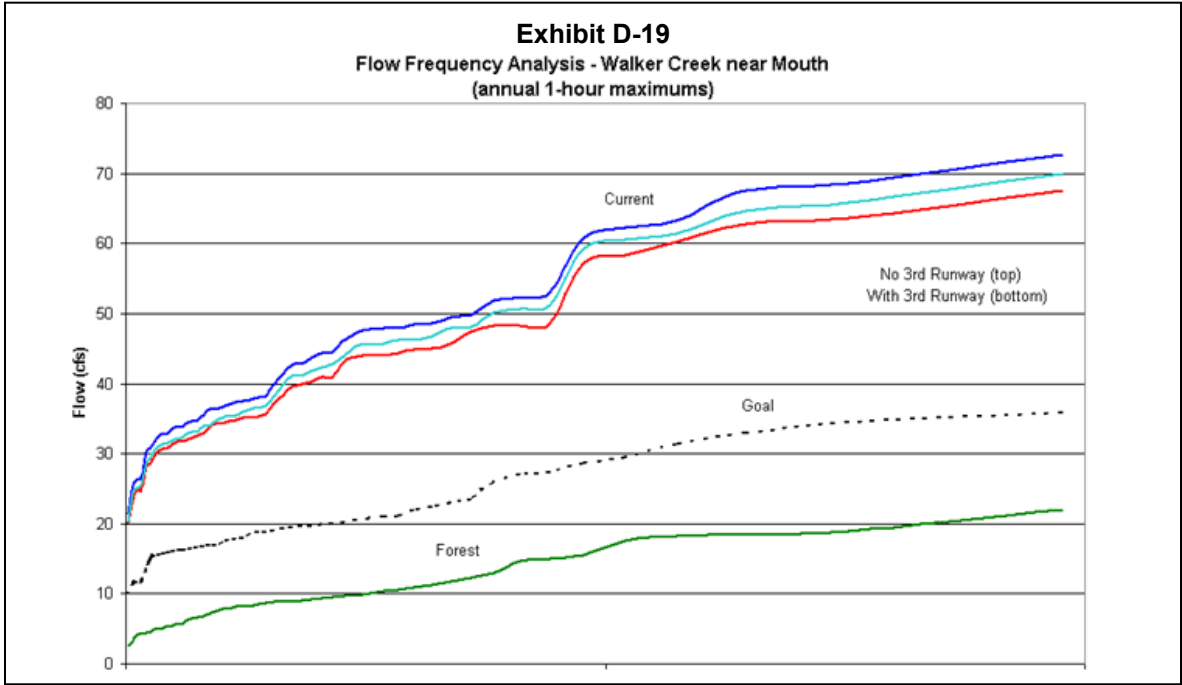
Exhibits D-19 and D-20 explore the impacts of the proposed third runway and its association mitigation on the peak flows in Walker Creek. Peak flows will actually decrease in Walker Creek due to construction of the third runway and its association mitigation. This is because the detention standard required by Ecology for the Port is a Level 2 (75/15/10) standard. This is a restorative standard that improves hydrologic conditions over those caused by current land use that is more developed than 75 percent forest, 15 percent grass, and ten percent impervious surface. Because the proposed runway is a large red parcel, mitigation of flows from it cause a relatively large positive effect on peak flows. This analysis underscores the importance of the Port fully and effectively implementing its required mitigation.

Analysis of Erosive Work

Field investigations revealed that Walker Creek has experienced fewer erosion problems than Miller Creek. To analyze the ability of the various peak flow reduction strategies (discussed above) to do further minimize erosion, a measure of mitigation of erosive work was developed. First, the erosive work on the stream was calculated for the range of flows expected under each scenario presented above. Then, the percent of mitigation of erosive work for any particular flow reduction option was expressed as the following ratio:

$$\text{(Erosive Work for Scenario X) / (Erosive Work for Forested Scenario)}$$

Where Scenario X is one of the peak flow reduction scenarios described above.



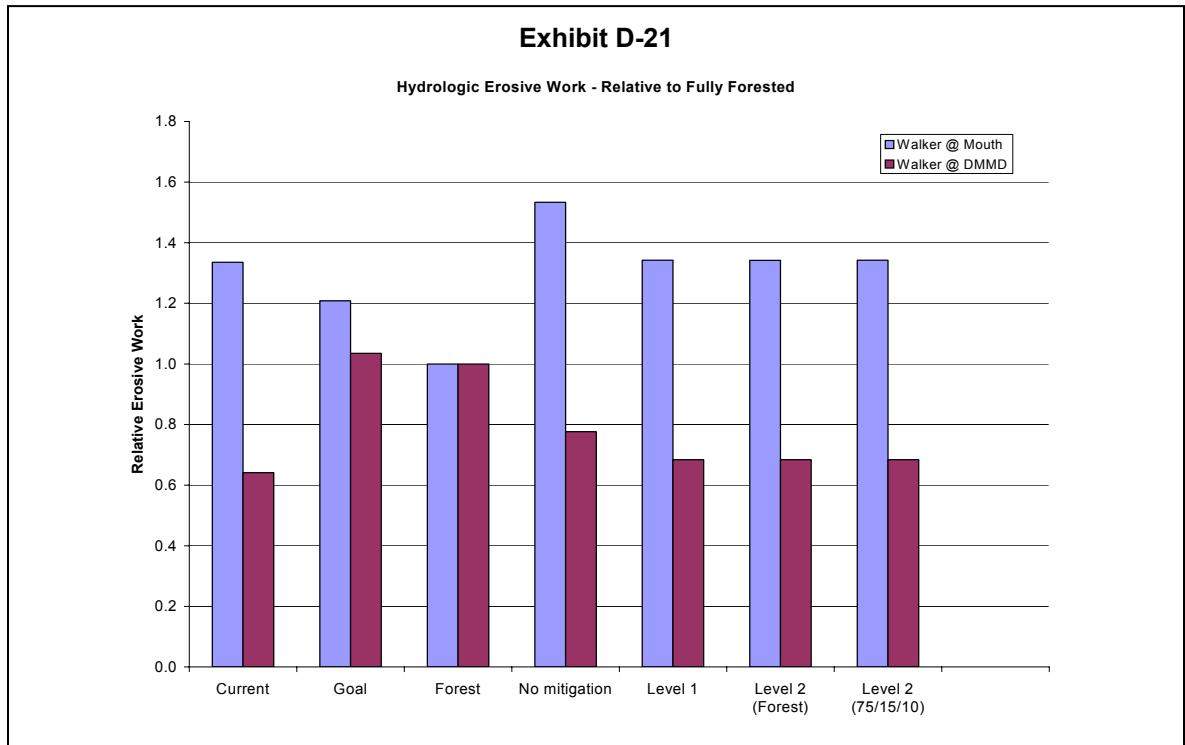


Exhibit D-21 shows the results of the relative erosive work analysis for Walker Creek. With the fully forested condition being the basis for comparison the other scenarios are shown as ratios. The total amount of erosive work for the no mitigation scenario is 55 percent greater than the forested condition at the mouth of Walker Creek. The no mitigation scenario has less erosive work than the forested scenario at the DMMD. Stream flow at the DMMD is due almost entirely to groundwater and only very minimally to surface water runoff. In addition, the groundwater basin in Walker Creek is larger than the surface water basin. This means there is a net import of water relative to what would be expected when examining just the surface area runoff characteristics. However, the surface flows in the basin at the DMMD are limited by this condition as well. This helps explain the otherwise counterintuitive reasoning for the lower numbers for erosive work as compared to the forested condition for the DMMD. Under current conditions the amount of erosive work is approximately 30 percent greater than forested at Walker Creek's mouth. Under the goal regime, the amount of erosive work is almost 20 percent greater than the forest scenario at the mouth of Miller Creek. None of the regulatory measures alone will achieve erosive mitigation equivalent to the goal flow at the mouth; however, all the scenarios are more effective at reducing erosive work than the goal scenario at the DMMD as explained above. The Level 1 and Level 2 detention regulations come within 20 percent of the required level of mitigation for achieving the levels for the goal flow regime at the mouth and are below the goal regime at the DMMD. Note that the Level 2 (Forest) and Level 2 (75/15/10) detention standards achieve essentially identical degrees of erosion mitigation.

Analysis of Low Flows

Exhibits D-22 and D-23 show the results of the low flow analysis. Although no problems relative to low flows have been reported in Walker Creek, there are reductions in low flows due to development. Low flows at the mouth have been reduced by up to about 15 percent relative to fully-forested conditions; at DMMD the reduction is up to about 25 percent. There is essentially no difference in the low flows expected under various regulatory scenarios (current, Level 1, and Level 2) - the multiple curves representing these scenarios have been combined. As part of the Port of Seattle's environmental mitigation for the proposed 3rd runway, the Department of Ecology has required low flow augmentation. The Port is required to release water to Walker Creek at a rate of 0.11 cfs continuously between August 1 and October 31 each year. The figures show the effect of this release on low flows.

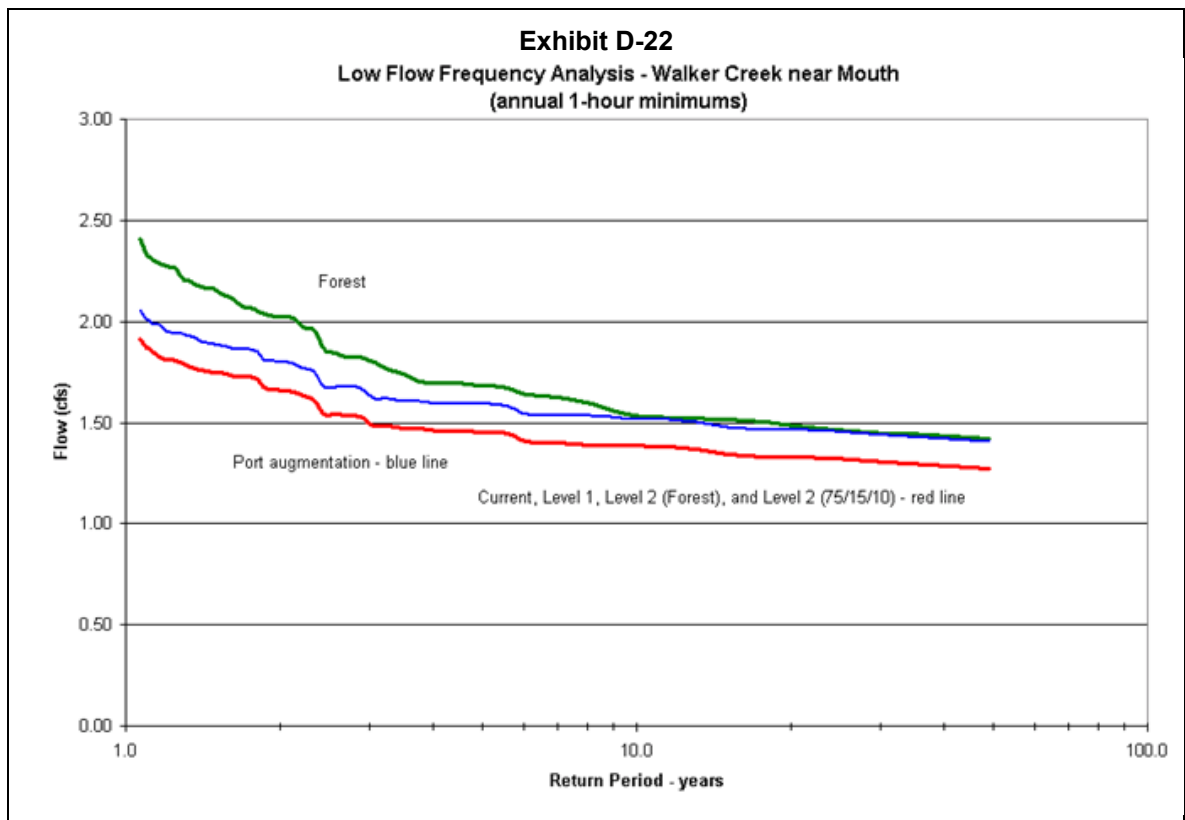
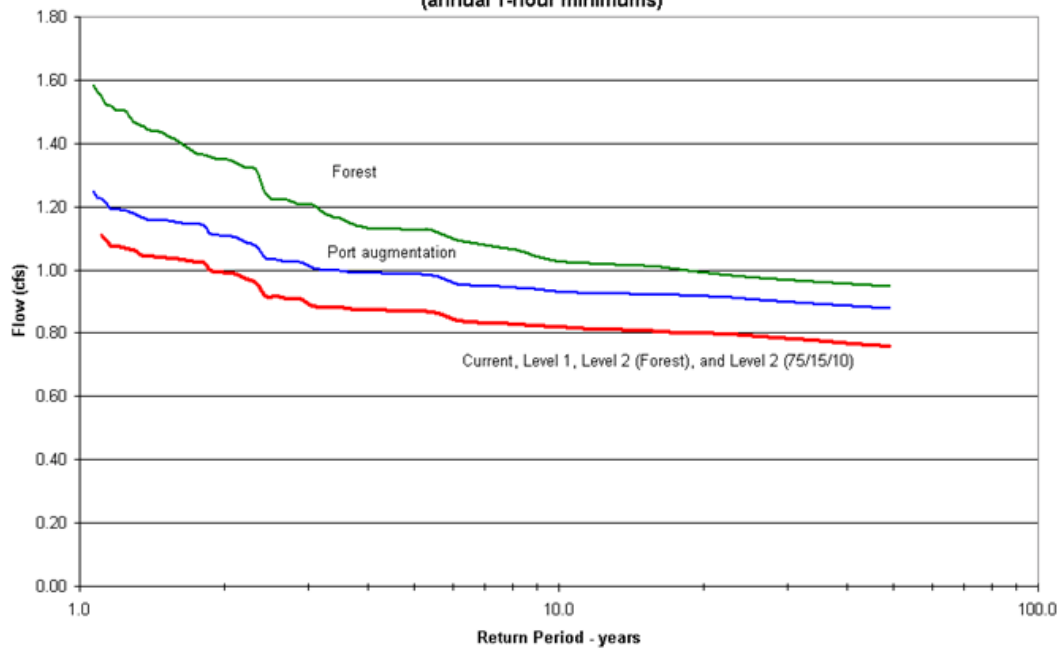


Exhibit D-23

Low Flow Frequency Analysis - Walker Creek @ DMMD (annual 1-hour minimums)



key to Modeling Runs

Forest

The model assumes that the only land cover in the basin is forest. The amount of runoff vs. infiltration for the forest cover is dependent on the underlying soil type, either till or outwash.

Goal

The land cover is assumed to exhibit runoff characteristic of a 75% forest, 15% grass, and 10% effective impervious area land cover. This goal flow should not be interpreted to be an absolute value. It is representative of a flow regime that is likely to provide a stable stream with desirable habitat. The goal flow alone will not solve water quality or habitat problems, but will work in concert with improved water quality and habitat improvements to enhance the stream.

Current

This scenario represents the hydrology in the basin given the development present during 1995. That year was used because land cover information, and a corresponding relationship to effective impervious area, was readily available. Although some changes have obviously occurred since 1995, the amount of conversion of land from forest or grass to impervious is believed to be relatively small (i.e., in a basin that is already nearly built out, not much change occurs over time).

Level 1

The model was run with the assumption that all new development (the red parcels) would apply Level 1 flow control to new impervious surfaces. Level 1 flow control is intended to reduce flooding by controlling the peak flow rates of storm water released from developed areas during frequent storm events (the 2-year and 10-year flow events). The two-year and ten-year post-development flow rates are to be equal to the pre-development flow rates. This is the current standard applied per the King County Surface Water Design Manual. The Port of Seattle's proposed airport expansion was assigned the mitigation approved by Department of Ecology in its Comprehensive Stormwater Management Plan, which is Level 2 (75/15/10).

Level 2 (Forest)

The model assumed that all new development (the red parcels) would use a Level 2 (Forest) flow rate and duration control for new and replaced impervious surfaces. The Level 2 (Forest) standard would require that both flow rates and flow durations after development be equal to those occurring under a 100 percent forested land cover for flows ranging from one-half of the two-year flow up to the 50-year flow. The Port of Seattle's proposed airport expansion was assigned the mitigation approved by Department of Ecology in its Comprehensive Stormwater Management Plan, which is Level 2 (75/15/10).

Level 2 (75/15/10)

The assumption was that all new development (the red parcels) would use a Level 2 (75/15/10) flow rate and duration control for new and replaced impervious surfaces. The Level 2 (75/15/10) standard would require that both flow rates and flow durations after development be equal to those occurring under a land cover of 75 percent forest, 15 percent grass, and ten percent impervious surface for flows ranging from one-half of the two-year flow up to the 50-year flow. The Port of Seattle's proposed airport expansion was assigned the mitigation approved by Department of Ecology in its Comprehensive Stormwater Management Plan, which is Level 2 (75/15/10).

No Third Runway

In this modeling run it was assumed that the Port's proposed third runway and all of its associated mitigation will not be constructed. All other potential development, the red parcels, was assumed to develop with a Level 2 (75/15/10) detention standard.

Detention

This assumed an additional 40 acre-feet (ac-ft) of storage at the Miller Creek Regional Detention Facility (MCRDF) for a total of 130 ac-ft of storage, plus 12 ac-ft of storage at the confluence of Arbor Lake and Hermes Depression, plus 12.5 ac-ft of additional storage at Ambaum Pond (for a total of 15 ac-ft of storage). It also assumed Level 2 (75/15/10) for all of the red parcels. For the MCRDF expansion, the following assumptions were made: Changed gate setting from 2 ft. to 1.5 ft. Changed overflow from 10 ft. to 12 ft. Decreased outflow by about 60% from original would require orifice control structure.

Appendix E

**Miller and Walker Creeks
Basin Plan**

Appendix E: Hydrologic Characteristics and Identified Problems of Miller and Walker Creeks

This appendix provides detailed information regarding the hydrologic characteristics and identified problems of Miller and Walker Creeks. This information comes from the hydrologic modeling completed by King County for Miller and Walker Creeks. The hydrologic model and supporting technical information is available to review at the office of the Stormwater Services Section of King County Water and Land Resources Division.

Miller Creek

Stormwater runoff resulting from precipitation falling on a basin varies greatly depending on the type and intensity of development in the basin. In a forest, there is generally more storage of water in the soils, more recharge of ground water leading to larger base flows in streams (adequate base flows are needed to prevent the stream from drying up when there is no rain), and less surface runoff. These factors generally lead to slower rates of release of the water to the stream as compared with a developed basin. The impervious surfaces in a developed basin, such as roads and rooftops, are unable to absorb and store water, decrease recharge of ground water, increase surface runoff, and generally lead to increased peak flows and decreased base flows.

