Thornton Creek Watershed Plan

City of Shoreline, Washington

November 2009

R·W·BECK

An SAIC Company

In association with:

nhc northwest hydraulic consultants

The Watershed Company

EnviroIssues

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Abbreviations and Acronyms Used in This Report

BCA	(FEMA) Benefit Cost Analysis
CIP	capital improvement program
CMP	corrugated metal pipe
Corps	United States Army Corps of Engineers
DO	dissolved oxygen
DOH	Washington State Department of Health
DSHS	Washington State Department of Social and Health Services
EIA	effective impervious area
ESA	Endangered Species Act
FCAAP	Flood Control Assistance Account Program
FCZD	(King County) Flood Control Zone District
FEMA	Federal Emergency Management Agency
GIS	geographic information system
HEC-RAS	Hydrologic Engineering Centers River Analysis System (modeling software)
HMGP	Hazard Mitigation Grant Program
HPA	Hydraulic Project Approval
HSPF	Hydrological Simulation Program—Fortran (modeling software)
IACWD	Interagency Advisory Committee on Water Data
IDDE	Illicit Discharge Detection and Elimination
LID	low impact development
LWD	large woody debris
NFIP	National Flood Insurance Program
NHC	Northwest Hydraulic Consultants
NPDES	National Pollutant Discharge Elimination System
PDM	Pre-Disaster Mitigation
PWTF	Public Works Trust Fund
SMC	Shoreline Municipal Code
SPU	Seattle Public Utilities
SWES	Surface Water and Environmental Services
SWM	Surface Water Management

TIA	total impervious area
TMDL	total maximum daily load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQI	Water Quality Index
WSDOT	Washington State Department of Transportation
XP-SWMM	a commercial version of the USEPA's Storm Water Management Model (SWMM) software

Introduction

This Thornton Creek Watershed Plan is the first individual basin plan to be completed by the City of Shoreline. This plan follows a city-wide Surface Water Master Plan that was conducted in 2005 (R. W. Beck 2005). While the Master Plan is a guide to an overall community-wide surface water management program, this watershed plan focuses specifically on the problems and issues that exist in the Thornton Creek watershed. Additional watershed plans for other City of Shoreline watersheds are planned for the future.

The purpose of this watershed plan is to look at the Thornton Creek watershed (within the city limits) as a whole and to use an integrated process to evaluate and address problems related to flooding, aquatic habitat, and water quality. This plan recommends projects and programs to address these problems, and includes estimated costs for these recommendations. At the same time this plan is being developed, a separate floodplain study is being conducted to define the floodplain for the North Branch of Thornton Creek from Ronald Bog to the city limits.

Study Objectives

This Watershed Plan provides a comprehensive examination of the surface water system within the watershed, including tributaries and storm drain trunk lines (see Figure ES-2). The Watershed Plan is intended as a guide for future management of the basin. The objectives of the plan, as illustrated by Figure ES-1, are to use a combination of regulatory measures, programmatic measures, and capital projects to:

- Reduce flooding,
- Improve water quality, and
- Protect and enhance existing habitat.

The watershed plan also identifies potential funding scenarios to implement the solutions through the City's capital improvement program.

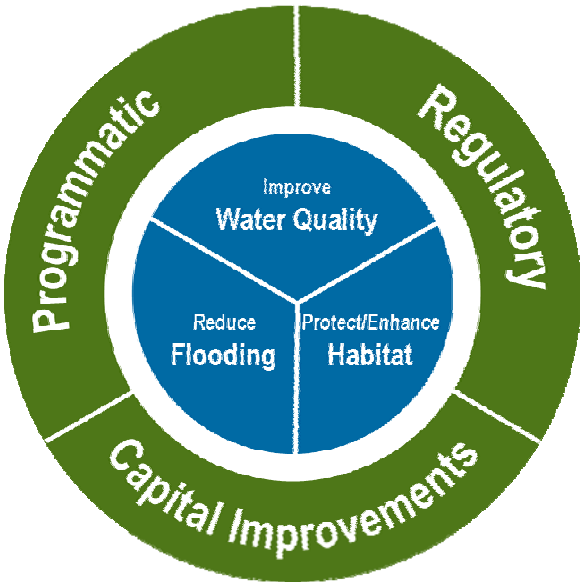

Figure ES-1. The watershed plan proposes programmatic measures, regulatory measures, and capital improvements to address flooding, habitat, and water quality problems within the Thornton Creek Watershed.

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The floodplain mapping work was undertaken due to the recurrence of extensive flooding downstream of Ronald Bog. The study includes determining the existing floodplain south of the bog. The hydraulic modeling developed as part of the floodplain mapping effort was also used to evaluate alternative solutions in this area.

In addition to the modeling of Ronald Bog and the downstream creek, separate hydraulic models were developed to analyze the complex drainage problems near 10th Avenue NE and NE 175th Street as well as the Serpentine drainage system.

Basin Characteristics and Problem Identification

The Thornton Creek watershed drains approximately 2,304 acres in the southeast quarter of the City of Shoreline (Figure ES-2). The three primary drainage courses that comprise the City of Shoreline portion of the Thornton Creek basin are: the North Branch of Thornton Creek, Littles Creek, and Hamlin Creek. The basin is almost completely developed. Land use in the basin is primarily single-family residences and roads; commercial areas are the next most prevalent land use type. A dominant constructed feature in the City of Shoreline portion of the Thornton Creek watershed is Interstate 5, which traverses the basin in a north-south direction.

The Thornton Creek drainage system within the City of Shoreline contains primarily piped and channeled stormwater conveyance. Natural water courses are largely absent from the upper basin because the drainage pattern has been altered by humans. Historically, much of Thornton Creek meandered within multiple channels through wetlands and across a broad alluvial floodplain. However, these floodplain connections are now much more limited due to encroachment of development, bank armoring, and channelization. In addition to the floodplains, many wetlands have also been filled. With the loss of these natural habitat features, important areas where stormwater runoff could be naturally stored and infiltrated to reduce peak flows were lost. Peat mining in Ronald Bog and Twin Ponds during the post-World War II era and construction of Interstate 5 in the 1960s significantly altered the basin. The piped stormwater conveyance systems in the upper basin collect much of the runoff from this area and convey runoff into Thornton Creek or one of its tributaries. Much of the urbanization within the drainage basin occurred prior to the time when stormwater controls were required for development. Consequently, this has resulted in areas of flooding, increased erosion and sedimentation due to increased peak flows, and water quality problems associated with temperature, low dissolved oxygen, and bacterial contamination.

Flooding has frequently occurred in a few areas within the basin. A significant area of flooding is immediately downstream of Ronald Bog, which has flooded at least four times in the recent past: January 18, 1986, January 1, 1997, October 20, 2003, and December 2, 2007. As many as 20 homes have been significantly flooded. Some homes have been inundated up to 3 to 4 feet above their finished floor elevations. Water levels in the bog and the neighborhood to the south are the result of the complex interaction of several factors including a flat, low gradient outlet pipe/channel system that is likely undersized, high groundwater, the volume of floodplain storage provided by the bog and surrounding wetlands as well as increased

stormwater inflow volumes resulting from upstream urbanization. The City made improvements to the downstream creek system in 2008 as part of the Ronald Bog South Drainage Improvements Phase 1 Project. The project included replacing three undersized pipes or culvert systems between N 171st Street and N 167th Street, including the N 167th Street culvert crossing. Hydraulic modeling, completed as a part of the floodplain mapping work, concluded that the 2008 improvements would help lower the bog flood levels by approximately 1 foot for the 100-year flood event. However, flooding will still occur to roadways and homes without further improvements. The floodplain mapping work is described in further detail below.

Other areas that have experienced flooding include:

- 5th Avenue NE near NE 178th Street,
- 12th Avenue NE and 11th Avenue NE between NE 175th Street and NE 170th Street,
- 12th Avenue NE near NE 148th Street,
- 10th Avenue NE near NE 174th Street,
- NE 148th Street between 12th Avenue NE and 15th Avenue NE, and
- N 167th Street and Wallingford Avenue N.

Water quality in Thornton Creek within the City of Shoreline appears to be typical of urban streams in the Puget Sound area. Pollution sources and contributing factors are likewise expected to be typical of those observed in Puget Sound urban watersheds. In its 2008 assessment, the Washington State Department of Ecology identified portions of Thornton Creek in Seattle, downstream of the City of Shoreline, as “impaired” for fecal coliforms, temperature, and dissolved oxygen. The segments of Thornton Creek within the City of Shoreline are upstream of the impaired stream segments in Seattle and the data in Thornton Creek within the City of Shoreline shows similar conditions to those downstream; therefore, though these segments are not currently listed by Ecology, they can be expected to exhibit similar water quality conditions.

Habitat in Thornton Creek is limited, partly due to downstream fish passage barriers and partly due to the compromised water quality of an urban stream. Natural stream systems provide functions such as facilitating food chain production, providing habitat for nesting, rearing and resting sites for aquatic, terrestrial and avian species, maintaining the availability and quality of water, among other things. The existing piped stream sections within the basin provide little in the way of stream function as defined, other than basic conveyance, and many of the channelized sections are providing little additional stream function. Many species of fish have been observed in Thornton Creek including cutthroat and rainbow trout, largemouth bass, carp and sunfish. In addition, juvenile chinook and coho salmon have been planted in the creek.

Floodplain Mapping

In 2008, the City contracted with Northwest Hydraulic Consultants (NHC) to perform a floodplain mapping study of the North Branch of Thornton Creek from Ronald Bog south to the city boundary. The purpose of the study was to delineate the flood hazard boundaries of the creek, thereby providing neighboring residents with the most current information available regarding their flooding risk. The creek was surveyed where rights-of-entry were available, and the stream geometry was coded into a HEC-RAS hydraulic computer model. The model was simulated with the standard FEMA discharge quantiles of the 10-, 50-, 100-, and 500-year events. These flows were determined using a detailed HSPF model of the Thornton Creek basin within the city limits.

A preliminary 100-year floodplain map has been prepared (Figure ES-3). The floodplain mapping study will be completed in winter 2009. Once NHC completes the project, the final study products will be submitted to the City for review. At that time, the City will determine how the floodplain delineation will be used. Options include submitting the study to FEMA for incorporation in the national flood insurance database, regulating the floodplain through the use of City building permits, or simply distributing maps of the floodplain to educate and prepare the neighbors of the North Branch Thornton Creek. The floodplain mapping may be modified in the future depending upon the flood reduction projects implemented in this area. The portion of the floodplain identified in the figure as Zone A (studied by approximate methods) reflects an area where right-of-entry was not available and a detailed survey could not be performed.

Recommendations to Improve Watershed Conditions

Watershed planning is intended to fully recognize and consider the interactions and interdependence among components of a watershed system, as opposed to relying on piecemeal approaches. To accomplish this, a wide array of solutions was considered to solve watershed problems. Typically, the array of solutions includes: capital projects, which are constructed improvements; regulatory measures such as development standards that can reduce surface drainage and water quality impacts; and programmatic measures including routine maintenance or public outreach. In general, capital projects are best suited for addressing acute site-specific problems, while regulatory or programmatic measures affect the entire basin. Solutions that consider changes in land use to control stormwater runoff were not considered for this watershed plan because the plan is intended to support the proposed future land use as described in the City of Shoreline's Comprehensive Plan.

A summary of specific watershed plan recommendations is presented in Table ES-1. This table indicates whether the recommendation is a regulatory measure, programmatic, or a capital improvement, and also identifies costs and priority. The following paragraphs discuss some of the highlights of these recommendations.

Basin-Wide Recommendations

The following paragraphs describe basin-wide regulatory and programmatic recommendations. In addition to these basin-wide recommendations, several of the specific recommendations in Table ES-1 also contain some regulatory and/or programmatic measures.

Regulatory Measures

Regulatory measures can be used to reduce runoff rates and volumes of stormwater runoff from new development and redevelopment. The City recently (February 2009) adopted new standards to meet the conditions of its Phase II National Pollutant Discharge Elimination System (NPDES) permit and to achieve goals for reducing stormwater impacts from development, protecting water resources, and complying with state and federal stormwater requirements. These new standards, which are applied to new development and redevelopment, will aid in reducing runoff and improving water quality. The new standards include:

- More stringent stormwater detention standards that store more runoff volumes on-site.
- Requiring low impact development (LID) techniques where practical. LID includes measures that increase the percentage of precipitation that is infiltrated on the site in order to reduce runoff rates and volumes, which will reduce flooding potential and protect water quality. Minimum levels of LID are included in the new adopted standards where practical and additional LID measures are encouraged by the City. Examples of LID include rain gardens and bioretention; rooftop gardens; vegetated swales, buffers, and strips; tree preservation; roof leader disconnection and infiltration systems; rain barrels and cisterns; permeable pavers; soil amendments; impervious surface reduction; and impervious surface disconnection.
- Administrative Orders in the Engineering Development Guide such as the restrictions on filling of drainage ditches within the right-of-way that could result in the loss of the infiltration capability and increase system flows.

The watershed plan considered a recommendation that the City adopt more stringent stormwater standards, which go beyond the state requirements, in frequently flooded areas such as Ronald Bog. However, because the City is mostly built out, benefits resulting from these more stringent standards would not be apparent for many years, as they would occur along with the long-term redevelopment in the basin. At the same time, basin management is a lifelong endeavor, and the City acknowledges that it may consider such recommendations in the future.

Programmatic Measures

Programmatic measures are activities such as maintenance of stormwater infrastructure, water quality monitoring, and public outreach.

The City's existing maintenance activities include: clearing catch basins, drainage ditches and pipes to maintain conveyance capacity; sweeping streets and cleaning

catch basins to remove solids and associated metals that become bound to these solids; maintaining regional and residential stormwater facilities to make sure they are functioning properly; and inspecting commercial and residential water quality stormwater facilities to ensure they are maintained to achieve their objectives.

Through events, workshops, and field activities, the City promotes recycling; natural yard care and sustainability; storm drain stenciling; green remodeling; and habitat restoration. The City reminds owners of private stormwater systems that they are responsible for maintenance of those systems. The City encourages voluntary actions by, for example, informing the public of the benefits of using LID techniques and natural yard care on private property.

In addition, the City is developing an Illicit Discharge Detection and Elimination (IDDE) Program in order to meet the conditions of the NPDES permit. The IDDE program will look for and eliminate illicit discharges via direct connections (e.g., wastewater piping either mistakenly or deliberately connected to the storm drains) or indirect connections (e.g., infiltration into storm drains or creeks from cracked sanitary systems, spills collected by drain outlets, or paint or used oil dumped directly into a drain).

This watershed plan makes the following specific programmatic recommendations:

- The City should encourage home and business owners to keep catch basin grates free of leaves and debris.
- The City should develop more watershed-specific outreach activities within the Thornton Creek watershed. One possible example may be an outreach program to streamside residents on natural yard care practices and encouragement of native riparian planting; both can locally improve stream habitat and water quality.
- Existing and future water quality and stream monitoring activities on Thornton Creek will allow the City to monitor stream health; the monitoring results may be used to guide the implementation of capital projects, outreach activities, and regulations to improve watershed conditions.
- The City should develop the IDDE program specific to each watershed; specifically in Thornton Creek, the IDDE plan should focus on the commercial business district in the North City area on 15th Avenue NE.
- One specific maintenance activity worth noting involves the 30-inch-diameter outlet pipe and downstream channel system from Ronald Bog, which is very flat and subject to sediment accumulation. Built-up sediments can reduce system conveyance capacity and result in higher water surface elevations in Ronald Bog during flood periods. The 30-inch pipe is aging and eventually needs to be replaced; but currently, annual maintenance to remove sediment and prevent root intrusion is recommended. In addition, an annual maintenance program for the open channel system between N 171st Street and N 167th Street is strongly recommended.

Specific Capital Improvement Recommendations

Because the Ronald Bog flooding is by far the most significant flooding problem in the basin, much effort was given to its analysis. This section focuses primarily on the Ronald Bog problem; all capital project recommendations are listed in table ES-1.

Ronald Bog

Nearly 30 potential alternative solutions were identified for this problem. The list of potential solutions was developed by the following process:

- Reviewed prior studies.
- Obtained input from City staff.
- Obtained input from the public.
- Performed hydrologic and hydraulic modeling of the system.
- Evaluated field conditions.

Alternative solutions were grouped into four types of capital solutions that could be evaluated at a conceptual level to ensure they were feasible prior to investing in more detailed analysis. These included:

- Constructing a flood barrier, such as an earthen berm or a wall, to hold back floodwaters along the south edge of the bog.
- Expanding Ronald Bog to provide more flood storage capacity.
- Increasing downstream flow capacity (e.g., by replacing the downstream pipe system with a larger system or by using a pump station).
- Floodproofing homes and acquiring property.

In addition, several regulatory and programmatic options were also explored. The regulatory options included a wide range of floodplain management options, greater development standards (e.g., building regulations, fill in the floodplain, etc.) and adopting the updated FEMA floodplain and managing it as such. Programmatic measures include maintenance of the downstream channel, as well as enacting a monitoring and emergency response program.

Because this is a neighborhood problem, community meetings as well as one-on-one meetings with affected residents were held to get input from the public regarding the problem and the potential solutions.

Due to the sensitive nature of this problem and potential high cost of an alternative solution, specific evaluation criteria were developed to help identify a recommended solution. Based on these evaluation criteria, a floodplain management strategy that seeks the highest possible flood protection that is practical and affordable is recommended. The floodplain management strategy includes advancing an approach that involves a combination of a constructed flood barrier (such as a flood wall or berm) and dry floodproofing of houses. Examples of dry floodproofing measures include installing backflow preventers on exterior and interior drains, installing floodgate/dams at garage doors, and in some cases, possibility vacating lower

basement areas and replacing these living spaces with added floor space on the main level.

The location, type, and extent of a flood barrier (i.e., flood wall/berm), as well as which properties may receive floodproofing, will be determined considering both input from individual property owners and cost/benefit analyses. The cost/benefit analyses are being done both to ensure that the ultimate project benefit outweighs the cost and to provide supporting data for potential grants. In addition, the City is implementing other measures to reduce the potential for flood damage, including enhanced maintenance of the outlet system, an early warning system to notify property owners when water levels in the bog reach an early flood stage, and installation/operation of a street pump system.

The cost for these projects to reduce flood impacts ranges from $650,000 to $1.4 million. The City is currently looking into grant opportunities to fund a portion of the Ronald Bog projects.

Other Areas

The recommendations for other specific problems are listed along with priorities in Table ES-1. More information is provided in Section 6 of this report.

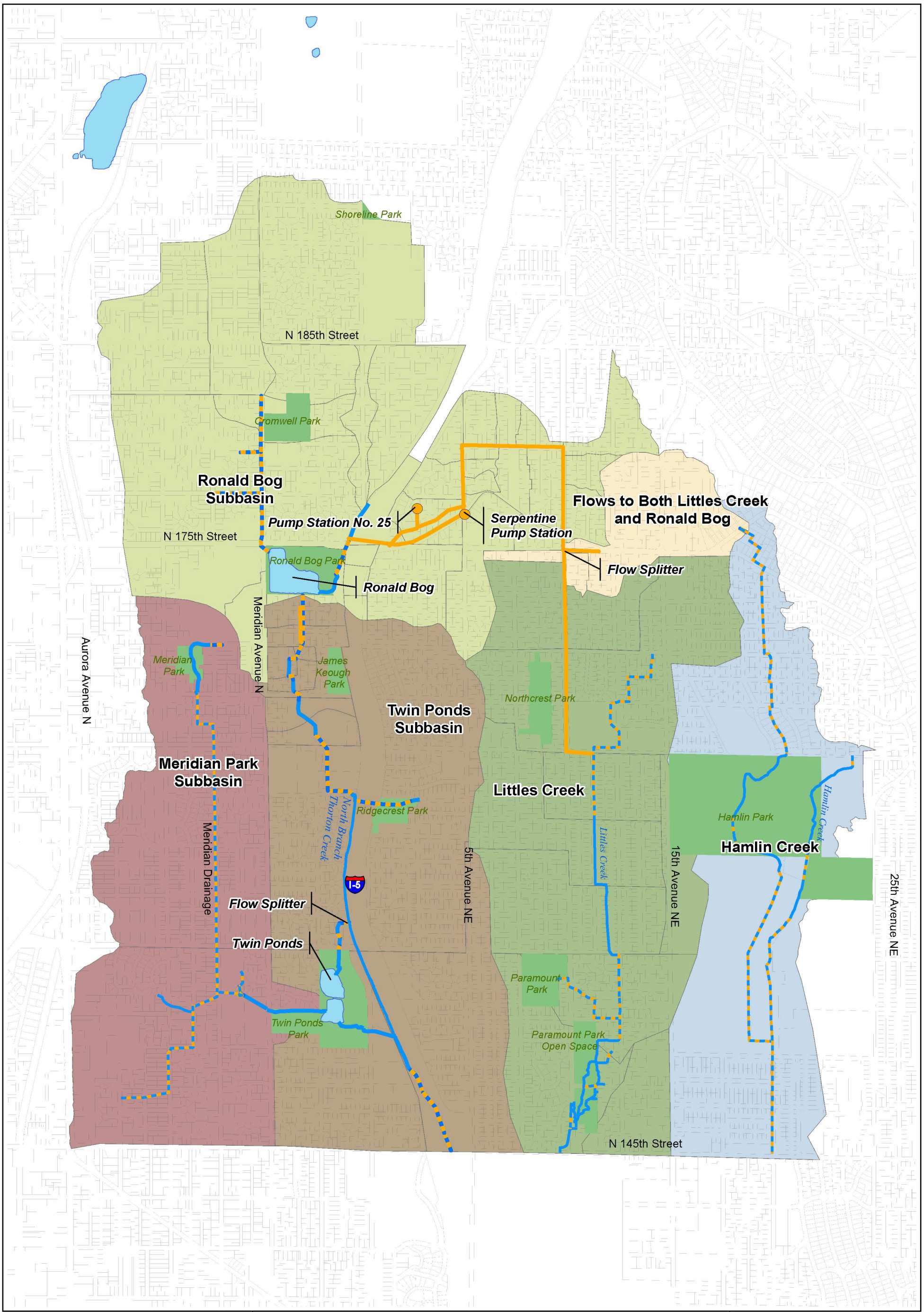
Project Priorities

Recommendations shown in Table ES-1 were generally prioritized based on their relative implementation horizon.

- Priority Level 1: Short Term
- Priority Level 2: Mid Term
- Priority Level 3: Long Term

Project Implementation

The City intends to implement the recommended capital improvement projects based on their priority level within the watershed, available funding, and priorities within the City's other watersheds. However, it is recognized that the existing SWM Utility Fund revenues and other grant and loan sources are limited and that grant funding or partnering may affect the order of implementation. The projected Thornton Creek capital project costs (approximately $11.5 to $12.5 million) for implementation are about half of the projected six-year City-wide CIP budget ($20.0 to $21.0 million). This watershed plan will allow the City to improve prioritization of projects.



Note:
Source of basemap and piped water course system is City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report (Tetra Tech, May 2004)

N

0 600 1,200 2,400 Feet

Legend

- City Limits
- Parcels
- Lakes
- Parks
- Hamlin Creek
- Littles Creek
- Meridian Park Subbasin
- Twin Ponds Subbasin
- Ronald Bog Subbasin
- Flows to Both Littles Creek and Ronald Bog
- Storm drain/road side ditch-culvert system
- Open water course
- Piped water course
- Streets

Figure ES-2
Thornton Creek Watershed Map

Thornton Creek Watershed Plan
City of Shoreline

R·W·BECK
An SAIC Company

R:\Seattle\011262 City of Shoreline\11-01257-10000 THORNTON CREEK WATER\Data-Analytical\report | 11-12-09

N

0 500 1,000 Feet

Legend

Creek Centerline

FEMA Flood Zones

Zone AE (studied using detailed methods)

Zone A (studied using approximate methods)

Figure ES-3
Draft 100-Year Floodplain

Thornton Creek Watershed Plan
City of Shoreline

nhc
northwest hydraulic consultants

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Table ES-1
Recommended Solutions

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Estimated Cost
Flooding Problems							
1	F1	Ronald Bog @ NE 175th St. & Meridian Ave.	Combination of Capital/Regulatory/ Programmatic	Given its outlet capacity, Ronald Bog does not provide enough water storage and overtops its southern bank, flooding up to 12 homes near the pond's outlet along Corliss Ave between N 172nd St. and N 171st St.	A combination of flood barrier in combination with selective property floodproofing. In addition, provide enhanced maintenance and early warning system.	A berm along the southern edge of the pond will prevent neighborhood surface water flooding. Property floodproofing will reduce property damage to individual homes.	$650,000 to $1.4 million
2	F2	Residential flooding from NE 170th St. to NE 175th St. between 13th Ave NE and 12th Ave NE (17021, 17029, 17042 11th Ave NE)	Capital	Detention pond at 17021 11th Ave NE floods during storm events because it has no outlet. The pond overflows, flooding the neighbor at 17029. Flooding also occurs upstream across the street in backyard of 17042.	Construct ditch with a control structure along 12th Ave NE as a first phase. If this proves to be insufficient, additional measures (rain garden swales and pipe improvements) could be implemented.	Flood reduction/prevention	$61,000 (for ditch/control structure) $247,000 (for other potential measures)
3	F3	Residential flooding on 5th Ave NE just north of NE Serpentine Pl.	Capital	Flooding due to maximum capacity at Serpentine Pump Station is not capable of handling 25-year storm and the pipe system on 5th Ave NE is insufficient.	Upgrade the pipe system along 5th Ave NE and NE 178th St and upgrade Pump Station 25.	Flood prevention.	$880,000
1	F4	Littles Creek flooding between 14849 & 15021 12th Ave NE	Capital	Littles Creek exits a culvert and turns west 90 degrees between two properties toward the Paramount Park Open Space.	Excavate the channel to improve conveyance capacity with a sump to trap sediment.	Flood reduction/prevention, stream/habitat restoration and enhancement. Improvement of neighborhood aesthetic.	$212,000
3	F5	Non-functional catch basin/1237 NE 148th St.	Capital and Programmatic	The catch basin in front of apartment building 1237 has no outlet, creating ponding each time the catch basin is full.	Install infiltration trench and also work with property owners to implement an LID solution.	Flood reduction/prevention.	$49,000
3	F6	Roadway storm drain overflow/along 10th Ave NE south of NE 175th St	Capital	Homes on the east side of 10th Ave NE are in a 4- to 10-foot depression relative to the road. The drainage system has insufficient capacity in a 25-year storm so that water will flow out of catch basins and down the driveways of properties along this street.	Add a detention pond at NE 175th St and 10th Ave NE and upgrade a portion of the existing conveyance system along 10th Ave NE between NE 175th St and NE 165th St.	Flood prevention.	$1,830,000
2	F7	N 167th St and Wallingford Ave N	Capital	The pipe under N 167th St and the pipe immediately downstream are undersized. In addition, the pipe system on the western side of 16533 Wallingford Ave N is also undersized. The undersized system has resulted in property flooding during high flow events.	Replace low- and high-flow pipe systems with open channel.	Flood reduction/prevention, stream/habitat restoration and enhancement.	$81,000
Wetland and Aquatic Habitat Problems							
2	AQ1	Fish passage of the outlet pipe system from Ronald Bog.	Capital	Partial fish passage barrier of pipe system at pond outlet.	Long-term solution is to replace the system to meet fish passage design standards for new construction.	Brought up to WDFW fish passage standards.	Cost of outlet pipe upgrade would vary depending on negotiations with WDFW. Maximum potential cost is $5 million, but this could be substantially lower if able to negotiate a smaller conveyance system size.
3	AQ2	Enhancement of wetland fringe areas around Ronald Bog.	Capital	Wetland and buffer areas along east edge of Ronald Bog Park are infested with invasive Himalayan blackberry and they lack a diverse native plant assemblage and habitat structures.	Excavate to enhance wetland hydrology; enhance and restore the inlet stream channel as fish and wildlife habitat, including placement of log structures; remove existing non-native vegetation; supplement topsoils; and implement a native revegetation plan.	Wetland/habitat enhancement.	$580,000

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Estimated Cost
2	AQ3	Daylighted stream channel and removal of partial fish passage barrier at the flow splitter upstream of Twin Ponds between Corliss Ave N. and I-5.	Capital	The flow splitter upstream of Twin Ponds has been identified as a fish passage barrier according to previous reports. This current study has classified it as a partial fish passage barrier.	Reconstruct the stream channel up- and downstream of the flow splitter based on site-specific information to daylight piped stream sections as feasible and improve fish passage. Provide revegetation, bank stabilization, log structures, non-native vegetation removal, and other habitat features to the localized area as appropriate.	Improved in-stream and riparian habitat and improved stream function. Improved fish passage through the area that is reported to be a barrier, ultimately expanding the geographic habitat availability for salmonid fish.	$257,000
2	AQ4	Reported fish passage barriers within Twin Ponds Park/culvert north of the north pond & culvert beneath a pedestrian trail.	Capital	Reports indicated 2 possible fish passage barriers in Twin Ponds Park. No obvious barriers were observed on site visits on 12/3/08 and 12/27/08. The culvert flowing into the park under N. 155th St. was small, but appeared fish passable. A larger culvert under a footpath just upstream of the north pond was fish passable, but could be made more fish friendly and aesthetically pleasing.	In-stream work to re-grade the channels and modify or supplement structures such that plunge pools will definitely allow fish passage. Line the culvert just upstream of the north pond with spawning sized gravel. Add native vegetation along the stream bank between the two culverts mentioned upstream of the north pond (especially along the left bank).	Stream/wetland/habitat enhancement. Creates a more natural park for the public to enjoy.	$60,000
2	AQ5	Low-flow fish passage barrier/culvert under 1st Ave NE (from Twin Ponds Park to Peverly Pond).	Capital	Reports document this culvert as a low-flow fish barrier. Current study observations show vegetation and mud present in culvert inhibit but do not prevent passage.	Clear mud and vegetation from within the culvert. Replace with gravel.	Defined fish passage.	$19,000
2	AQ6	Fish Passage Barrier/Outfall of Peverly Pond east of 1st Ave NE along I-5 and north of N. 149th St.	Capital	A concrete ramp channels outflow from Peverly Pond down ~5 feet to a straight channel adjacent to I-5.	Install a series of grade controls along the concrete channel leading up to the outlet of Peverly Pond such that the plunge from the pond is reduced to a fish-passable height. The resulting grade-controlled section of the concrete channel extending upstream of the pond outlet would provide a significant amount of off-channel, beaver-dam-like rearing habitat.	Fish passable stream. Stream/wetland/habitat enhancement.	$257,000
WSDOT Project	AQ7	Culvert under I-5, downstream of Peverly Pond.	Capital	Fish passage barrier.	Replace / improve culvert	Fish passable stream.	Funded by others. Would be estimated as part of a WSDOT project
2	AQ8	Weed-choked Meridian Creek, upstream to Meridian Ave N. from the south pond in Twin Ponds Park.	Capital	Fish passage barrier due to the cumulative effects of the stagnant, weed-choked channel. Some Himalayan blackberry has been removed and native plants have been added by community volunteers. Reed canary grass dominates some interior channel segments.	Construct better defined stream channel, add large woody debris, gravel, and stabilize banks. Replant with native wetland vegetation.	Fish passable stream. Stream/wetland/habitat enhancement.	$278,000
3	AQ9	Maintain previous restoration site in Paramount Park Open Space/along Littles Creek stream bank.	Programmatic	Past restoration site work does not appear to be maintained.	Grub out Himalayan blackberry and spray/remove reed canary grass. Replant with native wetland vegetation and increase native shrub densities to shade out reed canary grass.	Maintains/restores past improvement efforts.	$544,000
3	AQ10 - A	Lack of habitat and stream function along Hamlin Creek, south from the Fircrest campus along 20th Ave NE.	Capital	Hamlin Creek flows through a roadside ditch with no in-stream structure, no canopy cover and no native vegetation.	Construct better defined stream channel, add large woody debris, gravel, and stabilize banks. Replant with native riparian vegetation.	Stream/ habitat enhancement.	$500,000

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Estimated Cost
State Project	AQ10 - B	Much of Hamlin Creek is piped and/or has poor habitat.	Capital	Most of the length of two forks of Hamlin Creek on the state-owned Fircrest Campus is piped and would benefit from daylighting.	Daylight and/or restore sections of upper Hamlin Creek which are now conveyed mostly in piped systems across the Fircrest Campus property.	On-site habitat improvements for terrestrial and amphibious wildlife; downstream water quality and quantity benefits for fish and other aquatic wildlife in Thornton Creek farther downstream in perennial reaches.	To be developed as part of the state's Master Planning process for the Fircrest Campus site.
3	AQ11	Thornton Creek lacks coarse-grained sediment.	Capital	Much of the watershed lacks sufficient access to floodplain sediment and in-stream structure to trap and accumulate sediment.	Reduce bank armoring and streambed grade controls where feasible; allow stream access to floodplain gravel through channel migration. Provide in-stream structure to catch and accumulate sediment. Introduce additional gravel supply to sections of the stream that are sediment-starved and/or at locations where such gravel would be effectively distributed downstream. Examples of such locations are downstream of in-stream ponds or low-gradient reaches because such areas tend to accumulate course sediments and prevent their movement farther downstream.	Stream/ habitat enhancement.	$30,000 - $60,000
Citywide Project	AQ12	Coho prespawn mortality.	Programmatic	Coho prespawn mortality rates are high, averaging 79% throughout Thornton Creek.	Contribute to projects that improve water quality with the expectation of decreasing coho prespawn mortality downstream. Increase biofiltration of stormwater with more stringent treatment standards.	General water quality improvement will contribute to helping to decrease coho prespawn mortality rates	$200,000
Water Quality Problems							
2	WQ1	Reduce temperature in Thornton Creek	Programmatic/Capital	Elevated temperatures in Thornton, Littles, and Hamlin Creeks and reduced groundwater inputs.	Plant shade-producing vegetation in open channel reaches and monitor temperature in each tributary.	Shade and monitoring of conditions.	Cost included in applicable Stream Habitat projects
2	WQ2	Improve dissolved oxygen concentrations	Programmatic	Reduced dissolved oxygen concentrations and elevated nutrient levels.	Improve soils and ground vegetation in buffers. Implement education, outreach, and incentive programs to reduce fertilizer use.	Increased dissolved oxygen.	Cost included in applicable Stream Habitat projects
2	WQ3	Reduce bacterial contamination.	Programmatic	Bacterial contamination.	Improve soils and ground vegetation in buffers. Implement education, outreach, and incentive programs to control pet waste.	Reduced bacterial contamination.	Cost included in applicable Stream Habitat projects

Section 1
INTRODUCTION

1.1 Statement of Purpose/Objectives

The City of Shoreline prepared a Surface Water Master Plan (Master Plan; R. W. Beck 2005) to serve as a guide to its overall community-wide surface water management program. The Master Plan identified city-wide surface water problems, but it relied on previous studies and approximate field engineering methods to identify capital projects to solve these problems. The approach taken by the Master Plan was to develop just enough information so that capital projects and programs could be identified that 1) reflected the community's priorities, 2) met regulatory requirements, and 3) enabled the City to make decisions on funding. Part of the overall strategy was to follow the Master Plan with a series of watershed plans that would develop more detailed analyses of each of the City's major drainage basins. These plans would fully recognize and consider the interactions and interdependence among the components of a watershed system and identify current and potential future problems and solutions with respect to flooding, water quality, and stream-related habitat.

The Thornton Creek Watershed Plan is the first of these watershed plans to be completed. The purpose of the watershed plan is to perform a comprehensive examination of the surface water system within the watershed, including tributaries and storm drain trunk lines (see Figure 1-1).

The watershed plan is intended as a guidance document for future management of the basin. The objective of the plan is to use a combination of project, regulatory, and programmatic measures to reduce flooding, improve water quality, and protect and enhance existing habitat. The watershed plan also identifies potential funding scenarios to implement the solutions through the City's capital improvement program.

1.2 Review of Previous Studies

Numerous studies have been conducted in the Thornton Creek watershed prior to this watershed study. The following reports were used to identify problems to be investigated as part of this study, provide background information about the watershed, and gain an overall understanding of the watershed.

- *Ronald Bog Wetland Design* – Otak, March 5, 2002. This technical memorandum summarizes the investigations of the wetlands at Ronald Bog. It also discusses the possibility of regrading a portion of the wetland on the east side of the bog to provide additional storage and enhance the wetland. One concern about the regrading option was the possibility of disturbing contaminated soil. Other alternatives were also discussed.

- *Ronald Bog Drainage Improvements, Phase 1 Thornton Creek Tributary Flood Reduction Study* – Otak, December 7, 2001. The objective of this plan was to develop a preferred solution to the flooding at Ronald Bog and to involve the community in the development of the solution.
- *Review of Ronald Bog Subbasin Study City of Shoreline* – Gray and Osborne, 2001. The purpose of this study was to review the *Ronald Bog Drainage Improvement Phase 1 Thornton Creek Tributary Flood Reduction Study* completed by Otak in order to identify alternatives that offer savings of time or costs and/or confirm the findings in Otak's study.
- *Urban Creeks Legacy Maps* – Thornton Creek – Seattle Public Utilities, 2001. This is an overview of Seattle's urban creeks in northeast Seattle. It includes 1992 orthophotos with annotated GIS maps.
- *Thornton Creek Basinwide Flow Control Plan* – Entranco, 2001. This report documents the hydraulic analysis and alternatives evaluation performed by Entranco, Inc. for the Thornton Creek drainage basin and was done for Seattle Public Utilities. The principal study objectives were to control flooding and preserve or enhance fish and wildlife habitat.
- *Ronald Bog Drainage Study* – Rasmussen and Huse Consulting Engineers, March 1987. This document was a study conducted for King County to investigate local flooding that occurred in the vicinity of Pump Station No. 25 (owned at the time by King County; ownership was transferred to the City of Shoreline when the City incorporated).
- *Thornton Creek Hydrologic and Hydraulic Modeling* – Hydrologic and Hydraulic Model Plan – Entranco, March 2000. This plan was conducted for the City of Seattle to determine the magnitude and frequency of flows along the major creek system and to evaluate basin-wide solutions designed to address problems related to excessive flows.
- *Stormwater Drainage Analysis – King County Pump Station 25* – Rasmussen and Huse Consulting Engineers, July 1986. This report presents the analysis of the storm drainage flooding that inundated Pump Station No. 25 and vicinity that occurred around the time of the report. The report also documents recommended solutions.
- *Preliminary Study of Flooding Problem on 14849 12th Avenue NE* – Otak, March 9, 2001. This report summarizes the findings of a preliminary study of the flooding problem affecting the property at 14849 12th Avenue NE.
- *City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report* – Tetra Tech, May 2004. This document, prepared as part of the *City of Shoreline Stream and Wetland Inventory and Assessment*, characterizes the streams within the Thornton Creek watershed with respect to aquatic and riparian habitat conditions in relation to salmonid use as observed in spring and summer 2001. In addition, fish passage was evaluated.
- *City of Shoreline Surface Water Master Plan* – R. W. Beck, July 2005. The Surface Water Master Plan was written to guide the City of Shoreline's surface

water management program and to identify surface water problems, prioritize needs and develop long-term solutions that meet regulatory requirements, reflect the community's priorities, and can be funded by the City.

- *City of Shoreline Proposed 2004–2009 Capital Improvement Plan* – June 2003. The Capital Improvement Plan attempts to set funding strategies not only for the current year, but also to project future needs for major construction, land acquisition and equipment needs that improve the cultural environment, capital infrastructure, and recreational opportunities for the citizens of Shoreline.
- *Thornton Creek Draft Watershed Action Plan Working Draft* – Seattle Public Utilities, May 9, 2001. The plan sets goals and objectives and makes recommendations to improve management of water quantity and improve water quality from a range of viewpoints including stormwater; non-point pollution; habitat, education and stewardship; regulation and enforcement; implementation; and monitoring, analysis and evaluation.

1.3 Study Team and Acknowledgments

R. W. Beck wishes to acknowledge and thank the following City of Shoreline staff for their support and assistance in completing this Watershed Plan.

Ross Heller, P.E., Capital Project Engineer
Brian Landau, P.E., L.E.G., Surface Water and Environmental Services (SWES) Manager
Jesus Sanchez, Operations Manager, Public Works
Tricia Juhnke, P.E., Capital Projects Coordinator
Eric Gilmore, Surface Water Technician
Mark Relph, P.E., Public Works Director
Jerry Shuster, P.E., former SWES Manager

The study team included the following individuals:

R. W. Beck, Inc.
Steve Swenson, P.E. – Project Manager
Michael Giseburt, P.E.
Mary Weber, P.E.
Ken Ludwa, P.E.
Todd Crandell – Technical Editor

Northwest Hydraulic Consultants, Inc.
Chris Long, P.E.
David Hartley, P.E.

The Watershed Co.
Greg Johnston

EnviroIssues
Erin Tam
Lauren Stensland

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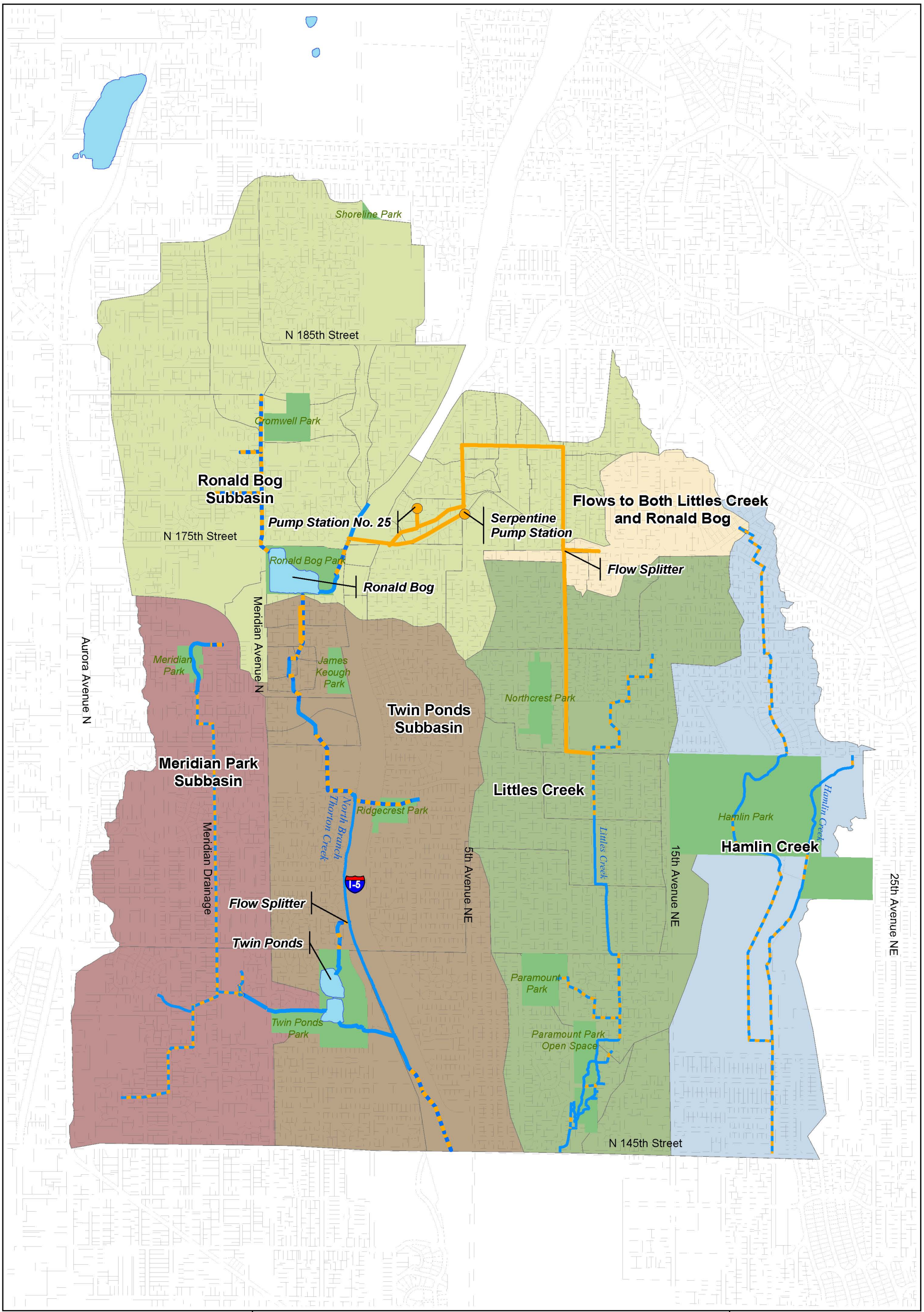

Note:
Source of basemap and piped water course system is City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report (Tetra Tech, May 2004)

N

0 600 1,200 2,400 Feet

Legend

- City Limits
- Parcels
- Lakes
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- Hamlin Creek
- Littles Creek
- Meridian Park Subbasin
- Twin Ponds Subbasin
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- Flows to Both Littles Creek and Ronald Bog
- Storm drain/road side ditch-culvert system
- Open water course
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Figure 1-1
Thornton Creek Watershed Map

Thornton Creek Watershed Plan
City of Shoreline

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Section 2
PUBLIC INVOLVEMENT

2.1 General

An extensive public involvement process was undertaken primarily to address the flooding problem downstream from Ronald Bog. The stakeholders downstream from Ronald Bog, including the affected property owners and neighborhood groups, provided input to guide the planning process. The public involvement process included:

- Interviews with owners of residences affected by flooding,
- Two community meetings,
- Community notification flyers, and
- Meetings with internal and external stakeholders.

The following sections describe the various public involvement efforts.

2.2 Public Meetings

Formal public meetings were held November 20, 2008, and April 22, 2009, with the community to discuss the Thornton Creek Watershed Plan.

The meeting on November 20, 2008 was held to:

- Discuss current City actions to address flooding and other issues with Thornton Creek
- Explain the community's role in this process
- Gather community input on evaluation criteria

The results of this public meeting are contained in Appendix A.

The meeting on April 22, 2009, was held to provide a status report on work to solve the Ronald Bog flooding problem. This included:

- Current level of flood protection achieved with 2008/2009 construction
- Status of Federal Emergency Management Agency (FEMA) mapping
- Basin study and proposed improvements
- Interim floodplain management

2.3 Neighborhood Groups

An informal meeting was held with the citizens in the neighborhood downstream from Ronald Bog in the fall of 2008. Representatives from FEMA were there to discuss the National Flood Insurance Program.

A less formal meeting with the citizens in the neighborhood downstream from Ronald Bog was conducted on May 19, 2009. This meeting discussed most of the same agenda as the public meeting on April 22, 2009.

2.4 Individual Property Owners/Residents

Meetings were held in the fall of 2008 with individual homeowners and residents in the area downstream from Ronald Bog that has been subject to severe flooding. These meetings were held to gather data on each of these homes and the extent of flooding, and to hear the homeowners' issues of concern and their opinions on flood protection strategies. The results of these meetings are summarized in Appendix A. In summary, 15 homeowners in the vicinity south of Ronald Bog were interviewed in order to understand community concerns about local flooding and priorities for potential flood-reducing strategies. The interviews were conducted in person by a member of the consultant team and a City representative. The overall themes of the feedback included:

- Most homeowners were familiar with the history of flooding in the area, but many were not aware of the steps the City of Shoreline had already taken to address flooding concerns.
- Homeowner opinions were divided on cost and level of protection, with some prioritizing cost savings and other prioritizing the highest level of protection against flooding. Overall, homeowners wanted funds to be spent wisely while providing homeowners with peace of mind.
- Homeowners were also divided on the idea of an open creek channel. Some considered an open creek a desirable feature, while others were concerned about safety and maintenance issues.

Additional individual private property owner meetings have been held throughout 2009. These discussions with individual homeowners are ongoing and are focused on collecting additional input associated with flood protection strategies. In the summer of 2009, City staff and a general contractor met with willing homeowners to evaluate potential floodproofing projects to their properties and discussed conceptual ideas for some type of flood barrier along the bog. The project recommendations for individual properties were provided to the residents.

Section 3
CURRENT CONDITIONS

3.1 Basin Description

The Thornton Creek watershed drains approximately 2,304 acres in the southeast quarter of the City of Shoreline (Figure 3-1). The basin generally slopes from north to south with the highest point (elevation 500) in the northeast corner near NE 179th Street east of 15th Avenue NE and the lowest point (elevation 310) near the outlet from the culvert under I-5 at NE 145th Street. The basin contains two main valleys: the one on the west side of I-5 contains the North Branch Thornton Creek and the one on the east side of I-5 contains Littles Creek. The high point between the two valleys runs approximately along 5th Avenue NE south of NE 175th Street.

The basin is almost completely developed. Land use in the basin is primarily single-family residences and roads; commercial areas are the next most prevalent land use type. A dominant constructed feature in the City of Shoreline portion of the Thornton Creek watershed is Interstate 5, which traverses the basin in a north-south direction.

The Thornton Creek drainage system within the City of Shoreline contains primarily piped and channeled stormwater conveyance. Natural water courses are largely absent from the upper basin because the drainage pattern has been altered by humans to the point where most predevelopment features are difficult to discern. Historically, much of Thornton Creek meandered within multiple confined and unconfined channels. The unconfined portions of the creek provided connections to floodplain and wetland areas. However, these floodplain connections are now much more limited due to encroachment, bank armoring, and channelization. In general, both the actual channel widths and corridor width available for meandering (the channel migration zone) have been reduced markedly over time (City of Seattle 2007). In addition to the floodplains, many wetlands have also been filled. With the loss of these natural habitat features, important areas where stormwater runoff could be naturally stored and infiltrated to reduce peak flows were lost. Peat mining in Ronald Bog and Twin Ponds during the post-World War II era and construction of Interstate 5 in the 1960s significantly altered the hydrologic cycle and damaged much of the natural wetland and riparian habitat. The piped stormwater conveyance systems in the upper basin accommodate much of the runoff from this area and drain into Thornton Creek or one of its tributaries. Over the years, urbanization of the drainage basin without mitigation to address runoff or water quality impacts has increased erosion and sedimentation due to increased peak flows as well as water quality problems associated with temperature, low dissolved oxygen, and bacterial contamination.

Three primary drainage courses comprise the City of Shoreline portion of the Thornton Creek watershed: the North Branch of Thornton Creek, Littles Creek, and Hamlin Creek. These are shown in Figure 1-1 (p. 1-5) and are described in the

following sections. Note that Figure 3-1 divides the Thornton Creek Basin surface water system into open water courses, piped water courses, and storm drain/roadside ditch and culvert reaches. Open water courses are open channels that display natural features; these may or may not meet the City's definition of a stream. Piped water courses are constructed stormwater conveyance trunk lines that likely replaced pre-existing natural drainages. The storm drain/roadside ditch and culvert reaches are constructed conveyances that are intended to route stormwater to the open or piped water courses.

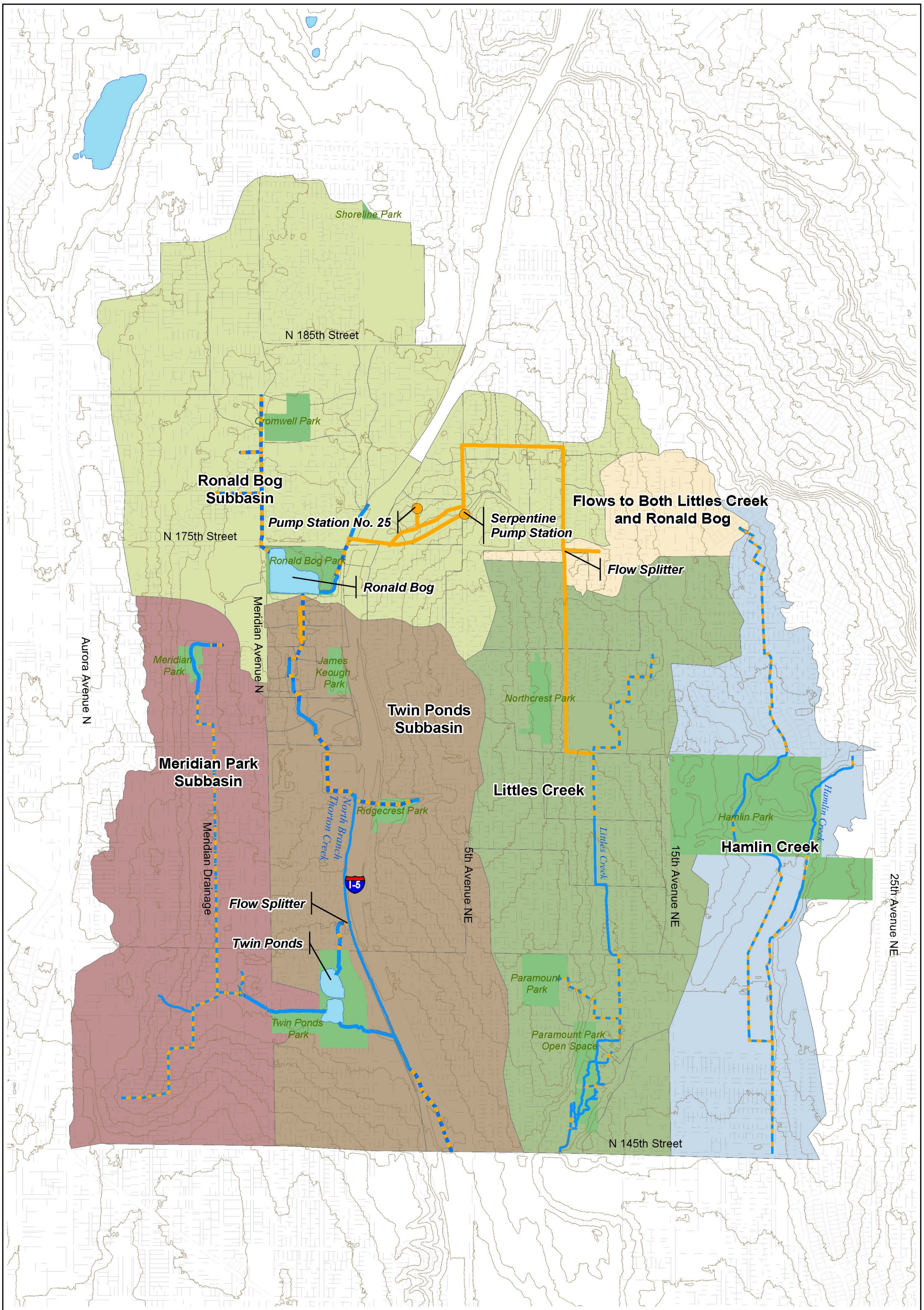
3.1.1 North Branch Thornton Creek

The North Branch of Thornton Creek is comprised of three subbasins: Ronald Bog, Twin Ponds, and the Meridian Park Drainage.

Ronald Bog

The Ronald Bog subbasin extends from N 193rd Street to the north, Midvale Avenue N to the west, 15th Avenue NE to the east, and about N 168th Street to the south. The total subbasin area is about 615 acres. The North Branch of Thornton Creek begins as a piped water course along Meridian Avenue N in the vicinity of Cromwell Park. This drainage flows through piped drainage systems mostly along Meridian Avenue N into Ronald Bog, a 7.7-acre former peat bog.

Ronald Bog and the surrounding park are a prominent feature in the basin that provides open water and wetland environmental, wildlife habitat, and recreational features. The bog was created during peat mining in the post-World War II era. The area surrounding the bog, particularly to the south, is low-lying and flat and becomes part of the floodplain during significant rainfall events. Water levels in the bog and the neighborhood to the south are the result of the complex interaction of several factors including a flat, low-gradient outlet pipe/channel system that is likely undersized; high groundwater; the volume of floodplain storage provided by the bog and surrounding wetlands; and increased stormwater inflow volumes resulting from upstream urbanization. The outlet pipe and channel system is extremely flat and the average system slope between the outlet of the bog to N 167th Street, approximately 1,300 feet to the south, is at 0.14 percent, which can create backwater that affects the capacity of the outlet system. When this backwater and capacity restrictions cause water levels to back up into the bog, the resulting high water levels function as flood storage, which helps attenuate flows downstream of the bog—in this way, the bog and its outlet system provide a form of natural flood storage/detention.



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- Piped water course
- Streets
- 10-foot Contours

Figure 3-1
Topography

Thornton Creek Watershed Plan
City of Shoreline

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R:\Seattle\011262 City of Shoreline\11-01257-10000 THORNTON CREEK WATER\Data-Analytical\report | 11-12-09

Photo 3-1. *Ronald Bog, 11/4/08.*

The area draining into Ronald Bog is primarily west of I-5. However, a portion of the watershed on the east side of I-5 is pumped, via Pump Station No. 25 and the Serpentine Pump Station, into a system along NE 175th Street that also drains to Ronald Bog. In addition, a flow splitter near NE 175th Street and 10th Avenue NE splits flows from a 65-acre upstream subbasin between Ronald Bog and Littles Creek. This is discussed more thoroughly in the Littles Creek section below.

Twin Ponds

Flow from Ronald Bog discharges into the Twin Ponds subbasin, which totals about 461 acres. The subbasin extends from N 172nd Street to the north to N 145th Street to the south and spans from Meridian Avenue N on the west side to as far as 8th Avenue NE on the east side.

Outflow from Ronald Bog flows through a 30/48-inch-diameter pipe extending along Corliss Avenue N and then through a ditch and culvert system to N 167th Street. In 2008, the failing infrastructure from Corliss Place cul-de-sac to N 167th Street was replaced with fish-passable box culverts as part of the Ronald Bog South Drainage Improvements Phase 1 project. These 2008 improvements are shown on Figure 3-2. This work was adjacent to Corliss Place N between N 171st Street and N 167th Street and included replacing the southernmost 95 feet of the Ronald Bog discharge pipeline with a 5.5-foot-high by 8-foot-wide box culvert.[1]

[1] The actual culvert dimensions are 8 feet by 5.5 feet. However, the bottom was filled in with approximately 1.5 feet of streambed gravel to meet fish passage requirements, so the open area is 8 feet by 4 feet.

The work in 2008 also included upsizing the culverts at the utilities crossings just north of N 167th Street and the culvert crossing at N 167th Street with 8-foot by 4-foot box culverts.[2] Subsequent to the construction of the project, the City also performed channel maintenance on approximately 350 feet of open channels between these pipe upgrades. The channel maintenance was intended to provide a constant channel slope between the replaced culverts. However, private improvements including a concrete lining of the stream limited the extent of the channel maintenance and so the design grades were not fully achieved although the north channel section is within 0.1 foot of the design. The remaining 30/48-inch-diameter pipeline requires annual cleaning due to root intrusion and gaps in the pipe. The 30/48-inch-diameter pipeline will require lining, repair, or replacement within the next 5 years.