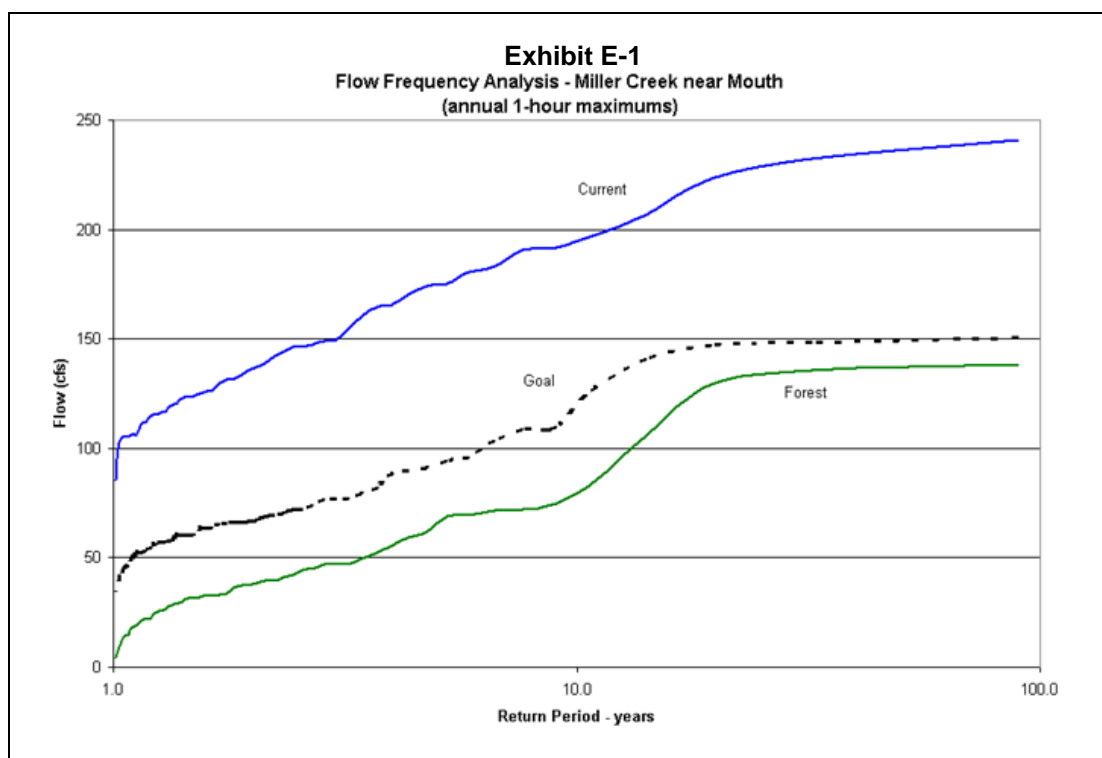
In addition to the potential changes in peak flows and base flows, development of a basin also can lead to increases in flow durations. Flow duration is the aggregate amount of time that stream flows are greater than or equal to a particular flow rate (usually the flow rate above which streambed erosion occurs). Flow durations are of concern because extended and more frequent periods of higher flows can cause erosion. So, even if the magnitude of peak flows are reduced, a stream may still experience erosion due to the increased amount of time (relative to a forested condition) that higher flows occur and perform erosive work on the stream.

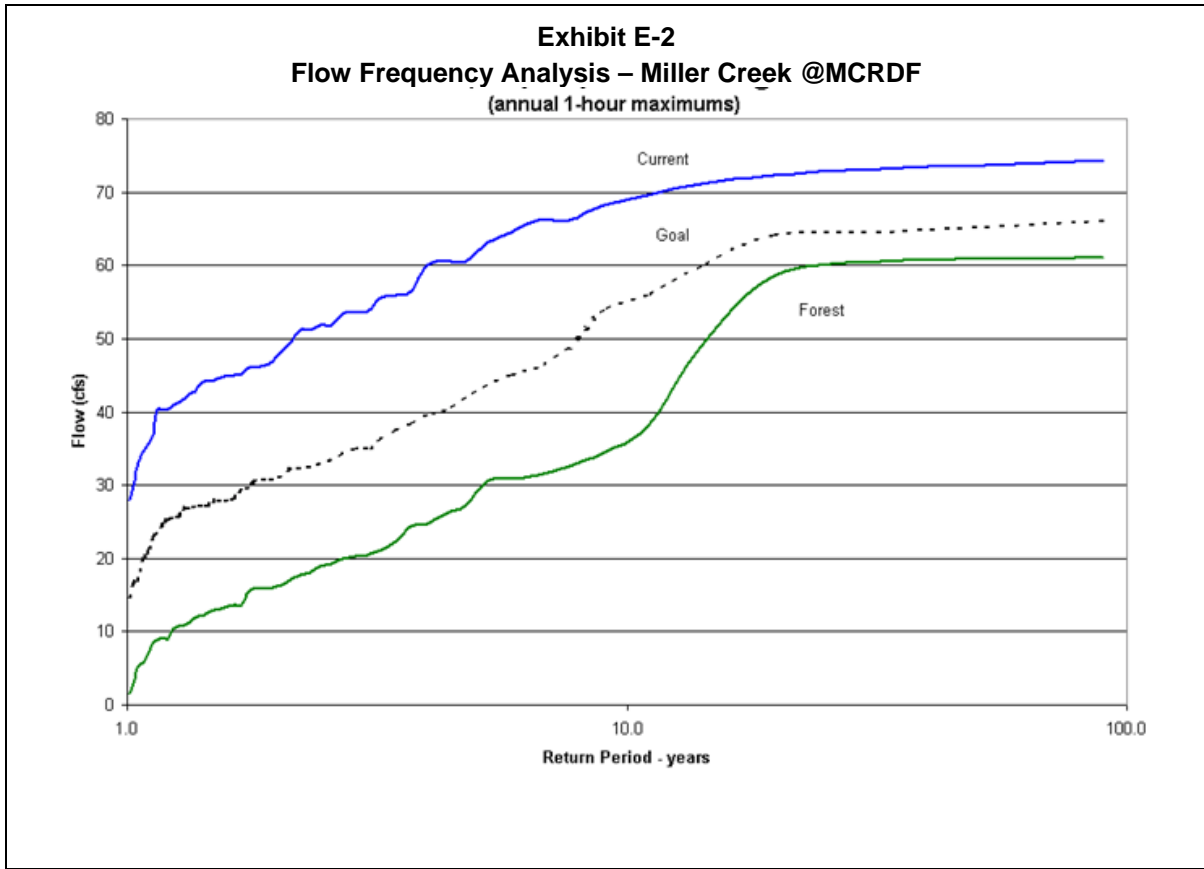
The Miller Creek basin receives an average of 36.5 inches of rainfall per year, based on the rainfall records at SeaTac Airport from 1949 to 1998. This rain falls on a basin that has changed dramatically during the past. Over time, the basin has changed from forested land cover to lawns, pastures, urban landscaping, roads, buildings. One result of this conversion is a total of 19 percent impervious surface coverage within the basin. To determine what happens to Miller Creek when it rains, the hydrologic characteristics of the Miller Creek basin, including peak flows, flow durations, and base flows, were evaluated through creation of a calibrated, continuous time-step model called HSPF (Hydrologic Simulation Program – Fortran). The model computes flow amounts for every hour over a 50-year period of precipitation record. The model was calibrated using precipitation and stream flow data collected in the basin.

Identified problems

The primary problem with respect to hydrology is that current flows are too erosive to allow the formation of gravel beds, a critical component of salmon habitat. By reducing the high flows and erosion, improvements to the geomorphology and habitat of the stream can be realized.

Exhibit E-1 shows high flow maximums near the mouth of Miller Creek under fully-forested and current conditions. In addition, a goal flow is shown that represents a basin-wide land cover of 75 percent forest, 15 percent grass, and 10 percent impervious surface. The high flows shown are the annual one-hour maximums (i.e., the highest flow expected in any year for a given return period based on statistical analysis of one-hour flow amounts generated for 50 years of precipitation data). **Exhibit E-1** shows that high flows in the basin are much higher now (Current) than they were prior to development (Forest). The increase ranged from approximately 70 to 1600 percent, with the largest increases occurring with more frequent flow events (those with smaller return periods).

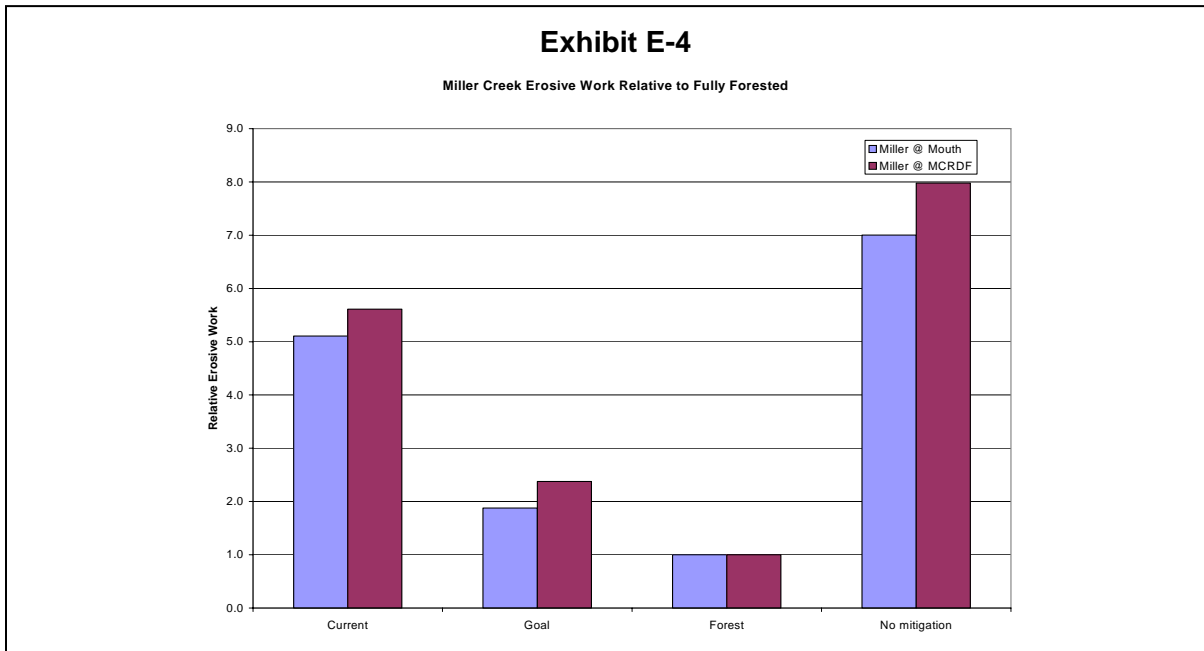




Under forested conditions, the range of storm flows expected would be approximately 6 cubic feet per second (cfs) for a 1-year return period (a storm flow likely to occur on average once every year) to 140 cfs for a 100-year return period (a storm flow likely to occur on average once every 100 years). Under current conditions, storm flows range from approximately 95 cfs to 240 cfs for the 1-year to 100-year return periods. The goal flows for the 1-year to 100-year return periods of 40 cfs to 150 cfs represent an approximate reduction of 60 to 40 percent relative to current flows.

Exhibit E-3 shows the same high flow information for Miller Creek at the Miller Creek Regional Detention Facility (MCRDF). Under forested conditions high flows would vary from approximately 2.5 cfs at a 1-year return period to 60 cfs at the 100-year, while under current conditions the high flows vary from about 30 cfs to 75 cfs. The goal flows represent a 50 to 12 percent reduction relative to current flows.

Exhibit E-4 shows the results of an analysis of erosive work performed for Miller Creek. Work is calculated as the total amount of time or duration of time exceeding a particular flow threshold. For erosive work that threshold is one-half the 2-year peak flow for forested conditions. Because field investigations revealed that Miller Creek has experienced severe erosion in many areas, a measure of erosive work was developed. First, the erosive work on the stream was calculated for the range of flows expected under various



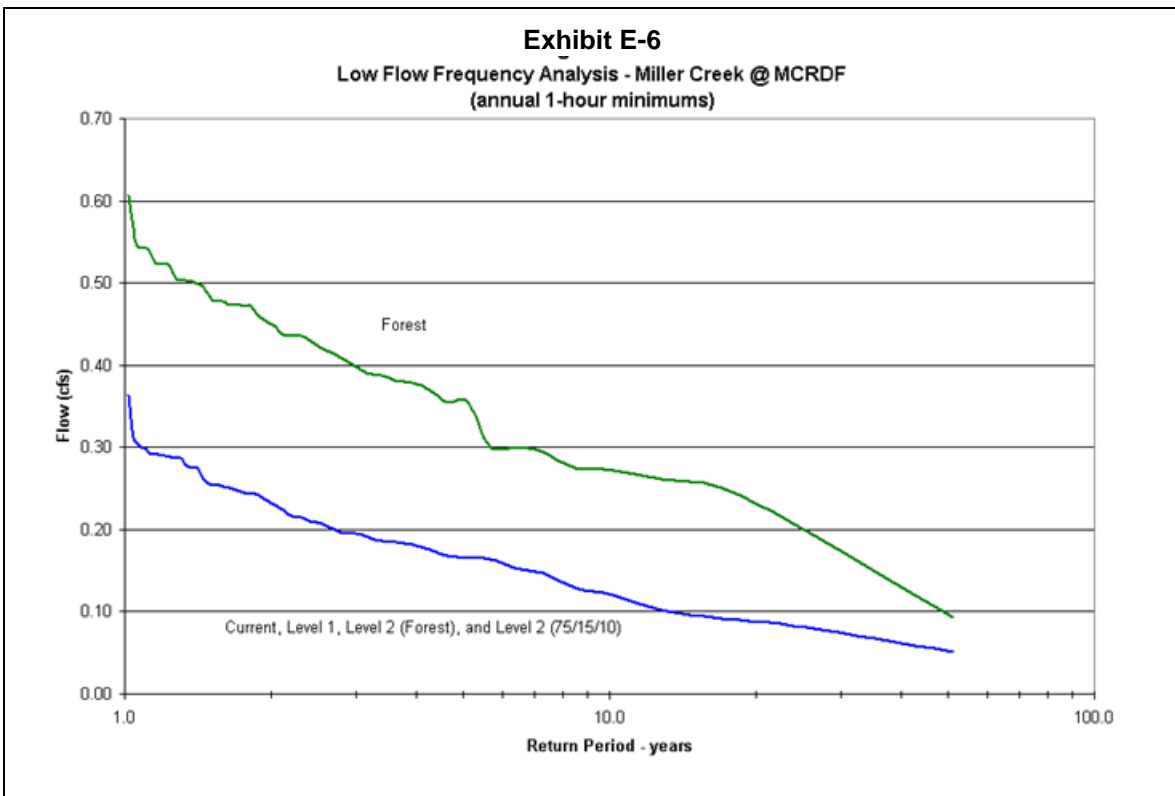
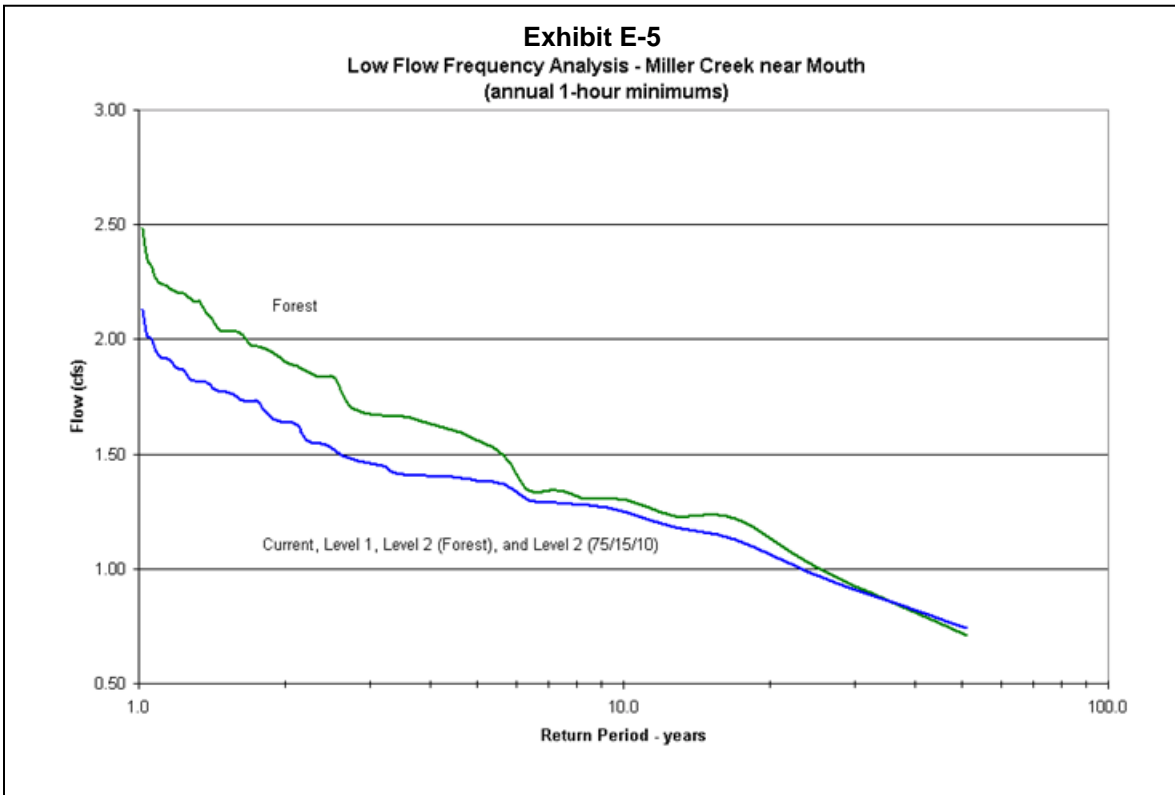
scenarios. Erosive work is expressed as a ratio relative to an undeveloped or forested condition as follows:

$$(\text{Erosive Work for Scenario X}) / (\text{Erosive Work for Forested Scenario})$$

In **Exhibit E-4** Scenario X was one of the following scenarios: current, goal, forest, or no mitigation.

With forested condition being the basis for comparison, the other scenarios are shown as ratios. As the graph shows the no mitigation scenario or the future scenario with no flow control has approximately 600 percent more erosive work than there would be for a forested condition at the mouth of Miller Creek and 700 percent more at the MCRDF. Under current conditions, erosive work is over 400 percent greater than it would be for a forested condition at the mouth of Miller Creek and 450 percent more at the MCRDF. The erosive work total for the goal scenario is approximately 100 percent more than the erosive work for the forested condition scenario at both the mouth and the MCRDF.

Unlike the high flows, the low flows in the stream do not appear to be of concern at the current time. **Exhibits E-5** and **E-6** show the results of the low flow analysis. Although no problems relative to low flows have been reported in Miller Creek, modeling results indicate that there are reductions in low flows due to development. **Exhibit E-5** shows that low flows at the mouth have been reduced by up to about 15 percent relative to fully-forested conditions. **Exhibit E-6** shows that low flows at the MCRDF have been reduced by up to 40 percent. If future monitoring shows that low flows are harming efforts to improve habitat, then strategies to improve low flows should be developed.



Walker Creek

Stormwater runoff resulting from precipitation falling on a basin varies greatly depending on the type and intensity of development in the basin. For a general discussion of the changes in hydrology that can be expected with development, please see the Miller Creek hydrology section found earlier in this report.

Changes in land cover specific to Walker Creek basin include conversion from a forested land cover to its current land cover consisting of 22 percent impervious surface. As in Miller Creek, hydrologic characteristics of the Walker Creek basin, including peak flows, flow durations, and base flows, were evaluated through the HSPF model.

Identified problems

The primary problem with respect to hydrology is that the current flows are too erosive to allow formation and maintenance of gravel beds in the stream that are conducive to salmon use, although not as erosive in this basin as in Miller Creek. By reducing high flows and erosion, improvement to the geomorphic and habitat conditions of the stream can be realized.

Exhibit E-7 shows peak flows near the mouth of Walker Creek under fully-forested and existing conditions. In addition, a goal flow is shown that represents a basin-wide land cover of 75 percent forest, 15 percent grass, and 10 percent impervious surface. The high flows shown are the annual 1-hour maximums (i.e., the highest flow expected in any year for a given return period). Peak flows in the basin are 3 to about 8 times higher now (Current) than they were prior to development (Forest), with the largest increases occurring with more frequent flow events (those with smaller return periods).

Under forested conditions, the range of storm flows expected would be approximately three cubic feet per second (cfs) for a one-year return period based on a statistical analysis of 1-hour flow amounts generated for 50 years of precipitation data to 22 cfs for a 100-year return period. Under current conditions, storm flows range from approximately 23 cfs to 73 cfs for one-year to 100-year return periods. In order to meet the goal flows ranging from 11 to 36 cfs for the one-year to 100-year return periods, respectively, a reduction of approximately fifty percent is needed relative to current flows.

Exhibit D-8 shows the same peak flow information for Walker Creek at Des Moines Memorial Drive (DMMD). Under forested conditions peak flows would vary from approximately two cfs to 12 cfs, while under current conditions the peak flows vary from about eight cfs to 26 cfs. The goal flows represent a 40 to 50 percent reduction relative to current flows.