Downstream of Ronald Bog, the drainage flows through backyards, ditches and culverts, and through pipes under King County Metro's bus facility, located about 0.4 mile downstream of the bog.

Approximately 0.8 mile downstream from Ronald Bog is a flow splitter that directs low flows to Twin Ponds and diverts high flows to a bypass channel constructed along I-5 (see Figure 1-1, p. 1-5). Peak flows in excess of approximately 17 cubic feet per second[3] are diverted around Twin Ponds, flowing southward through a concrete-lined channel along the west side of I-5 (Tetra Tech/KCM 2004).

Twin Ponds is another former peat bog and is located approximately one mile downstream of Ronald Bog. Each of the Twin Ponds, which are situated within the 21-acre Twin Ponds Park, occupies about 2 acres. Like Ronald Bog, Twin Ponds currently functions, in part, to provide detention for its upstream contributing area (City of Seattle 2007). The wetlands near the ponds combine to cover an additional estimated 2.4 acres. Runoff from approximately 1,300 acres passes through one or both ponds (Tetra Tech/KCM 2004).

Downstream of Twin Ponds, the water course passes through a small wetland called Peverly Pond and eventually joins back with the high-flow, concrete-lined channel that continues south and discharges into 1,500-foot-long, twin 72-inch-diameter culverts under I-5. The culverts emerge as an open channel in the City of Seattle's Jackson Park Golf Course (R. W. Beck 2005).

[2] See footnote 1.
[3] High-flow diversion begins at about 13 cubic feet per second.

1st Ave NE

I-5

James Keough Park

Corliss Ave N

N 171st St

Ronald Bog Park

30-inch System

48-inch System

Culvert Upgraded in 2008

North Branch Thornton Creek

Replaced 18-inch System
Serving Corliss in 2008

N 176th St

N 175th St

N 172nd St

N 167th St

Pipe Upgraded in 2008

Channel Cleaned/Maintained in 2008

Meridian Ave N

N

0 100 200 400 Feet

Legend

- Lakes
- Parks
- Parcels
- Open water course
- Piped water course
- Storm drain/road side ditch-culvert system

Figure 3-2
Existing System Near Ronald Bog

Thornton Creek Watershed Plan
City of Shoreline

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Photo 3-2. *Facing north (upstream) along the concrete-lined channel along I-5, just downstream of Peverly Pond, 3/3/08.*

Photo 3-3. *Culvert inlet at the North Branch of Thornton Creek's Interstate 5 crossing, 3/3/08.*

Meridian Park Drainage

The Meridian Park Drainage subbasin is about 350 acres. The subbasin extends from about N Corliss Avenue and to a lesser extent N 171st and 172nd Streets would continue to be subject to flooding 172nd Street to the north to N 145th Street to the south. It spans from about Aurora Avenue N on the west side to Meridian Avenue N on the east.

The drainage system originates north of Meridian Park as an open water course flowing through the Meridian Park wetland and continues south to N 152nd Street in a pipe. From there, it flows eastward and daylights just east of Burke Avenue N at Evergreen School. From the school, the creek heads eastward through a culvert beneath Meridian Avenue N and eventually flows into the southwest corner of the more southerly pond of the Twin Ponds (Tetra Tech/KCM 2004 and R. W. Beck 2005). Upstream of Meridian Avenue N, near Evergreen School, flow is seasonal.

Between Meridian Avenue N and Twin Ponds, the Meridian Park Drainage flows in a channelized section for several hundred feet through a brushy and forested area. This open channel portion, from Evergreen School to Twin Ponds, is also known as Evergreen Creek.

The stream passes through an approximately 42-inch-diameter, fish-passable corrugated metal pipe (CMP) culvert located approximately 200 feet east (downstream) of Meridian Avenue N. Between Meridian Avenue N and a culvert approximately 50 feet upstream from the pond, the stream is somewhat channelized, has a mucky substrate, and is partially shaded by young alder trees. An oily sheen was noted on the water surface in places, and orange-colored deposits, often an indication of anaerobic or low oxygen conditions, were also observed. The low-gradient, ditch-like channel through this area is approximately 3 to 4 feet wide and is largely choked with Himalayan blackberry, nightshade, and reed canary grass. Though some shade is provided by shrubs and adjacent alder trees, the relatively stagnant water in the channel may warm up during the summer to temperatures higher than would be tolerated by salmonid fish.

Roughly 50 feet upstream of the ponds, the stream crosses through an approximately 12-foot-long, 30-inch-diameter CMP culvert, which does not constitute a migration barrier for fish (The Watershed Company 2001; observations confirmed November 4, 2008).

The angular gravel substrate in Meridian Creek extends upstream from the mouth.

Photo 3-4. *Meridian Park Drainage culvert inlet under Meridian Avenue N, 7/2/01.*

Photo 3-5. *Meridian Park Drainage upstream of Twin Ponds, 11/4/08. Note Japanese knotweed and Himalayan blackberry.*

3.1.2 Littles Creek

Littles Creek flows in a southerly direction east of Interstate 5 to Thornton Creek and collects flow from mostly residential areas. The Littles Creek subbasin is bounded by about N 175th Street to the north and N 145th Street to the south, and spans from 5th Avenue NE on the west to as far as 22nd Avenue NE on the east. The total area in the Little's Creek subbasin is about 466 acres.

Littles Creek flow originates as a piped system near NE 175th Street and 10th Avenue NE. A flow splitter near the intersection of NE 175th Street and 10th Avenue NE splits flow from a 65-acre upstream contributing basin, dividing it between Littles Creek and Ronald Bog. The flow splitter consists of a catch basin on the southeast corner of the intersection that includes a low-flow pipe to the north and a high-flow pipe to the south. In addition, north of the intersection along 10th Avenue NE, there is a gate on the low-flow pipe that is partially closed. The gate can be adjusted to back up flows in order to force more flow to be routed to the south.

From NE 175th Street and 10th Avenue NE, the piped water course continues in a southerly direction with some open channel sections and ultimately passes through the Paramount Park Open Space, which has a 6.9-acre wetland system and two open-water ponds. After the creek passes through the Paramount Park Open Space, it crosses N 145th Street into the City of Seattle.

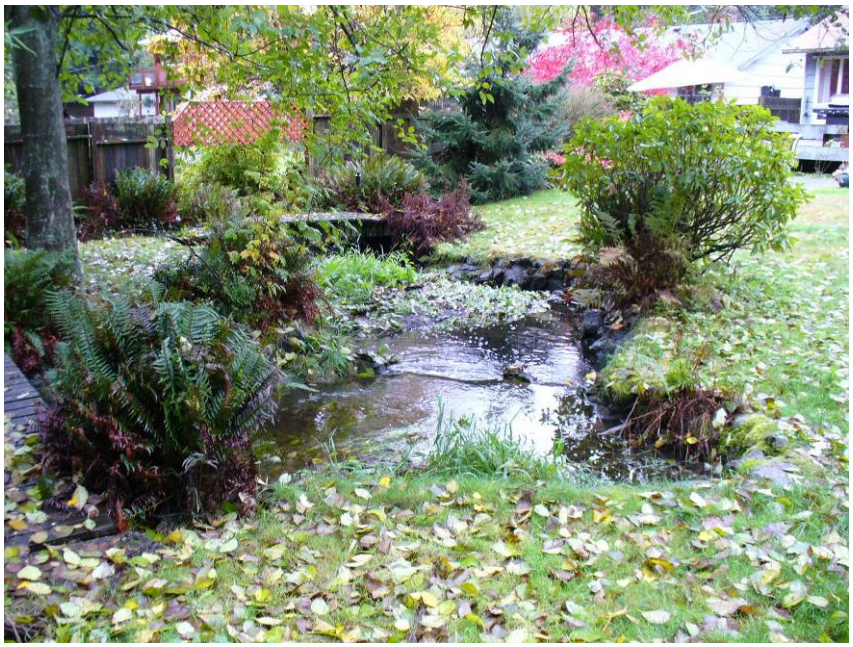


Photo 3-6. *Littles Creek in the City of Shoreline downstream of Paramount Park open space, 11/4/08.*

Photo 3-7. *Littles Creek in the City of Shoreline's Paramount Park open space, 11/4/08.*

3.1.3 Hamlin Creek

The Hamlin Creek subbasin totals about 348 acres and includes the mostly forested Hamlin Park (see Photo 3-8), the adjacent commercial and educational facilities (including the Fircrest Campus), and the surrounding residential neighborhood. The subbasin is roughly bounded by NE 177th Street to the north and N 145th Street to the south, and extends as far as 12th Avenue NE to the west and almost to 25th Avenue NE on the east.

Hamlin Creek joins the Thornton Creek mainstem in the City of Seattle near 20th Avenue NE just south of NE 130th Street, well south of the Shoreline city limits. The upper drainage consists of east and west stems that join on the Fircrest campus. The drainage for the west stem originates near NE Serpentine Place, south of NE 177th Street; the east stem begins southwest of the intersection of 23rd Avenue NE and NE 165th Street. The drainage in both stems is mostly piped. The east stem begins with a short section of pipe and continues as an open water course to NE 160th Street. The west stem flows through Hamlin Park as an intermittent drainage discharging to the piped system at the south edge of the park until it connects with the culverted eastern tributary on the Fircrest campus near the southern property line.

Hamlin Creek's flow through Hamlin Park and the Fircrest Campus is ephemeral; water has been observed flowing in the open-channel sections of the drainage at Fircrest only during and for periods shortly following significant storm events (Golder Associates, Inc. 2002a and 2002b). Hamlin Creek appears to have more reliable flows downstream (south) of NE 145th Street, outside of the City of Shoreline.

Photo 3-8. *Facing upstream along the west fork of Hamlin Creek in a wooded ravine in Hamlin Park, 11/4/08.*

Photo 3-9. *Facing upstream along the east fork of Hamlin Creek in Hamlin Park between the toe of the slope and a baseball field, 8/4/08.*

Photo 3-10 *Hamlin Creek's ditched channel along the west side of 20th Avenue NE, downstream of the Fircrest Campus, 9/17/08.*

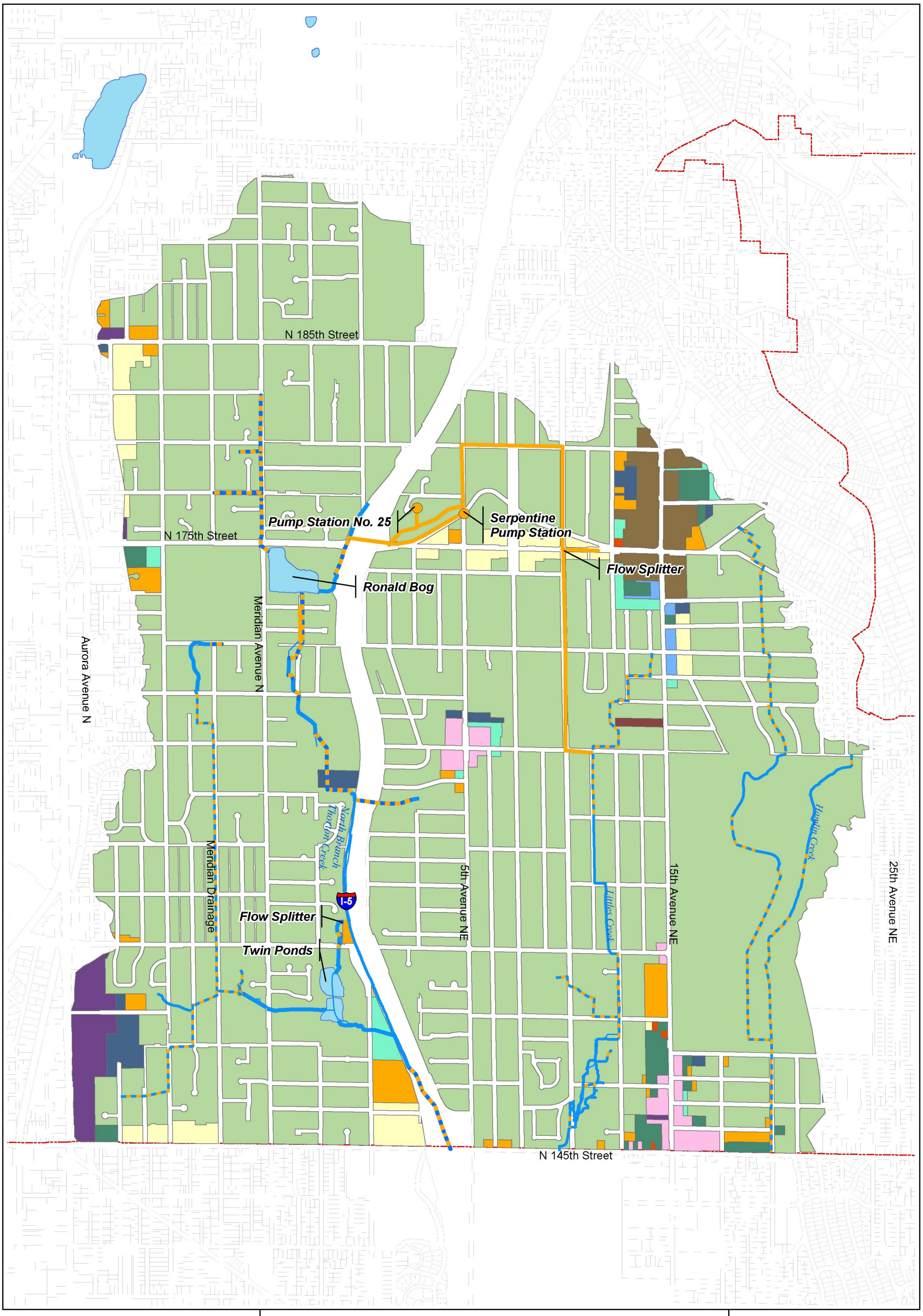
3.2 Land Use

The Thornton Creek watershed is almost completely developed. Land use is shown in Figure 3-3. The City's *Thornton Creek Basin Characterization Report* (Tetra Tech/KCM 2004) reported that only about 3 percent of the watershed remains as vacant or open space. The watershed is primarily zoned single-family residential. The commercial zones, mostly at the north and south ends of 15th Avenue NE, constitute the next largest land use. Institutional uses, such as Fircrest, schools, and other public facilities, also make up a significant portion of the Thornton Creek watershed. The City has several large parks including Ronald Bog Park, Twin Ponds Park, Cromwell Park, Paramount Park, and Hamlin Park. There is a relatively small amount of multifamily use or apartments. A notably dominant feature within the City of Shoreline portion of the Thornton Creek watershed is I-5, which traverses the watershed in a north-south direction. The interstate and the extensive residential development result in a high proportion of the basin within the City being categorized as impervious road surfaces (R. W. Beck 2005). Land cover in the 1490.1-acre watershed consists of approximately 695 acres of impervious surface (approximately 47 percent of the basin), 771 acres of grass (approximately 52 percent of the basin), 13 acres of forest (less than 1 percent of the basin), and 10 acres of open water. The current land use in the watershed is also characterized for the purpose of hydrologic modeling as described in Appendix B.

3.3 Geology and Soils

Surficial geology and soils were reviewed for this report. A soils map for the watershed is included in Appendix B. Soils are the result of the weathering of surficial geology. The surficial geology is made up primarily of Vashon Till (Alderwood soils) with a large upside-down U-shaped area of Advanced Glacial Outwash Deposits (Esperance sands). The Esperance Sands extend along the I-5 corridor south of Ronald Bog up north to the area around Serpentine Place and then down again to the upper portions of Littles Creek and Hamlin Creek subbasins. Vashon Till is glacial till, a mix of mostly gravel, sand and silt that the glacier was carrying before it receded. The till was compacted by the glacier, resulting in a largely impermeable layer that allows only very slow and inefficient infiltration of stormwater runoff. Esperance sand is the glaciofluvial deposit prograded in front of the advancing glacier and is predominantly permeable, clean, uniform sand. Unlike the till, the sand is highly permeable since it was not compacted by the glacier and it has a more uniform particle distribution. Esperance Sands provide excellent opportunity for infiltration as a means of surface water management.

Soils in the basin also include Norma fine sandy loam, Everett gravelly sandy loam, Greenwood peat, Mukilteo peat, and Rifle peat. The peat soils are found around Ronald Bog and Twin Ponds. Peat was mined from Ronald Bog and Twin Ponds from the late 1940s through the 1960s.



Source: City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report (Tetra Tech, May 2004)

N

0 600 1,200 2,400 Feet

Legend

- Commercial Business
- Coastal Zone
- Neighborhood Business
- North City Business District
- Open Space
- Residential 12
- Residential 18
- Residential 24
- Residential 48
- Residential 6
- Residential 8
- Regional Business

Figure 3-3
Current Land Use

Thornton Creek Watershed Plan
City of Shoreline

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3.4 Aquatic, Wetlands, and Riparian Habitat

3.4.1 Aquatic and Riparian Habitat

The Thornton Creek watershed lies predominantly within the City of Seattle with the North Branch headwatering in the City of Shoreline and then proceeding in a southeasterly direction downstream through Seattle to Lake Washington at Matthews Beach. Tributaries Hamlin Creek and Littles Creek also headwater in Shoreline and join the North Branch to the south, in Seattle. While some aspects of habitat description and evaluation may be addressed on a very localized or site-specific level, others, such as those relating particularly to migratory fish, require a basin-wide perspective.

Throughout its basin, including those portions within Shoreline, Thornton Creek is generally dominated by plane-bed channels (those generally lacking a distinct sequence of bed features such as riffles and pools), high proportions of fine sediments, armored banks, and low-quality riparian corridors due to narrow effective buffers and/or inadequate native riparian vegetation. The effects of low-quality riparian habitat along Thornton Creek are amplified by the lack of floodplain connections that would naturally help contain and moderate high-flow events (City of Seattle 2007).

Urbanization in both cities has also eliminated or severely impacted fish and wildlife habitat as some stream sections were placed in pipes, others were channelized, and riparian habitat was reduced. These changes have resulted in a loss of open water courses and degradation of the remaining sections. Residential development along the stream banks has further degraded the natural environment around the remaining sections of open water courses of Thornton Creek.

In general, fish habitat is relatively poor throughout the Thornton Creek basin, due primarily to fish passage barriers, riparian encroachment, and bank hardening (Tetra Tech 2004). High peak flows and generally volatile flows result from the extensive impervious surface areas throughout the basin, and in turn lead to bank erosion, sedimentation, and the filling of pools. Improvement of the riparian corridor is needed along most sections, as much of Thornton Creek is bordered on each side by narrow corridors of primarily low-quality riparian habitat.

The Thornton Creek channel is generally deficient in coarse-grained sediment, which, when present in sufficient quantities, contributes to channel stability and provides a spawning-gravel substrate. The primary source of in-channel coarse sediment is bank erosion, leading to channel migration across gravelly floodplain areas which have also been occupied by former stream channels. Such bank erosion and associated channel migration has been greatly reduced throughout the Thornton Creek basin due to bank armoring, thereby reducing the stream's access to floodplain gravel. At the same time that the sources of coarse sediment have been removed, the ability of the stream to transport these same sediments has increased due to higher and more volatile stream flows, resulting in a "sediment-starved" channel along many sections. Such channels are typically deep and narrow, and have cut downward to less erodible parent

materials such as bedrock or, within the Thornton Creek basin, glacial till. Much of the watershed now lacks this needed access to floodplain sediment, and a lack of in-stream structure (including log and debris jams) further inhibits the stream's ability to trap and accumulate such sediment (City of Seattle 2007).

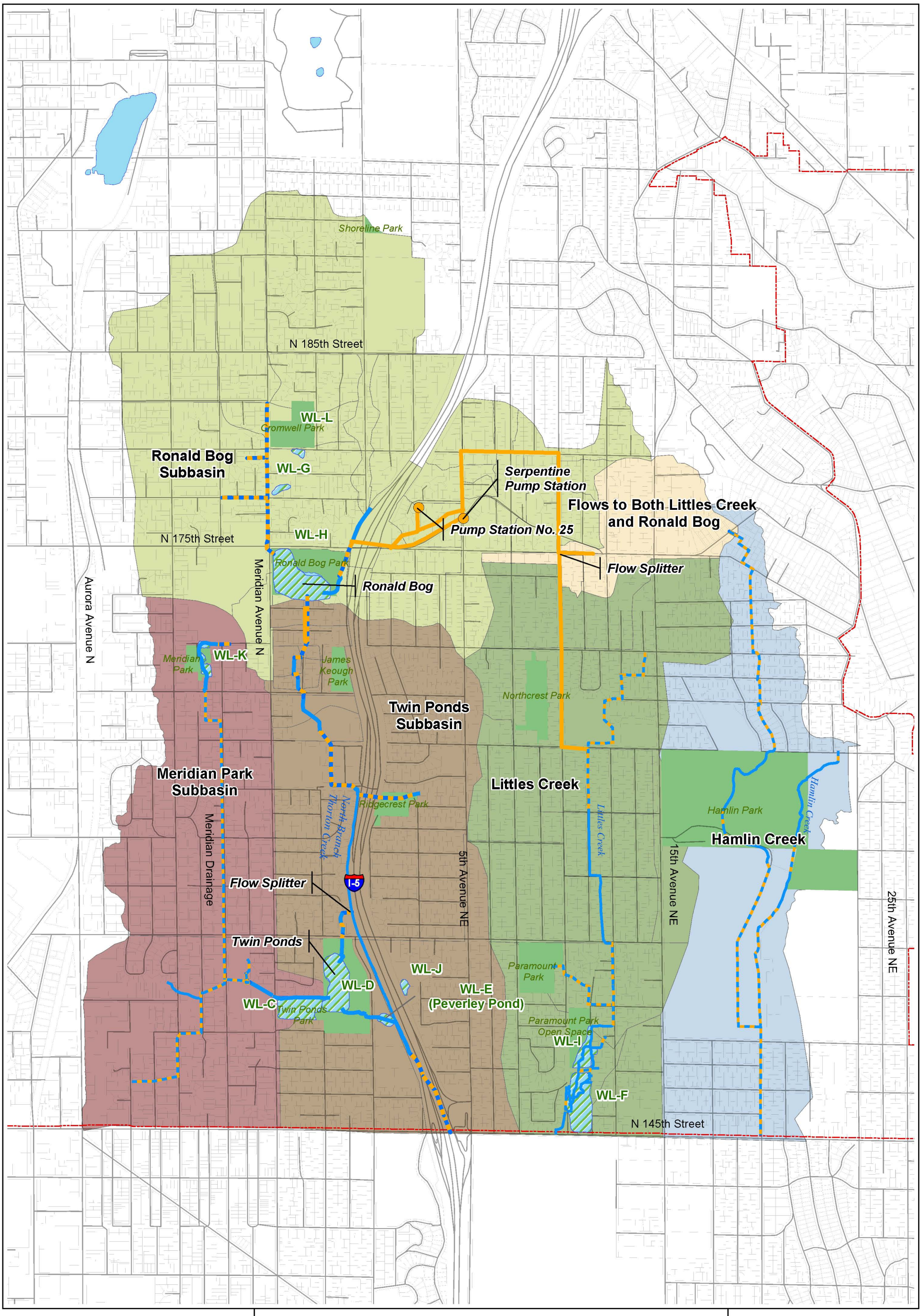
3.4.2 Wetlands

In 2003, the City of Shoreline's Wetland Inventory and Classification identified 10 wetland areas in the City's portion of the Thornton Creek watershed (Tetra Tech 2003). Information about these wetlands is summarized in Table 3-1 and their locations are shown on Figure 3-4.

Table 3-1
Thornton Creek Wetlands in the City of Shoreline

Site	Name	Size (approx. in acres)	Wetland Classes (Cowardin, et al. 1979)	Comments
WL-C	Meridian Avenue	4	palustrine forested	in Twin Ponds park and part of the Twin Ponds wetland system
WL-D	Twin Ponds (complex)	2.4 (5.4)	palustrine forested/ emergent	
WL-E	Peverly Pond	>1	palustrine forested/ scrub-shrub/emergent	between 1st Ave NE and Interstate 5
WL-F	Paramount Park	6.9	palustrine forested/ scrub-scrub/emergent	also known as Littles Creek, between 10th and 12th Avenue NE, north of NE 145th Street
WL-G	Thornton Creek (reach 13)	0.4	palustrine forested	near Thornton Creek reach 13 at N 179th Street and 21st Avenue N
WL-H	Ronald Bog (complex)	1 (7.7)	palustrine forested/ scrub-shrub/emergent	at NE 175th and Meridian Avenue N
WL-I	Kim Wetland	0.4	palustrine forested/ scrub-scrub	near NE 148th Street and 11th Avenue NE
WL-J	Unnamed wetland (I-5 and N. 152nd St.)	0.4	palustrine scrub-shrub/ emergent	at Interstate 5 and North 152nd Street
WL-K	Meridian Park	1.1	palustrine forested/ scrub-scrub	within Meridian Park
WL-L	Cromwell Park	0.3	palustrine forested/ scrub-scrub	in Cromwell Park

Source: Tetra Tech/KCM 2004.



Note:
Source of basemap and piped water course system is City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report (Tetra Tech, May 2004)

N

0 600 1,200 2,400 Feet

Legend

- WL-C Wetland ID
- Lakes
- Parks
- Hamlin Creek
- Littles Creek
- Meridian Park Subbasin
- Twin Ponds Subbasin
- Ronald Bog Subbasin
- Flows to Both Littles Creek and Ronald Bog
- Storm drain/road side ditch-culvert system
- Open water course
- Piped water course
- Streets
- City Limits
- Parcels

Figure 3-4
Wetlands and Channel Reaches

Thornton Creek Watershed Plan
City of Shoreline

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Ronald Bog

Ronald Bog Park, including its pond and associated wetlands (1 acre), is one of the largest wetland complexes (7.7 acres) in the City of Shoreline. The bog and its surrounding park provide open water and habitat for resident and migratory birds. Examples of vegetation include red alder, black cottonwood, and willow trees, as well as non-native Himalayan blackberry, salmonberry, giant horsetail, creeping buttercup, and reed canary grass. The bog is a former peat deposit. The area surrounding the bog, particularly to the south, is low-lying and flat and becomes part of the floodplain during significant rainfall events. Also refer to the discussion of Ronald Bog under Section 3.1.1.

Photo 3-11. *Wildlife utilization of the pond at Ronald Bog, 9/10/08.*

Twin Ponds

South of Ronald Bog, the North Branch of Thornton Creek flows approximately one mile to Twin Ponds, a former peat deposit that also functions as detention ponds for its tributary area (City of Seattle 2007). Twin Ponds Park consists of 21 acres of land adjacent to the two ponds of about 2 acres each (Tetra Tech/KCM 2004). Several wetlands are located near the edge of the ponds occupying 2.4 acres collectively (Tetra Tech/KCM 2004). Approximately 1,300 acres of land drain into the ponds. The north pond collects drainage from the North Branch of Thornton Creek and the south pond also receives drainage from Meridian Park Drainage (Tetra Tech/KCM 2004).

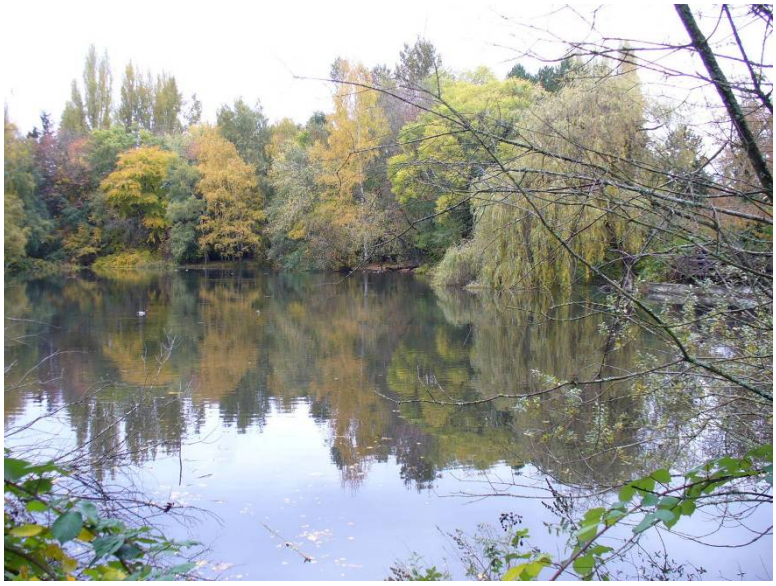


Photo 3-12. *Twin Ponds, 11/4/08.*

Paramount Park Open Space

At approximately 6.9 acres, Paramount Park Open Space is home to the largest palustrine system within the Thornton Creek watershed (R. W. Beck 2005). The Paramount Park wetland is associated with a series of wetlands, ponds, and connecting channels (Littles Creek) (Tetra Tech 2003).

3.4.3 Fish Use and Passage Constraints

Approximately 12 miles of stream channels within the overall Thornton Creek watershed are potentially fish-bearing, including both branches and the lower segments of Littlebrook, Willow, and Maple tributaries (Washington Trout 2000). Within the City of Shoreline, this would include the North Branch extending downstream of and including Ronald Bog where fish use is generally limited to resident fish, as reliable access by migratory fish is blocked by several full or partial migration barriers in and bordering the City of Seattle.

The Thornton Creek watershed generally does not offer prime habitat for fish. Significant problems affecting fish survival include high storm flows, channelized banks, sedimentation, lack of food, poor water quality, high temperatures, low dissolved oxygen levels, barriers to passage, inadequate in-stream wood and rock structures, and lack of refuge, spawning and rearing areas (SPU 2000).

Salmonid species present in the overall Thornton Creek basin, encompassing the Cities of Shoreline and Seattle, include:

- Chinook salmon,
- Coho salmon,
- Sockeye salmon,

- Coastal cutthroat trout,
- Steelhead trout, and
- Rainbow trout (Kerwin 2001 and Williams et al. 1975).

Non-salmonid species found in the Thornton Creek watershed include:

- Peamouth chub,
- Largescale sucker,
- Threespine stickleback,
- Several sculpin species,
- Lamprey,
- Long nose dace,
- Nonnative rock bass,
- Pumpkinseed,
- Largemouth bass, and
- Oriental weatherfish (City of Seattle 2007).

Of these, coastal cutthroat trout are the only salmonid fish to be reliably found in those portions of the North Branch and its tributaries within Shoreline, due primarily to migration barriers and the small size of headwater streams. Exceptions have occurred due to outplanting programs, and a single recent steelhead sighting has been documented, as described below. Many more of the above-listed non-salmonid or "warm water" fish are found in Shoreline, particularly in Ronald Bog and Twin Ponds. Thornton Creek fish use, including specifically within the City of Shoreline, is also summarized in Table 3-2.

Both coho and chinook fry have been released into Thornton Creek by various schools participating in the "Salmon in the Classroom" program run by Washington Department of Fish and Wildlife (WDFW). Most of the juvenile coho and chinook found throughout the watershed are likely the result of classroom releases from that program (Tetra Tech 2003). In 1998, for example, participating schools received 3,350 coho eggs and 1,050 chinook eggs (SPU 2000).

Coho is the most numerous of the Pacific salmon species using Thornton Creek, but use occurs almost exclusively in the stream sections downstream of Shoreline, in Seattle. Based on carcass counts between 1999 through 2005, an average of 33 adult coho spawn in Thornton Creek each year (City of Seattle 2007). However, in spite of such spawning, results from smolt trapping efforts initiated by WDFW and SPU in 2000 indicate that Thornton Creek has an extremely limited capacity to support coho through their first year (D. Seiler, personal communication to K. Lynch, 2000, and Kerwin 2001). Overall, the system provides very few coho smolts, with just a few per day emigrating past the smolt trap (WDFW/SPU unpublished smolt trapping data 2000), compared to other regional systems of comparable size which produce hundreds to thousands of smolts per day for the same sample period (D. Seiler, personal communication to K. Lynch, 2000, and Kerwin 2001). In addition, coho

prespawn mortality rates are high, averaging 79% throughout Thornton Creek, in comparison to Fauntleroy Creek (39%), Piper's Creek (56%) and Longfellow Creek (71%) (City of Seattle 2007). It is postulated that these observed high prespawn mortality rates for coho in urban streams are due to some aspect of poor water quality; however, this phenomenon is not fully understood.

Currently, adfluvial (lake-rearing) and anadromous (ocean-rearing) cutthroat and rainbow trout (steelhead), and anadromous chinook, coho, and sockeye salmon all spawn in (lower) Thornton Creek, exclusively in sections within the City of Seattle (City of Seattle 2007). Cutthroat trout are the most prevalent and widespread fish species in Thornton Creek, found where flow and fish passage conditions allow. An annual adult count of migratory cutthroat trout averaged over 200 live fish on the spawning grounds (City of Seattle 2007). However, due to the presence of multiple barriers to upstream migration, the presence of these migratory fish along the upper North Branch and its tributaries within the City of Shoreline is expected to be nonexistent or exceedingly rare under existing conditions except for juvenile fish that are the result of outplanting programs as described below.

Though open-water creek sections within the City of Shoreline are limited, many of them do support generally non-migratory fish, such as sculpin, dace, stickleback, and possibly resident cutthroat trout (Tetra Tech/KCM 2004). Trout and non-salmonid species are thought to occupy several of the larger wetland ponds in the watershed, including Ronald Bog, Twin Ponds, and Peverly Pond. These ponds generally provide an excellent source of food, including mayfly, stonefly nymphs, and gammarid shrimp (Tetra Tech 2003). Documentation supports Ronald Bog as having largemouth bass, carp, and sunfish (and possibly rock bass, bluegill, and pumpkinseed) (Tetra Tech 2003). Littles Creek has no fish, presumably due to the barriers that are downstream of the confluence with the North Branch (City of Seattle 2007). Hamlin Creek within the City of Shoreline similarly lacks fish primarily because of the lack of a suitable flow regime.

Overall Thornton Creek fish use by species and location is summarized in Table 3-2, followed by summaries of fish use for each of the tributaries within the City of Shoreline.

Table 3-2
Fish Observations in the Thornton Creek Watershed

Species	City of Seattle	City of Shoreline					
	Mainstem & North Branch	North Branch	Ronald Bog	Twin Ponds	Littles Creek	Hamlin Creek	Meridian Park Drainage
Chinook salmon	X	X[1]			0	0	
Coho salmon	X	X[1]			0	0	
Sockeye Salmon	X				0	0	
Chum salmon	X				0	0	
Steelhead	X	X[2]			0	0	
Cutthroat trout (adfluvial & resident)	X	X			0	0	
Rainbow trout (resident)	X	X			0	0	
Largemouth Bass	X	X	X		0	0	
Carp	X	X	X		0	0	
Sunfish (rockbass, bluegill, and pumpkin seed)	X	X	X	X	0	0	
Various non-salmonids[3]	X	X			0	0	

1 Juveniles resulting from outplanting programs.
2 One observation: WDFW and Shoreline staff, 2/4/04 as reported in Tetra Tech/KCM 2004.
3 Peamouth chub, largescale sucker, threespine stickleback, sculpin, lamprey, long nose dace, oriental weatherfish

Key: X Documented as Present
0 Documented as Not Present
(blank) Not Documented/Unknown

North Branch Thornton Creek

Along the North Branch of Thornton Creek in Shoreline, juvenile migratory salmon, including coho and chinook, have been present at times but are likely the result of the "Salmon in the Classroom" program described below in the "Fish Use and Passage Constraints" section (Tetra Tech/KCM 2004). Non-migratory salmonid species, primarily cutthroat trout, have been observed in the North Branch.

Ronald Bog

Trout and non-salmonid fish species are thought to occupy Ronald Bog. Documented reports indicate that Ronald Bog is home to largemouth bass, carp, and sunfish (and possibly rock bass, bluegill, and pumpkin seed) (Tetra Tech 2003).

Twin Ponds

Fish use has been documented in the North Branch of Thornton Creek in the lower half of the Twin Ponds subbasin. Documented fish use includes: coho salmon,

cutthroat trout, and aquarium billfish reported in the reach along I-5 downstream of the confluence of the high- and low-flow channels from Twin Ponds (Tetra Tech/KCM 2004); a 10-inch cutthroat trout was observed where the creek crosses NE 155th Street (SPU 2000); and, on February 4, 2004, both WDFW staff and City of Shoreline staff observed one steelhead in a small pool just north of N 155th Street (Tetra Tech/KCM 2004).

There has been no documentation of salmonid fish use of Twin Ponds, even though it provides an excellent food source (Tetra Tech/KCM 2004). Factors that may inhibit salmonid use of Twin Ponds include temperature and stormwater runoff (Tetra Tech 2003). Non-salmonid fish were observed in Twin Ponds on October 5, 2001, mostly consisting of very small juveniles that appeared to be recently spawned sunfish or bass (Tetra Tech 2003).

Meridian Park Drainage

Salmonid fish use of Meridian Park Drainage is undocumented, but is a reasonable presumption from its mouth at Twin Ponds upstream for a few hundred feet (approximately one-third to one-half of the distance between the ponds and Meridian Avenue N), due to the presumed presence of fish in the ponds and the relatively beneficial character of the channel and its flows in that lower section. Farther upstream, however, salmonid fish use becomes doubtful because of the cumulative and additive effects of the weed-choked channel; its mucky, organic substrate; stagnant, likely anaerobic conditions; possible unfavorably high temperatures; and possible unfavorable fish passage conditions through the long culvert under Meridian Avenue N (The Watershed Company 2001).

Littles Creek

Littles Creek within the City of Shoreline (including within Paramount Park) has no fish, not even resident populations. In the City of Seattle, Littles Creek flows through and along portions of Jackson Park Golf Course, terminating at 15th Avenue NE and NE 133rd Street at the end of a confined culvert that is greater than 1,600 feet in length. This culvert acts as a fish passage barrier due to its length and flow velocity (K. Lynch [SPU], personal communication, Nov. 14, 2008). Littles Creek may have been home to resident cutthroat and/or rainbow trout historically, but currently none are present, and no reports or documentation of present or past fish use have been found. The creek is ranked as having poor in-stream quality, even though the riparian quality varies between poor and moderate (City of Seattle 2007).

Hamlin Creek

Neither the east nor west tributaries of Hamlin Creek in the City of Shoreline through Hamlin Park and the Fircrest Campus currently support fish populations, and, due to their physical characteristics (numerous extended pipe sections, limited exposed channel, and intermittent flow), these tributaries probably do not have the potential to support fish. This condition and flow regime clearly precludes any kind of direct, on-site fish use of Hamlin Creek within the City of Shoreline. Sections of the drainage system downstream of Shoreline in the ditched channel along 20th Avenue NE in the

City of Seattle appear to have more reliable flows; however, fish use there has not been documented. In addition, the culvert outfall at the mouth of Hamlin Creek in the City of Seattle, where it flows into Thornton Creek, is likely a barrier to upstream fish migration (including anadromous salmon and trout). The gradient is steep and the vertical distance from the culvert outfall to the surface of Thornton Creek is 18 to 24 inches, depending on flow conditions. The culvert is in poor condition with water passing through gaps in its bottom rather than out the end (Golder Associates, Inc. 2002a).

Fish Passage Barriers

Any anadromous salmonid attempting to return to the North Branch of Thornton Creek faces at least three definite and four to five potential barriers, including a culvert under Lake City Way in the City of Seattle which acts as a near-complete barrier to both adult and juvenile migration (Tetra Tech 2003). Hence no spawning occurs, reliably, above that point (Tetra Tech 2003). Therefore, resident rather than migratory forms of cutthroat and (possibly) rainbow trout are most likely the salmonid species expected in the upper Thornton Creek sections within the City of Shoreline, with the exception of the stocked juvenile salmon, such as coho, mentioned above. A series of barriers further obstructs anadromous salmon and anadromous and adfluvial trout access upstream of Jackson Park Golf Course, just south of the Shoreline city limits at NE 145th Street. Resident cutthroat and pumpkinseed are found in the golf course's stream and ponds, respectively (City of Seattle 2007).

As identified in *Fish Utilization in City of Shoreline Streams* (Tetra Tech 2004, Appendix C) definitive fish passage barriers along the North Branch within the City of Shoreline include 1) the culvert under Interstate 5, 2) the weir at the outfall of Peverly Pond, and 3) the high flow diversion structure upstream of Twin Ponds. Several other possible barriers were listed, including the long piped section and catch basin at the outlet of Ronald Bog.

The 30-inch-diameter outlet pipe at Ronald Bog and associated catch basin have been postulated in previous reports to be a barrier or partial barrier to upstream-bound fish movements (Tetra Tech/KCM 2004). However, recent calculations (NHC 2008) have indicated that velocities for 10 percent exceedance flow through various sections of the pipe range from 0.9 to 1.6 feet per second. WDFW's Design of Road Culverts for Fish Passage (WDFW 2003, Chapter 5) gives a maximum velocity through culverts longer than 200 feet as 2 feet per second for 6-inch trout and larger salmonid fish at the fish passage design flow. Cutthroat trout and other salmonid fish are known to be able to pass fairly readily through long, dark culverts, provided velocities are relatively low (Holser, personal communication, 2008). While the Ronald Bog outlet pipe likely does not meet current design standards for new culvert placement in all aspects, it does not appear to present a velocity barrier to upstream fish movements, and therefore may present no more than a hindrance or low-level partial barrier to upstream fish passage.

3.5 Water Quality

The City has monitored water quality at several locations in the Thornton Creek watershed (Figure 3-5). Monitoring includes ambient parameters (parameters that can be measured continuously using probes), collected from 2002 to present, and Water Quality Index (WQI) parameters, collected from 2007 to present (Table 3-3). Raw data are presented in Appendix C and summary statistics are shown in Figure 3-5.

Table 3-3
Water Quality Parameters Monitored by City of Shoreline

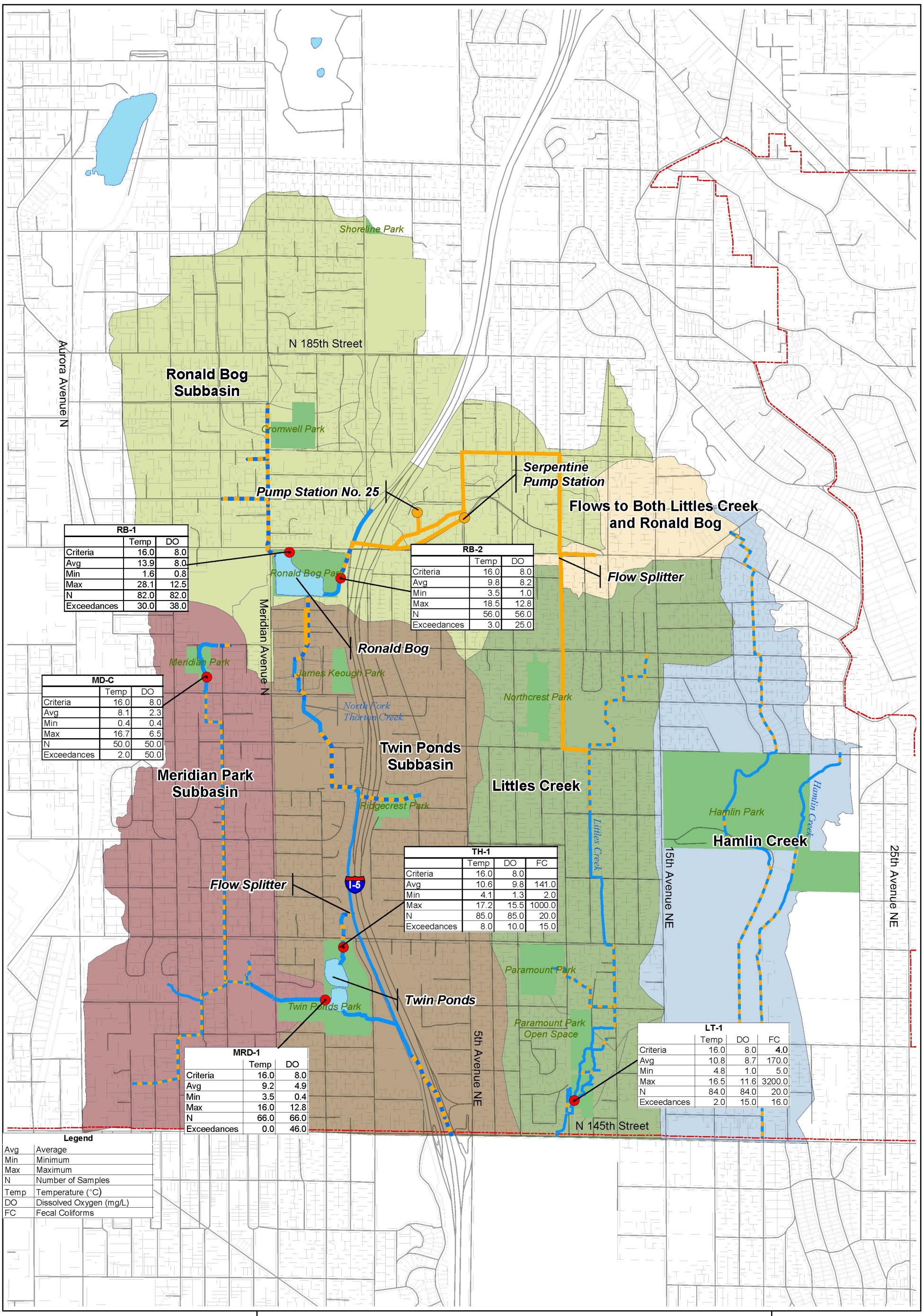
Monitoring Station ID and Location		Ambient Parameters (2002-2008) DO, Temp, Cond, Salinity, pH, Turb, Flow	Water Quality Index Parameters (2007-2008) TSS, TN, TP, FC
RB-1	Ronald Bog Inlet	X	
RB-2	Ronald Bog Inlet	X	
MD-C	Meridian Creek	X	
MRD-1	Meridian Creek	X	
TH-1	Thornton Creek	X	X
LT-1	Littles Creek	X	X

Designated uses for Thornton Creek are not specified in WAC 173-201A-602 (Fresh Water Designated Uses by Waterbody). WAC 173-201A-600 (Use Designations – Fresh Waters) states that surface waters not named are to be protected for the designated uses of:

- salmonid spawning, rearing, and migration,
- primary contact recreation,
- domestic, industrial, and agricultural water supply,
- stock watering,
- wildlife habitat,
- harvesting,
- commerce and navigation,
- boating, and
- aesthetic values.

Additionally, WAC 173-201A-600 states that all feeder streams to lakes are also to be protected for the designated uses of:

- core summer salmonid habitat, and
- extraordinary primary contact recreation.



RB-1	Temp	DO
Criteria	16.0	8.0
Avg	13.9	8.0
Min	1.6	0.8
Max	28.1	12.5
N	82.0	82.0
Exceedances	30.0	38.0

RB-2	Temp	DO
Criteria	16.0	8.0
Avg	9.8	8.2
Min	3.5	1.0
Max	18.5	12.8
N	56.0	56.0
Exceedances	3.0	25.0

MD-C	Temp	DO
Criteria	16.0	8.0
Avg	8.1	2.3
Min	0.4	0.4
Max	16.7	6.5
N	50.0	50.0
Exceedances	2.0	50.0

TH-1	Temp	DO	FC
Criteria	16.0	8.0	
Avg	10.6	9.8	141.0
Min	4.1	1.3	2.0
Max	17.2	15.5	1000.0
N	85.0	85.0	20.0
Exceedances	8.0	10.0	15.0

MRD-1	Temp	DO
Criteria	16.0	8.0
Avg	9.2	4.9
Min	3.5	0.4
Max	16.0	12.8
N	66.0	66.0
Exceedances	0.0	46.0

LT-1	Temp	DO	FC
Criteria	16.0	8.0	4.0
Avg	10.8	8.7	170.0
Min	4.8	1.0	5.0
Max	16.5	11.6	3200.0
N	84.0	84.0	20.0
Exceedances	2.0	15.0	16.0

Note:
Source of basemap and piped water course system is City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report (Tetra Tech, May 2004)

N

0 600 1,200 2,400 Feet

Legend

- Monitoring Stations
- Lakes
- Parks
- Hamlin Creek
- Meridian Park Subbasin
- Twin Ponds Subbasin
- Ronald Bog Subbasin
- Littles Creek
- Flows to Both Littles Creek and Ronald Bog
- Storm drain/road side ditch-culvert system
- Open water course
- Piped water course
- Streets
- City Limits
- Parcels

Figure 3-5
Monitoring Stations

Thornton Creek Watershed Plan
City of Shoreline

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The water quality criteria (WAC 173-201A) for dissolved oxygen, temperature, and bacteria (fecal coliforms) corresponding to the above designated uses are provided in Table 3-4. These are the parameters whose criteria are most commonly not met in Thornton Creek.

Table 3-4
Water Quality Criteria (WAC 173-201A) for Dissolved Oxygen, Temperature, and Bacteria

Category	Dissolved Oxygen (Lowest 1-Day Min.)	Temperature (Highest 7-Day Max.)	Bacteria (Fecal Coliforms)
Core Summer Salmonid Habitat	9.5 mg/L	16°C (60.8°F)	
Salmonid Spawning, Rearing, and Migration	8.0 mg/L	17.5°C (63.5°F)	
Extraordinary Primary Contact Recreation	--	--	Geomean <50 colonies/100 mL, with <10% of samples >100 colonies/100 mL.
Primary Contact Recreation	--	--	Geomean <100 colonies/100 mL, with <10% of samples >200 colonies /100 mL.

The Washington State Department of Ecology (Ecology) did not include Shoreline's data in its 2008 Water Quality Assessment (the "303(d) list," or determination of impaired waterbodies). No impaired waterbody segments are identified in Thornton Creek within the City of Shoreline. However, this may be due to lack of data rather than definitive data showing that Thornton Creek meets tested standards. In its 2008 assessment, Ecology identified portions of Thornton Creek in Seattle, downstream of the City of Shoreline, as "impaired and needing a TMDL" (Category 5 on Ecology's Candidate 303(d) listing) for fecal coliforms, temperature, and dissolved oxygen. The Water Quality Assessment listings for Thornton Creek in Seattle are summarized in Table 3-5. "Impaired" means that there is sufficient data to show that the waterbody does not meet criteria for a specific parameter.

Table 3-5
Department of Ecology Water Quality Assessment Reporting
for Thornton Creek in the City of Seattle
(Downstream of Shoreline)

Parameter	Category	Category Description
Temperature	5	Polluted waters that require a TMDL
pH	1	Meets tested standards is for clean waters
Dissolved Oxygen	5	Polluted waters that require a TMDL
Fecal Coliform	5	Polluted waters that require a TMDL
Ammonia-N	1	Meets tested standards is for clean waters
Mercury	2	Waters of concern

A TMDL (total maximum daily load) is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL study includes a problem formulation and an analysis of how to control the discharge of particular pollutants to surface waters. Ecology has not yet completed a TMDL for Thornton Creek, and Thornton Creek is not included in any TMDL studies or plans scheduled for 2009.

Although no segments of Thornton Creek in Shoreline are listed in Ecology's 303(d) list, this watershed plan (Section 6.4) recommends actions to improve the conditions of these temperature, dissolved oxygen, and fecal coliforms. This is because Shoreline is upstream of the impaired stream segments in Seattle and the data in Thornton Creek within the City of Shoreline shows similar conditions to those downstream.

The 2007-2008 water year WQI Score for station LT-1 is 26, and the score for station TH-1 is 32. (See Figure 3-5, p. 3-31, for locations of these two monitoring sites.) Ecology states that scores less than 40 indicate that the conditions "did not meet expectations and are of highest concern." Criteria for fecal coliforms, temperature, and dissolved oxygen were not met on several occasions at these two locations. While conditions at these sites warrant concern, the water quality appears to be typical of urban streams in the Puget Sound area. In particular:

- Despite high temperatures upstream (in particular, station RB-1, with a maximum of 28.1°C), temperatures at station TH-1 generally meet criteria. Although 8 of 85 observations showed an exceedance of the 16°C criterion, the maximum is 17.2°C. These observations suggest that the temperature generally recovers downstream of Ronald Bog. For Littles Creek, only 2 of 84 observations exceeded the 16°C criterion, with a maximum of 16.5°C. Temperatures appear to be only marginally elevated above the criterion.
- As expected, dissolved oxygen (DO) is inversely correlated with temperature (Figure 3-6). At stations TH-1 and LT-1, DO concentrations less than the 8 mg/L criterion most commonly occur at higher temperatures, particularly above 11°C. When DO falls below the criterion, it usually remains above 7 mg/L, less than 1 mg/L below the criterion.
- While fecal coliforms regularly exceed the criterion (50 colonies/100 mL), the geometric means at station TH-1 and LT-1 (141 and 170 colonies/100 mL) are relatively low for urban streams. The maxima (1000 and 3200 colonies/100 mL) do not indicate severe pollution.

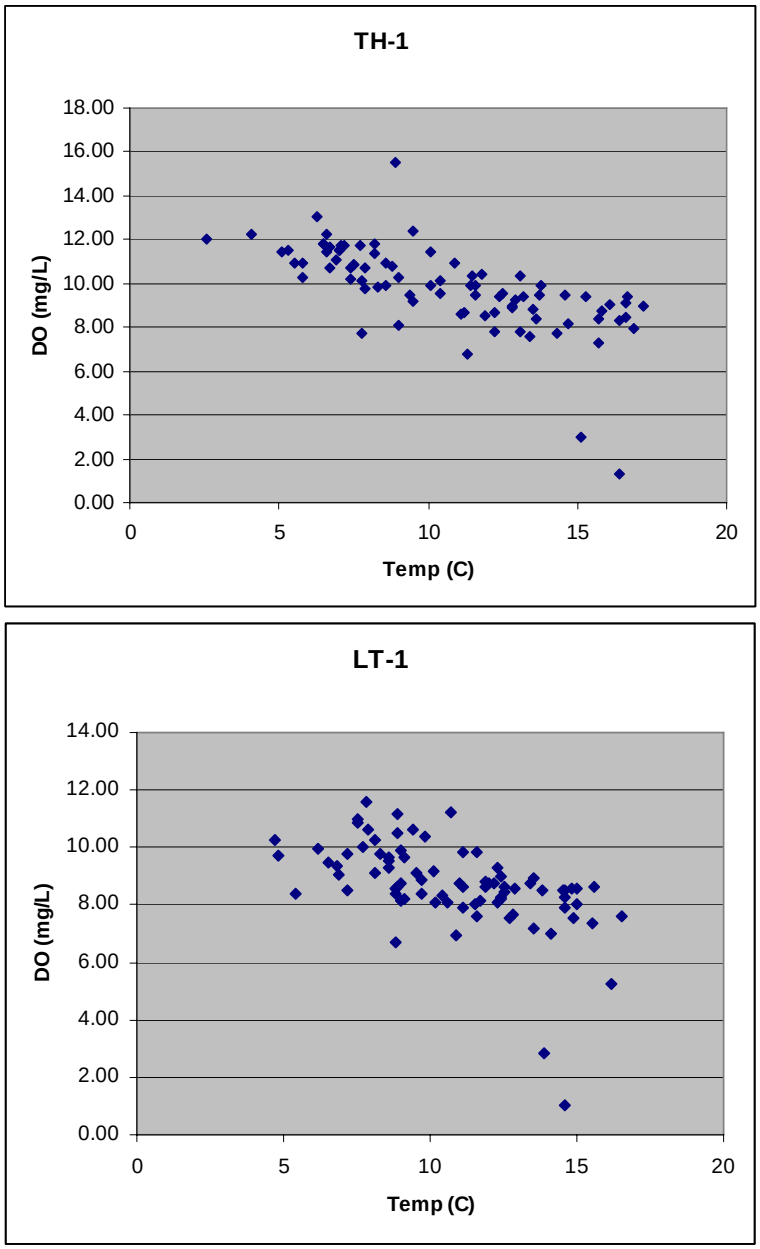


Figure 3-6. Dissolved Oxygen Versus Water Temperature at Stations TH-1 (Thornton Creek) and LT-1 (Littles Creek)

Section 4
PROBLEM IDENTIFICATION

4.1 Introduction

This section describes the flooding, water quality, wetland, and habitat problems that were identified as part of the Thornton Creek Watershed Plan. Problem locations are shown in Figure 4-1.

For flooding problems, this plan focuses on problems already identified in previous plans (see Section 1 for a list of plans that were reviewed).

Habitat problems listed in this plan were identified by the study team during recent stream habitat assessment work and during a review of data provided by the City.

The study team characterized water quality problems based on monitoring data, observed watershed conditions, generally established causes of water quality degradation in Puget Sound urban streams, and problems identified in reports published by other agencies.

4.2 Flooding Problems

The flooding problems evaluated in this plan are those that were previously identified in the City of Shoreline Surface Water Master Plan (R. W. Beck 2005) for Thornton Creek. These are:

- Problem F1: Ronald Bog – Corliss Avenue N (Problem 4 in the Master Plan)
- Problem F2: 12th Avenue NE and 11 Avenue NE between NE 175th Street and NE 170th Street (Problem 3 in the Master Plan)
- Problem F3: NE 175th Street/NE 178th Street at Serpentine Place near 5th Avenue NE (Problem 5 in Master Plan)
- Problem F4: 12th Avenue NE (near NE 148th Street) (Problem 9 in the Master Plan)
- Problem F5: NE 148th Street (Problems 2 and 14 in the Master Plan)
- Problem F6: 10th Avenue NE near NE 174th Street (Problem 15 in the Master Plan)
- Problem F7: N 167th Street and Wallingford Avenue N (Problem 10 in the Master Plan)

No new analysis was performed under this planning effort to identify other problem areas.

4.2.1 Thornton Creek

Problem F1: Ronald Bog – Corliss Avenue N

As mentioned previously, flooding of the bog and the neighborhood to the south are the result of the complex interaction of several factors which including a single flat, low-gradient outlet pipe/channel system that is likely undersized; high groundwater; the volume of floodplain storage provided by the bog and surrounding wetlands; and increased stormwater inflow volumes resulting from upstream urbanization. The outlet pipe and channel system is extremely flat and the average system slope between the outlet of the bog to N 167th Street, approximately 1,300 feet to the south, is at 0.14 percent, which can create backwater that affects the capacity of the outlet system. In addition, the outlet, a 30-inch diameter concrete pipe, is in need of repair/replacement. In several locations its joints have separated, creating some sinkholes and allowing for root intrusion.