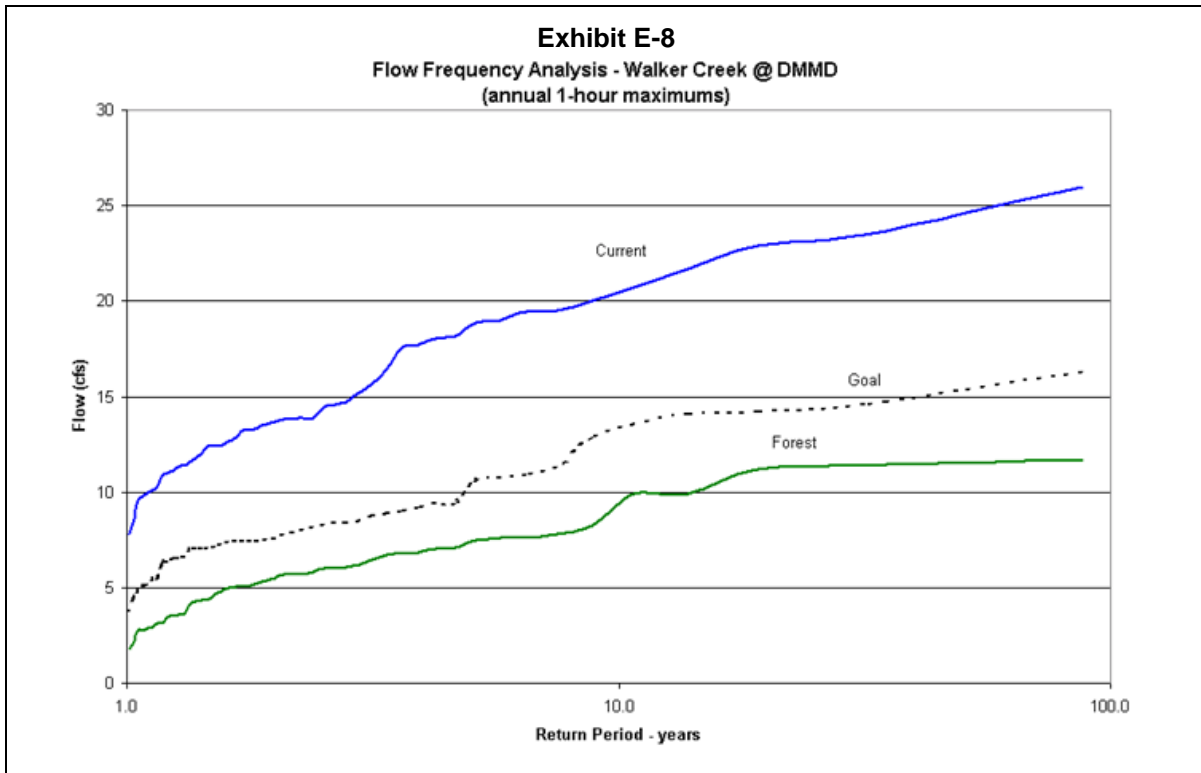
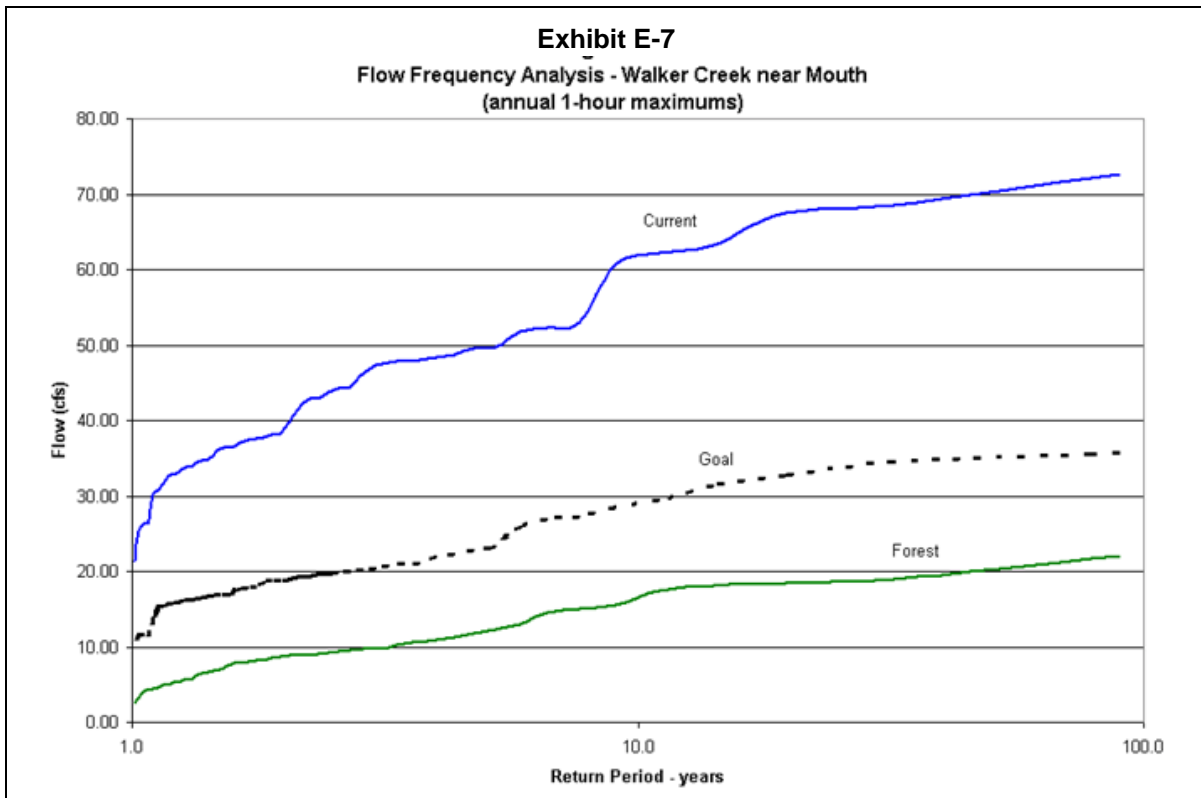


Exhibit E-9 shows the results of an analysis of erosive work performed for Walker Creek. As with Miller Creek, the forested condition is the basis for comparison of the other scenarios. Erosive work is expressed as a ratio relative to an undeveloped or forested condition as follows:

$$\frac{\text{(Erosive Work for Condition X)}}{\text{(Erosive Work for Forested Condition)}}$$

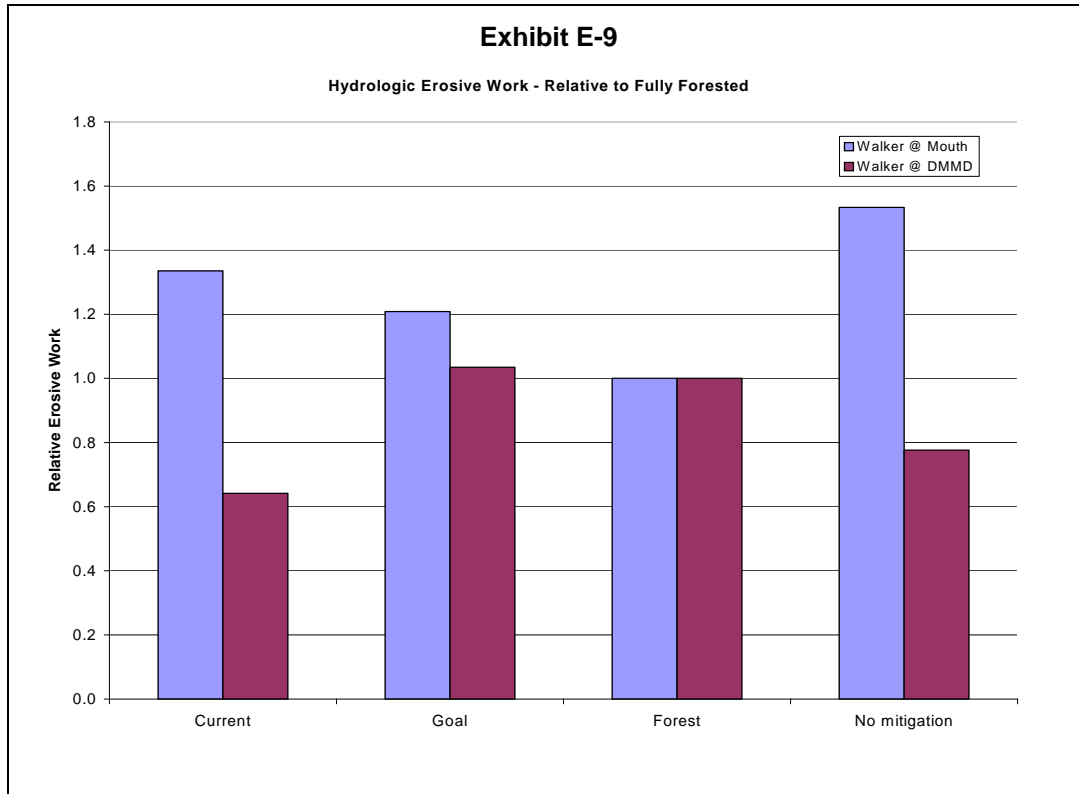
In **Exhibit E-10** Scenario X was one of the following scenarios: current, goal, forest, or no mitigation.

With forested condition being the basis for comparison, the other scenarios are shown as ratios. As the graph shows, the no mitigation scenario or the future scenario with no flow control has approximately 60 percent more erosive work than the forested condition at the mouth of Walker Creek and 20 percent less at the DMMD. Under current conditions the amount of erosive work is over 30 percent greater at the mouth of Walker Creek compared to fully forested conditions and 40 percent less at the DMMD.

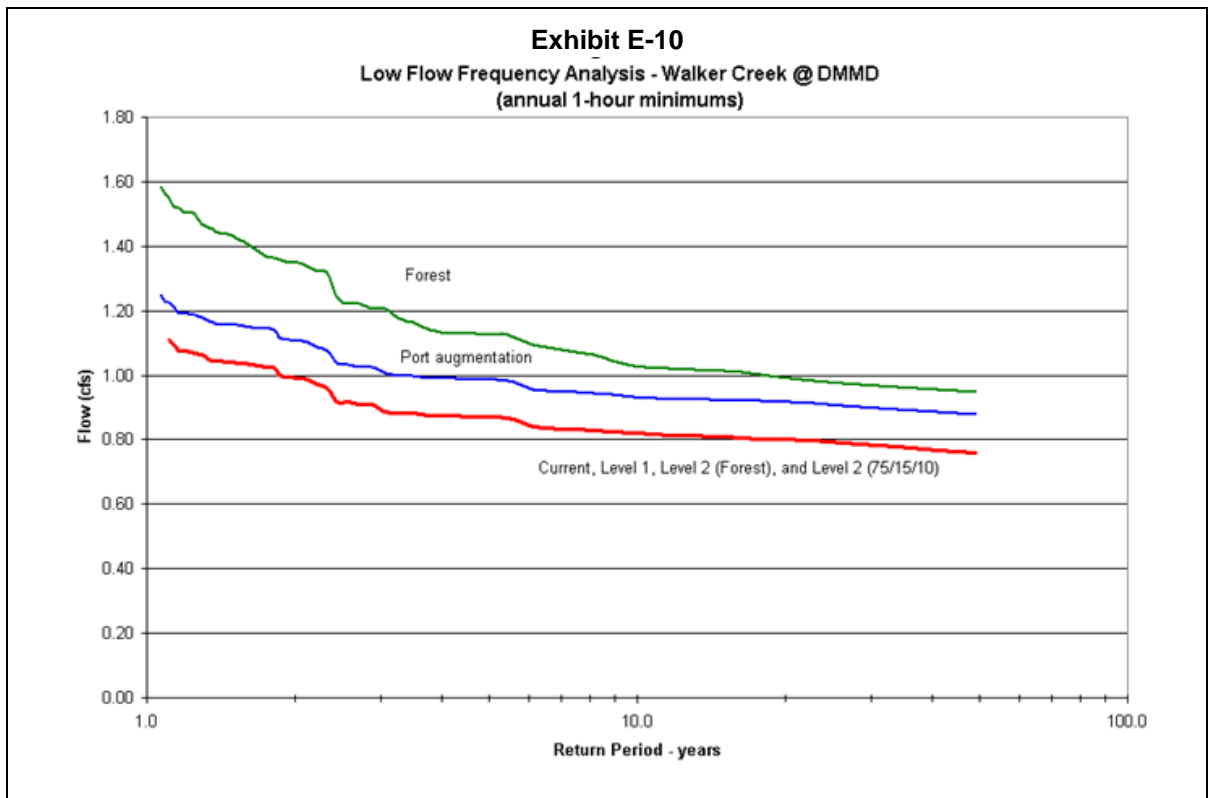
At the DMMD location, the modeling results are somewhat counterintuitive in that they show a reduction in erosive work relative to fully forested conditions for both the no-mitigation scenario (20% reduction) and current condition scenario (40% reduction). This is because the source of stream flow

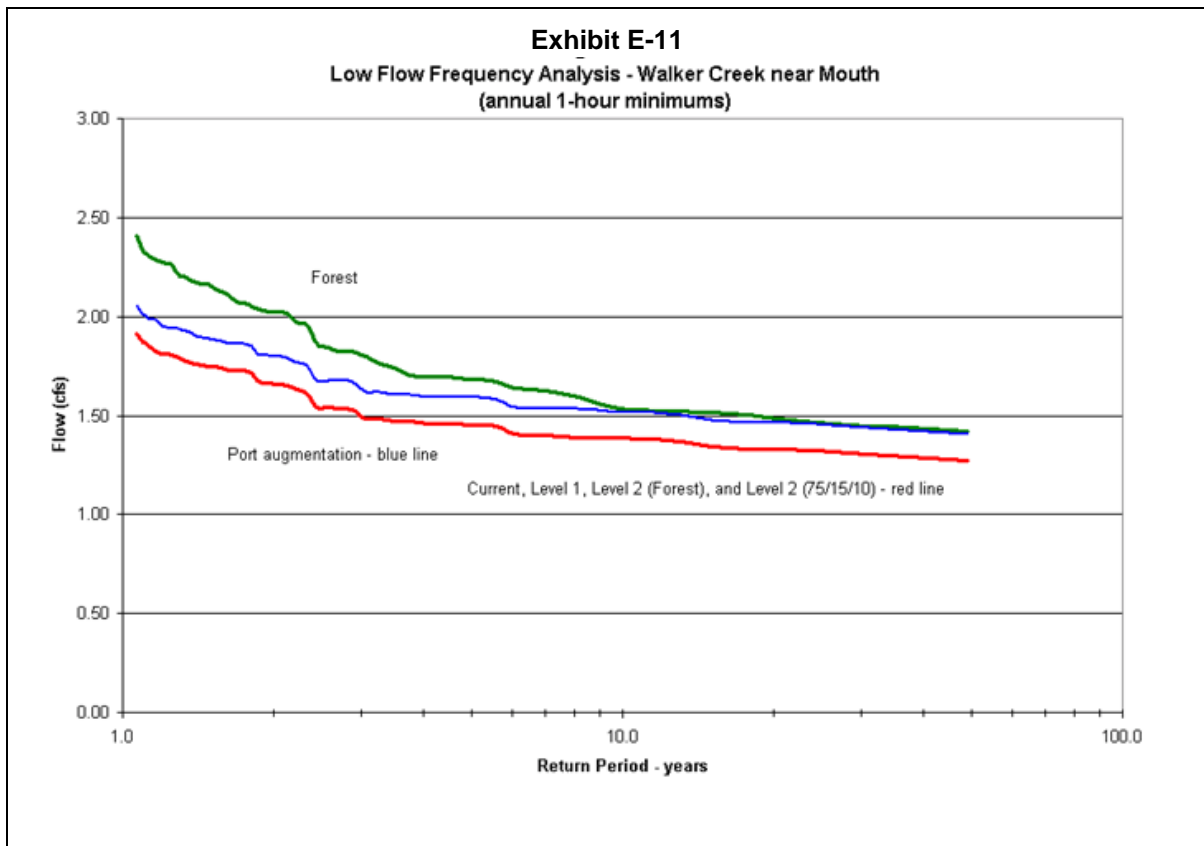
at DMMD is almost entirely from groundwater and only very minimally from surface water runoff. In addition, the groundwater basin in Walker Creek is larger than the surface water basin. This means that there is a net import of water relative to what would be expected when examining just the surface area runoff characteristics. So, there is currently less erosion at DMMD than would be anticipated under a fully-forested condition because increased forest cover in those areas of the groundwater basin outside the surface water basin would tend to increase the groundwater component of stream flow, thereby leading to more erosion. This counterintuitive reduction in erosive work is supported by King County field observations of stream flow, geology, and habitat in the basin. Specifically, King County staff have not observed the extent of erosion in Walker Creek that they have seen in Miller Creek.

Unlike the high flows, the low flows in the stream do not appear to be of concern at the current time. **Exhibits E-11** shows the results of the low flow analysis. Although no problems relative to low flows have been reported in Walker Creek, there are reductions in low flows due to development. Low flows at the mouth have been reduced by up to about 15 percent relative to fully-forested conditions; at DMMD the reduction is up to about 25 percent. As part of the Port of Seattle's environmental mitigation for the airport's third runway, the Department of Ecology has required low flow augmentation. The Port is required to add water to Walker Creek at a rate of 0.11 cfs continuously between August 1 and October 31 each year. The water added is stormwater collected during the winter in storage vaults and treated prior to release. The figures show the effect of this augmentation on low flows. If future monitoring shows that the low flow augmentation is not sufficient to protect and improve habitat, contingency measures approved by the Department of Ecology will be implemented. Most likely, the strategies would include more low-impact development (re-forestation, infiltration of



stormwater generated on-site), and analysis of the potential for further winter water storage and summer release.





Appendix F

**Miller and Walker Creeks
Basin Plan**

Appendix F: Water Quality Characteristics and Identified Problems of Miller and Walker Creeks

As in any urbanized basin, there are numerous potential sources of pollutants that may be carried in stormwater in the Miller/Walker Creeks Basin and discharged to the creeks and other water bodies. These sources include residential and commercial development, roads and highways, and a portion of Sea-Tac Airport.

In general, vehicle-related impacts to water quality include the potential introduction of metals (particularly zinc and copper) and hydrocarbons to the watershed from road, runway, and parking lot runoff. Detergents and solvents used in vehicle washing and repair can also be detrimental. Lawn care activities can introduce herbicides, insecticides, and excess nutrients. Pet feces and droppings from nuisance water fowl can cause pollution from fecal coliform. Galvanized metal surfaces such as roofs, sheds, and guardrails can leach zinc into stormwater and cause pollution of streams. Paints, solvents, used oil, and other materials can also reach streams through illegal dumping into storm drains.

Managing sources of pollutants through the use of stormwater best management practices (BMPs) can greatly reduce the frequency and degree of pollutant input to stormwater and water bodies. Pollutants can be managed by either preventing the pollutant from getting to stormwater and streams (source control) or by removing the pollutant once it has entered stormwater (treatment). Source control is essentially 100% effective because the pollutant is not available to be transported to the waterbody by stormwater, but is an impractical means of preventing pollution from sources such as automobiles driving on roadways; therefore, treatment of stormwater to remove pollutants is an important component to an overall water quality improvement strategy.

The method of treatment is to filter or settle pollutants from stormwater before it is released into the receiving water body (i.e. stream, wetland, etc.). Examples of stormwater treatment methodologies include biofiltration swales and wetponds.

Most development in the Basin occurred before the requirement for stormwater treatment was in place, so is not required to treat now. Most existing road and highway runoff is either not treated at all or receives minimal treatment.

The potential for future development and redevelopment to trigger treatment requirements depends on the nature of the development. In any case, treatment removes only 50% to 80% of non-dissolved pollutants in the stormwater (and is less effective than those rates in removing dissolved pollutants), so although some new development may

require water quality treatment, overall pollutant loads in the Basin will increase. To accommodate new development in the Basin while meeting antidegradation requirements of Washington's Water Quality Standards and without increasing overall pollutant loading, retrofitting of areas not currently being treated will be necessary. Please refer to the "Federal and State Water Quality Standards and Regulations" section of this chapter for further information on pertinent water quality regulations and requirements.

Identified Water Quality Problems in the Miller/Walker Creeks Basin

Stormwater data (see Water Quality Studies section below) have shown that elevated concentrations of metals, fecal coliform bacteria, and pesticides discharge to Miller Creek. Although comprehensive in-stream study data do not currently exist and the links between pollutants such as metals, fecals and pesticides and sub-lethal impacts to organisms have not been fully determined, it is possible that these pollutants may be present in the creeks at concentrations that can adversely affect biota. Three comprehensive monitoring programs have been initiated in Miller and Walker Creeks by the Port of Seattle and are focused on in-stream receiving waters directly adjacent to Sea-Tac Airport. These studies were recently initiated and resulting data was not available for incorporation into this plan. For purposes of evaluating water quality issues for this Basin Plan, a number of past studies were examined to identify potential and existing water quality problems in Miller and Walker Creeks.

The earliest water quality study indicating that elevated metals may be found in Miller and Walker Creeks (King County, 1991 and 1993) showed that Miller Creek exceeded acute water quality criteria for zinc and copper at nearly every sample location. The same studies indicated that Walker Creek samples exceeded acute water quality criteria for zinc and copper approximately 25 percent of the time at the stations monitored; however, the water quality standards in effect at that time were based on total metal concentrations and are not necessarily indicative of an exceedance of the current dissolved-based criteria. 1997 data from the Port of Seattle showed possible excursions beyond the standards and was the cause for listing the creek as a 'Water of Concern' in 2005. A more recent study (Port of Seattle, 2002) performed on one segment of Miller Creek and within the headwaters of Walker Creek indicated that zinc and copper concentrations below the current (i.e. effective in 2005) criteria. In 2002, fecal coliform counts exceeded the state water quality criteria. Six pesticides were detected in a 1998 USGS pesticide study.

One area of particular concern for commercial runoff is at Ambaum Detention Pond, which serves as the drainage outlet for the commercial

area along 1st Avenue South. Past sampling (see “King County Stormwater Sampling” in the “Previous Water Quality Studies –Miller and Walker Creek Basins” section below) indicated that stormwater discharges to Ambaum Pond contained high levels of pollutants; outflow from the Pond is discharged into Miller Creek without significant treatment. Another area of concern is SR 509 and SR 518, both of which discharge to Miller Creek with little or no treatment, although the Lake Reba Stormwater Facility does provide treatment for runoff from some areas of SR 518 as well as other upstream runoff. Runoff from the Port’s airport property to Miller Creek is currently required by the Department of Ecology to undergo treatment before discharge to Puget Sound or nearby streams.

Numeric standards for surface waters (including water bodies such as creeks) have been established by the Washington Department of Ecology (DOE) to protect the designated uses of the specific water body. Designated uses for Miller and Walker Creeks include recreational and aquatic life uses. Numeric standards for specific parameters including dissolved oxygen, temperature, pH, and toxic substances (e.g. metals) are set for aquatic life support. Bacterial limits are set to protect human health and recreational uses.

The federal Clean Water Act (CWA) requires that DOE prepare and report water quality conditions to the federal Environmental Protection Agency. This reporting includes a listing of waters that do not meet water quality standards as set within *CWA Section 303(d)* and an assessment of all of the state’s waters as required by *CWA Section 305(b)*.

Based on monitoring done in 2004 by DOE near the mouth, and as of August 2005 pending federal confirmation, Miller Creek has been listed per *CWA Section 303(d)* as not meeting water quality standards for fecal coliform (FC) bacteria. FC are bacteria found in the intestinal tract of all warm-blooded mammals, and the presence of FC in surface waters indicates the water has come into contact with animal (wild or domestic) or human wastes, and that pathogens may also be present - a human health concern for water contact recreational uses. The fecal coliform listing (known as a Category 5 listing) will require that a TMDL (Total Maximum Daily Load), or Water Cleanup Plan, be prepared by the state and implemented for the Miller Creek Basin. The TMDL will identify specific actions to reduce FC concentrations to assure that water quality standards are met. Jurisdictions within the basin will be required to implement the TMDL/Water Cleanup Plan through their NPDES Municipal Stormwater Permits issued by DOE.

The Clean Water Act requires that large and medium municipalities (known as “Phase 1” municipalities, including King County) obtain a NPDES (National Pollutant Discharge Elimination System) Municipal

Stormwater Permit. It is anticipated that small municipalities (known as “Phase 2” municipalities, including Burien, Federal Way, Normandy Park, and SeaTac) will be issued permits in 2005. Municipal NPDES permits require that the jurisdiction develop and implement programs that control pollutant sources and that stormwater treatment is provided for new development above a specific size threshold (these thresholds are different for Phase 1 and Phase 2 municipalities).

The Port of Seattle operates under its own NPDES permit that requires pollutant source controls, treatment, and monitoring to meet specific pollutant discharge limits.

The upper reach of Miller Creek has been listed as a “Water of Concern” (CWA Section 305(b) – known as a Category 2 listing) for copper and zinc. This listing indicates a potential problem and will require additional data to make any further determinations.

Pre-spawn fish mortality (PSM) has been observed in urban creeks in the Puget Sound region, including Miller Creek (Hillman, 1999). PSM is an observed high rate of mortality in salmonid females prior to spawning. The cause of PSM is currently undetermined, but it is the subject of an ongoing study in the Puget Sound Basin (not specifically including Miller Creek) being conducted by the National Oceanic and Atmospheric Administration/Northwest Fisheries Science Center (NFSC).

According to NFSC study information available on the NOAA website, “The precise cause of PSM is not known. However, at present, the weight of evidence suggests that the widespread coho die-offs are a consequence of non-point source water pollution. It appears that coho, which enter small urban streams following fall storm events, are acutely sensitive to non-point source stormwater runoff containing complex mixtures of pollutants that typically originate from urban and residential land use activities.

“A variety of diagnostic approaches are currently being used to investigate the potential causes of coho PSM. These include water quality monitoring, biological indicators of contaminant exposure, histopathology, molecular and conventional analyses of infection and disease, and neurochemistry. In addition, the initial research effort has been recently expanded to evaluate the effects of urban stormwater on other coho life history stages, including embryos, parr, and smolts” (NOAA, 2005).

Federal and State Water Quality Standards

Water Quality Standards for Surface Waters of the State of Washington; Chapter 173-201A WAC (Washington Administrative Code). The Department of Ecology (DOE) has developed water quality standards that apply to waterbodies in the state. These standards set numerical and descriptive standards for water characteristics (e.g. temperature, pH, dissolved oxygen) and pollutant concentrations (metals, toxics, bacteria). All surface water in the state of Washington must meet these “in-stream” standards (they do not apply to stormwater runoff). If a standard is exceeded, the waterbody must be identified on the 303(d) list, and a Water Cleanup Plan must be developed and implemented.

Antidegradation. The antidegradation requirements of the water quality standards (WAC 173-201A-070) require that existing beneficial uses be maintained and protected and no further degradation that would interfere with or become injurious to existing beneficial uses be allowed.

303(d). Section 303(d) of the Clean Water Act (CWA) requires the identification of waterbodies that do not meet water quality standards. The waterbodies not meeting water quality standards must have a Water Cleanup Plan developed for them and are identified as **Category 5** waterbodies on DOE’s integrated list.

Water Clean up Plan or Total Maximum Daily Load (TMDL). These terms are often used interchangeably. The Clean Water Act requires states to identify sources of pollution in waters that fail to meet state water quality standards, and to develop a Water Cleanup Plan to address those pollutants. The Cleanup Plan, or TMDL, identifies pollutant sources and establishes limits on pollutants that can be discharged to the waterbody and still allow standards to be met. A Detailed Implementation Plan (DIP) identifies actions that are needed to reduce and/or eliminate the pollutant load and, when implemented, meet the pollutant limits in the TMDL. The TMDL is developed to address the specific pollutant that does not meet the water quality standard. TMDLs are implemented through permits to point source dischargers and through non-regulatory programs for nonpoint sources. The TMDL and DIP are developed by DOE and are required to be implemented by the local jurisdictions through the Municipal Stormwater National Pollutant Discharge Elimination System (NPDES) permits.

305(b). Section 305(b) of the CWA requires the state to prepare a water quality assessment report of the condition of the state’s waters. This statewide assessment is part of DOE’s integrated report and includes polluted waters that do not require a TMDL (Category 4), **Waters of Concern (Category 2)**, and waters that meet the standards (Category 1). There are several reasons why a waterbody would be of concern (Category 2): it might have pollution levels that are not quite high enough to violate the water quality standards; there may not have been enough violations to categorize it as impaired (Category 5, 303(d)) according to DOE’s listing policy; or there might be data showing violation of water quality standards, but the data were not collected using proper scientific methods. Waters that are listed as a concern are waters that DOE will continue to test.

Previous Water Quality Studies Miller and Walker Creek Basins

The following provides a list, and in some cases a summary, of water quality studies and analyses which have been performed by various agencies and jurisdictions over the past few years. These technical studies and data are available to review at the Stormwater Services Section of King County Water and Land Resources Division, or can be obtained from the originating agency.

► **Summary Report of Preliminary Data Collected for the Site-Specific Water Quality Assessment (SSA) Study.**

Seattle-Tacoma International Airport, June 2002

In-stream concentrations of dissolved Zinc (Zn) and Copper (Cu) were measured at various locations in Miller and Walker Creeks. Up to four baseflow samples and up to five stormflow samples were analyzed at each sampling location. Miller Creek sampling locations included:

1. outfall from Lake Reba Stormwater Facility;
2. below the mixing zone from the Lake Reba Stormwater Facility outfall;
3. Miller Creek at 8th Street (below current & future drainages to Miller Creek); and
4. upstream of Lake Reba Stormwater Facility (background to airport discharges to Lake Reba Stormwater Facility); only one stormwater sample analyzed.

Walker Creek sampling locations include:

1. near the 176th Street overpass; and
2. at the 171st Street overpass.

Several samples were collected during each event. In total, eleven baseflow and 19 storm events/locations were analyzed.

There were no exceedances of Washington State Surface Water Quality Standards.

► **Dissolved Oxygen (DO)/Deicing Reports** prepared for the Port of Seattle:

Dissolved Oxygen Deicing Study, August 1999

1. Examining the Effects of Runway Deicing on Dissolved Oxygen in Receiving Waters: Results of the 1999-2000 Winter Season, Volume 1, November 2000.

2. Examining the Effects of Runway Deicing on Dissolved Oxygen in Receiving Waters: Results of the 1999-2000 Winter Season, Volume 2, January 2001.

The Port conducted two seasons of monitoring the effects of deicers on DO. The reports showed that the DO levels in Lake Reba Stormwater Facility fluctuated during storm events, but could not conclude that the fluctuations were a result of deicing operations.

► **Master Plan Update for Improvements at the Seattle-Tacoma International Airport, Biological Assessment, June 2000.**

Includes habitat assessments in Miller and Walker Creeks.

► **Fact Sheet for NPDES Permit WA-002465-1; Facility Name: Sea-Tac International Airport; Washington Department of Ecology (Ecology).**

This *Fact Sheet* was prepared by Ecology as background information to develop/issue the Port's revised NPDES permit. The report summarizes monitoring data that has been submitted as a requirement of the NPDES permit, and describes drainage infrastructure stormwater BMPs.

► **King County Stormwater Sampling**

King County sampled stormwater at 17 locations within the Miller and Walker Creek Basins during four storm events between 1991 and 1993. These samples were analyzed for conventional water quality parameters, bacteria, and total metals.

Metals (Copper and Zinc): During the time that the samples were taken, the Washington Surface Water Standards for toxic metals were based on total metal concentration. This standard has subsequently changed to being based on the dissolved fraction. Results, using total metal standards in effect at the time, showed exceedances in most samples, with particularly high metal concentrations at locations in Miller Creek north of SR518, adjacent to SR509 at S 136th Street, and at Ambaum Pond.

Turbidity, total suspended solids (TSS), and bacteria (fecal coliform): Turbidity and TSS were relatively low for stormwater. Fecal coliform bacteria exceeded the surface water standard (100 colonies per 100 ml) in all instances.

King County Sediment Sampling

Sediment samples were taken at eight locations throughout the basin. Samples were analyzed for semivolatile organics, oil and grease, total petroleum hydrocarbons, pesticides/herbicides, PCBs, and metals. Results for all constituents were low and did not indicate problems.

► **Southwest Suburban Sewer District**

Southwest Suburban routinely monitors instream water quality adjacent to the treatment plant located on Miller Creek. Routine

monitoring includes analysis for Dissolved Oxygen (DO), Temperature, pH, and Fecal Coliform bacteria. Fecal Coliform bacteria counts exceed the standard consistently, even at baseflow, and are the highest during storm events. DO and temperature have exceeded the standards during summer months. pH is within an acceptable range.

► **USGS Pesticide Sampling**

United States Geologic Service (USGS). USGS studied several urban streams in the Puget Sound region for the presence of pesticides. Miller Creek was one of the urban streams sampled. Three stormwater samples were tested for the presence of pesticides in 1998.

Six pesticides were detected in Miller Creek: Atrazine, Matolachlor, Prometon, Carbaryl, Diazinon, and Malathion. Both Carbaryl and Diazinon exceeded the recommended chronic toxicity criteria. Atrazine and Malathion did not exceed the recommended toxicity criteria. No aquatic toxicity criteria were available for Metolachlor or Prometon. The effects of pesticides in very low concentrations to aquatic organisms is not well understood. Several studies have indicated that low levels of pesticides may have sub-lethal behavioral effects. It is also speculated that low levels of pesticides may contribute to pre-spawn mortality observed in coho utilizing the streams.

Toxicity (bioassay) testing was not performed for Miller Creek. However, toxicity testing was performed for Lyon Creek, a tributary to Lake Washington located in southern Snohomish County and Lake Forest Park; it showed chronic toxicity to *Ceriodaphnia dubia* and *Selenastrum capricornuntum*. The toxicity could not be directly attributed to the pesticides. Lyon Creek had similar pesticide concentrations to those detected in Miller Creek.

Whereas most of the pesticides detected are available for residential use, Atrazine has little or no retail sales in King County according to a 1997 survey of pesticide sales. This indicates that this Atrazine may be applied in non-residential uses such as rights-of-way areas.

► **King County Capital Improvement Projects (CIPs)**

A few existing or proposed King County CIPs had very limited water quality monitoring associated with them. Storm water sampling from the Walker Creek Wetland CIP, Ambaum Pond, and Lake Reba Stormwater Facility sampling showed elevated pollutant levels.

► **Port of Seattle Miller Creek Outfalls / Lake Reba Stormwater Facility**

Stormwater from SeaTac Airport is currently discharged to Miller Creek, via Lake Reba Stormwater Facility, from four outfalls.

These outfalls are routinely monitored for compliance with the Port's NPDES permit.

► **Outfalls**

Outfalls are monitored for: pH, total petroleum hydrocarbon, fecal coliform bacteria, total suspended solids, turbidity, five-day biological oxygen demand, glycol, copper, lead, zinc, and WET (Whole Effluent Toxicity). Results of outfall monitoring indicated a zinc problem from one outfall. Further investigation identified that the elevated zinc levels are primarily from metal roofs within the drainage area. The Port is currently investigating elimination of the zinc source or treatment of the roof runoff to remove zinc.

► **Lake Reba Stormwater Facility**

Lake Reba Stormwater Facility is a regional detention and water quality facility. Lake Reba Stormwater Facility receives flows from Sea-Tac Airport, as well as other sources.

► **Water Quality Facilities at Sea-Tac Airport**

The Port of Seattle holds an NPDES permit for both stormwater discharges and operation of the Industrial Waste System (IWS). Stormwater from SeaTac Airport is either collected into the IWS or discharged to receiving waters.

The IWS collects industrial wastewater that is primarily from rainfall that falls on the terminal, air cargo, deicing areas, hangars, and maintenance areas. Areas of the airport that contain aircraft-related activity have been diverted away from being discharged to Miller Creek and are treated at the IWS. Forty-six acres of stormwater that previously discharged to Miller Creek from areas of aircraft-related activity have been diverted to the IWS. The IWS provides industrial wastewater treatment and the stormwater is ultimately discharged directly to Puget Sound through the Midway Sewer District's outfall.

► **Future Discharges from Sea-Tac Airport**

The airport expansion will create several new outfalls; seven to Miller Creek and three to Walker Creek. Prior to discharge from these outfalls, enhanced stormwater treatment will be provided. The goal of enhanced treatment is a higher level of metals removal than basic water quality treatment.

► **Stormwater Best Management Practices**

The Port of Seattle is required to implement stormwater pollutant source control best management practices (BMPs) to prevent and/or reduce pollutants from entering the storm system. BMPs that have been implemented include: Diverting deicing runoff to the IWS and using alternative deicing chemicals that result in a lower potential for water quality effects. In addition, zinc sources are being identified and either coated to prevent zinc from leaching, or provided with additional metal removal treatment.

► **DOE Water Quality Monitoring Station 09D070**

The Department of Ecology sampled near the mouth of Miller Creek in 2004. This non-storm event sampling indicated exceedances above the standard for Fecal Coliform bacteria. Based on this data, Miller Creek was listed as water quality impaired for Fecal Coliform. Metal concentrations did not exceed the standards.

Appendix G

**Miller and Walker Creeks
Basin Plan**

Appendix G: Geology Characteristics and Identified Problems of Miller and Walker Creeks

Miller Creek

A geologic characterization of the Miller/Walker Creeks Basin was undertaken based on field investigation and review of aerial photographs and maps. The Miller Creek basin contains three distinct physiographic subdivisions – upland, ravine, and alluvial fan. The upland portion is characterized by rolling, relatively low-gradient topography with average elevations of approximately 400 to 450 feet above sea level. It is underlain by glacial till, which is exposed in low hills. The hills are separated by swales filled by coarse (sand and gravel) glacial outwash deposits. Natural surface drainage in this part of the basin is generally conveyed in low-gradient channels that feed and drain natural lakes and wetlands including Arbor Lake and Tub Lake. The basin has two closed depressions (Hermes depression and SW 142nd Street depression) which have no natural drainage outlet.

Surface drainage from this upland area flows into a network of steep and steep-sided ravines that convey the stream from the uplands down to sea level. The ravine area was carved into the upland plateau by down-cutting of streams through layers of predominately glacial sediments. Layers of fine-grained sediments exposed in the ravines lead to perched water tables and zones of mid-slope seepage within the ravines. These areas of seepage are often prone to landsliding. Channel erosion and land sliding are natural processes in this landscape, but these processes can be dramatically accelerated by human alteration, and have been in the past.

As the stream emerges from its ravine and approaches sea level, the channel gradient decreases. Deposits of sediment occur as the stream flows across its alluvial fan. Under pristine conditions, parts of this area were wetland and tidal estuary. Much of the former estuary at the mouth of Miller Creek has been filled to create dry land. Sediment discharged from the mouth of Miller Creek provides an important source of sediment to the marine shoreline of Three Tree Point.

Identified problems

In general, streambed sediments in the basin are very coarse because stormwater runoff from past development has entered the basin largely unmitigated. The resulting increased flow peaks have preferentially removed finer sediments from the channel beds leaving the present coarse material (i.e. predominantly coarse gravel and cobbles). In some areas, the stream bed has been eroded down to the underlying till. In many areas channels have enlarged and incised abandoning formerly active floodplains which are now present as abandoned terraces.

This is not to say, however, that all areas in the basin have been equally affected by the past erosion. Also, it is important to note that continuing severe erosion is not currently a problem in most areas. In fact, it appears as though the basin has re-equilibrated to some extent to the existing flow regime and that, in general, it is geologically stable. This relative stability, however, should not be confused with any semblance of a pristine condition. Only by reducing high flows and erosion in the stream and preventing the introduction of sediments, will the stream morphology begin to return to a more habitat-supportive state.