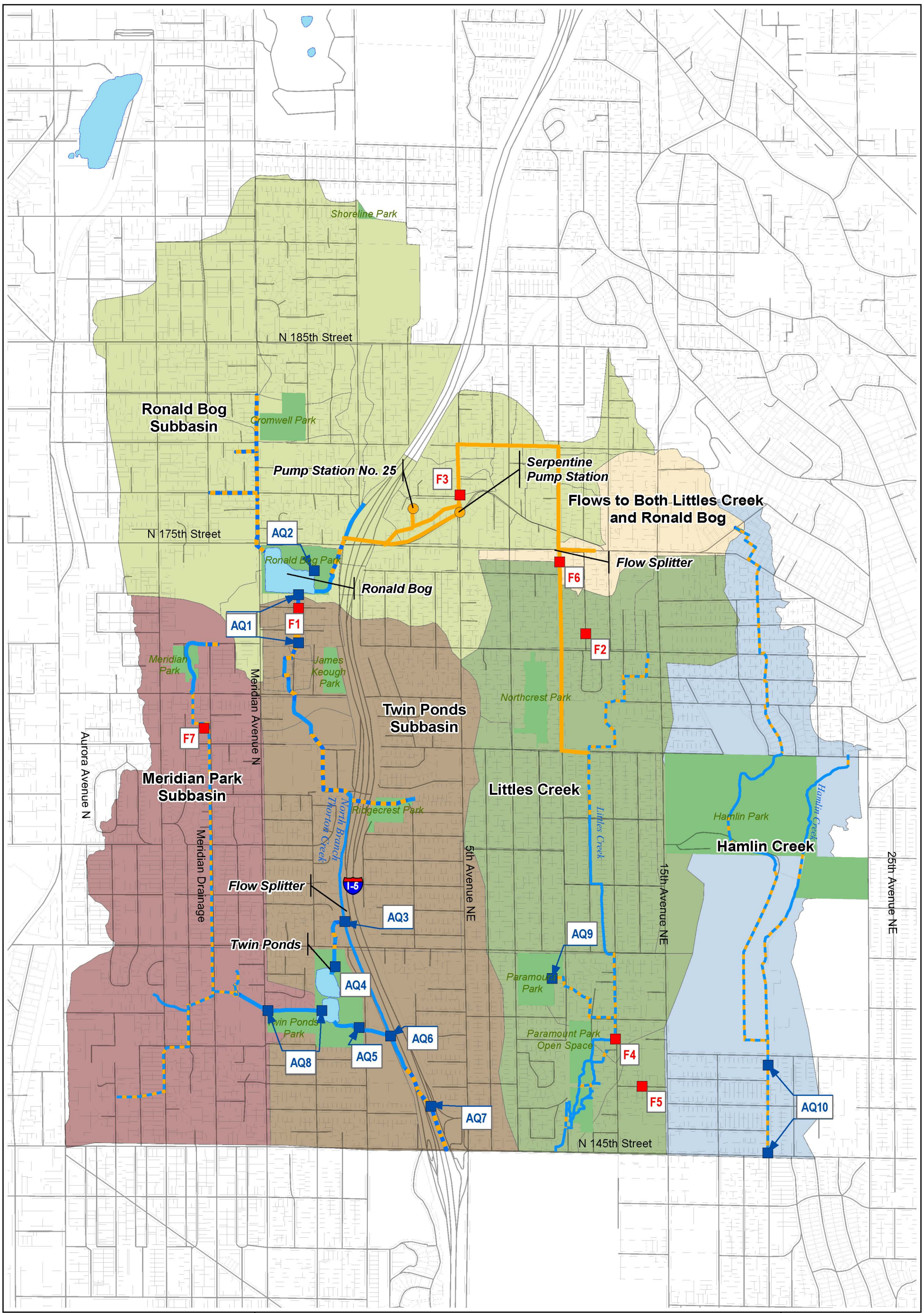
The lack of outflow capacity and the low gradient cause stormwater flows to back up in Ronald Bog and overtop its banks. In the past, as many as 20 homes have been significantly flooded. Some homes have been inundated up to 2 feet above their finished floor elevations. Flooding of this area has occurred at least four times in the recent past: January 18, 1986, January 1, 1997, October 20, 2003 and December 3, 2007. The 2007 flood occurred after the City had done considerable maintenance, including the cleaning of the 30-inch outlet pipe. The return frequency of these events, based on the floodplain hydrology analysis, is shown in Table 4-1.

Table 4-1
Return Periods of Past Ronald Bog Flooding Events

Storm Event	Approximate Return Period[1] (Years)
December 3, 2007	100
January 1, 1997	50
January 18, 1986	10
October 20, 2003	10

1. Based on a frequency analysis of HSPF-predicted stages in Ronald Bog assuming current land use and current conveyance conditions. Also see Figure 5-3

Ronald Bog overflows the area to the south when the water surface elevation of the bog is higher than approximately 367.5 feet. This elevation has been generally described as the elevation at which major flooding occurs (Otak 2001). It is noted, however, that the low areas along Corliss Avenue can be as low as approximately 366.5 feet. This system is show in Figure 3-2 (p. 3-7).



Note:
Source of Basemap and Piped Watercourse System is City of Shoreline Thornton Creek and West Lake Washington Basins Characterization Report (Tetra Tech, May 2004)

N

0 600 1,200 2,400 Feet

Legend

- Aquatic Resource Problems
- Flooding Problems
- Lakes
- Parks
- Hamlin Creek
- Meridian Park Subbasin
- Twin Ponds Subbasin
- Ronald Bog Subbasin
- Littles Creek
- Flows to Both Littles Creek and Ronald Bog
- Storm drain/road side ditch-culvert system
- Open water course
- Piped water course
- Streets
- City Limits
- Parcels

Figure 4-1
Problem Locations

Thornton Creek Watershed Plan
City of Shoreline

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Figure 4-2 shows an approximate area of inundation during the December 2007 storm event. Subsequent to this flood, the City implemented conveyance improvements in the downstream system in 2008. These improvements included replacing three undersized pipes or culvert systems between N 171st Street and N 167th Street, including the N 167th Street culvert crossing; channel maintenance of the open channels between the bog and N 167th Street; and replacement of some failing pipes on Corliss Avenue N. The City also installed a water level gage to monitor the levels in the bog as well as a portable pump to be available in emergency flood conditions.

Computer modeling, described in Section 5, concluded that the 2008 improvements will help lower the bog flood levels by approximately 1 foot for the 100-year flood. However, much of the neighborhood to the south would continue to flood without further improvements. Figure 4-3 shows a computer simulation that predicts the approximate area that would be flooded if the downstream improvements constructed in 2008 had been in place during the December 3, 2007, storm event.

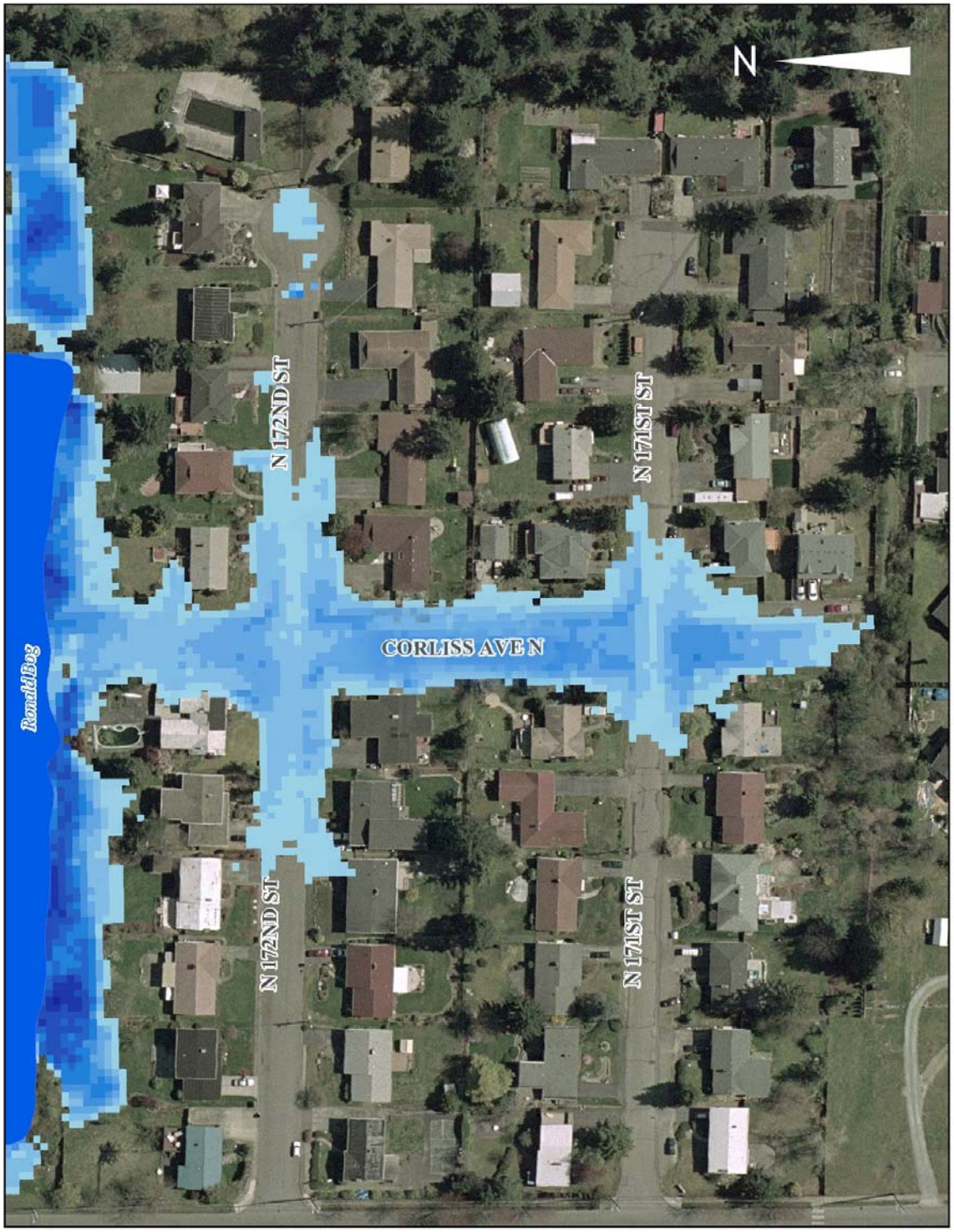
According to the computer simulation, the 2008 downstream improvements are responsible for decreasing the frequency of flooding above elevation 367.5 from a 20 percent chance of occurring in any given year to approximately a 6 percent chance of occurring.

Problem F3: NE 175th Street/NE 178th Street at Serpentine Place near 5th Avenue NE

During the December 2007 storm event, the largest storm on record, it was noted that the Serpentine Pump Station was operating at maximum capacity (i.e., both pumps were operating), but there was flooding in 5th Avenue NE, which overtopped the curb on the east side of the street and also overflowed the intersection to the west. These overflows continued west and into the 5th Avenue NE drainage system and ultimately contributed to flooding at Pump Station No. 25. (See Figure 6-5, p. 6-29.) Based on City observation, this is a recurrent problem. Table 4-1 (p. 4-2) shows how the December 2007 storm compares with other storms of significance.

Source: NHC.

Figure 4-2. Simulated Flooding Area for December 2007 Storm Event Assuming December 2007 Conveyance Conditions



Source: NHC.

Figure 4-3. Simulated Flooding Area for December 2007 Storm Event Assuming Current Conveyance Conditions

4.2.2 Littles Creek

Flooding problems in the Littles Creek basin are described in the following paragraphs. Note that figures showing these areas are included in Section 6 in the discussion of problem solutions.

Problem F2: 12th Avenue NE and 11 Avenue NE between NE 175th Street and NE 170th Street

The existing drainage system from NE 170th Street to NE 175 Street, between 13th Avenue NE and 12th Avenue NE, daylights on the west side of 12th Avenue NE and discharges flow into residential backyards. (See Figures 6-2 through 6-4, starting on . 6-19.) The water is then collected in catch basins on 11th Avenue NE and conveyed to a pond located at 17021 11th Avenue NE. The pond was designed to infiltrate flows and has no outlet. This is a recurrent problem. During the December 2007 storm event (approximately a 100-year event), flow ponded on the neighboring property (17029 11th Avenue NE), where sand bags were used to prevent flow from entering the garage. In addition, flooding has been noted in the backyard of 17042 11th Avenue NE during storm events.

Problem F4: 12th Avenue NE (near NE 148th Street)

During the December 2007 storm event, Littles Creek backed up and flooded 12th Avenue NE where the creek exits a culvert and takes a 90-degree turn to the west between the properties at 14849 and 15021 12th Avenue NE. (See Figure 6-7, p. 6-35.) The residents at 15021 12th Avenue sandbagged their driveway to prevent flooding of their garage. The residents at 14849 12th Avenue NE reported that they raised the grounds surrounding their house by about 6 inches in order to reduce the potential for their house to be flooded. Residents also reported flooding of NE 150th Court during heavy rains. Based on discussions with local residents, this is a recurrent problem.

Problem F5: NE 148th Street

The outlet pipe from the catch basin in front of the apartment building at 1237 NE 148th Street is not connected to any system, resulting in ponding of the area during storm events. (See Figures 6-8 and 6-9, starting on p.6-39.) According to the City, the pipe, a 12” CMP, is partially filled with sediment and is bricked in at the downstream end. This is a recurrent problem.

Problem F6: 10th Avenue NE near NE 174th Street

During the December 2007 storm event, 10th Avenue NE south of NE 175th Street was flooded. (See Figures 6-10 through 6-12, starting on p. 6-47.) Based on City observation, this is a recurrent problem. The roadway drainage system backed up and flow came up out of the catch basins on the east side of the roadway, which resulted in stormwater flowing down the driveways into garages at 17112 and 17030 10th Avenue NE. A project had recently addressed the flooding that used to occur on NE 175th Street just east of the intersection with 10th Avenue NE. It is possible the

additional flow that was diverted away from this location contributed to the December flooding south of 175th Street. In addition, a board was found blocking flow through a downstream culvert which may have also contributed to flooding at this location.

Problem F7: N 167th Street and Wallingford Avenue N

Runoff from Meridian Park drains southward through private property, across N 167th Street in an 18-inch-diameter concrete pipe and then continues south again through private property in a series of 12-inch-diameter CMP and concrete pipes until it reaches a short 20-foot-long open channel section on the west side of 16533 Wallingford Avenue N. Following the open channel section, low flows enter an 8-inch-diameter storm drain that routes flow south and then east around the property at 16529 Wallingford Avenue N until it joins the drainage system in the Wallingford Avenue N right-of-way. There is also a secondary pipe that conveys high flow from the short 20-foot-long open channel section behind 16533 Wallingford Avenue N. This secondary system conveys flow east between the properties at 16533 and 16529 Wallingford Avenue N until it joins the conveyance system within the Wallingford Avenue N right-of-way.

Conveyance capacity is limited at the N 167th Street crossing and the subsequent pipes that lead southbound through private property. In addition, both the low flow and high flow pipes that convey the flow from the short open channel section to the Wallingford Avenue N right-of-way are undersized and during very large events, the properties at 16533 and 16529 Wallingford Avenue N both flood. Based on City observation, this is a recurrent problem.

4.3 Wetlands and Habitat Problems

The Shoreline Muncipal Code (SMC 20.20) defines “stream functions” as:

> Natural processes performed by streams including functions which are important in facilitating food chain production, providing habitat for nesting, rearing and resting sites for aquatic, terrestrial and avian species, maintaining the availability and quality of water, such as purifying water, acting as recharge and discharge areas for ground water aquifers, moderating surface water and stormwater flows and maintaining the free flowing conveyance of water, sediments and other organic matter.

In addition, according to SMC 20.80.460 (B):

> Stream areas and their associated buffers provide important fish and wildlife habitat and corridors; help to maintain water quality; store and convey stormwater and floodwater; recharge groundwater; and serve as areas for recreation, education and scientific study and aesthetic appreciation.

The existing piped stream sections within the City provide little in the way of stream function as defined, other than basic conveyance, and many of the channelized sections are providing little if any additional stream function. Arguably, the piped

sections provide shade to keep water temperatures cool; however, where flows are seasonal or ephemeral (sporadic), little or no flow is typically present during the warmer-weather periods and temperature for those headwater segments is typically not an issue. Virtually all wildlife habitat function is also typically lacking for the piped segments along their alignments. In contrast, those few remaining more natural, daylighted channel sections provide most of the wildlife and at least some of the fish habitat functions as listed and described above.

Floodplain connectivity is also limited along most of the North Branch of Thornton Creek, affecting the City's flood-prone areas including Ronald Bog, Serpentine Place, and Paramount Park (SPU 2000).

Basin-wide wetlands and habitat problems can be addressed at a local or project level to help alleviate some of the effects urbanization has had on Thornton Creek. Listed below are some basin-wide issues, identified from various sources, that should be addressed in general or on a project-by-project basis.

Habitat *factors of decline* specifically identified for the Thornton Creek basin in the *Salmon and Steelhead Habitat Limiting Factors Report for the Cedar - Sammamish Basin* (Kerwin 2001) include:

1. Fish access and passage barriers.
2. Increased sedimentation/altered sediment transport processes.
3. Loss of channel complexity/connectivity.
4. Degradation of riparian conditions.
5. Altered hydrology/flow.
6. Increased temperature.
7. Poor water quality.

Types of stream and fish habitat-related problems for Thornton Creek in the City of Shoreline can be categorized as follows:

1. Poor *in-stream* habitat.
   a. Lack of sufficient in-stream structure, including: large woody debris (LWD), log and debris jams, and possibly rock structures.
   b. Lack or scarcity of suitable spawning gravel substrates for salmonid fish.
   c. Poorly formed and shallow pools with insufficient cover; poorly formed pool/riffle sequences.
   d. Armored channels.
2. Poor *riparian* habitat.
   a. Narrow functional buffers due to encroachment from residential and other types of development.
   b. Insufficient native vegetation within the width of buffers present.
3. Fish passage – Distinct fish passage obstructions related to high plunges or velocities, or low flows, the resolution of which would define a specific capital project. Examples may be associated with culverts, weirs, catch basins, and/or extensive piped sections.

4. Piped stream sections:
   A. Loss of most stream habitat functions for the piped segments.
   B. Definitive or indistinct barriers or questionable fish passage conditions.
5. Narrow, ditched, open channel sections characterized by poor in-stream and riparian habitat as listed above.
6. Water Quality – Urban runoff with various non-point source pollutants; pre-spawner mortality; poor aquatic insect food supply production. For example, coho prespawn mortality rates are high, averaging 79% (City of Seattle 2007). No underlying biological causes (such as infection, disease, or parasites) have been identified. The exact cause is unknown, but a combination of water quality, sediment quality, and other environmental factors is under investigation (City of Seattle 2007).
7. Water Quantity – Flashy urban flows; erosion, bank failures, etc.; lower dry season flows.

Identification of general and site-specific habitat problems and solutions is the first step toward restoring stream function to the City's Thornton Creek watershed. Problem identification and description leads to the formulation of problem solutions. Organized by tributary subbasin, the identified stream, wetland, and other habitat-related problems are listed below. Preliminary solutions to these problems are described in Section 6.

One issue that should be noted, though it has not been identified as a specific problem in this report, is that the City's current system of stream classification has resulted in some confusion with respect to permitting. Whether a water course is classified as a stream, as opposed to a ditch or some other type of conveyance, has an effect on the permits required for development projects. A recommendation related to this issue is provided in Section 7.2.2.

4.3.1 North Branch, mainstem (including the Ronald Bog and Twin Ponds Subbasins)

Problem AQ1: Ronald Bog Outlet Pipe and Catch Basin

The 650-foot-long, 30-inch-diameter outlet pipe from Ronald Bog and associated catch basin may present a partial barrier or hindrance to upstream fish movement.

As described previously in Section 3.4.3, previous reports have postulated this outlet pipe to be a barrier or partial barrier to upstream-bound fish movements. However, recent observations and calculations indicate this pipe may only present a partial barrier. This is discussed in more detail in Section 6.3.1.

Problem AQ2: Wetland Fringe Areas Around Ronald Bog Park

Wetland fringe areas of Ronald Bog Park are in need of enhancement, particularly in the southeast corner and portions in the northern grassy portion.

Problem AQ3: Flow Splitter Upstream of Twin Ponds

The flow splitter upstream of Twin Ponds may function as a barrier or partial barrier at either high or low flow conditions.

This flow splitter has been reported to be a fish passage barrier (Tetra Tech 2004, Appendix C). However, current information suggests that the piped stream section associated with the splitter does not pose a velocity barrier during all flow conditions; it may function as a barrier or partial barrier at either high or low flow conditions.

Problem AQ4: Log Structures in Twin Ponds Park

In Twin Ponds Park, log structures have been placed below a culvert upstream of the ponds to effectively backwater it and eliminate a previously described (Tetra Tech/KCM 2004; R. W. Beck 2005) plunge at its outfall. However, a moderate plunge now occurs at the lower log structure.

Problem AQ5: Culvert Beneath 1st Avenue NE

The culvert beneath 1st Avenue NE may be a low-flow fish blockage (Tetra Tech/KCM 2004, R. W. Beck 2005).

Problem AQ6: Outfall from Peverly Pond

The outfall from Peverly Pond is a barrier to upstream fish migration as the water plunges out of the pond and into the concrete-lined, canal-like ditch conveying flow southward along the west side of Interstate 5.

Problem AQ7: Culvert under I-5

The culvert under Interstate 5 is a fish passage barrier (Tetra Tech 2004, Appendix C).

4.3.2 Meridian Park Drainage

Problem AQ8: Channel from Twin Ponds Upstream to Meridian Avenue N

Salmonid fish use becomes doubtful proceeding upstream to Meridian Avenue N from Twin Ponds due to the cumulative effects of the stagnant, weed-choked channel.

4.3.3 Littles Creek

Problem AQ9: Restoration Project in Paramount Park Open Space

Invasive plant species are invading the restoration project in the Paramount Park Open Space (Tetra Tech/KCM 2004, R. W. Beck 2005).

4.3.4 Hamlin Creek

Problem AQ10: Hamlin Creek Habitat Problems

Habitat problems identified or confirmed for Hamlin Creek in the 2000 *Thornton Creek Watershed Characterization Report* (SPU 2000) focus on the high proportion of piped stream length and the poor habitat with little vegetative cover along the ditched and piped sections extending southward from the campus along 20th Avenue NE (SPU 2000). See Photo 3-10.

4.3.5 Basin-Wide

Problem AQ11: Lack of Coarse-Grained Sediment

Thornton Creek lacks coarse-grained sediment. Much of the watershed lacks sufficient access to floodplain sediment and in-stream structure to trap and accumulate sediment.

Problem AQ12: Coho Prespawn Mortality Rates

Coho prespawn mortality rates are high, averaging 79% throughout Thornton Creek, in comparison to Fauntleroy (39%), Piper's (56%) and Longfellow (71%) Creeks (City of Seattle 2007). The causes are not fully understood, but are likely closely linked to water quality issues associated with streams in highly urbanized basins, epitomized by Thornton Creek. As headwater areas, the portions of the Thornton Creek basin within the City of Shoreline affect the habitat quality and suitability of the entire length of channel downstream through water quality and quantity, and related issues such as sediment transport.

In addition, although not identified as a specific problem, one recommendation for further analysis is to perform a stream typing (i.e., classification) study to specifically define streams according to the City's definition. The current system of classification, which tends to rely on independent study and observation, has created some confusion with respect to permitting.

4.4 Water Quality Problems

As indicated in Section 3.5, water quality in Thornton Creek within the City of Shoreline appears to be typical of urban streams in the Puget Sound area. Pollution sources and contributing factors are likewise expected to be typical of those observed in Puget Sound urban watersheds. In its 2008 assessment, Ecology identified portions of Thornton Creek in Seattle, downstream of the City of Shoreline, as "impaired and needing a TMDL" (Category 5 on Ecology's Candidate 303(d) listing) for fecal coliforms, temperature, and dissolved oxygen. These three parameters are addressed as problems WQ1, WQ2, and WQ3 in this watershed plan.

Ecology also identified Thornton Creek in Seattle as "waters of concern" (Category 2) for mercury. Because Thornton Creek is not yet identified as impaired for mercury, and because sources of mercury are ubiquitous (historical and possibly current airborne deposition), mercury is not addressed in this watershed plan.

The following problems were identified based on the State of Washington information described above, as well as City of Shoreline water quality monitoring data described in Section 3.5.

Problem WQ1: Elevated Water Temperatures

Elevated temperatures likely occur due to solar exposure in stream segments with sub-optimal riparian canopy, exposure in open ponds (Ronald Bog and Twin Ponds), and reduced groundwater inputs due to increased impervious area and stream channelization.

Problem WQ2: Reduced Dissolved Oxygen Concentrations

Reduced dissolved oxygen (DO) concentrations are often due to elevated temperatures, which reduce the potential DO saturation level. Additionally, elevated nutrient levels due to fertilizer runoff lead to increased biological activity (periphyton and bacteria) in the stream, increasing the DO demand; this effect is compounded with elevated water temperatures as biota become more active with increased temperature.

Problem WQ3: Bacterial Contamination

The sources of bacterial contamination in Thornton Creek and Littles Creek remain unknown. Domestic and wild animals are a likely source, as found in a bacterial analysis conducted in Seattle's Pipers Creek, a similar urban stream.[4] All homes in the Thornton Creek watershed within Shoreline are connected to sanitary sewer, eliminating septic systems as a source.

[4] Seattle conducted a study in 1992 to track the source of fecal coliform in Pipers Creek (Seattle Drainage and Wastewater Utility, 1993). The study examined ribonucleic acids (RNA) found in fecal coliforms from creek samples and compared it to fecal coliform from a variety of sources including excrement of humans, dogs, birds, and small mammals. This study concluded that the fecal coliforms found in Pipers Creek were not human in origin. It came from a number of sources; of the approximately 40% that could be traced, the primary sources were cat and dog wastes.

Section 5
HYDROLOGIC AND HYDRAULIC ANALYSIS

5.1 Introduction

This section contains a description of the hydrologic and hydraulic methodology used to assess the flooding problems and solutions within the Thornton Creek watershed. Much of the modeling work builds from hydrologic and hydraulic modeling developed as part of a concurrent floodplain mapping study being prepared for the North Branch of Thornton Creek between the Shoreline city limit and Ronald Bog. The floodplain mapping work was undertaken due to the recurrent extensive flooding that exists downstream of the bog. This work is being done by Northwest Hydraulic Consultants (NHC) and the purpose is to delineate the flood hazard boundaries of the creek, thereby providing neighboring residents with the most current information available regarding their flooding risk. The model that was developed to determine the existing floodplain was modified as a part of this study to evaluate alternative solutions in this area.

While most of the discussion in this section relates to the hydrologic and hydraulic modeling of upper Thornton Creek downstream from Ronald Bog, separate hydraulic models were developed to evaluate identified flooding problems in the Littles Creek basin. This modeling is discussed at the end of this section.

5.2 Modeling Approach

The study team used USEPA's HSPF computer modeling program (USEPA 1988) to develop the hydrology for the Thornton Creek watershed, quantify the flooding problem at Ronald Bog, and evaluate the effectiveness of the mitigation alternatives. HSPF is a sophisticated computer modeling program that simulates land surface and in-stream hydrologic processes on a continuous basis. The program is commonly used to transform long-time series of observed rainfall and evaporation data into concurrent time-series of streamflow data based on continuous accounting of soil moisture levels. This approach offers some distinct advantages over the more traditional event-based modeling approaches. Event-based models simulate streamflow for individual storm events and their accuracy depends on numerous assumptions including soil moisture levels at the start of the storm event being modeled. In addition, event-based models cannot be used to simulate low flows and, hence, are of little value in characterizing the overall hydrologic regime for a given watershed.

Continuous hydrologic modeling is of particular value in studying a watershed such as that draining to Ronald Bog because it allows for close examination of the relationship between the flows into and out of a detention pond. Because the stage of Ronald Bog is the principal determinant in the extent of flooding, the metric used to quantify the

flooding problem and to evaluate the effectiveness of the proposed solutions was a stage-frequency analysis at the bog. The HSPF model enabled continuous calculation of the pond stage at 15-minute intervals for 60 years (water years 1949 through 2008). By extracting the peak annual stages and fitting a curve through the data, the annual exceedance probability associated with the entire range of bog stages, including high stages that cause flood damage, could be estimated. The development of probability curves for historic, existing, and proposed conditions at Ronald Bog provided a convenient method of comparing the modeled scenarios.

In addition to HSPF, the study team used the XP-SWMM computer model to evaluate the Serpentine Pump Station and the flooding problem in Littles Creek on 10th Avenue NE near NE 175th Street. XP-SWMM was selected because it can model a feature, such as a pump station, whose hydraulic response changes over time. XP-SWMM can also route the continuous hydrology developed in HSPF, which makes it more accurate than simpler, steady state models. In addition, XP-SWMM can model the flow splitter located at NE 175th Street and 10th Avenue NE.

The design storm event used to evaluate the flooding problems and their solution was the 25-year storm event. However, due to the severity of the flooding problem, the number of home affected and to be consistent with the FEMA floodplain mapping, the 100-year storm was used to evaluation the flooding problem and the solutions at Ronald Bog.

5.3 Ronald Bog Modeled Scenarios

The HSPF model was used to simulate the function of Ronald Bog under six different conditions:

1. Prior Condition

The first condition, labeled the Prior Condition, reflects the circumstances under which the bog operated prior to channel improvements that began in February 2008.

2. Design Condition

The second condition, labeled the Design Condition, characterizes the bog's hydrologic and hydraulic response based on the City of Shoreline's culvert replacement and channel improvements in October 2008 as they were designed.