Sediment has accumulated near the mouth on private property containing the Normandy Park Community Club causing the property owners to be concerned about flooding. The sediment accumulation here is probably a reflection of both an increased upstream sediment supply due to human disturbance combined with a naturally-depositional environment. However, during the reconnaissance level field surveys, discrete areas of severe erosion were not identified. Much of the present sediment supply in the system appears to originate from pervasive and ongoing channel incision and enlargement. Again, a basin-wide reduction in the erosive power of the stream will, to some extent, reduce the amount of sediment being transported to this area

In a number of areas the stream has been channelized, largely to prevent meandering across private property. This has usually been accomplished through bank hardening (i.e., placement of concrete, bricks, or large rock along the stream banks); in some areas the stream is constrained within culvert pipes. In addition to habitat impacts such channel modification often reduces natural storage and increases flow velocities, exacerbating increased peak flows downstream.

Walker Creek

A geologic characterization of the basin was undertaken based on field investigation and review of aerial photos and maps. The Walker Creek basin contains three distinct physiographic subdivisions – upland, ravine, and alluvial fan, just as in the Miller Creek basin. The general geologic and geomorphic circumstances are quite similar.

The Walker Creek basin contains several wetlands, most notably the headwater wetland along Des Moines Memorial Drive. Surface drainage from this upland area flows into the ravine area that starts at 2nd Avenue SW and SW 168th Street. The ravine then empties into an area of low gradient near the Normandy Park Community Club. Walker Creek joins Miller Creek at two locations, one near the club house and one further downstream (after exiting from a small pond known as the Beaver Pond).

Identified problems

The geology problems in Walker Creek are similar to those discussed for Miller Creek, although of a less severe nature; please see the Miller Creek Geology discussion for more general information. The degree of scour of the stream bed is somewhat less in Walker Creek than in Miller Creek, probably due to the larger areas of outwash soils in Walker Creek that infiltrate (soak up) more stormwater and the headwater wetland that buffers runoff from storm events.

There are some areas in Walker Creek and one of its tributaries, Sequoia Creek, that may be experiencing accelerated erosion. A reduction in flow peaks and durations will protect those areas not yet degraded and reduce the rate of erosion in the basin. Sediment discharge from Walker Creek also contributes to sediment accumulation in the common estuary area for the Miller/Walker Creeks Basin.

Appendix H

**Miller and Walker Creeks
Basin Plan**

Appendix H: Options for the Miller Creek Basin

High-flow and Erosion Reduction Options

The management objective for high-flow and erosion reduction specified a hydrologic goal for the basin that assumes a land cover of 75 percent forest, 15 percent grass, and ten percent impervious surface. Three options are presented to meet this goal:

- Detention regulations only;
- Regional capital facilities and detention regulations;
- Low-impact development retrofits, regional capital facilities, and detention regulations.

Each of the options is discussed below and summarized in **Exhibit H-1**.

**Exhibit H-1
Miller Creek Flow Regime Management Options**

OPTION	CAPITAL COST	PROS	CONS
FLOW CONTROL			
<p>Regulations Only Level 2 (75/15/10) detention standard</p>	\$0	<ul style="list-style-type: none"> • Large improvement in flow regime • Relatively easy to implement • Limited expenditure of public funds • Restorative standard that is consistent with Port's detention requirements 	<ul style="list-style-type: none"> • Only new development and re-development pays • Cost could be impediment to development • May take a long time for improvements to occur • Will not reach goal flows for basin
<p>Regional Capital Facilities and Regulations Miller Creek Regional Detention Facility – increase by 40 ac-ft to 130 ac-ft Ambaum Pond – increase from 2.5 ac-ft to 15 ac-ft City Light Property – 12 ac-ft plus Level 2 (75/15/10) detention standard</p>	<p>Miller Creek RDF - \$3,800,000 \$10,300,000 \$17,500,000 Ambaum Pond - \$600,000 City Light - \$1,200,000 Total \$5,600,000 - \$19,300,000</p>	<ul style="list-style-type: none"> • Can reach goal flows for basin • More equitable cost share between public and private • Can see benefits to stream sooner 	<ul style="list-style-type: none"> • Requires public funding source • Cities incur additional operation and maintenance responsibility and liability • Limited space to expand or construct new detention facilities
<p>Low-Impact Development Retrofits plus Regional Capital Facilities and Regulations</p>	\$?	<ul style="list-style-type: none"> • Same as above • Provides water quality benefits • Provides flow regime benefits 	<ul style="list-style-type: none"> • Same as above • Ability to accomplish dependent on site conditions • Need access to private property

1. Detention Regulations Only

This option requires each jurisdiction to establish and follow new stormwater regulatory requirements when permitting construction activities. The detention regulations currently in effect in each jurisdiction are summarized in **Exhibit H-2**. Several modeling runs were made to determine which detention standard would be necessary to achieve the goal flow.

There are two basic types of stormwater regulations that were considered: Level 1 and Level 2. Level 1 detention standards require peak runoff from new development to match existing peak runoff for flows for the two-year and ten-year flow events. The Level 1 standard is intended to curtail increases in peak flows caused by new impervious surfaces. Level 2 detention standards require new development and re-development to match pre-development condition peak flow durations for flows from fifty percent of the two-year flow to the fifty-year flow. In many jurisdictions, including King County prior to 2005, the predevelopment condition has been assumed to be existing site conditions. In the DOE manual, the predevelopment condition is assumed to be forest unless revised through an approved basin plan or study. The Port's mitigation plan for the third runway was approved with a predevelopment condition of 75% forest, 15% grass, and 10% impervious. The Level 2 standard as applied in the DOE Manual is intended to reduce existing peak flows and durations from developed areas as they re-develop.

Exhibit H-2
Summary of Detention Regulations in Effect as of January 2006

JURISDICTION	DETENTION REGULATION CURRENTLY USED
Burien	Level 2 (Existing site conditions) per Burien standards as modified from the King County Design Manual (King County, 2005)
King County	Level 2 (75/15/10) per King County Design Manual (King County, 2005)
Normandy Park	Level 1 per King County Design Manual (King County, 1998)
SeaTac	City area not within Des Moines Creek Basin: Level 2 (75/15/10) per King County Design Manual (King County, 2005) City area within Des Moines Creek Basin: Level 1 per per King County Design Manual (King County, 2005)
Port of Seattle	Level 2 (75/15/10) per Port Comprehensive Stormwater Management Plan (Parametrix, 2001c)
Washington State Department of Transportation	Level 2 (Existing site conditions unless otherwise specified by an approved basin plan) per WSDOT Highway Runoff Manual (Washington State Department of Transportation, 2004)

Exhibit H-3 depicts the effect of two different stormwater regulations on peak flows near the mouth of Miller Creek. If a Level 1 detention standard is used for the red parcels (except for the Port of Seattle that is required to use Level 2 (75/15/10), it does little to reduce the peak flows below current levels. A Level 2 (Forest) detention standard for the red parcels [except for the Port of Seattle that is required to use Level 2 (75/15/10)] does measurably reduce peak flows, but still does not attain the goal flow. This modeling run indicated that a Level 2 detention standard should be used instead of a Level 1 standard but that the goal flow rate cannot be achieved by regulation only.

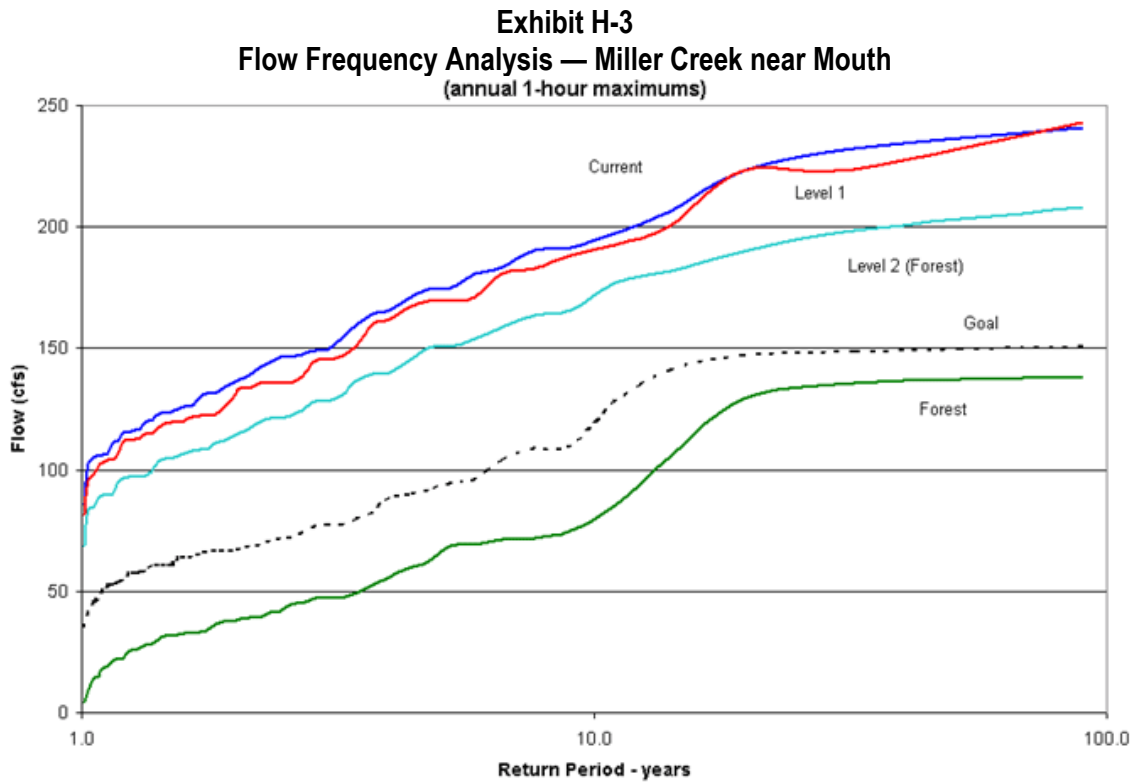
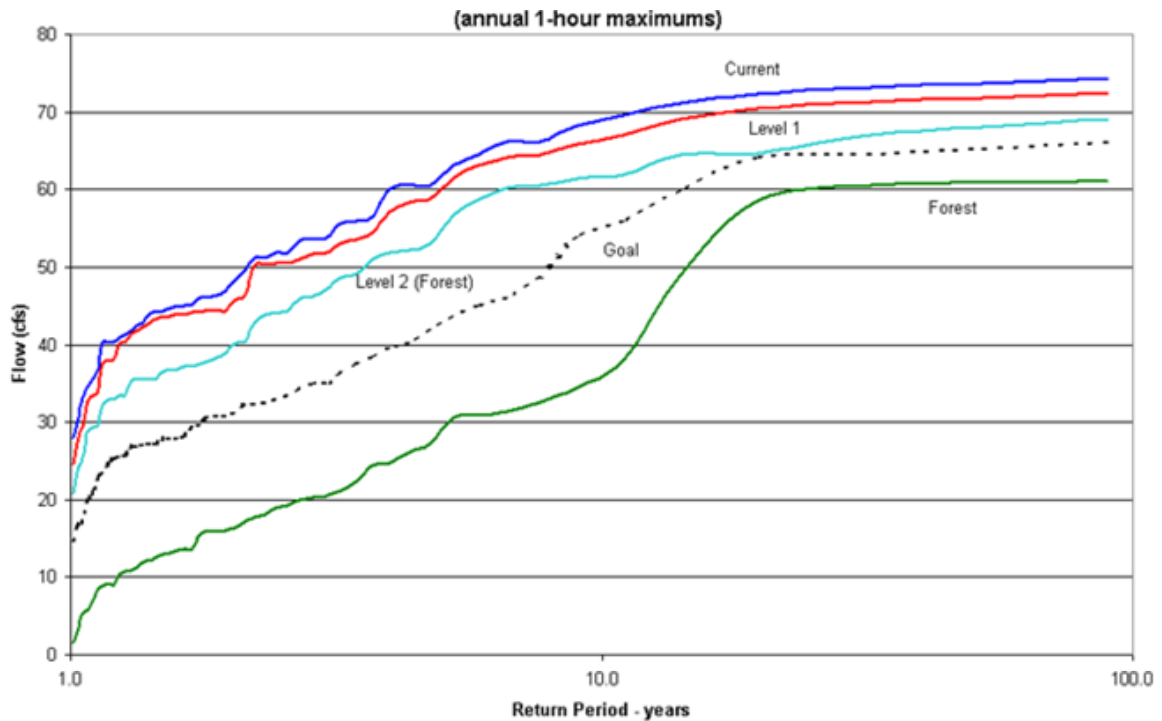


Exhibit H-4 compares Level 1 and Level 2 detention standards for Miller Creek at the MCRDF. Again, this modeling run indicates that Level 2 detention standards are preferable, although unable to achieve the goal flow.

Exhibit H-4 Flow Frequency Analysis — Miller Creek @ MCRDF



Exhibits H-5 and H-6 compare two different Level 2 detention standards, the state Department of Ecology Stormwater Management Manual Level 2 (Forest) standard versus the Level 2 (75/15/10) standard approved by Ecology for use by the Port of Seattle. The difference in the standards is that the Forest standard requires the new development or re-development to match a forested pre-development condition, while the 75/15/10 standard requires the new development or re-development to match flow durations expected under a land cover of 75 percent forest, 15 percent grass, and ten percent impervious surface coverage. The different standards produce nearly identical results. This was an important finding as the Level 2 (75/15/10) standard will be much more affordable for red parcel developers to meet than the Level 2 (Forest) standard. Also, it did not seem equitable to hold differing developments in the basin to differing detention standards. Because Ecology has already approved such a standard for the Port of Seattle, there is precedent to apply it to the basin as a whole, although Ecology would need to concur with such a standard.

Exhibit H-5 Flow Frequency Analysis — Miller Creek near Mouth

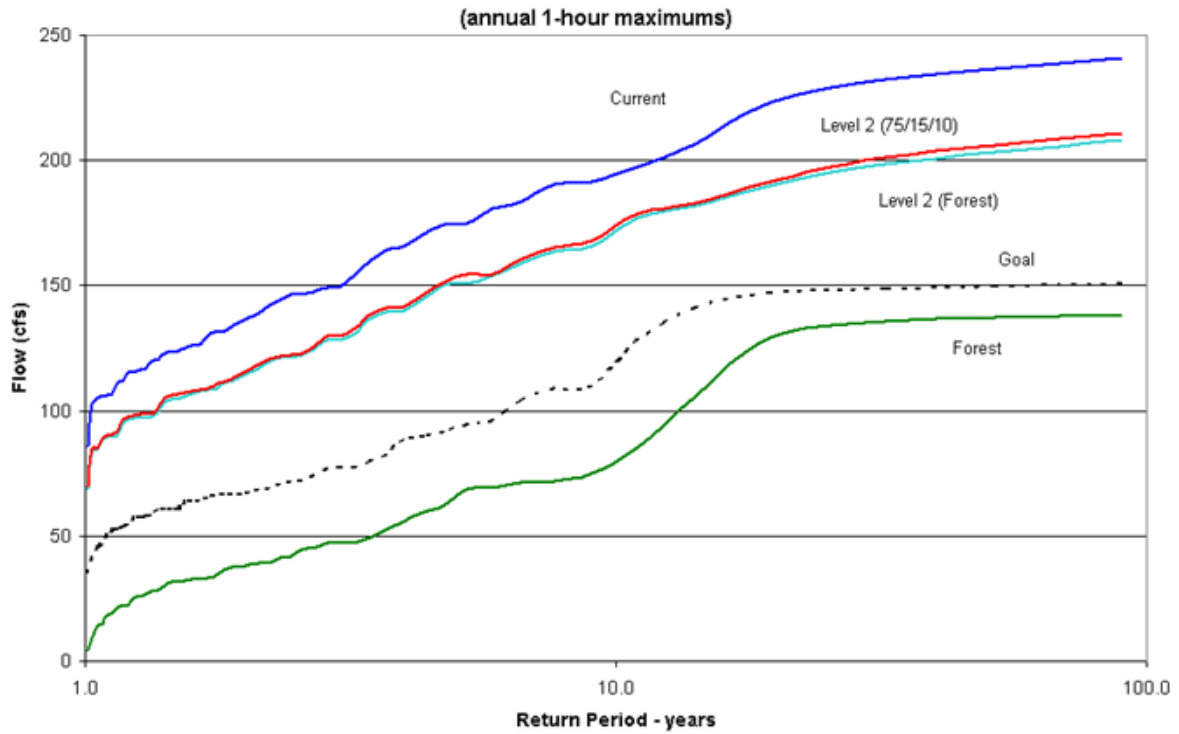


Exhibit H-6 Flow Frequency Analysis — Miller Creek @ MCRDF

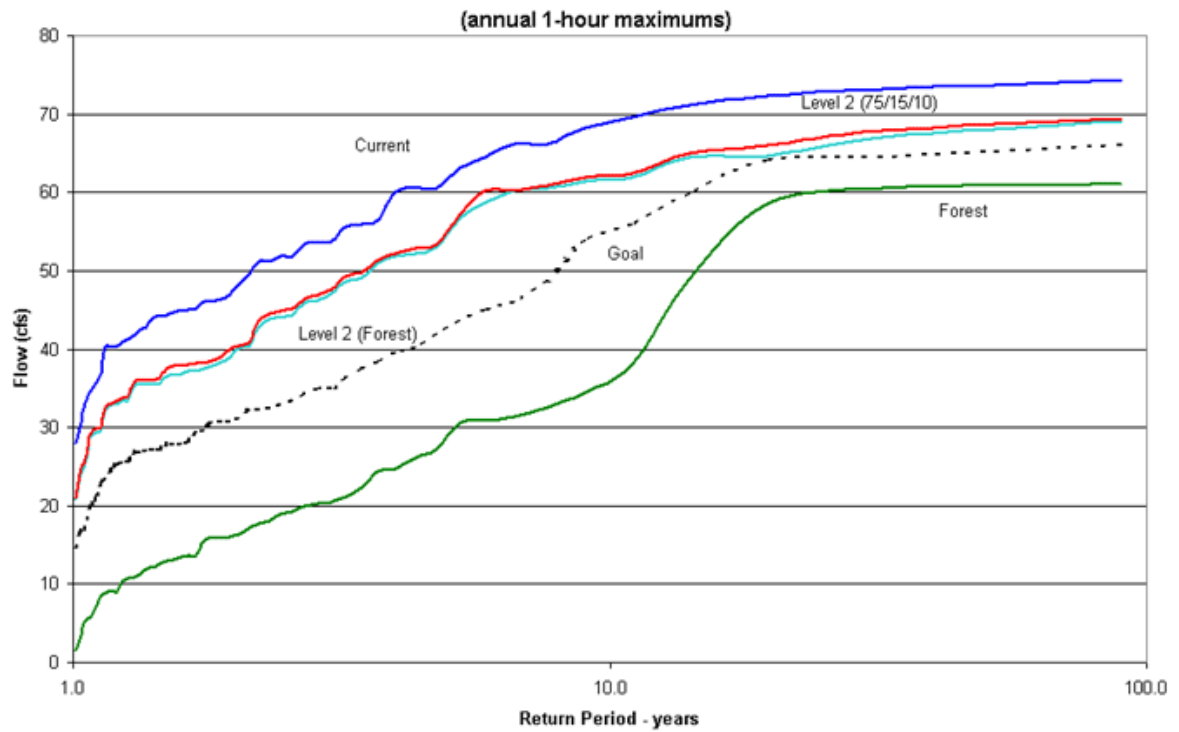
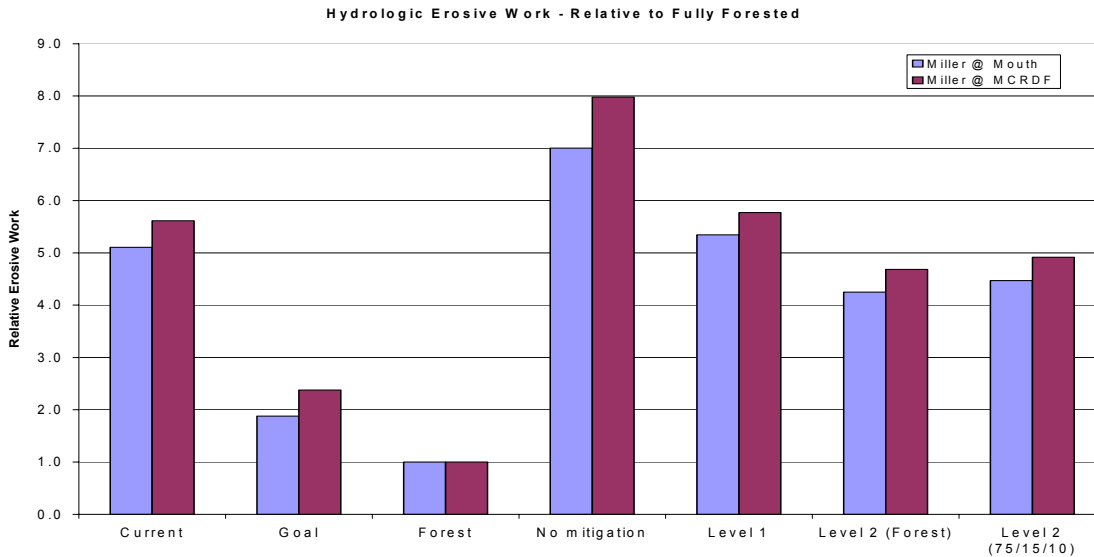


Exhibit H-9 shows the results of the erosive work analysis comparing different detention standards. None of the regulatory measures alone will achieve erosive mitigation equivalent to the goal flow. The Level 1 detention standard will achieve about 30 percent of the needed mitigation. Level 2 (Forest) and Level 2 (75/15/10) detention regulations will achieve comparable degrees of mitigation.

**Exhibit H-9
Miller Creek Degree of Mitigation of Erosive Work
Comparison of Detention Standards**



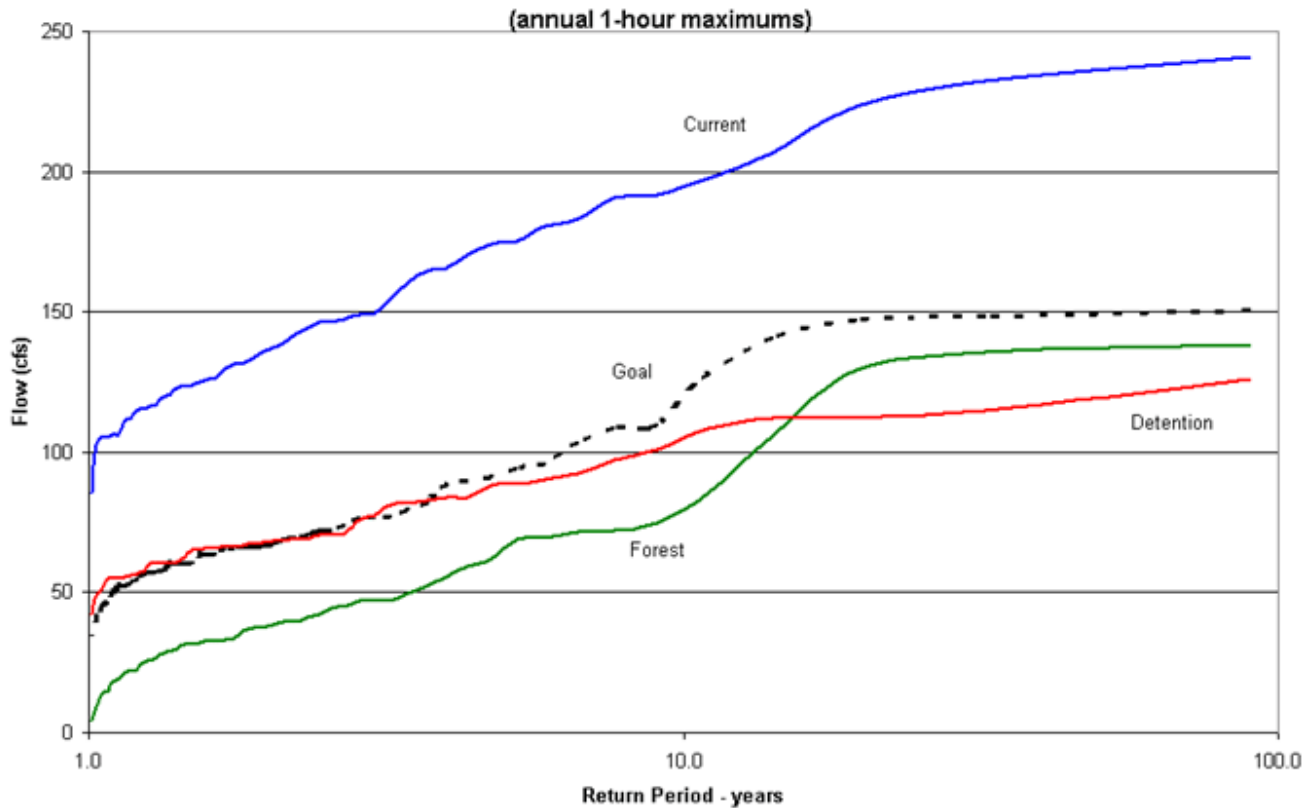
2. Regional Capital Facilities and Detention Regulations

In order to better meet the flow regime goal, the construction of capital facilities was considered as an addition to the regulations discussed above. The capital facilities considered included detention facilities and a by-pass line. The PMT’s evaluation of a by-pass line was not fully pursued because the Executive Committee believed that the by-pass line option was not desirable.

Because of the high degree of development in the basin, there are limited areas for construction of detention facilities. The three facilities identified below are not necessarily the only such facilities that could be constructed, but they do represent three potentially available detention sites that would provide detention at key areas in the basin. Two of the proposed projects are expansions of existing detention facilities, while one project is located on a currently undeveloped parcel.

Exhibits H-10 and H-11 and Exhibit H-7 examine the effects of additional stormwater detention facilities on peak flows at the mouth and at the MCRDF, respectively (this is in addition to the stormwater regulations discussed above). The detention option not only meets the goal flow, but provides more forest-like flows. **Exhibit H-11** shows that

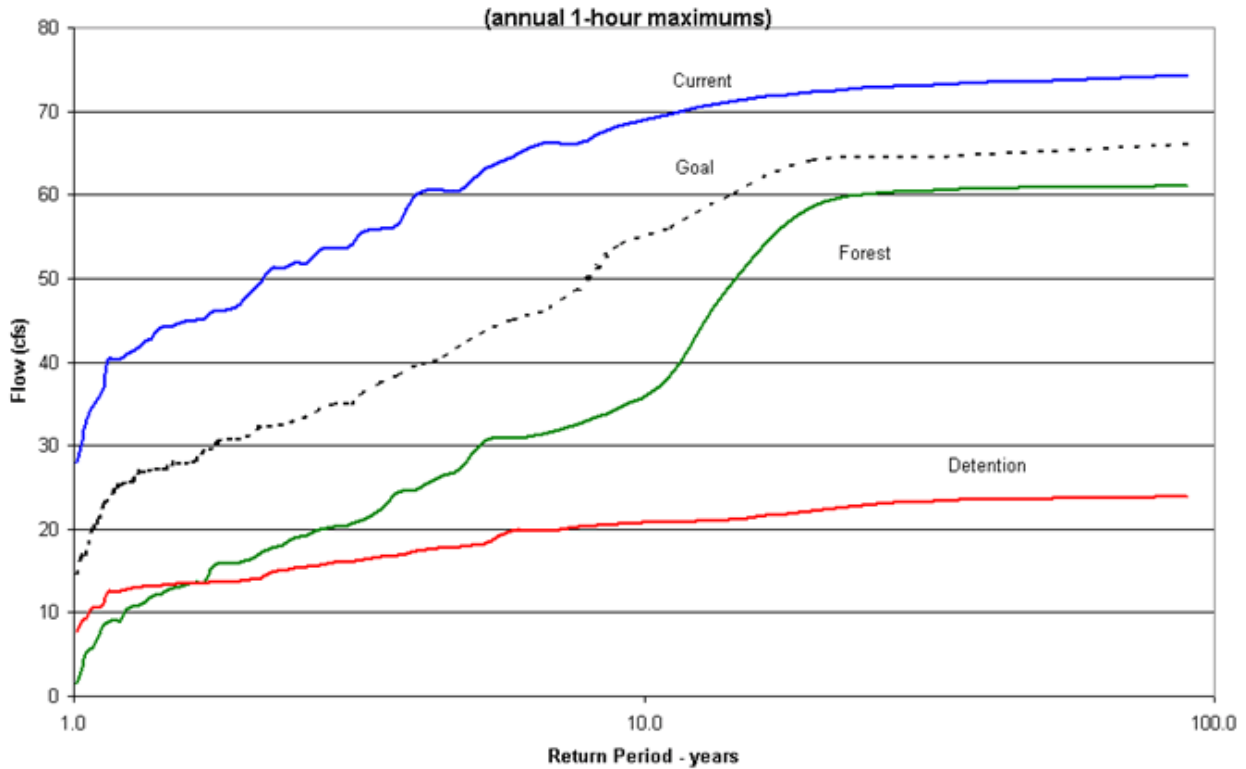
**Exhibit H-10
Flow Frequency Analysis — Miller Creek near Mouth**



the proposed detention facility expansion at the MCRDF will provide flows that are greatly reduced relative to forested conditions. Although this level of flow will result in a basin-wide achievement of the goal flow, it will be important to evaluate the flows near the MCRDF over time to ensure that their greatly reduced levels do not cause excessive accumulations of fine materials.

While there are other potential detention options in addition to those considered in this modeling run, the important point is that approximately 65 acre-feet of additional stormwater detention in the basin plus implementation of the stormwater regulations discussed above can achieve the goal flow at the mouth of Miller Creek. It should be noted that in some cases the predicted flow is well below the goal flow and, in some cases, below the forest flow; however, this result occurs only at the MCRDF which is located in the upper reaches of Miller Creek. It was necessary to over-detain flows along this reach in order to meet the goal flows at the mouth. During engineering design for the proposed facilities, a more detailed review of facility sizing should be conducted to evaluate the specific hydrologic and hydraulic effects of the facilities.

**Exhibit H-11
Flow Frequency Analysis — Miller Creek @ MCRDF**



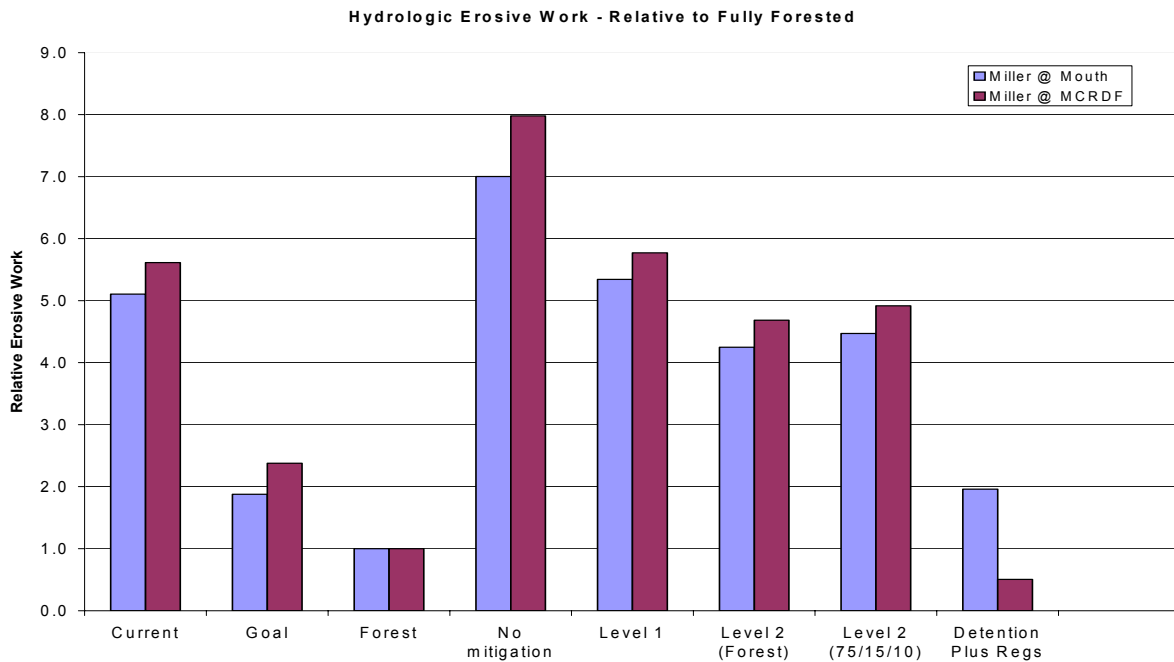
**Exhibit H-7
Miller Creek High Flows at Mouth and at Miller Creek Regional Detention Facility
Under Goal, Level 2 (75/15/10), and Detention and Regulations**

RUNOFF EVENT	GOAL FLOW (CFS)		LEVEL 2 (75/15/10) (CFS) (RED PARCELS ONLY)		DETENTION AND REGULATIONS (CFS)	
	Mouth	MCRDF	Mouth	MCRDF	Mouth	MCRDF
100-yr	171	74	215	73	128	25
50-yr	158	68	204	70	123	24
25-yr	141	61	191	67	115	23
10-yr	114	51	168	61	101	20
5-yr	88	41	145	53	84	18
2-yr	44	25	101	35	50	12

Exhibit H-12 shows the results of the erosive work analysis for the detention plus regulations option. That option, which includes Level 2 (75/15/10) detention standards and 65 ac-ft of additional detention in the basin, does a very good job of approximating the goal. The goal is exceeded for erosive work at the MCRDF by over fifty percent (i.e., there

is less erosion in the detention option than in the goal). In fact, the detention plus regulations option results in less erosive work than even the forested option at the MCRDF. Erosive work at the mouth is nearly identical to the goal option.

**Exhibit H-12
Miller Creek Degree of Mitigation of Erosive Work
Detention Plus Regulations Option**



The three detention facilities considered as part of the detention plus regulations option are discussed below:

a. Expansion of the Miller Creek Regional Detention Facility

The Miller Creek Regional Detention Facility (MCRDF) is a 90 ac-ft detention facility located on Miller Creek near the north end of Sea-Tac airport. It is owned and operated by the Port and is located around the periphery of the Lake Reba Stormwater Facility detention facility (i.e., the Lake Reba Stormwater Facility overflows into the larger MCRDF). The facility could be expanded to provide an additional 40 ac-ft by raising the elevation of the adjoining roads approximately two feet. This would impound more storm flows and allow them to be released at a controlled rate. The facility would cause some backwatering (increasing upstream water levels due to downstream conditions), but there do not appear to be any structures in the area that would be affected. It is estimated that this option would cost between \$3,800,000 to \$17,500,000

for design, permitting, and construction. It was assumed that there would be no property acquisition or easement costs.

The wide range of costs is due to uncertainty about Federal Aviation Administration (FAA) requirements for bird control near the airport; in general, the FAA discourages areas of open water near runways (Refer to Appendix H). The lowest cost estimate, \$3,800,000, is for a facility expansion with netting installed over any areas of potential open water. A cost of approximately \$10,300,000 would be required for a facility expansion with a floating cover installed over areas of potential open water. The most expensive option, with a cost of approximately \$17,500,000, is for a 40 ac-ft detention vault, essentially an underground storage tank.

Before any expansion of this facility could occur, FAA and Port concerns about airport safety due to the potential for bird strikes would need to be fully addressed. Impacts to roads and wetlands in the area would also need to be considered.

b. Expansion of Ambaum Detention Pond

The Ambaum Detention Pond is located on the east side of 1st Avenue South where South 163rd Place would be, if extended. It currently provides 2.5 ac-ft of stormwater detention. The sub-basin it serves is 367 acres in size, with over 215 acres of effective impervious area (impervious area directly connected to the drainage system, i.e., pipes, ditches, etc.). The facility could be expanded by acquiring additional property or easements on a vacant and undevelopable parcel immediately to the south of the existing facility.

The City of Burien is negotiating the purchase of the undevelopable parcel. Once the property is acquired, some excavation and berming would be needed in addition to construction of a new outlet structure or modification of the existing one. Water quality treatment should be incorporated into the design as this sub-basin is the most intensely developed of any sub-basin in Miller Creek. The estimated cost is \$600,000 for property acquisition, design, permitting, and construction. Water quality costs are discussed separately (see below).

c. City Light property

This 4.6-acre property is located adjacent to the west side of SR 509 at South 136th Street. It is currently owned by Seattle City Light, but is vacant. A previous study (Kato and Warren, 1996) identified this parcel as suitable for construction of a 12 to 14 ac-ft detention facility at a cost of \$1,080,000. This report assumes a 12 ac-ft facility at a cost of \$1,200,000. Seattle City Light should be contacted to determine if they are interested in selling the property. One consideration for them may be the availability of another site in the area for future construction of a power sub-station. The proposed project would include excavation and construction of an outlet structure. Water quality treatment should also be incorporated into the design. Water quality costs are discussed

separately (see below). It should also be noted that the City of Burien has considered purchasing this property for the development of soccer fields. Any development of the property for detention would need to consider the potential for multiple uses.

3. Low Impact Development Retrofits plus Regional Capital Facilities and Detention Regulations

In order to help meet the flow regime goal, new development in the basin could be required to implement low impact development practices, such as maximizing on-site retention and infiltration of stormwater runoff and retention of native vegetation on the lot. In addition, existing development could be retrofitted to minimize impacts to the hydrology by implementing best management practices that maximize retention and infiltration of roof, driveway, and sidewalk runoff. Examples include construction of dry wells for roof infiltration, construction of infiltration galleries for flows from driveways and sidewalks, and construction of rain gardens and permeable pavement driveways among others. Of course, this option would require the participation of property owners; property access, liability, and responsibility for maintenance would be among the issues to be resolved. This option should be further explored if flow and habitat monitoring data show that there is a further need to reduce flows or if some capital projects aren't constructed.

Water Quality Improvement Options

The management objective for water quality identified a water quality treatment goal to reduce pollution in the basin; namely, a reduction in total suspended solids and metals. This goal is in addition to the existing source control and public education programs already provided by the jurisdictions in the basin. Three options are presented to meet this goal:

- Regulations only
- Retrofits of existing development and regulations
- Regional capital improvements, retrofits, and regulations

Each of the options is discussed below and summarized at the end of this section in **Exhibit H-13**.