3. Current Condition

The Current Condition, is similar to the Design Condition, except that it uses the "as-built" grades for the channels between N 167th Street and N 170th Street. Following the channel improvements described under the Design Condition above, the City performed "as-built" surveying and found that the channel bed was not lowered to the design grades. This was in part because private improvements, including a concrete lining of the stream, were encountered, which hindered the work. The final grade of the channel in some areas was as much as 0.9 foot higher that the design grades, although the north section is within 0.1 foot of the design.

4 through 6. Alternative Solutions

Conditions 4 through 6 reflect three alternative conditions, which are described in detail in Section 6.

Table 5-1 itemizes significant characteristics of the Prior Condition, Design Condition, and Current Condition modeled scenarios.

HSPF computes three runoff components that may be routed to basin streams and open water storages. These include surface runoff, shallow subsurface (interflow), and groundwater flow. These runoff components are calculated using linear and non-linear reservoirs. Connectivity of runoff is extremely flexible; the user may direct runoff components individually or as a group to a downstream drainage element. HSPF does not model groundwater by explicitly representing the three-dimensional hydrogeologic environment. Rather, linear and optional non-linear reservoir parameters are calibrated to enforce a match between simulated water levels and discharges and observed values at a point or points of interest within the drainage network. To perform this calibration, it is especially useful to compare pond level and/or stream discharges during the base flow season when other runoff components are inactive. In the Ronald Bog basin, an extremely good match was achieved between observed and simulated bog levels in all seasons, lending credibility to the model's representation of groundwater runoff (see Section 5.4.6, Model Calibration).

Table 5-1
Ronald Bog Prior, Design, and Current Condition Modeled Scenarios

Modeled Scenario	Description
Prior Condition	■ Based on bog hydraulic conditions prior to February 2008. ■ Includes 3 old culverts, north & south channels geometry before cleaning/maintenance. ■ Bog stage vs. volume based on live storage above Elevation 363.7 ft (the lowest elevation of the downstream system that controlled water surface elevations in the bog).
Design Condition	■ Based on current hydraulic conditions (post-October 2008). ■ Includes 3 new culverts, north & south channels geometry as designed for the cleaning/maintenance work. ■ Bog stage vs. volume based on live storage above Elevation 362.67 ft (the lowest elevation of the downstream system that controlled water surface elevations in the bog; note that it was lowered with the 2008 downstream improvements).
Current Condition	■ Based on current hydraulic conditions (post-October 2008). ■ Includes 3 new culverts, north & south channels geometry after "as-built" survey of the cleaning/maintenance work. ■ Bog stage vs. volume based on live storage above Elevation 362.67 ft (the lowest elevation of the downstream system that controlled water surface elevations in the bog. Note that it was lowered with the 2008 downstream improvements).

Note: Each modeled scenario used current conditions land use. Future land use was not considered in the modeled scenarios.

5.4 Hydrologic Modeling

As noted in Section 5.2, the study team used HSPF to evaluate the past and present frequency of flooding and the effectiveness of proposed flooding solutions. In general, the process of developing the HSPF model included the following steps:

- Collection of hydrometeorological (precipitation and evaporation) data for the watershed.
- Segmentation of the watershed into smaller modeling subbasins.
- Analysis of soils and land use to determine the physical characteristics of each subbasin.
- Estimation of stage-area-storage-discharge relationships for routing flows through stream reaches, ponds, or conduits.
- Determination of appropriate hydrologic response parameters based on a calibration exercise.

The following sections describe how these steps were accomplished for the Thornton Creek watershed.

5.4.1 Hydrometeorological Data

Fifteen-minute precipitation data used in the hydrologic model was obtained from three sources. Preference was given to rain gages located nearest the watershed; however, the nearest rain gages have recorded data for the shortest periods. A table summarizing the rainfall source, the period of record, and any adjustment factor is included in Appendix B. Only rain from the SeaTac gage was adjusted. The adjustment factor accounts for proximity of the gage to the study area and is based on mean annual rainfall trends in the Puget Sound. Pan evaporation data for the model were obtained from the Puyallup evaporation station at a daily interval. A pan constant of 0.75 is used to convert pan evaporation to potential evapotranspiration.

5.4.2 Subbasins

The North Branch Thornton Creek watershed was divided into 53 subbasins. Some of the subbasins were identified in the *Thornton Creek Tributary Flood Reduction Study* completed by Otak (2001) and others were identified in a study by Pace Engineers to evaluate the redevelopment of Cromwell Park (Pace 2008). The remaining subbasins were delineated using a combination of topographic subbasin boundaries and drainage network linkages found in the City's GIS database. In general, subbasins were delineated from key basin features, principally road crossings and distinct elevation breaks.

Subbasin delineation included the Littles Creek area. These subbasins were modified to be able to evaluate the existing flooding problems in the Littles Creek basin.

The modeled subbasins and a model schematic are shown on figures included in Appendix B.

5.4.3 Soils

Soils mapping for the Thornton Creek watershed was derived from USGS quadrangle geology maps that have been digitized and slightly modified by the Washington Department of Natural Resources. These maps identified only two soil units within the basin: Vashon Till and Advance Glacial Outwash Deposits. For this study, a third category, saturated (or "wetland") soils, was added in those areas defined as wetlands or open water in the City's GIS database. Appendix B includes a figure that shows the location of the surface geology layers in the basin.

5.4.4 Land Use

Current land use categories and land cover conditions within the Thornton Creek watershed were extracted from the City's GIS database. Total Impervious Area (TIA) ratios were previously assigned in the *Thornton Creek Basin Characterization Report* developed by Tetra Tech/KCM (2004). For residential properties, the TIA value was assigned based on a review of 1999 aerial photos. For non-residential properties, the TIA value was assigned based on the 2001 King County Assessors Database. Land use categories for future conditions were extracted from the zoning layer within the City's database. The future total impervious area ratio assumes that the watershed will be fully built-out according to the maximum allowed impervious area as specified in the City's Development Code. Appendix B includes figures that depict the existing and future land uses in the basin.

For modeling purposes, HSPF differentiates between impervious and pervious surfaces. For each land use category, the total impervious area is calculated using the TIA ratios described above. From the total impervious area for each land use, a second fraction, the effective portion, is assumed to contribute runoff directly to the drainage system. The effective impervious area (EIA) for each land use class is computed by multiplying the total impervious area by the effective factor. The effective factors used in this study are based on the study team's professional experience modeling Puget Sound area watersheds with characteristics similar to the Thornton Creek watershed. A discussion of current and future land use and their assumed percent effective impervious area, as well as how the effective impervious area was derived, is provided in Appendix B.

5.4.5 Stage-Area-Storage-Discharge Relationships

HSPF uses user-defined stage-area-storage-discharge relationships, called FTABLEs, to simulate routing of runoff and estimate downstream flows. In general, FTABLEs are created for each subbasin based on pipe or open-channel hydraulics, as appropriate. In some cases, dummy storage FTABLEs may be used in HSPF when there is no significant storage in the subbasin.

For the Thornton Creek model, the FTABLEs for all subbasins draining to Ronald Bog except one were estimated using simple equations that account for the size and average slope of the subbasin. This simplified approach was accepted because all subbasins draining to the bog convey water through storm pipes that have negligible

storage. The exception to this approach is an FTABLE that defines a flow splitter located at the intersection of NE 175th Street and 10th Avenue NE. This splitter sends low flows directly to Ronald Bog, but at higher flows also sends discharge to Littles Creek. This FTABLE was estimated based on the size of pipes leaving the splitter and an assumed difference in pipe inverts.

Significant effort went into establishing the FTABLE for Ronald Bog because it is key to the accurate simulation of flood levels at the bog. The hydraulic relationships found in the FTABLE were extracted from two sources and were altered depending on the scenario being modeled. The stage vs. storage portion of the FTABLE was generated using GIS to analyze the elevation contours within and surrounding the bog. In previous work for the City of Shoreline (Otak 2001), bathymetric contours of the bog were generated. These contours were combined with overbank elevations generated by the Puget Sound LiDAR Consortium in 2000 to develop a three-dimensional representation of the ground surface. Using this surface, storage volumes were computed at incrementally higher stages for the area within the bog's banks and the area south of the bog on the residential streets. Appendix B contains the stage vs. storage curves that were extracted from the GIS for the modeled scenarios.

The stage vs. discharge portion of the FTABLE was generated using a XP-SWMM model. The XP-SWMM model was first developed by R. W. Beck in 2007 as part of the Thornton Creek Corridor Project (R. W. Beck, 2007a). This model was modified to simulate a quasi-steady backwater analysis at discrete discharges; thereby establishing the bog stage corresponding to each modeled discharge. The intent of this approach was to develop a stage vs. discharge relationship that implicitly accounts for much of the hydraulic complexity that is considered in XP-SWMM. The geometry of the XP-SWMM model was changed as appropriate to reflect each of the scenarios being analyzed. Stage vs. discharge curves for the modeled scenarios are included in Appendix B.

Three other FTABLEs of note are those that describe the hydraulic interaction in Twin Ponds, a second flow splitter located approximately one mile downstream of Ronald Bog, and a proposed detention pond at Cromwell Park. The FTABLE that defines hydraulic routing through Twin Ponds was developed as part of a report titled *Draft Thornton Creek Hydrologic and Hydraulic Modeling* (Entranco 2000). The FTABLE that defines the flow splitter was studied in detail by R. W. Beck and documented in a memorandum titled *Thornton Creek Flow Splitter Evaluation, Draft Technical Memorandum* (R. W. Beck 2007b). The Cromwell Park FTABLE was estimated from information contained in a technical memorandum (Pace 2008) that analyzed sizing for a proposed stormwater pond at this site. Again, this latter FTABLE was used for modeling of alternatives and is further described in Section 6.

5.4.6 Model Calibration

Observed Bog Stages

The primary calibration source for the HSPF model was recorded pond elevations of Ronald Bog. Beginning in January 2005, volunteers noted the bog stage on an

approximately every other day basis using a staff plate installed by the City. A pressure transducer was subsequently installed in the northwest corner of the bog in May 2006. The transducer, which is maintained by the City of Shoreline, has recorded bog stage at 15-minute intervals since its installation.

The transducer output was first adjusted for changes in barometric pressure since it is an absolute pressure recorder. Upon plotting the recorded bog stages, it was obvious that the sensor had steadily drifted from the time of its installation. Fortunately, the pond elevation on the staff plate was noted when the transducer output was downloaded, thereby providing a reference point to quantify the drift. Using 11 reference points distributed equally in time, the recorded stages were corrected. Appendix B contains a figure that illustrates water surface elevations in Ronald Bog recorded via staff plate through May 2006 and those recorded with the pressure transducer (corrected and not corrected) since then.

Note that the peak stage recorded at Ronald Bog occurred on the afternoon of December 3, 2007. In fact, according to the HSPF model, the bog reached its highest elevation since 1949 on this date. The survey of a high water mark recorded by a resident on N 171st Street established the pond elevation at 369.64 feet NAVD 88. This independent check of the peak stage attained on December 3, 2007 confirmed the drift correction applied to the pressure sensor.

Hydrologic Response Parameters

The HSPF model uses a set of parameters to define the characteristics of a land surface's response to meteorologic inputs. These parameters represent the physical characteristics and boundary conditions, and can be adjusted (calibrated), as necessary, to allow the model to better match simulated flow data. The parameters initially used in the Thornton Creek model were developed by the USGS based on a regional study of a number of basins in the Puget Sound area (Dinicola 1990). These regional parameters have been found by many users in western Washington to provide a good basis for model application in the absence of good calibration data. The parameter modifications that were made as part of the calibration are discussed in Appendix B.

Figures 5-1 and 5-2 illustrate the correlation between the observed and simulated stages at Ronald Bog for the wet months of November and December of 2006 and 2007. Note that special consideration was given to matching the peak stage observed on December 3, 2007 since the primary purpose of this study is to quantify flood events.

5.4.7 Model Verification

Verification of the HSPF simulated peak stages in Ronald Bog was performed using the XP-SWMM model. The process involved modifying the XP-SWMM model to include the available storage at the Ronald Bog node and specifying the rainfall-runoff inflows to the bog for selected storms. Three of the four largest storms to rain on the bog since 1949 were simulated in the hydro-dynamic model: January 1990, February 1951, and December 2007. The results compared favorably, as can be seen in Table 5-2. On average, XP-SWMM predicted an absolute peak stage approximately 0.5 foot

lower than HSPF. This average difference in peak stage between the models is acceptable considering the HSPF model was calibrated to accurately simulate the pond stage hydrograph for the largest event in the period of record (December 2007) and the peak stage exactly reflects the observed data and the independent survey. Of note is the extremely close difference in the peak stage each model simulates for the conditions before and after the 2008 construction of the improvements downstream of Ronald Bog. For the three simulated storm events, the difference between the prior and design condition simulations respective to each model averaged less than 0.1 foot.

Table 5-2
Verification of HSPF Results with XP-SWMM

Storm	Model	Ronald Bog Stage Prior Condition	Ronald Bog Stage Design Condition	Difference
Dec 2007 Event	HSPF	369.60	368.63	0.97
	SWMM	368.99	368.24	0.75
		0.61	0.39	
Feb 1951 Event	HSPF	368.78	367.75	1.03
	SWMM	368.38	367.34	1.04
		0.40	0.41	
Jan 1990 Event	HSPF	368.35	367.53	0.82
	SWMM	367.71	367.01	0.70
		0.64	0.52	

Note: Elevations are based on the NAVD 88 vertical datum.

HSPF Model Calibration

Observed vs. Simulated Stages at Ronald Bog

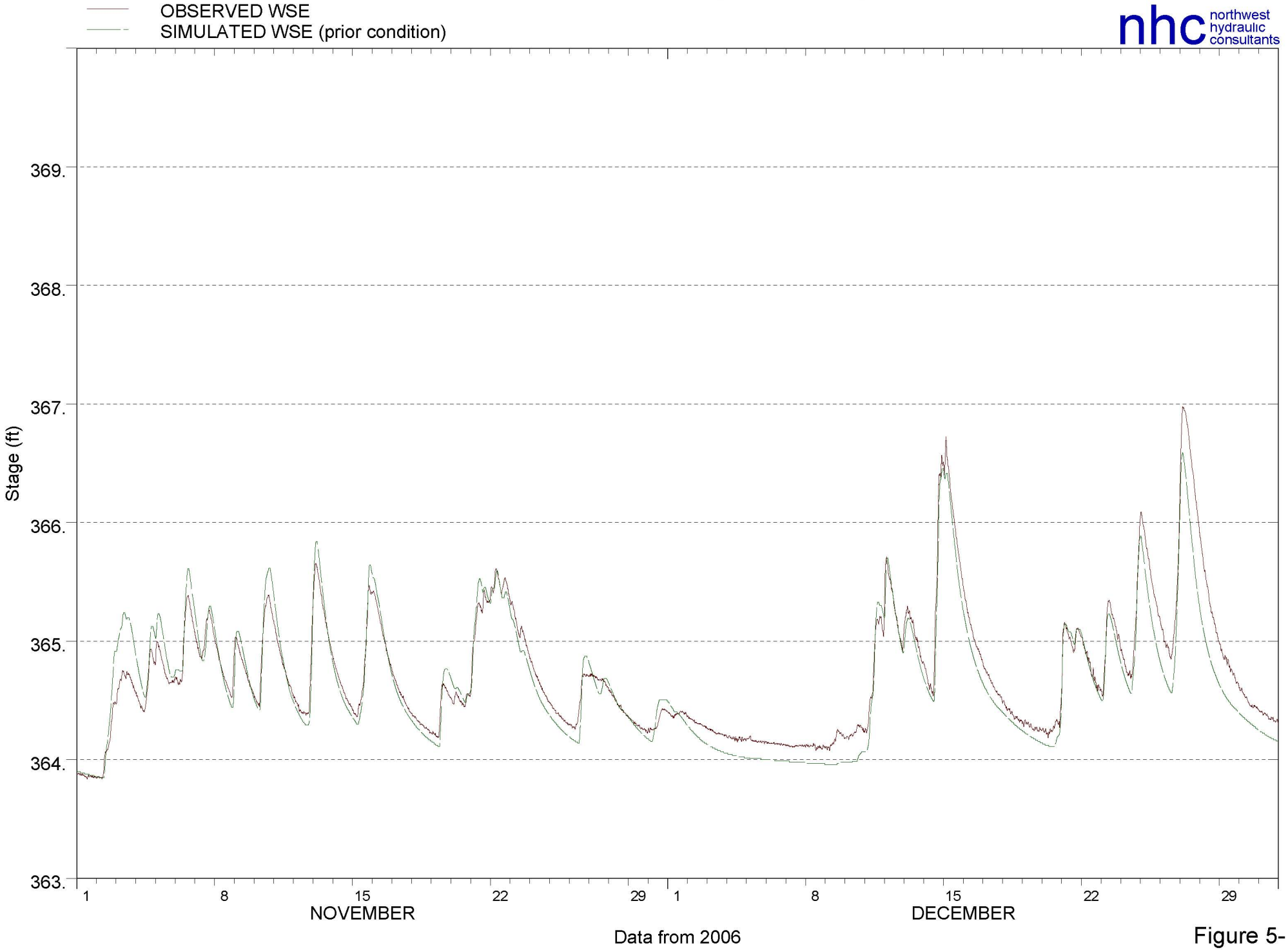


Figure 5-1

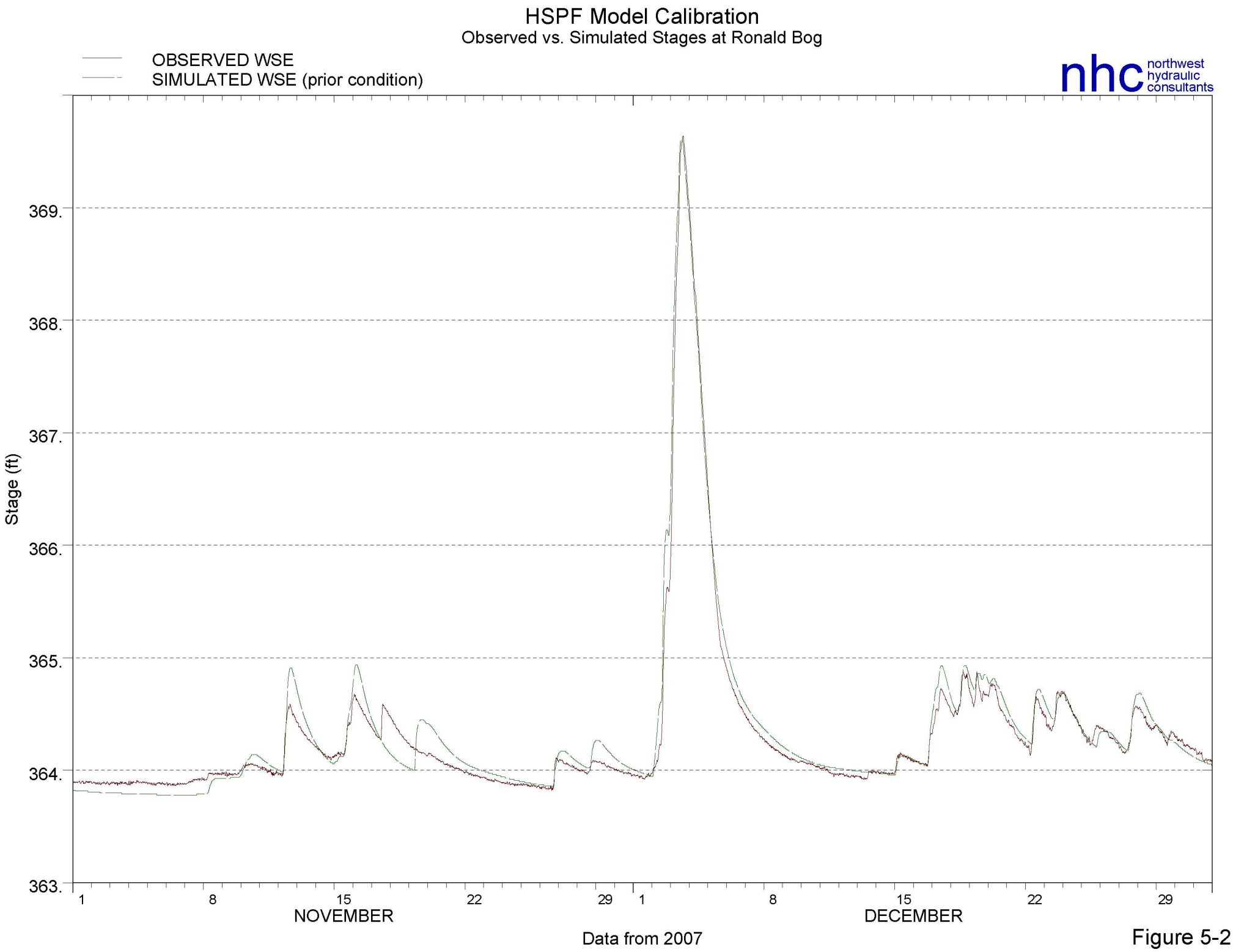

HSPF Model Calibration
Observed vs. Simulated Stages at Ronald Bog
OBSERVED WSE
SIMULATED WSE (prior condition)
nhc northwest hydraulic consultants
Stage (ft)
369.
368.
367.
366.
365.
364.
363.
1
8
15
22
29
NOVEMBER
1
8
15
22
29
DECEMBER
Data from 2007

Figure 5-2

5.5 Results for Ronald Bog

The tool used to quantify flooding for the previous, design, and current conditions at Ronald Bog was a stage-frequency plot. For each condition modeled, the peak annual stages were identified for water years 1949 through 2008. Following the procedures outlined in the IACWD Bulletin 17B (IACWD 1982), a log-Pearson Type III distribution was used to assign bog water surface elevations to annual exceedance probabilities (also described as "average recurrence intervals" or "annual frequencies"). The stage-frequency curves for the prior and current conditions have been plotted on Figure 5-3 to facilitate comparison of these scenarios. The bog stage for the most often quoted average recurrence intervals are listed in Table 5-3. Table 5-3 also provides results for the design modeled condition.

Table 5-3
Ronald Bog Stage-Predicted Maximum Water Surface Elevations

Average Return Period (years)	Modeled Condition (feet)		
	Prior	Design	Current
2	366.6	365.6	365.7
5	367.5	366.4	366.5
10	368.0	367.0	367.1
25	368.7	367.6	367.8
50	369.2	368.1	368.3
100	369.7	368.6	368.8
500	370.8	369.7	369.9

Notes: A brief description of the modeled conditions is found in Table 5-1.
Elevations are based on the NAVD 88 vertical datum.
Elevation 367.5 is generally accepted as the flood stage.

Figure 5-3 illustrates that a significant reduction in flood elevations was achieved with the downstream culvert replacements and channel maintenance work completed in 2008. Table 5-3 shows that a 0.1- to 0.2-foot additional decrease in water levels in the bog could be achieved if the City was able to clean and lower the channel inverts as designed. As previously noted, the City had planned to clean out the channel to create a constant slope between the culverts north of N 167th Street along Corliss Avenue. The City was unable to do this work because of the discovery that portions of the side slopes and channel invert had been lined with brick and mortar, making excavation impossible within the WDFW permitted construction time period.

Also noteworthy is that the "as-built" survey work was performed after the modeling of alternative improvements, discussed in Section 6, and that the modeling of alternatives was based upon the Design condition for these downstream channels. Therefore, the results presented for the alternatives assume that the channels will be cleaned to the design condition. Until this work is completed, the water surface elevations in the bog would likely be 0.1 to 0.2 feet higher.

5.6 Hydraulics and Floodplain Mapping

5.6.1 Floodplain Mapping of North Branch of Thornton Creek

As described previously, the hydraulic modeling in the reach downstream from Ronald Bog on the North Branch of Thornton Creek to the Shoreline city limit was performed in order to provide floodplain mapping that is being conducted concurrently to this study.

The creek was surveyed where rights-of-entry were available, and the stream geometry was used to create a HEC-RAS computer model. The model was simulated with the standard FEMA discharge return periods of the 10-, 50-, 100-, and 500-year events. These flows were determined using the detailed HSPF model described previously.

A preliminary 100-year floodplain mapped has been prepared (Figure 5-4). The floodplain mapping study will be completed in winter 2009. Once NHC completes the project, the final study products will be submitted to the City for review. At that time, the City will determine how the floodplain delineation will be used. Options include submitting the study to FEMA for incorporation in the national flood insurance database, regulating the floodplain through the use of City building permits, or simply distributing maps of the floodplain to educate and prepare the neighbors of the North Branch Thornton Creek. The floodplain mapping may be modified in the future depending upon the flood reduction projects implemented in this area. The portion of the floodplain identified as Zone A (studied by approximate methods) reflects an area where right-of-entry was not available and a detailed survey could not be performed.

5.6.2 Littles Creek

A portion of the storm drain system for Littles Creek was modeled using XP-SWMM (XPSoftware, Version 10.63).

Model Description

The model includes the drainage system along NE 175th Street from about 12th Avenue NE to 10th Avenue NE and then along 10th Avenue NE from NE 175th Street to NE 165th Street. High flow from the Serpentine system overflows into Littles Creek and was included in the model as well. The Serpentine system extends north along NE 10th Avenue from NE 175th Street to NE 180th Street. At NE 180th Street, the system turns west and continues on NE 180th Street to 5th Avenue NE where it turns south.

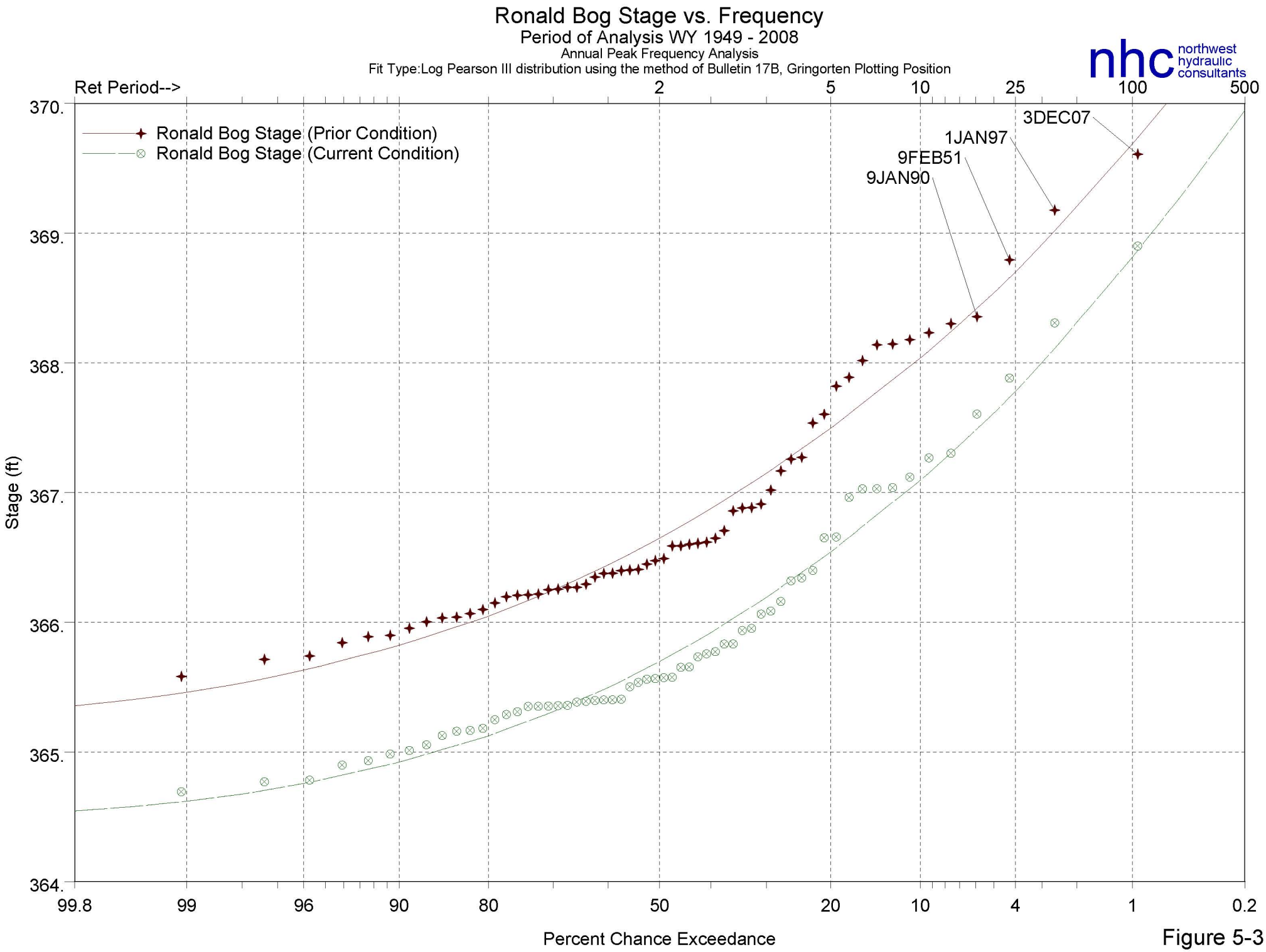

Ronald Bog Stage vs. Frequency
Period of Analysis WY 1949 - 2008
Annual Peak Frequency Analysis
Fit Type:Log Pearson III distribution using the method of Bulletin 17B, Gringorten Plotting Position
nhc northwest hydraulic consultants
Ret Period-->
2
5
10
25
100
500
Ronald Bog Stage (Prior Condition)
Ronald Bog Stage (Current Condition)
3DEC07
1JAN97
9FEB51
9JAN90
370.
369.
368.
367.
366.
365.
364.
Stage (ft)
99.8
99
96
90
80
50
20
10
4
1
0.2
Percent Chance Exceedance

Figure 5-3

N

0 500 1,000 Feet

Legend

Creek Centerline

FEMA Flood Zones

Zone AE (studied using detailed methods)

Zone A (studied using approximate methods)

Figure 5-4
Draft 100-Year Floodplain

Thornton Creek Watershed Plan
City of Shoreline

nhc
northwest hydraulic consultants

Q:\21629_Shoreline_Basin_Plan\GIS\Figure ES-3.mxd

On 5th Avenue NE, just south of NE 178th Street, the flow enters a control structure. The orifice in the control structure meters low flow out to a system that extends west through private property between NE 178th Street and NE Serpentine Place. This system discharges into a system in NE 175th Street that ultimately conveys flow to Ronald Bog. High flows at the control structure back up and enter the Serpentine Pump Station. The pump station pumps flow up to NE Serpentine Place where it is conveyed west and discharged into the same NE 175th Street system as the low flows. Pump Station 25, located south of NE 178th Street near 2nd Place NE is also included in the model.

In addition, a smaller XP-SWMM model we developed for the system in the vicinity of 11th and 12th Avenue NE and NE 175th and 170th Street. This system discharges into an existing infiltration pond on the west side of 11th Avenue NE just north of NE 170th Street. No infiltration data was available for this site so an estimate of 4 inches per hour was used based on information provided by the City for another project in the vicinity.

Data for the storm drain systems were taken from a survey performed during November and December 2008 as well as as-builts of the Serpentine Place project in August 2003. The pump station pump information was provided by the City. The pump on and off control levels for Pump Station No. 25 are unknown and were therefore estimated for modeling purposes.

Hydrographs, developed using the HSPF model discussed in previous paragraphs for the 25-year storm event, were used as the hydrologic input into the XP-SWMM models. Unrouted flows from the August 1968 storm event were factored up to create the 25-year storm event for this analysis. This storm was selected based on a frequency analysis of flows at NE 175th Street and 10th Avenue NE.

The Littles Creek XP-SWMM models were subsequently modified as part of the alternative analysis. This is discussed in Section 6.

Model Results

Existing condition XP-SWMM models developed for the Littles Creek area generally agreed with observed historical flooding. In the model, flooding is represented by water surface elevations above catch basin grate elevations. Flooding was simulated at the following locations for the 25-year event:

- Flooding of the low point along NE 175th Street east of 10th Avenue NE as well as flooding along 10th Avenue NE south of NE 17th Street.
- Flooding of the existing infiltration pond along 11th Avenue NE north of NE 170th Street.
- Flooding at the Serpentine Pump Station located along 5th Avenue NE north of Serpentine.

Section 6
PROJECT RECOMMENDATIONS TO IMPROVE WATERSHED CONDITIONS

6.1 Introduction

Watershed planning is intended to fully recognize and consider the interactions and interdependence among components of a watershed system, as opposed to relying on piecemeal approaches. To accomplish this, a wide array of solutions was considered to solve watershed problems. Typically, the array of solutions includes: capital projects, which are constructed improvements; programmatic measures such as routine maintenance or public outreach; and regulatory measures. Solutions that consider changes in land use to control stormwater runoff were not considered for this watershed plan because the plan is intended to support the proposed future land use as described in the City of Shoreline's Comprehensive Plan.

The following sections describe the flooding, wetlands and habitat, and water quality solutions that were considered for the problems identified in Section 4. For selected flooding problems, computer modeling was performed to assess potential solutions, as discussed below.

The solutions we recommend in this section for individual problems are prioritized in Section 7 as part of developing a basin-wide Capital Improvement Program.

Note that all cost estimates listed in this report are considered preliminary and include a 30% construction contingency, tax, and an allowance of 30% for engineering design, administration, permitting, and construction engineering.

6.2 Projects to Reduce Flooding

6.2.1 Problem F1: Ronald Bog – Corliss Ave N Thornton Creek

Nearly 30 potential alternative solutions were identified for this problem. (See Figure 4-1, p. 4-3, for problem location.) The complete list of the potential alternative solutions is included in Appendix E. The list of potential solutions was developed by the following process:

- Reviewed prior studies.
- Obtained input from City staff.
- Obtained input from the public.
- Performed hydrologic and hydraulic modeling of the system.
- Evaluated field conditions.

The alternatives were grouped into four types of solutions that could be evaluated at a conceptual level to ensure they were feasible prior to investing in more detailed analysis. These included:

- Constructing a flood barrier to hold back floodwaters along the south edge of the bog, such as an earthen berm or a wall.
- Expanding Ronald Bog to provide more flood storage capacity.
- Increasing downstream flow capacity.
- Floodproofing homes and acquiring property.

These four types of solutions are discussed in the paragraphs below, followed by a discussion of the modeling of alternatives and a recommendation.

Alternatives

Alternative 1 – Construct a Flood Barrier Along the South Side of Ronald Bog

Alternative 1 involves adding a flood barrier to hold back floodwater along the southern edge of Ronald Bog during major storm events that will protect the downstream properties from flooding. Adding a flood barrier of sufficient height, such as an earthen berm or a wall, would provide a level of protection to eliminate major surface flooding in a 100-year storm (i.e., 1 percent chance that flooding will occur in any given year).

The exact location and configuration of this barrier would depend on input from the property owners who are affected. The City is currently working with the affected property owners to determine a potential alignment and configuration as well as their preferences on a flood barrier. The design, location, and configuration of a flood barrier would depend on input from affected property owners and other preliminary design information. Options for the type of structure could include a simple landscaped mound of earth, a short wall constructed of ornamental pavers with fill and landscaping behind, a cast-in-place concrete wall, or other techniques.

One significant issue that needs to be resolved when determining the final design, location, and configuration of a flood barrier is whether or not the barrier should be designed using standards that are FEMA-accredited. As discussed earlier, the City is preparing floodplain maps for the area downstream from Ronald Bog, and if the City decides to adopt these maps, then constructing a FEMA-accredited flood barrier would allow the City to remove this area from the floodplain designation.

The major physical difference between a structure that is accredited and non-accredited would be the top elevation. The top elevation for the non-accredited flood barrier would be 369.7 feet, which provides 1 foot of freeboard. To be accredited by FEMA, the flood barrier's top elevation would be 371.7 feet. In other words, the FEMA-accredited flood barrier needs to be 2 feet higher than the non-accredited flood barrier because FEMA requires that added safety factor. Most of the backyards in the area have an average elevation ranging from 367 to 370 feet, so that the top of the barrier would be in the range of about 1 to 3 feet higher than the existing yards for the

non-accredited structure and nearly 2 to 5 feet higher for the accredited structure. These heights would be lower if the barrier were located closer to the homes where the ground is higher. Figure 6-1 illustrates a conceptual barrier of both the berm and wall if located closer to the homes. The berm is depicted assuming a non-FEMA-accredited barrier. The wall is depicted with a range of heights to illustrate walls that meet and do not meet FEMA standards.

It is noted that there is high groundwater in the area south of the bog and that groundwater levels fluctuate with the water levels in the bog. The flood barrier would need to be designed with an appropriate cut-off wall below the ground surface to minimize the amount of groundwater that flows below and around the flood barrier. The City has installed a monitoring well to assess this.

Other factors that would need to be addressed in a future design process to select the location and type of flood barrier include:

- Input from property owners adjacent to the bog regarding landscape design, impacts to views, access to the water, and obtaining easements.
- Results of a detailed topographic survey of the area.
- Results of a soils investigation to provide recommendations for design of the flood barrier, including addressing the high groundwater.
- Input from regulatory agencies.
- Providing habitat along the bank for fish and other wildlife, likely including native vegetation along with possible log structures, grading to provide localized emergent vegetation benches, nesting boxes, and/or feeders.

In the future, with the flood barrier in place, during extreme events such as the December 2007 event, the water level in the bog behind the new flood barrier would be higher than the roadways south of the bog, including Corliss Avenue N, N 172nd Street, and N 171st Street. This will cause the 30-inch-diameter outlet pipe system from the bog to become pressurized. To prevent flows from coming up out of the 30-inch-diameter pipe system when it is pressurized, manhole lids would need to be locked down and any open grates on this system would need to be replaced with solid lids. In addition, some of the catch basins have brick and mortar risers that will not withstand system pressures and would need to be replaced. If there are foundation drains or other direct connections to the 30-inch pipe, these need to be removed and reconnected to the 18-inch pipe that handles the street drainage. Also, a backflow prevention device would need to be installed in the 18-inch-diameter pipe collection system serving Corliss Avenue to prevent flows from backing up into and then out of the catch basins attached to this local conveyance system.

The existing 30-inch outlet pipe from the bog was never designed to be a pressurized system, and even though the manhole lids and grates would be retrofitted to withstand the pressure, there is concern about the integrity of the 30-inch pipe and its ability to withstand pressure. As part of a separate project, the City is investigating slip lining or other rehabilitation techniques as a way to enhance the structural integrity of this pipe.

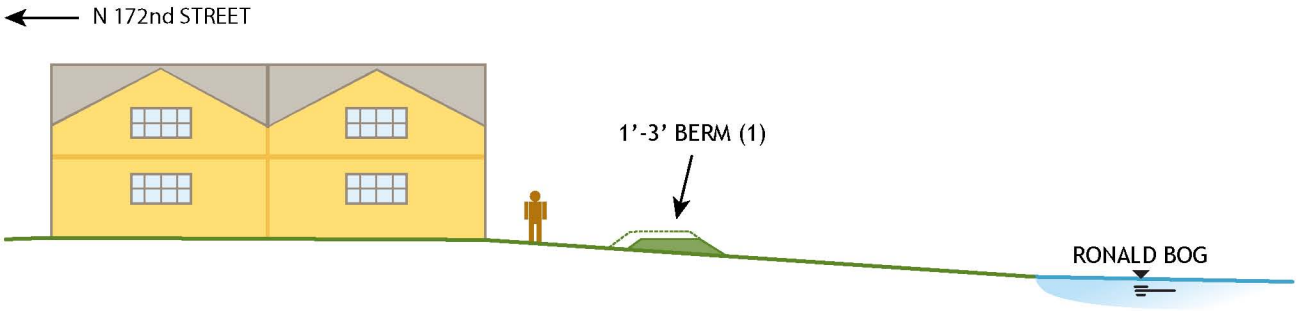
During major floods, there would be a short period when local stormwater flowing into the Corliss Avenue system (from N 172nd Street and N 171st Street) could not enter the 30-inch-diameter pipe system because it would be pressurized. This local runoff would build up and potentially back up into the low-lying areas of the street. Thus, temporary pumping of these relatively small volumes of water may be necessary, using portable pumping equipment. Because the area that drains to the Corliss Avenue system is small, the portable pumping equipment would be expected to keep this ponding to a minimum.

Another issue related to this alternative is that water from the bog could back up onto Meridian Avenue N during extreme flow events. In the December 2007 storm event, flood waters from the bog backed up onto Meridian Avenue N. Based on hydrologic modeling, Meridian Avenue N would continue to be inundated during extreme flood events starting around the 50-year storm event and would still be drivable in the middle lanes during a 100-year event with this alternative.

Permitting Considerations: City staff had an initial discussion with the Washington State Department of Fish and Wildlife (WDFW) habitat manager on November 4, 2008, about flooding of the Ronald Bog area. The construction of a flood barrier was discussed and the habitat manager indicated that obtaining a Hydraulic Project Approval (HPA) from WDFW for a flood barrier would likely not require a costly replacement of the entire 30-inch pipe system on Corliss Avenue with a system that meets current fish passage design requirements. One suggestion given by the habitat manager was that the design of the barrier should have native plantings on the side facing the bog for near-shore habitat.

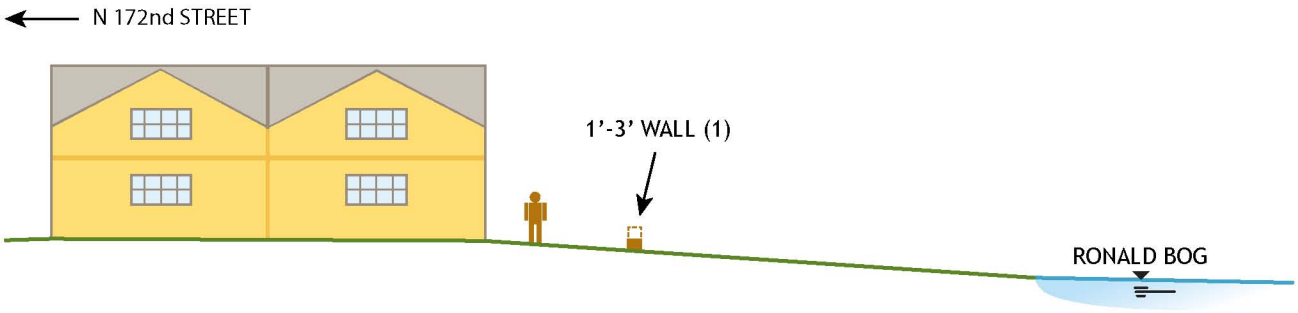
Depending upon the exact location of the flood barrier, a newly constructed barrier may also require permits from the U.S. Army Corps of Engineers (Corps). If fill were proposed within the limits of a wetland associated with Ronald Bog, a permit from the Corps would become necessary. The Corps regulates wetlands under Section 404 of the Clean Water Act. The Corps may also decide that due to Ronald Bog's connection to habitat containing species listed under the federal Endangered Species Act (ESA), a Biological Evaluation must be prepared to assess effects of the proposed project on listed species (e.g., Chinook salmon). Compliance with the ESA would require that the Corps consult with and receive concurrence from the U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service (known together as "the Services"). ESA consultation by the Corps is possible, albeit remote, because the nearest endangered species are known to occur approximately two miles from the wetland. The need for a Corps permit would also trigger the requirement for a Section 401 Water Quality Certification and Coastal Zone Management Consistency determination from the Washington State Department of Ecology (Ecology).

However, if all fill associated with the proposed flood barrier is kept outside the limits of wetland areas, Corps, Ecology, and HPA permits would not be necessary.



Schematic Berm Section

NOT TO SCALE



Schematic Wall Section

NOT TO SCALE

R·W·BECK
An SAIC Company

Note:
(1) The location of the berm and wall shown is schematic. It could be designed into the back yards as a landscaped feature and the design/location could vary from property to property. The height of the wall/berm would determine the level of flood protection and the number of properties (backyards) that would be affected.

Figure 6-1
Schematic Sections for Flood Barrier Options

Ronald Bog is classified by the City of Shoreline as a Type I wetland, requiring a standard buffer of 150 feet. Impacts to a Type I wetland are prohibited and would only be allowed pursuant to the exception outlined in SMC 20.30.333 - Critical Areas Special Use Permit. This exception "allows development by a public agency or utility when the strict application of the critical areas standards would otherwise unreasonably prohibit the provision of public services." This exception would allow for the flood barrier, although mitigation consistent with SMC 20.80.350(D) would still be required. Mitigation done to satisfy City of Shoreline regulations would likely be sufficient to satisfy state and federal requirements.

For those portions of the flood barrier located entirely outside of the wetland, impacts to the wetland buffer would need to be mitigated at 1:1 to satisfy City of Shoreline criteria, as long as it can be documented that buffer enhancement results in equal or greater wetland functions [pursuant to SMC 20.80.330(C)(2)].

Cost: $650,000 – $1.4 million

Alternative 2 – Expand Ronald Bog for Flood Storage

Alternative 2 would create additional flood storage in Ronald Bog by expanding the bog's active storage footprint. Expanding the flood storage of the pond would reduce water levels during major flood events. To reduce water levels, a significant amount of new storage would need to be provided. The greatest opportunity to provide additional storage at this site would be to excavate and expand the open water section of the bog. To perform the calculations necessary to determine the effectiveness of the additional storage on reducing water levels, a realistic estimate was made of the maximum amount of additional storage that could be achieved at this site.

One option for expanding the bog would be to excavate in the east portion of the site, which is presently wooded and contains some wetlands and interpretive trails. Pools could be formed and the interpretive trails could be relocated to extend around the pools. Wetland areas could likely be expanded and enhanced in the process, resulting in a net increase in habitat quantity and quality over time.

Another area to create storage is in the open grassed area north and east of the bog. This area could be lowered and then re-grassed to maintain an open grassed area. This area would be a few feet in elevation above the normal bog water levels, but would flood when the bog levels rise during storm events.

This level of expansion could create up to a maximum of approximately 15 acre-feet of additional flood storage and require excavation of more than 30,000 cubic yards. As described later in this section, this alternative provides flood protection to the downstream neighborhood in up to a 50-year storm event. Anecdotal information about Ronald Bog indicates that portions of the area around the bog were used as an old fill site for materials such as construction debris, pavement, and concrete. We have not been able to locate information on the type or extent of any fill materials. Removal and disposal of such waste material would be much more expensive than excavation of native earth. There could also be some risk of encountering hazardous materials that would require special disposal procedures.

Under this alternative, Corliss Avenue and to a lesser extent N 171st and 172nd Streets would continue to be subject to flooding during storms that exceed the 10-year storm.

Permitting Considerations: State, federal, and local permitting as described in the discussion for Alternative 1 would also be necessary for Alternative 2. To summarize, the expansion of the bog would require an HPA from WDFW, permits from the Corps (and possibly consultation with the Services), permits from Ecology, and a Critical Areas Special Use Permit exception from the City of Shoreline. Mitigation for impacts associated with expansion of the bog would also be required. This alternative involves excavation of wetland areas and it should be noted that there is a strong possibility that despite adequate mitigation, permits from one or more agencies may not be granted.

Cost: $4.5 million – $5 million

Alternative 3 – Increase Outlet Conveyance Capacity

Alternative 3 involves increasing the downstream conveyance capacity to reduce flooding at the bog. This alternative could include any solution that would create additional outlet capacity, such as:

- Adding a pump station and force main.
- Upsizing the existing outlet pipe system.
- Replacing the existing outlet system with an open channel system.
- Adding a parallel outlet system.

Increasing the outflow during certain storm events would reduce the water level in the bog. If sized accordingly, improving the conveyance capacity would prevent the bog from overtopping its banks and flooding the properties to the south.

Without adding a substantial amount of flood storage volume in the system downstream from Ronald Bog, this alternative would cause increased downstream peak flows. An evaluation of the downstream system revealed that flood storage sites of sufficient volume to mitigate the increased flows would be very difficult and likely not possible to implement given the severe disruption it would create for current property owners and land use. These increased flows would contribute to flooding and erosion problems downstream along the North Branch and extending into the main stem of Thornton Creek. Without these increased flows, Thornton Creek already has a history of flooding and fish and wildlife habitat issues. The increase in peak flows would send flood waters currently stored at the bog and create or exacerbate flooding at other locations downstream. In addition, erosion would likely be detrimental to fish and wildlife habitat.

Increasing conveyance would also require that fish passage and habitat impacts be mitigated, which would increase the cost of design, construction, and in some cases, maintenance. For example, if this alternative included a pump station, the pump inlet would likely need to be screened to prevent fish, including small fry, from entering it. The fairly small screen size needed to keep small fry out of the pump station would

make the pump intake difficult to keep free from debris, especially when pumping at the high rates needed to alleviate or prevent flooding.

If this alternative included upsizing the existing outlet pipe system, WDFW would require the system to be fish-passable and/or would require mitigation at another site. Typically, a fish-passable conveyance system would need to be oversized beyond what would be required for conveyance alone, which would increasing the cost of this option. This could include installation of a series of long box culverts, similar in size to the box culverts installed in 2008 (5 feet wide). One possibility that could be more affordable would be to replace the pipe system with a pipe that provides adequate capacity but is the smallest diameter pipe possible that meets WDFW's "Hydraulic Design Option." This would need to be negotiated with WDFW because a long pipe system without open channel breaks would be less desirable. In either case, there would be an increase in downstream peak flow rates. Replacing the existing pipe system with a fish-passable system is also discussed under Section 6.3.1.

Permitting Considerations: Regardless of the type of increased conveyance that could be used, all types would involve significant environmental permitting challenges and requirements that would likely be costly and time-consuming to address. WDFW would have to issue an HPA and the Corps and Ecology would have to issue 404 and 401 permits for wetland impacts. A Critical Areas Special Use Permit exception from the City of Shoreline would likely be required as well.

Cost: $4.5 million – $5 million (but could be less if the City were able to negotiate a smaller conveyance system size)

Alternative 4 – Floodproofing and Property Acquisition

Alternative 4 includes a combination of property acquisition from willing sellers and floodproofing. Property acquisition would involve working with willing property owners whose homes are severely impacted, and purchasing their property and removing the home. Depending on the location, it may be possible to use the land for additional flood storage, park or picnic areas, and/or the restoration of functional habitat areas, including stream, wetland, and/or lake buffers where applicable.

Floodproofing can involve several different methods which may include waterproofing basements, installing backflow preventers on exterior and interior drains, installing floodgate/dams at garage doors and berming around structures. Floodproofing may also include relocating basement living space by adding floor space on the main level above the flood elevation. Pumps could be used as back-ups to keep floodproofed basements and the areas surrounded by berms sufficiently dry. The focus of floodproofing is to implement measures to reduce the damages caused by flooding as opposed to solving the flooding problem. Raising the finished floor of houses is one other floodproofing method, but this approach was not considered viable for the house in the Ronald Bog area.

Under this alternative, no change to the conveyance system would be included and, therefore, water surface elevations would not change. Consequently, even if certain

properties are acquired and others are floodproofed, Corliss Avenue and to a lesser extent N 171st and 172nd Streets would continue to be subject to flooding.

The City is currently in discussions with the property owners downstream of the bog who have been affected by the flooding. The discussions with the property owners will determine whether floodproofing and/or property acquisition is an appropriate alternative to help reduce the potential for future flood-related damages to their homes. Because the extent of floodproofing and property acquisition is unknown at this time, the cost for implementing this alternative can vary considerably. A FEMA Benefit Cost Analysis (BCA) was used to determine the cost-effectiveness of floodproofing options. A cost-effective (e.g., project cost is less than future monetary damages to property) home elevation and/or property acquisition project is eligible for federal grant funding through FEMA. In addition, for those homes where dry floodproofing was recommended, the City is developing a floodproofing program to assist eligible homeowners. Dry floodproofing is not eligible for FEMA funding.

Permitting Considerations: This alternative would not require any state or federal permits and local permitting would be minimal (likely limited to demolition and/or building permits from the City of Shoreline). Since some work would be within the wetland buffer, it is conceivable that some form of on- or off-site mitigation would be required. This would likely take the form of wetland buffer enhancement plantings, removal of invasive vegetation, or similar actions.

Cost: $1.6 million – $3.4 million

Hydrologic/Hydraulic Modeling to Determine Effectiveness of Alternative Capital Solution Alternatives for Problem F1, Ronald Bog

The hydrologic and hydraulic models developed for this study and described in Section 5 were also used to evaluate the effectiveness of the types of alternatives to reduce water surface elevations in Ronald Bog and the neighborhood south of the bog. This section describes the key assumptions about the modeling analysis as well as the modeling results. More detailed information about the modeling of alternatives is included in Appendix B. For the modeling of alternatives for Problem F1, additional flood storage was included to reflect flood storage volume that is being constructed as part of an ongoing City park project at Cromwell Park. The park is being redeveloped and as a part of these improvements the City is providing flood storage. At the time the modeling was conducted, the concept was preliminary and the new storage was anticipated to be 2 acre-feet. Since then, the project has moved into final design and the actual volume that will be provided is 4 acre-feet. The modeling was not redone, but it is anticipated that this storage at Cromwell Park will reduce peak flows to the bog and should result in reducing water levels in the bog by 0.1 to possibly 0.2 foot.

Table 6-1 lists the some of the major modeling assumptions and also notes where alternatives were not modeled. Table 6-2 provides a summary of the modeling results.

Table 6-1
Modeling of Ronald Bog Alternative Solutions

Alternative	Discussion/Major Assumptions
Alternative 1 – Flood Barrier Along South Side of Bog	■ Hydraulics of outlet system based on recent pipe upgrades and north and south channel maintenance (assuming the design condition for the channel maintenance) ■ Includes approximately 2 acre-feet of flood storage at Cromwell Park (design has since changed and storage volume is now 4 acre-feet, but the model was not revised) ■ Includes flood barrier along south side of bog (with minimum top elevation of 369.5) ■ Assumes system downstream of bog is equipped with devices to prevent pressure flows from exiting the outlet pipe system
Alternative 2 –Ronald Bog Expansion	■ Hydraulics of outlet system based on recent pipe upgrades and north and south channel maintenance (assuming the design condition for the channel maintenance) ■ Adds approximately 15 acre-feet of additional flood storage at Ronald Bog ■ Includes approximately 2 acre-feet of approximate flood storage and proposed at Cromwell Park (design has since changed and storage volume is now 4 acre-feet, but the model was not revised)
Alternative 3 – Outlet Conveyance Capacity Increase	■ Conveyance-type solutions were modeled during a prior study[1] ■ The results of the prior modeling indicate that conveyance could be sized to limit maximum water surface elevations in the bog to below 367.5, which is the 100-year storm event water surface elevation in Ronald Bog ■ Based on the prior modeling, the anticipated result is that conveyance capacity increase would result in significant increases in peak flows to downstream system
Alternative 4 - Floodproofing and Property Acquisition	■ Was not modeled ■ Water levels would be similar to current conditions

Note: Each modeled scenario used current conditions land use. Future land use was not considered for the preliminary draft.

[1] *Thornton Creek Corridor Project: Preliminary Engineering Report, Final Report.* R. W. Beck, Inc., 2007.

Table 6-2
Ronald Bog Predicted Maximum Water Surface Elevations

Average Annual Return Period	Current	Alternative 1		Alternative 2	Alternative 3	Alternative 4
		Bog Level	Corliss Ave.			
2	365.7	365.5	365.5	365.2	See note 3	365.7
5	366.5	366.4	366.4	366.0	See note 3	366.5
10	367.1	367.0	366.5	366.4	See note 3	367.1
25	367.8	367.7	366.5	367.0	See note 3	367.8
50	368.3	368.2	366.5	367.5	See note 3	368.3
100	368.8	368.7	366.5	367.9	See note 3	368.8
500	369.9	369.9	366.5	368.9	See note 3	369.9

1 Elevations are based on the NAVD 88 vertical datum.

2 Elevation 367.5 is generally accepted as elevation at which flooding occurs.

3 Was not modeled, however, pump station would be sized to limit the water surface elevation at the bog to 367.5 for the 100-year event.

Increased conveyance in Alternative 3 would be sized to eliminate most flooding. If the City wanted to eliminate all flooding in Corliss Avenue, the increased conveyance capacity would need to be sized to reduce water level in the bog down to about 367.5 feet in a 100-year storm event. Although this alternative was not modeled during this study, conveyance-type solutions were modeled during a prior study (R. W. Beck 2007a), which showed that conveyance upgrades using pipe system improvements could reduce the water levels in the bog to approximately 366.8 feet. If the conveyance improvements were done by replacing the existing pipe system with open channels, the water levels could be reduced to approximately 365.1 feet. The increase in peak flow rates from the previous analysis suggest that peak flows at N 167th Street could increase by 33 to 48 percent depending on the type of conveyance improvements implemented.

The flooded area corresponding to Alternative 4 would be the same as current conditions, as shown previously in Figure 4-3 (p. 4-7).

Recommendations for Problem F1

Due to the sensitive nature of this problem and potential high cost of an alternative solution, specific evaluation criteria were developed to help identify a recommended solution.

Table 6-3 includes a description of the criteria used to compare and evaluate the alternatives. These criteria were developed with input from the public (to be incorporated).

Table 6-3
Alternative Evaluation Criteria

Criterion	Considerations
Cost	What is the cost of the alternative? This provides information about how affordable it is to implement.
Effectiveness in Solving Problem	How effective is the alternative in solving flooding and providing flood protection up to a 100-year flood?
Impacts to Neighborhood	The community's perspective on the impacts to property and neighborhood.
Ease of Permitting	How difficult will it be to obtain permits for implementing the alternative?
Downstream Impacts - Flows	Will the alternative result in increased downstream flow rates?
Downstream Impacts - Habitat	How will the alternative impact or improve habitat conditions?
Downstream Impacts - Water Quality	How will the alternative impact or improve water quality conditions?

The criteria defined in Table 6-3 are then used in Table 6-4 to compare the alternatives. Table 6-4 also includes cost estimates for each alternative. Detailed back-up for the cost estimates is included in Appendix D. Cost estimates are considered preliminary and include a 30% construction contingency, tax, and an allowance of 30% for engineering design, administration, permitting, and construction engineering.