1. Regulations Only

This option includes both stormwater treatment and pollutant source control. Much of the future development in the basin will be required to provide enhanced water quality treatment that is designed to remove metals from stormwater runoff. The DOE Manual requires enhanced treatment in the following areas:

**Exhibit H-13
Miller Creek Water Quality Management Options**

OPTION	CAPITAL COST	PROS	CONS
WATER QUALITY			
<p><u>Regulations Only</u> Require new development and re-development to provide enhanced treatment for high-impact land uses. Establish water quality codes and implement source control BMPs.</p>	\$0	<ul style="list-style-type: none"> • Will remove not only 80% TSS but also 50% of total metals, a primary pollutant in the basin • Using BMPs to prevent pollutants from entering stormwater is the most cost-effective approach 	<ul style="list-style-type: none"> • Treatment will only be provided as development and re-development occurs and will only affect large developments • Source control requires a long-term commitment to be effective
<p><u>Retrofits of Existing Development and Regulations</u> Retrofit existing highways, high-use local roads and high-density developments Includes coating or replacing galvanized guard rails Retrofit untreated runoff in existing residential development</p>	TBD	<ul style="list-style-type: none"> • Will treat polluted water from existing development • Runoff from galvanized surfaces (a source of zinc) would be treated • Focusing on high-use areas allows for more effective treatment • Residential retrofits will address many areas of existing development 	<ul style="list-style-type: none"> • Requires available space • Guardrail coating requires periodic maintenance • Extremely expensive when implemented throughout basin
<p><u>Regional Capital Improvements, Retrofits, and Regulations</u> Construct capital projects to provide water quality treatment (see below)</p>		<ul style="list-style-type: none"> • Provides treatment on a sub-basin level • No need to wait for development to occur 	<ul style="list-style-type: none"> • Expensive • Treatment may not be as effective as treatment at the source
<p><u>1. Hermes Depression</u> Move intake lines to pumps to floating platform</p>	\$100,000	<ul style="list-style-type: none"> • Existing large detention area • Allows for pollutant removal prior to discharge to Miller Creek • Relatively simple modifications 	<ul style="list-style-type: none"> • Ensure that flood protection capacity is not reduced
<p><u>2. Ambaum Pond</u> Create an additional 10 ac-ft of dead storage or large sand filter treatment</p>	\$500,000	<ul style="list-style-type: none"> • Basin draining to facility has large number of pollutant sources – treatment here will benefit basin 	<ul style="list-style-type: none"> • Space is extremely limited • Need to acquire adjacent property

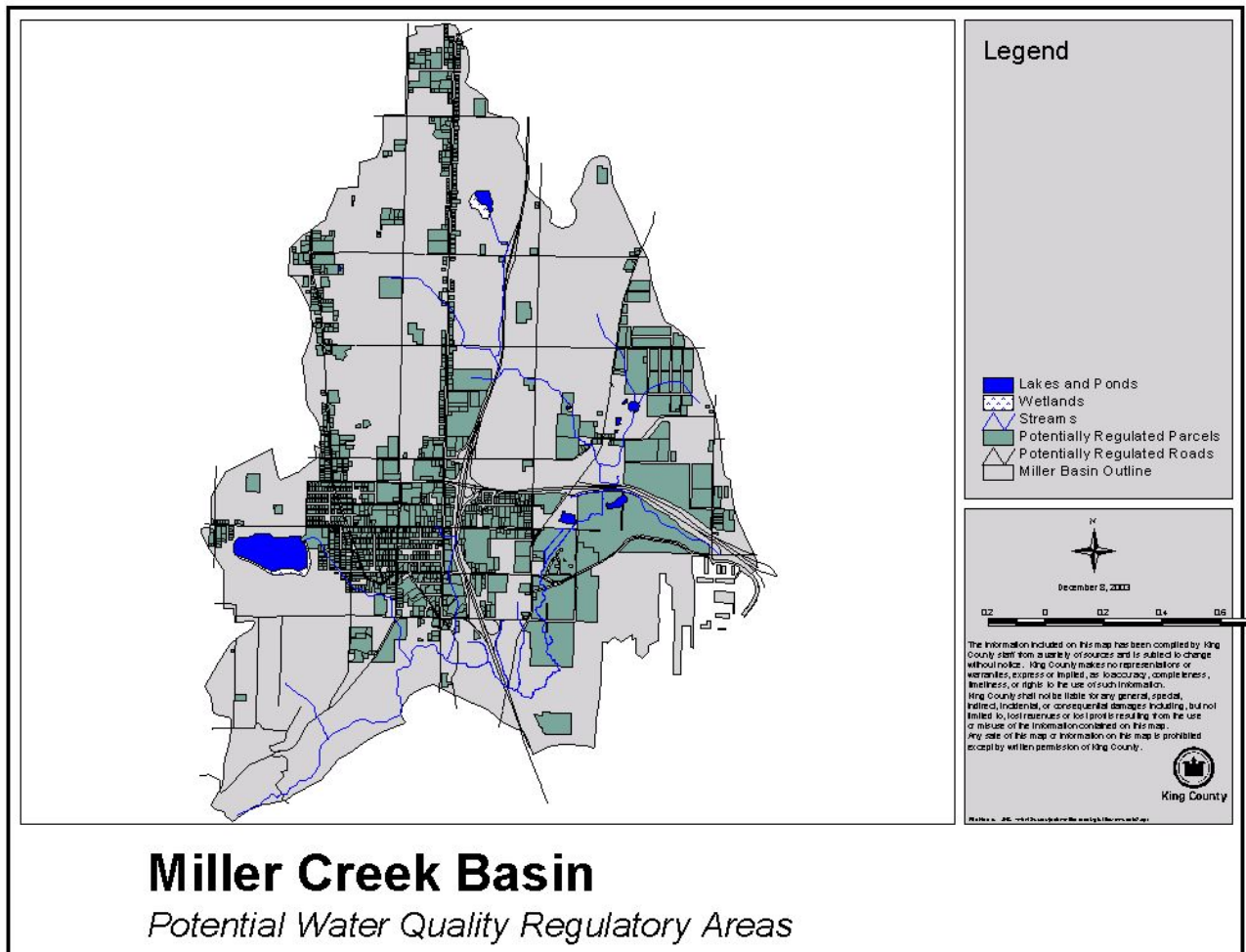
“Enhanced treatment is required for:

- ▶ Industrial project sites,
- ▶ Commercial project sites,
- ▶ Multi-family project sites, and
- ▶ Arterials and highways

that discharge to fish-bearing streams, lakes, or to waters or conveyance systems tributary to fish-bearing streams or lakes.”

Exhibit H-14 depicts those properties in the basin that may be required to provide enhanced treatment when development or re-development occurs. The figure shows a proposed threshold that includes capture of residential areas with greater than 8 dwelling units per acre. The cost of these treatment facilities will be borne largely by the private sector, although some public sector costs will also be incurred, primarily in new road construction.

Exhibit H-14
Enhanced Water Quality Treatment Parcels and Roads



Jurisdictions in the basin currently have water quality treatment requirements for new development meeting certain thresholds. Although all of the jurisdictions require enhanced treatment in some situations, the number of cases in which enhanced treatment will be required is likely to increase in the future as new Department of Ecology water quality treatment regulations are implemented.

In addition, each jurisdiction should ensure that it has established water quality codes consistent with Ecology's *Stormwater Management Manual for Western Washington* and is implementing programs that identify pollutant sources, require implementation of measures to control the pollutant (Best Management Practices, BMPs), and enforce violations. BMPs should also be equivalent to those in the Stormwater Management Manual for Western Washington. Jurisdictions in the basin should also ensure that they have implemented integrated pest management programs to minimize the use of pesticides (both herbicides and insecticides) for maintaining public right-of-way. These changes in program management often can be achieved for little or no cost.

2. Retrofits of Existing Development and Regulations

Sole reliance on water quality regulations will address only new development and re-development. The majority of the basin, however, is not expected to be subject to those regulations because it is unlikely to change much in the next several decades. In order to address the water quality problems attributable to the existing development, retrofitting of existing development should be considered.

On-site water quality treatment should be provided for surface water runoff from existing development that is not currently treated. This is a long-term strategy that will improve the water quality of Miller Creek. Treatment should be provided to the maximum extent practicable in the following priority:

a. Retrofits of Existing Roads and Highways

Currently, there is very little stormwater treatment of roads or highways in the Miller Creek basin. Roads and highways can contribute high concentrations and loads of toxic metals and oils to stormwater due to these materials being discharged from vehicles. Pollutant removal efficiencies of stormwater treatment facilities increase with high influent concentrations. Treatment of these higher-concentration areas will provide the greatest reduction of pollutant concentrations in Miller Creek.

- ▶ SR 509 and SR 518 both contribute pollutant concentrations and loadings and should be retrofitted to include water quality treatment. Priority areas of the highways are those areas that discharge directly to Miller Creek. Treatment facilities that provide increased metals removal should be used. Emerging technologies such as the Ecology embankment or swale, which

utilize perlite for enhanced metal removal, should be considered for highway and road retrofits.

- ▶ Local road systems also are pollutant sources and should be retrofitted with treatment systems if their expansion will not otherwise trigger treatment requirements. Priority for providing treatment should be based on the amount of vehicle use, commonly expressed as average daily trips (ADT). More heavily-used roadways accumulate more pollutants and therefore are a higher priority for providing treatment.

b. High-Density Development

These are commercial, industrial, and single- and multi-family residential areas that are highly developed and that discharge directly to the stream or drainage system. These areas currently do not provide any attenuation of stormwater flows or removal of pollutants because they were developed prior to SEPA and drainage regulations. Retrofits could include filtering through vegetation (e.g., bio-swale), infiltration, and sand and compost filters.

3. Regional Capital Improvements, Retrofits, and Regulations

In some areas of the basin, there are potential opportunities to negotiate with property owners to acquire currently undeveloped property, either through outright purchase or through easements, and provide more immediate water quality improvement through capital projects designed to treat water, or otherwise improve its quality, on a sub-basin level. Several potential capital improvement projects have been identified.

a. Seattle City Light parcel

Seattle City Light owns a vacant parcel of land adjacent to the west side of SR 509 at S 136th Street. (see the related detention project above). The detention project proposed for the site would include excavation and construction of an outlet structure. Water quality treatment should be incorporated into the design. The most probable treatment at that site would be either dead storage or a treatment wetland because the site is very flat. The estimated cost for this project for design, permitting, and construction is \$250,000. This assumes that the project will be part of the larger detention project and does not include separate land acquisition costs.

c. Ambaum Detention Pond

The Ambaum detention pond should be retrofitted to provide water quality treatment. Ambaum pond provides some level of detention for approximately 367 acres, 215 acres of which are impervious surface, although not sufficient by today's standards. Stormwater entering the facility has been identified as containing high levels of pollutants,

particularly metals. Space for retrofitting the pond is limited and the benefits of providing water quality treatment have to be weighed against providing additional detention. There is not sufficient space to provide treatment consistent with the goals of basic water quality treatment (80% TSS removal); however, adding dead storage to the existing pond could provide measurable treatment of the stormwater. Perhaps even better, would be creation of a stormwater wetland, as they are more effective in metals removal than dead storage is. In addition, a stormwater wetland would require less volume than dead storage for a comparable level of treatment; however since water level fluctuations cannot exceed three feet for wetland plant survival, this option is highly dependant on the live storage (detention) choice.

Depending on the flow regime management option selected, it is possible that all of the existing facility, and even an expanded facility, might be available for water quality treatment. Because this water quality project is so dependent on the flow regime option selected, only a very approximate cost can be given – about \$500,000. This cost and the size and effectiveness of the water quality treatment facility could vary considerably.

d. Hermes Depression

Water stored in Hermes depression is currently pumped to Miller Creek. The inlet for the pumps is currently located near the bottom of the pond. By altering the pump inlet to pipes suspended on a floating platform, an increase in water quality should be realized. This is because as stormwater is retained in the depression, solids and associated adsorbed pollutants settle to the bottom of the depression. The floating pump inlet should be suspended just below the surface of the water level so that the cleanest water is pumped out to Miller Creek. This is a very easy capital fix requiring minimal design and no permitting, property purchase, or change in operation. Capital costs are estimated at \$100,000 or less.

Habitat Protection and Improvement Options

The management objective for habitat calls for increases in fish returns. Several options are presented to meet this goal. Each of the options is discussed below and summarized at the end of this section in **Exhibit H-15**.

**Exhibit H-15
Miller Creek Habitat Management Options**

OPTION	PUBLIC COST	PROS	CONS
<i>HABITAT</i>			
<p><u>Estuary Restoration</u> Re-create estuary habitat by removing some fill material and establishing estuary plantings</p>	<p align="center">\$? Depends on the projects agreed to by the community club owners</p>	<ul style="list-style-type: none"> • Critical to restoring fish populations • Would benefit not only Miller and Walker Creeks, but Puget Sound • Relatively easy to do • Benefits are nearly immediate • Provides habitat for amphibians and birds 	<ul style="list-style-type: none"> • Could adversely impact community club owners unless potential projects are fully coordinated with them and approved by them
<p><u>Culvert Replacement at 1st Av. S</u> Existing culvert is fish passage barrier because it's too steep and flow velocities are too high</p>	<p align="center">\$500,000 - \$1,000,000</p>	<ul style="list-style-type: none"> • Improved passage for juvenile salmonids 	<ul style="list-style-type: none"> • May be of limited value if areas of estuary habitat not restored
<p><u>Add Riser to Sewer Manhole</u> Sewer manhole submerged in Miller Creek just downstream of 1st Av S culvert</p>	<p align="center">\$50,000</p>	<ul style="list-style-type: none"> • Prevents de-watering of stream and excessive I/I in sewer 	<ul style="list-style-type: none"> • Requires coordination with sewer district and work in the stream
<p><u>Remove Concrete Weirs</u> Weirs in stream bed just downstream of submerged sewer manhole</p>	<p align="center">\$350,000</p>	<ul style="list-style-type: none"> • Restoring gravels in area provides habitat 	<ul style="list-style-type: none"> • Weirs supposedly provide protection for sewer line • Requires coordination with sewer district and private property owners to work in the stream
<p>Purchase property or conservation easements whenever possible</p>	<p align="center">Variable</p>	<ul style="list-style-type: none"> • Will provide habitat and allow options for future management strategies 	<ul style="list-style-type: none"> • Jurisdictions have limited funds • Often difficult to reflect importance of preservation in limited budgets
<p><u>Remove Asphalt Ditch</u> Conveying Miller Creek along SR 509 and replace with gravel and replant riparian corridor</p>	<p align="center">\$400,000</p>	<ul style="list-style-type: none"> • Provides habitat improvement and reduces pollutant input to stream 	<ul style="list-style-type: none"> • Access could be an issue • Need to ensure not to damage road prism

1. Remove Concrete Weirs

Just downstream from the 1st Avenue South culvert and the in-stream sewer manhole is a series of concrete weirs in the stream bed. The weirs are evidently intended to protect the sewer line buried beneath the creek, although their efficacy is questionable. It appears that the weirs could be removed and replaced with appropriately-sized gravel that would improve habitat by providing areas for insects to live and fish to spawn. In addition, large woody debris or boulders could be added to create some roughness elements in the stream, and native plants could be used to re-vegetate the stream bank. The project would need to be done in coordination with Southwest Suburban Sewer District, the owner of the sewer line. The estimated cost for design, permitting, and construction is \$350,000.

2. Add Riser to Sewer Manhole in Stream

Just downstream from the 1st Avenue South culvert is a sewer manhole located directly in the stream. It appears to be submerged for much of the time. A riser should be added to the manhole to reduce the potential for de-watering of Miller Creek and excessive inflow to the sewer system. The project would need to be done in coordination with Southwest Suburban Sewer District, the owner of the manhole. The estimated cost for design, permitting, and construction is \$50,000.

3. Culvert Replacement at 1st Avenue South

The existing 72-inch culvert is a fish passage barrier, especially to juvenile fish, because it is steep and the velocities of the water flowing through it are high. Given the flows passing through it, it may be oversized. Replacement of the existing culvert with a new culvert to aid fish passage is estimated to cost between \$500,000 to \$1,000,000, including design, permitting, and construction. Note: May be a FAA/wildlife attractant issue.

4. Purchase Property or Conservation Easements

One of the best ways to protect Miller Creek and allow for future management options to be made is to purchase riparian property beyond the regulatory buffers or obtain conservation easements on such property whenever possible. Public ownership or stewardship of such properties will allow for future restoration to occur as money is available. Even if no restoration is done on a site for long periods of time, the site will at least remain undeveloped and the stream passing through it can function more naturally than if the property were to be developed. Because of the large variation in property sizes and prices, it is not possible to provide a cost estimate for this project.

5. Estuary Restoration

The confluence of Miller and Walker creeks occurs in an area that formerly contained more estuary habitat than is currently present. Some areas of the estuary were filled in the 1960s as the lowland area was developed as a privately-owned park and recreation area, the Normandy Park Community Club, jointly owned by about 1,800 homeowners in the area. The loss of estuarine function has caused a corresponding loss of habitat for amphibians, small mammals, birds, insects, wetland plants, and fish. If the habitat management goal is to be met, then improvements in estuarine function should occur.

Recent stream restoration work proposed by the Normandy Park Community Club involves removal of invasive plant species, planting of native species, placement of large woody debris, meandering of the stream (particularly Walker Creek), and restoration of lost salt-water and fresh-water marshes. This restoration work will be very beneficial to the basin and will improve estuarine function.

Further restoration of the estuary is an important part of the habitat strategy for this plan. Jurisdictions should work with the property owners to find ways to create further habitat improvements.

6. Remove Miller Creek from Asphalt Ditch

Miller Creek is currently channeled into an asphalt ditch along the west side of SR 509 between approximately South 127th Street. (if extended) and South. 136th Street. The asphalt should be removed and replaced with appropriately-sized gravel and soils. In addition, native vegetation should be planted along the re-established stream bed to create a riparian area. This will provide some treatment of stormwater prior to its entry into Miller Creek. It will also allow for infiltration of some of the flows. The estimated cost for this project, including design, permitting, and construction, is \$400,000.

Monitoring and Stewardship Options

Although there are no specific goals in this basin plan regarding monitoring and stewardship, it is imperative to have both activities if the basin plan is to be successful. Monitoring of stream flows, water quality, and habitat will provide scientific information so that decisions concerning the basin are not made in a vacuum. Monitoring data allow the most basic questions to be answered. One frustration encountered in preparing this basin plan was that there are very few data available regarding water quality and habitat for Miller Creek or Walker Creek.

Stewardship activities will educate and inform the public so that they feel connected to the basin and will engage in behaviors that will protect and support it. Stewards can act as clearing houses for information for both the public and the agencies operating in the basin. For example, a steward could be the point of contact for providing best management

practices information for water quality source control to businesses in the basin. They can also coordinate volunteer activities such as stream cleanups, invasive weed removals, native vegetation plantings, and monitoring activities. Outreach to schools is also another important job that stewards can perform.

One potential opportunity for collecting monitoring data and fostering and coordinating stewardship is a partnership with existing community groups. One of those community groups is the Environmental Science Center Foundation at Seahurst Park. Although Seahurst Park is not within the Miller or Walker Creek basin, the foundation is designed to promote an understanding of both marine and fresh water habitats. The Normandy Park Community Club is another existing community group that may be interested in further participating in monitoring and stewardship activities.

Both monitoring and stewardship programs are on-going commitments that must be funded annually. Annual costs are estimated at \$50,000 for each program and include the activities for both Miller Creek and Walker Creek. **Exhibit H-16** summarizes the monitoring and stewardship programs.

Exhibit H-16
Miller Creek Monitoring and Stewardship Management Options

OPTION	PUBLIC COST	PROS	CONS
MONITORING AND STEWARDSHIP – ANNUAL COSTS			
<p><u>Flow, Water Quality, And Habitat Monitoring</u> Establish an on-going environmental monitoring program to collect basic hydrologic information (precipitation and stream flow), water quality data (temp, DO, hardness, fecals, nutrients, metals), and habitat data (fish counts, B-IBI)</p>	\$50,000 Annual Cost	<ul style="list-style-type: none"> Will allow evaluation of effectiveness of regulations, capital projects, and operations and maintenance practices Only way to be able to tell if stream is improving or not 	<ul style="list-style-type: none"> Requires on-going financial commitment
<p><u>Basin Stewardship</u> Fund a half-time position to coordinate public outreach and information, including an annual report on basin condition and coordination of volunteer activities</p>	\$50,000 Annual Cost	<ul style="list-style-type: none"> Offers one-stop shopping for citizens interested in the health of the basin Serves as a point of coordination within and between agencies Results in improved water quality and habitat through education and volunteer projects 	<ul style="list-style-type: none"> Requires on-going financial commitment

Appendix I

**Miller and Walker Creeks
Basin Plan**

Appendix I: Options for the Walker Creek Basin

High-flow and Erosion Reduction Options

The management objective for high-flow and erosion reduction specified a hydrologic goal for the basin that assumes a land cover of 75 percent forest, 15 percent grass, and ten percent impervious surface. Two options are presented to meet this goal:

- Detention regulations only;
- Low-impact development retrofits and detention regulations.

Each of the options is discussed below and summarized at the end of this section in **Exhibit I-1**.

1. Detention Regulations Only

This option requires each jurisdiction to establish and follow a new stormwater regulatory requirement when permitting construction activities. The detention regulations currently in effect in each jurisdiction are summarized in **Exhibit H-2** in the **Appendix H**.

Exhibit I-1
Walker Creek Flow Regime Management Options

OPTION	CAPITAL COST	PROS	CONS
<i>FLOW CONTROL</i>			
<u>Regulations Only</u> Level 2 (75/15/10) detention standard	\$0	<ul style="list-style-type: none"> • Large improvement in flow regime • Easy to implement • No expenditure of limited public funds • Consistent with Port's detention requirements • Appropriate protective standard for the basin 	<ul style="list-style-type: none"> • Only new development and re-development pays • Cost could be impediment to development • May take a long time for improvements to occur • Will not reach goal flows for basin
<u>Low-impact Development Retrofits plus Regulations</u> Infiltrate runoff from roofs, driveways, and sidewalks for both new and existing development	\$?	<ul style="list-style-type: none"> • Should be relatively easy to do in Walker Creek because of outwash soils • Provides water quality benefits 	<ul style="list-style-type: none"> • Need access to private property

Exhibit I-2
Flow Frequency Analysis — Walker Creek near Mouth

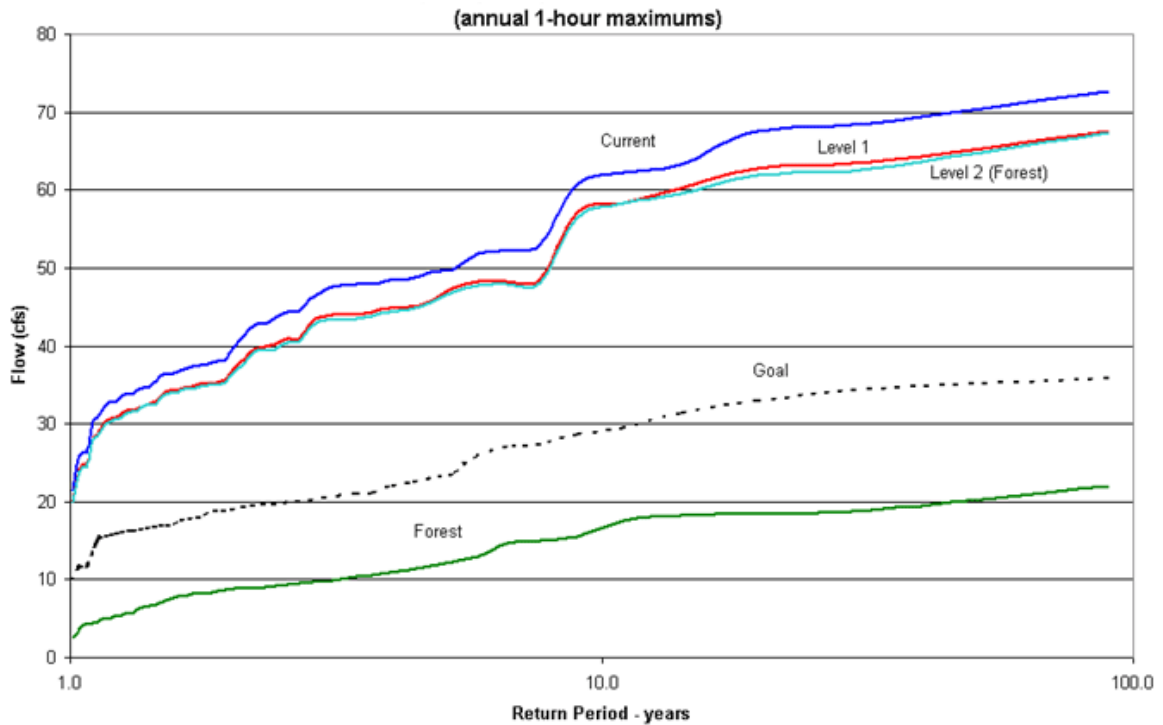


Exhibit I-2 depicts the effect of two different stormwater regulations on peak flows near the mouth of Walker Creek. The general differences between Level 1 and Level 2 detention requirements are discussed in the Miller Creek Management Options section of this report. If a Level 1 detention standard is used for the red parcels [except for the Port of Seattle that is required to use Level 2 (75/15/10)], it reduces the peak

flows below current levels by several cfs (0 to 5). A Level 2 (Forest) detention standard for the red parcels [except for the Port of Seattle that is required to use Level 2 (75/15/10)] achieves nearly identical reductions in peak flows, but still does not attain the goal flow. This modeling run showed that there was little difference between the Level 2 (Forest) and Level 1 standard. In order to protect the higher-quality habitat generally found in Walker Creek, a Level 2 (75/15/10) standard is proposed for the basin. It will be a protective standard (**Exhibit I-3**) and yet much more affordable for developers than Level 2 (Forest). In addition, it will be consistent with proposed Miller Creek detention standards and those approved for the Port.

Exhibit I-3
Walker Creek High Flows at Mouth and at Des Moines Memorial Drive Under Goal and Level 2 (75/15/10) Conditions

RUNOFF EVENT	GOAL FLOW (CFS)		LEVEL 2 (75/15/10) (CFS)	
	Mouth	DMMD	Mouth	DMMD
100-yr	38	17	71	23
50-yr	35	15	67	22
25-yr	32	14	62	20
10-yr	28	12	54	18
5-yr	24	10	47	15
2-yr	18	7	35	10

Exhibit I-4
Flow Frequency Analysis — Walker Creek @ DMMD

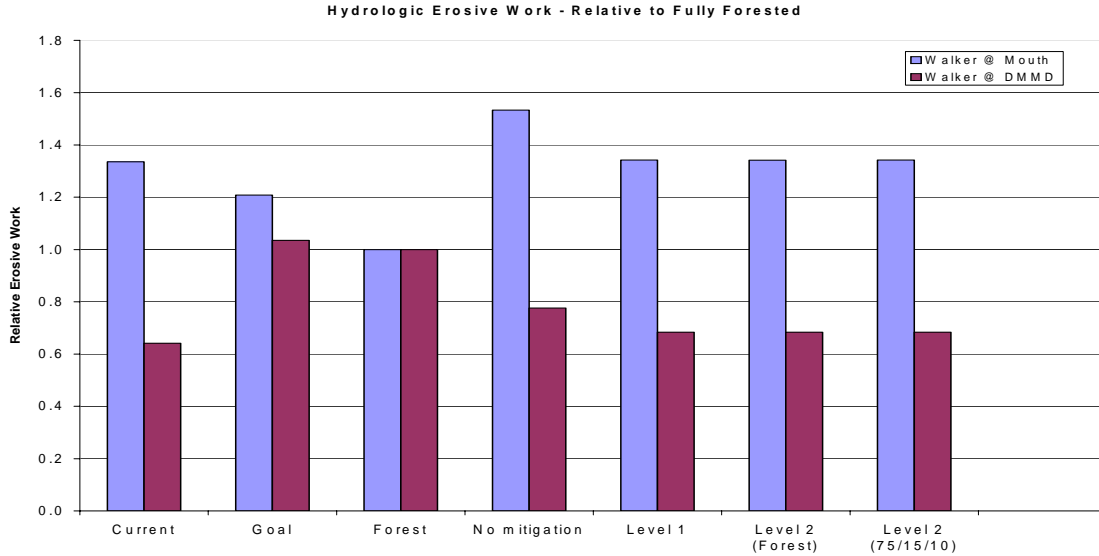


Exhibit I-4 compares Level 1 and Level 2 detention standards for Walker Creek at DMMD. The detention standards achieve identical results for peak flows, a reduction in a few cfs, although neither is able to achieve the goal flow. Again, a Level 2 (75/15/10) detention standard is proposed in order to be protective (**Exhibit I-3**).

The Level 2 (75/15/10) detention standard would require new or replaced impervious surfaces over 5,000 square feet to match discharge durations to 75/15/10 land cover durations for the range of 75/15/10 discharge rates from fifty percent of the 2-year peak flow up to the full fifty-year peak flow. In addition, the standard would require the new or replaced impervious area to match peak flow rates for the two-year and ten-year storms to those existing under a 75/15/10 land cover. If the existing peak flow rates and flow durations were less than expected under a 75/15/10 land cover, then the new or replaced impervious surfaces would be required to match those lesser quantities. There are a number of possible exemptions to this detention standard. The detention standard is summarized in **Exhibit H-8** in **Appendix H**.

Exhibit I-5 shows the results of the erosive work analysis comparing different detention standards. None of the regulatory measures alone will achieve erosive mitigation equivalent to the goal flow. The Level 1 and Level 2 detention regulations will all achieve the same degree of mitigation of erosive work at the mouth of Walker Creek, a level equal to the current condition. At DMMD, various detention standards all achieve the same degree of mitigation, similar to that present under

**Exhibit I-5
Walker Creek Mitigation of Erosive Work
Comparison of Detention Standards**



current conditions (the degree of erosive work under the detention scenarios is less than what would occur under a fully-forested condition).

2. Regional Capital Facilities and Detention Regulations

At this time no additional flow control projects are being suggested for Walker Creek. This decision is made based on field surveys that indicate that, in general, Walker Creek is stable and is in much better condition than Miller Creek. A flow, water quality, and habitat monitoring program is proposed for both Miller Creek and Walker Creek so that any changes, either good or bad, can be observed. If conditions in Walker Creek worsen over time, then additional flow control measures, such as detention or infiltration facilities, can be proposed.

3. Low Impact Development Retrofits plus Detention Regulations

In order to better meet the flow regime goal, new development in the basin could be required to implement low impact development practices, such as maximizing on-site retention and infiltration of stormwater runoff and retention of native vegetation on the lot. In addition, existing development could be retrofitted to minimize impacts to the hydrology by implementing best management practices that maximize retention and infiltration of roof, driveway, and sidewalk runoff. Examples include construction of dry wells for roof infiltration and construction of infiltration galleries for flows from driveways and sidewalks. Of course, this option would require the participation of property owners; property access, liability, and responsibility for maintenance would be among the

issues to be resolved. This option should be further explored if flow and habitat monitoring data show that there is a further need to reduce flows.

Water Quality Improvement Options

The management objective for water quality identified a water quality treatment goal to reduce pollution in the basin; namely, a reduction in total suspended solids and metals. This goal is in addition to the existing source control and public education programs already provided by the jurisdictions in the basin. Two options are presented to meet this goal:

- ▶ Regulations only;
- ▶ Retrofits of existing development and regulations.

Each of the options is discussed below and summarized in **Exhibit I-6**.

Exhibit I-6
Walker Creek Water Quality Management Options

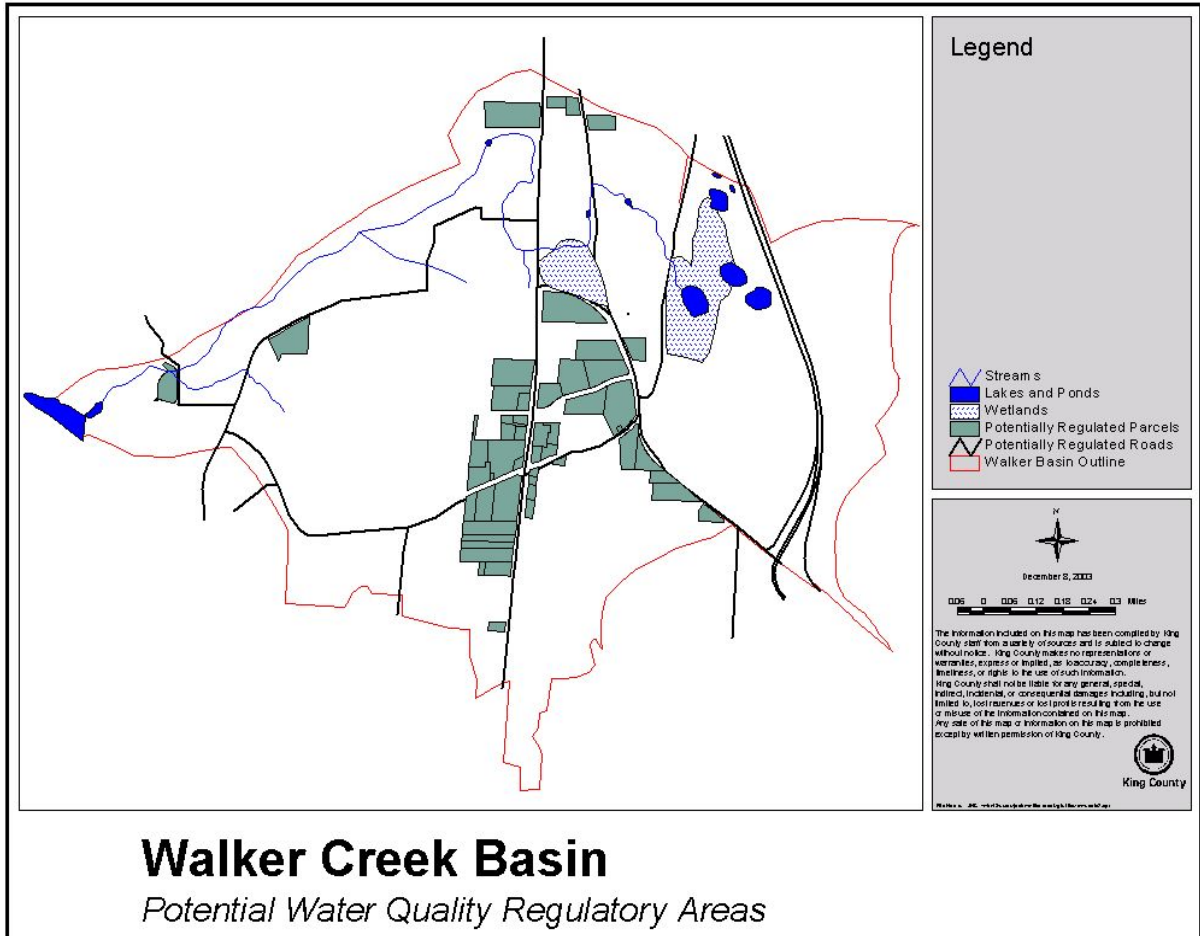
OPTION	PUBLIC COST	PROS	CONS
<p>Regulations Only Require new development and re-development to provide enhanced treatment for high-impact land uses</p>	\$0	<ul style="list-style-type: none"> • Will remove not only 80% TSS but also 50% of total metals, a primary pollutant in the basin 	<ul style="list-style-type: none"> • Treatment will only be provided as development and re-development occurs
<p>Retrofits to Existing Development and Regulations Retrofit existing highways, high-use local roads and high-density developments Includes coating or replacing galvanized guard rails Retrofit untreated runoff in existing residential development</p>	\$? for high-use areas TBD	<ul style="list-style-type: none"> • Will treat polluted water from existing development • Runoff from galvanized surfaces (a source of zinc) will be treated • Focusing on high-use areas allows for more effective treatment • Residential retrofits will address many areas of existing development 	<ul style="list-style-type: none"> • Requires willing property owners or new regulations • Guardrail coating requires periodic maintenance • Extremely expensive when implemented throughout basin

1. Regulations Only

Much of the future development in the basin will be required by Department of Ecology water quality regulations to provide enhanced water quality treatment that is designed to remove metals from stormwater runoff. See discussion of this topic in the Miller Creek section. **Exhibit I-7** depicts those properties in the basin that may be required to provide enhanced treatment when development or re-development occurs. The figure shows a proposed threshold that includes capture of residential areas with greater than eight dwelling units per acre. The cost of these treatment facilities will be borne largely

by the private sector, although some public sector costs will also be incurred, primarily in new road construction.

Exhibit I-7 Enhanced Water Quality Treatment Parcels and Roads



Jurisdictions in the basin currently have water quality treatment requirements for new development meeting certain thresholds. Although all of the jurisdictions, except the Port, require enhanced treatment in some situations, the number of cases in which enhanced treatment will be required is likely to increase in the future as new Department of Ecology water quality treatment regulations are implemented.

In addition, each jurisdiction should ensure that it has established water quality codes consistent with Ecology's *Stormwater Management Manual for Western Washington* and is implementing programs that identify pollutant sources, require implementation of measures to control the pollutant (Best Management Practices, BMPs), and enforce

violations. BMPs should also be equivalent to those in the Stormwater Management Manual for Western Washington. Jurisdictions in the basin should also ensure that they have implemented integrated pest management programs to minimize the use of pesticides (both herbicides and insecticides) for maintaining public right-of-way. These changes in program management often can be achieved for little or no cost.

2. Retrofits of Existing Development and Regulations

Sole reliance on water quality regulations will address only new development and re-development. The majority of the basin, however, is not expected to be subject to those regulations because it is unlikely to change much in the next several decades. In order to address the water quality problems attributable to the existing development, retrofitting of existing development should be considered.

On-site water quality treatment should be provided for surface water runoff from existing development that is not currently treated. This is a long-term strategy that will improve the water quality of Walker Creek. Treatment should be provided to the maximum extent practicable in the following priority:

a. Retrofits of Existing Roads and Highways

Currently, there is no stormwater treatment of roads or highways in the Walker Creek basin, other than the recent 1st Avenue South project by Normandy Park that installed detention and basic treatment for the entire road section (existing and expanded portion) from the northern city limits to South 174th Street. Roads and highways can contribute high concentrations and loads of toxic metals and oils to stormwater due to these materials being discharged from vehicles. Pollutant removal efficiencies of stormwater treatment facilities increase with high influent concentrations. Treatment of these higher-concentration areas will provide the greatest reduction of pollutant concentrations in Walker Creek.

- SR 509 contributes pollutant concentrations and loadings and should be retro-fitted to include water quality treatment. Priority areas of the highways are those areas that discharge directly to Walker Creek. Treatment facilities that provide increased metals removal should be used. Emerging technologies such as the Ecology embankment or swale, which utilize perlite for enhanced metal removal, should be considered for highway and road retrofits. In addition, galvanized guard rails, fences, and sign posts could either be coated or replaced with other materials that do not leach zinc.
- Local road systems also are pollutant sources and should be retro-fitted with treatment systems. Priority for providing treatment should be based on the amount of vehicle use, commonly expressed as average daily trips (ADT). More heavily-used

roadways accumulate more pollutants and therefore are a higher priority for providing treatment.

b. High-density Development

Many commercial and single- and multi-family residential areas do not provide any attenuation of stormwater flows or removal of pollutants because they were built prior to SEPA and drainage regulations, or were built more recently but did not exceed the regulatory threshold. Retrofits could include filtering through vegetation (e.g., bio-swale), infiltration, and sand and compost filters. If, as discussed above, the infiltration retrofits for flow control are pursued, then some water quality treatment will also automatically occur. For commercial areas with higher pollutant loadings, some water quality pre-treatment will be required prior to infiltration.

Habitat Management Protection and Improvement Options

To address the habitat management goal, several projects are proposed. Each of the projects is discussed below and summarized in **Exhibit I-8**.

**Exhibit I-8
Walker Creek Habitat Management Options**

OPTION	PUBLIC COST	PROS	CONS
<i>HABITAT</i>			
Estuary Restoration	See Miller section of report	See Miller section of report	See Miller section of report
Headwater Wetland Purchase	In process	<ul style="list-style-type: none"> Will permanently protect wetland flow, water quality, and habitat functions 	<ul style="list-style-type: none"> Need to have willing property seller
Purchase Property or Conservation Easements Whenever Possible	Variable	<ul style="list-style-type: none"> Will provide habitat and allow options for future management strategies 	<ul style="list-style-type: none"> Jurisdictions have limited funds Often difficult to convince elected officials of importance of preservation

1. Purchase of Headwater Wetland

The City of Burien is completing the purchase of 21 acres of the headwater wetland that are not developable. This is a critical purchase for the basin because the wetland provides flow control, water quality,

and habitat benefits. It is surprising to find such an extensive and relatively pristine wetland in an urbanized area. After purchase, some small additional amount of funding should be spent on improved mapping and identification of the wetland, exploration of whether or not existing water quality regulations for surrounding properties are sufficient to protect it, invasive weed removal, and native planting. Some of these projects could be coordinated as public involvement activities.

2. Purchase Property or Conservation Easements

One of the best ways to protect Walker Creek and allow for future management options to be made is to purchase riparian property or obtain conservation easements on such property whenever possible. Public ownership or stewardship of such properties will allow for future restoration to occur as money is available. Even if no restoration is done on a site for long periods of time, the site will at least remain undeveloped and the stream passing through it can function more naturally than if the property were to be developed. Because of the large variation in property sizes and prices, it is not possible to provide a cost estimate for this project.

3. Estuary Restoration

This project is discussed as part of the Miller Creek habitat management options. Please see that section of the report for details.

Monitoring and Stewardship Options

The monitoring and stewardship options discussed in the Miller Creek section of this report are also applicable to Walker Creek. The costs given for Miller Creek include Walker Creek activities also (see **Exhibit H-16** in the Miller Creek Section).