Table 6-4. Evaluation of Alternatives for Ronald Bog Flooding (Problem F1)

Alternative	Cost[1]	Effectiveness in Solving Problem	Impacts to Neighborhoods	Ease of Permitting	Downstream Impacts		
					Flows	Habitat	Water Quality
Alternative 1 - Flood Barrier Along South Side of Bog	$650,000 to $1.4 million	▪ Provides flood protection for 100-year event ▪ Some temporary pumping for local flows along Corliss may be required during extreme floods ▪ Minor flooding of Meridian would continue	▪ Primarily impacts neighbors on south side of bog. Design would need to incorporate input from citizens with regard to location, aesthetics, and maintaining access to shoreline.	▪ Obtaining permits (HPA, Corps) appear favorable. Depending on barrier location, there may be some impact to wetland along shoreline.	▪ Does not increase downstream peak flows	▪ Temporary construction impacts would need to be mitigated. Design could include restoration of bank areas along shoreline currently subject to erosion.	▪ Temporary construction impacts would need to be mitigated. Design could include restoration of bank areas along shoreline currently subject to erosion.
Alternative 2 - Major Expansion to Ronald Bog	$4.5 million to $5 million	▪ Provides flood protection for approximately 50-year event ▪ Flooding of Corliss Avenue would continue in storms above the 10-year event	▪ Temporary impacts to park use would be significant. ▪ There would be reduction in park usable space. ▪ Park would be inundated during large storm events such as greater than a 2-year event	▪ There would be impacts to wetlands	▪ Does not increase downstream peak flows	▪ There would be significant temporary impact during construction ▪ Long-term impact would need to be further evaluated	▪ There would be significant temporary impact during construction. There is some concern about historical waste fill areas being exposed and released ▪ Additional open water areas could increase temperatures; could be mitigated by planting trees for shade
Alternative 3 - Increased Conveyance	$4.5 million to $5 million	▪ Could be designed to provide flood protection for 100-year event	▪ Lower impact to neighborhood since work is primarily within Corliss right-of-way and doesn't impact Ronald Bog Park	▪ WDFW may consider this element as major change to 30-inch outlet system and require either fish passage or mitigation (i.e., removal of another fish passage barrier)	▪ Would result in significant increase in downstream peak flows. This increase would lesson as flows travel downstream	▪ Depends on the conveyance system used. A pumped system would have a significant impact on fish. But an open-channel fish-passable system would have a fish habitat benefit	▪ Minimal during construction because nearly all construction could be done independent from creek and bog ▪ Could increase erosion of downstream channels due to higher flows
Alternative 4 - Floodproofing and Property Acquisition	$941,000 to $3.4 million[2]	▪ Focus is on reduction of flood damages, flooding of Corliss Avenue would continue	▪ Continued flooding of Corliss Avenue, affecting access to 171st and 172nd east of Corliss	▪ Few, if any, permits necessary	▪ Does not increase downstream peak flows	▪ Few environmental impacts. These impacts would be limited to where any work is done.	▪ Few water quality impacts which would be limited to where any work is done.

1 Note that cost estimates were also prepared for system replacement of the 30-/48-inch-diameter pipe system and range between $820,000 and $3.8 million depending on whether fish passage improvements are required. This is discussed under the Alternative 1 description in Section 6, but would be applicable to all alternatives.

2 Note that the low range of costs for Alternative 4 assumes other floodproofing techniques (not elevating homes).

In addition to ranking these alternatives according to their score, there are some criteria that *must* be achieved in order for that alternative to be viable. It would be irresponsible to increase downstream peak flows. Further exacerbating existing flooding and fish habitat problems in the downstream system is not something that the City could reasonably propose, so Alternative 3 must be eliminated from further consideration. Area residents need to be provided with a flood protection level of service that would prevent the neighborhood from flooding in an event like the one that occurred in December 2007. Alternative 2 will not provide this level of protection and was also eliminated from further consideration.

Based on this, a floodplain management strategy that seeks the highest possible flood protection that is practical and affordable is recommended. The floodplain management strategy includes advancing an approach that involves a combination of a constructed flood barrier (Alternative 1) and floodproofing of houses (Alternative 4).

The location, type, and extent of a flood barrier, as well as which properties may receive floodproofing, will be determined considering both input from individual property owners and cost/benefit analyses. The cost/benefit analyses are being done to both ensure that the ultimate project benefit outweighs the cost and to provide supporting data for potential grants. In addition, the City is implementing other measures to reduce the potential for flood damage, including enhance maintenance of the outlet system, an early warning system to notify property owners when water levels in the bog reach an early flood stage, and preparing for the ability to provide temporary pumping.

As mentioned previously, the cost for this project ranges from $650,000 to $1.4 million. This cost range represents the lower and upper range for the flood barrier, with the lower end of the floodproofing option ($941,000) falling into the middle of this range. While there could be some combination of flood barrier and floodproofing (for example, a full flood wall plus floodproofing some portion of the homes) that could be more expensive than this, it is likely that such a combination would be cost-prohibitive; thus, that possible outcome was not included here. The City is currently looking into grant opportunities to pay for this project.

6.2.2 Problem F2: NE 170th Street to NE 175 Street between 11th and 13th Avenue NE

Three alternatives were developed to help alleviate this flooding problem. (See Figure 4-1, p. 4-3, for problem location.) The first alternative is a small, low-cost project that was developed to add some additional storage on an interim basis. Alternative 2 is a larger, more traditional engineered solution; Alternative 3 is similar to Alternative 2, but includes low impact development (LID) bioretention techniques and/or non-traditional engineered solutions to reduce runoff. Refer to Figures 6-2 through 6-4 for these alternatives.

Alternatives

Alternative 1

Alternative 1 includes expanding the existing ditch along 12th Avenue NE for use as an infiltration ditch. The ditch would provide additional storage and help infiltrate runoff to help attenuate the flows coming into the area. A control structure would be required to ensure flows coming from the east will back up into the ditch. The control structure will overflow into backyards between NE 170th and 175th Streets and 11th and 12th Avenues NE.

Cost: $61,000

Alternative 2

Alternative 2 includes a trench infiltration system and improvements to the existing infiltration facility to address this flooding problem. The solution includes installing an overflow structure on 12th Avenue NE where the existing storm drainage discharges into backyards between NE 170th and NE 175th Streets and 11th and 12th Avenues NE. The overflow structure would maintain water quality flows along the existing path; however, high flows would be diverted into an infiltration trench that would extend south along 12th Avenue NE. This overflow structure could be oversized to act as a sediment trap to capture sediment prior to discharging flow to the infiltration trench. An infiltration trench is proposed to take advantage of the outwash soils in the area. The proposed drainage system would turn to the west on NE 170th Street. Because the grade along NE 170th Street between 12th and 11th Avenues NE is steep, this section consists of a solid drain pipe rather than an infiltration trench. At 11th Avenue NE, the system would turn north and connect into the existing system that discharges into an existing infiltration facility. The new section along 11th Avenue NE, not including the section crossing the road, would also consist of an infiltration trench.

The solution also includes cleaning out the bottom of the existing infiltration facility to remove sediment build-up and re-establish grading.

Cost: $362,000

Alternative 3

Alternative 3 is similar to Alternative 2, but is a non-traditional engineered approach that incorporates low impact development (LID) techniques. In lieu of the infiltration trenches, a rain garden could be used to treat and encourage infiltration along 12th and 11th Avenues NE. The rain garden would consist of landscaped, almost flat retention areas with an underlayer of drain rock along the edge of the road. The retention areas would act as a swale in higher flows. During lower, more frequent events, flow would be retained in the soil planting mix or infiltrate into the underlying soil.

Cost: $247,000

Permitting Considerations

None of the alternatives requires any environmental permits.

Alternative Solution Hydraulic Analysis

The XP-SWMM modeling analysis shows that Alternative 1 would reduce but not completely alleviate the flooding for the 25-year event. However, this may be a good, low-cost first phase to help alleviate the problem.

Alternatives 2 and 3 would solve the flooding problem for the 25-year event if the assumed infiltration rate (4 inches per hour) is accurate for the infiltration pond and the infiltration trenches. This rate was chosen based on infiltration tests performed for another project in the same general vicinity. However, infiltration rates can vary greatly and we recommend that infiltration tests be performed at the project site to assess the actual infiltration rates before implementing this solution.

Recommendation for Problem F2

Based on discussions with the City, we concur that the City should implement Alternative 1 as a first phase. If this solution proves to be insufficient on its own, the City could implement Alternative 3 due to its lower cost. It is important that the City verify the infiltration rates in the area prior to implementing this solution.

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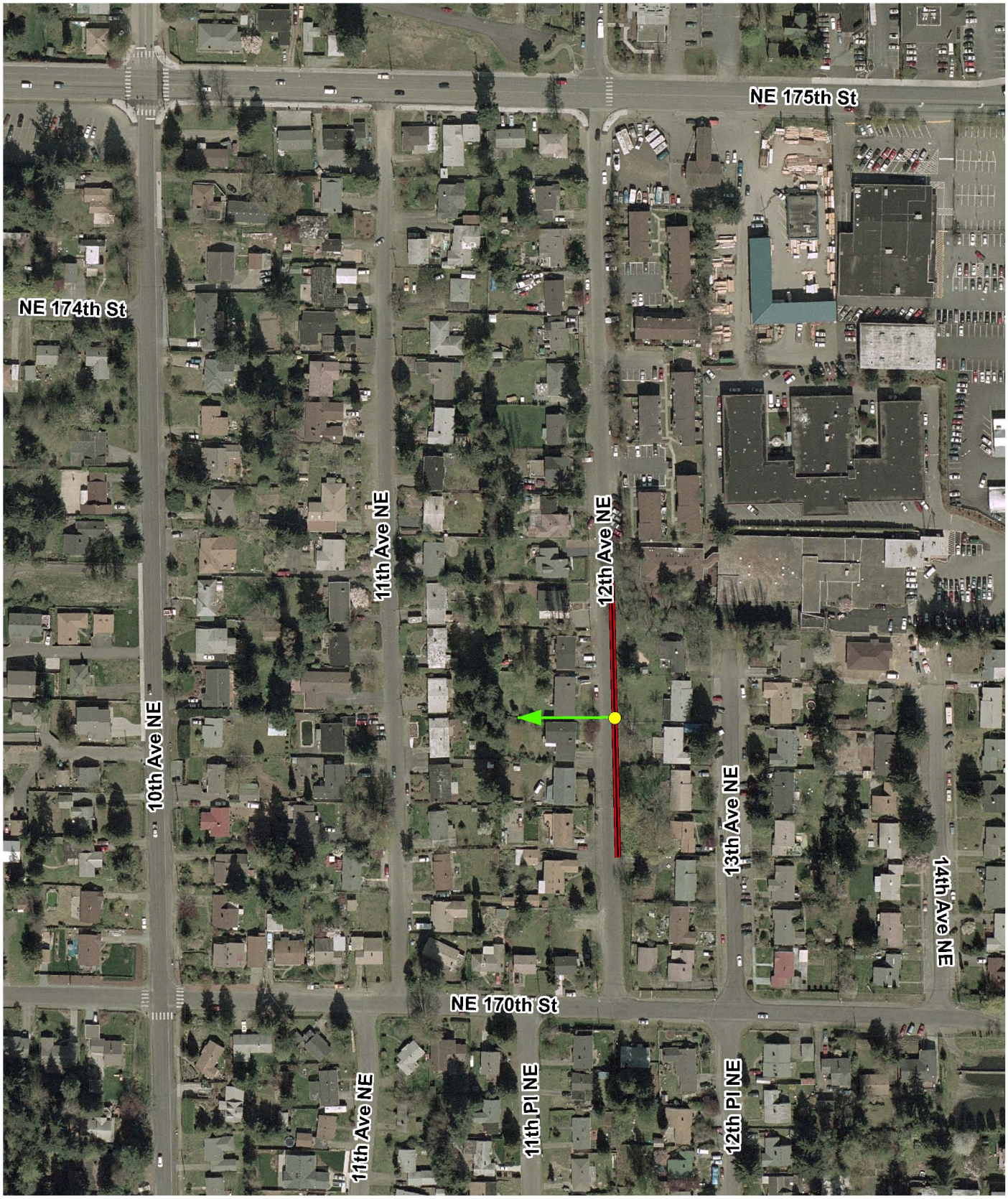

N

0 100 200 400 Feet

Legend

- Proposed overflow structure
- Direction of flow
- Proposed infiltration ditch

Figure 6-2
Problem F2 Solution
Alternative 1

Thornton Creek Watershed Plan
City of Shoreline

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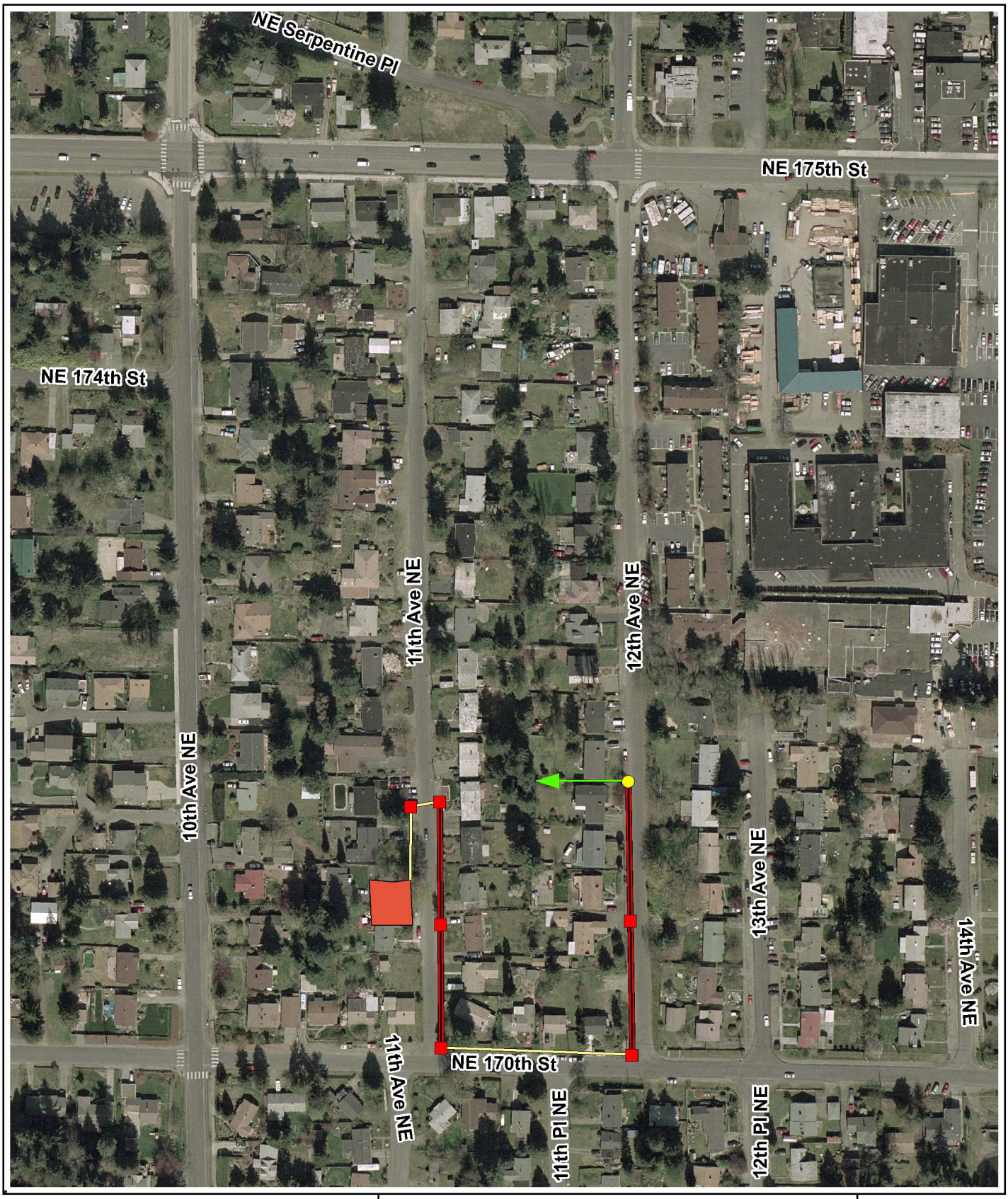

N

0 100 200 400 Feet

Legend

- Proposed catchbasin/manhole
- Proposed overflow structure
- Direction of low flow
- Proposed 18-inch-diameter storm drain
- Proposed infiltration trench
- Proposed improved infiltration pond

Figure 6-3
Problem F2 Solution
Alternative 2

Thornton Creek Watershed Plan
City of Shoreline

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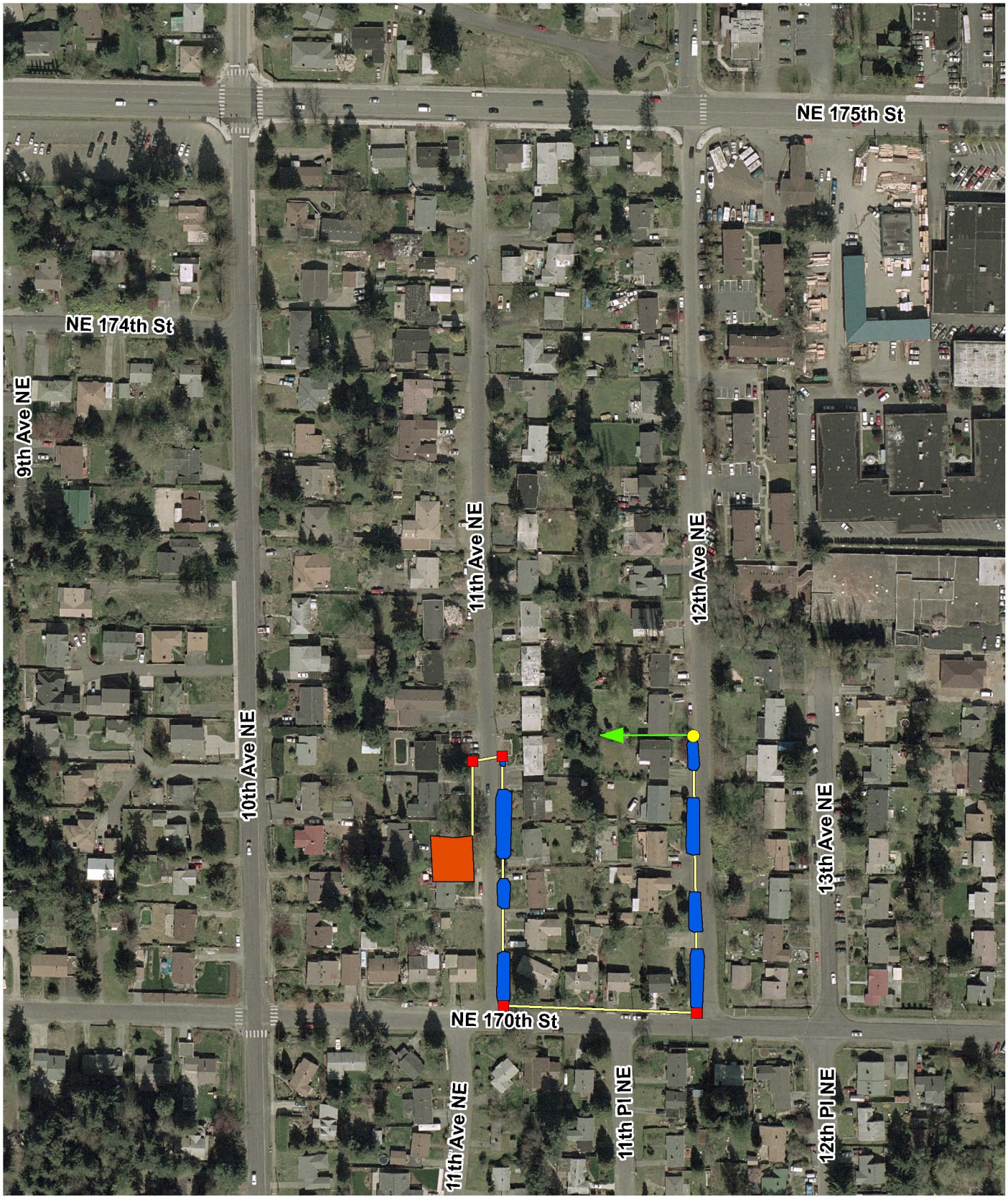

N

0 100 200 400 Feet

Legend

- Proposed overflow structure
- Proposed catch basin/manhole
- Proposed 18-inch-diameter storm drain
- Direction of low flow
- Improved infiltration pond
- Proposed bioretention swales

Figure 6-4
Problem F2 Solution
Alternative 3
Thornton Creek Watershed Plan
City of Shoreline

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6.2.3 Problem F3: Serpentine Pump Station

As discussed in Section 4.2.2, the Serpentine drainage system is a complex set of gravity pipes and pump stations that currently does not provide a 25-year level of service for flood protection. (See Figure 4-1, p. 4-3, for problem location.) Drainage currently accumulates at the low spot on 5th Avenue NE near NE 178th Street because the capacity of the Serpentine Pump Station is inadequate to convey the necessary flow up into the system that runs down NE Serpentine Avenue. In addition, modeling shows that the contributing pipe system along 5th Avenue NE is undersized for the 25-year storm. Two alternatives were considered for solving this problem.

Alternative 1

Alternative 1 is shown in Figure 6-5 and includes upsizing approximately 820 feet of pipe to 24-inch-diameter pipe and about 20 feet to 18-inch-diameter pipe along 5th Avenue NE and removing the existing orifice in the control structure near the Serpentine Pump Station. This would send more flow to an existing 18-inch-diameter concrete pipe that extends through private property beginning at 5th Avenue NE and between NE 178th Street and NE Serpentine Place. In addition, this solution includes connecting the drainage along 5th Avenue NE from NE 175th Street to the system along Serpentine upstream from the Serpentine Pump Station.

The above improvements were modeled to assess system performance. While these improvements reduced the problem, simulated flooding still occurred at the low point of 5th Avenue NE. As a result, additional elements to this alternative were included. These include providing an 8-inch-diameter high-flow overflow pipe from the 5th Avenue NE system to the NE 178th Street system and then upsizing about 395 feet of pipe on NE 178th to be upsized to 18-inch-diameter pipe so that these flood waters can be diverted to Pump Station 25, which is proposed to be upgraded.

The City is already planning to upgrade Pump Station 25 because its electrical system has malfunctioned during storm events. The City would also like to upgrade the force main between Pump Station 25 and NE Serpentine Place. For this alternative, Pump Station 25 was sized to accommodate overflows from the flooding on 5th Avenue NE. Modeling shows that based on the local flow plus the overflow contribution from 5th Avenue NE, the pump station should be sized to handle up to approximately 4.5 cfs for the 25-year storm event.

It was assumed that Pump Station 25 would be upgraded to provide this capacity by using two pumps in separate manhole wetwells. Note that this does not provide redundancy for this pump station. However, providing two pumps will mean that the pumps can alternate operation during most storm events, thereby extending the amount of time before either needs to be maintained. For this report, it is assumed that there will be a separate 8-inch-diameter force main for each pump. It is expected that using two force mains is less expensive than the cost of the valves and manifold that would be required to have a single force main. The force mains would convey flow up to the gravity system in NE Serpentine Place. It is also noted that three-phase power would likely be needed for the pump station upgrade. Currently, only single phase

power is available at the site. Depending on how far away three-phase is located and whether the City or Seattle City Light provides the power upgrade, this could add cost to the pump station upgrade.

Note that this alternative sends more flow to the existing storm drain system on private property between NE 178th Street and NE Serpentine Place west of 5th Avenue NE. The City has TVed this storm drain system and it appears functional with the exception of some separation of joints. The City has indicated that if this alternative were to be implemented, the City would make improvements to the joints to prevent leaking and that this would be a separate project. The costs of these improvements are not included in this alternative.

Cost: $880,000

Alternative 2

Alternative 2 is shown in Figure 6-6 and differs from Alternative 1 by not using the existing 18-inch-diameter storm drain within private property between NE 178th Street and NE Serpentine Place. This storm drain on private property would be abandoned in place. As a result, more flow would be directed down NE 178th Street to Pump Station 25. Under this alternative, since the City is replacing Pump Station 25 and the force mains already, they could be upsized to handle the increased flow from the 18-inch-diameter storm drain that runs on private property. This alternative was modeled for the 25-year storm. The system improvements on 5th Avenue NE would be the same as Alternative 1. The improvements along NE 178th Street would include upgrading about 570 feet of the pipe system with 18-inch-diameter pipe and about 180 feet with 24-inch-diameter pipe. These improvements along NE 178th Street assumed that the existing system would be replaced with the larger piped system as opposed to having a parallel system. The pump station would need to have a capacity of approximately 14 cfs. The cost estimate for this alternative assumes that the pump station upgrade would include three pumps within a vault, header manifold, and one 18-inch-diameter force main to the gravity system in NE Serpentine Place. Like Alternative 1, three-phase power would be required.

Cost: $1.8 million

Permitting Considerations

Neither of the alternatives would require environmental permits. It is uncertain whether the City has all of the easements for the 18-inch-diameter storm drain on private property. Thus, if Alternative 1 is selected, the City may need to ensure the maintenance easements are obtained.

Alternative Solution Hydraulic Analysis

As noted above, the XP-SWMM model using the 25-year storm event was developed for both alternatives. Both alternatives provide flood protection for the 25-year event.

Recommendation for Problem F3

The primary advantage under Alternative 2 is that the existing 18-inch-diameter storm drain on private property between NE 178th Street and NE Serpentine Place can be abandoned and the City will not need to maintain this line. Having such lines in private property are difficult to maintain. Also, as noted above, it is uncertain whether the City has maintenance easements for this storm drain.

The primary advantage of Alternative 1 is lower costs. As noted above, Alternative 1 does not include the cost for rehabilitating the 18-inch-diameter storm drain on private property. This cost would need to be included with this alternative for an equal comparison.

No recommended alternative is included in this draft report. The City will make a determination on which alternative to undertake based on criteria to be established during project feasibility and a downstream analysis.

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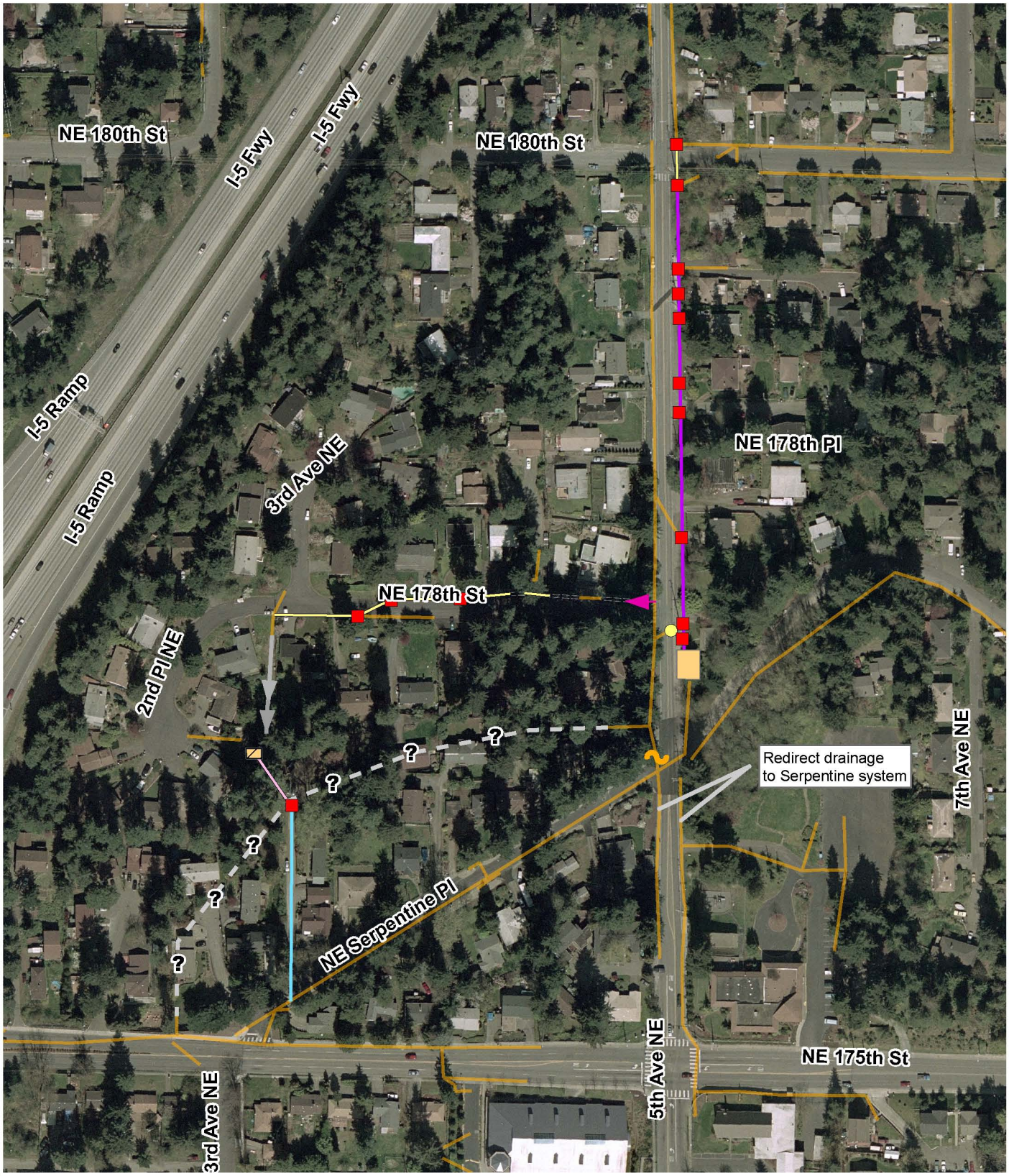

N

0 100 200 400 Feet

Legend

- Proposed Updated Pump Station 25
- Serpentine Pump Station
- Proposed catch basin/manhole
- Control structure
- Cap existing pipe
- Storm drain/road side ditch-culvert system
- Ditch
- Proposed 8-inch-diameter highflow overflow
- Proposed twin 8-inch-diameter force mains
- Storm drain system (location not verified)
- Proposed 18-inch-diameter pipe
- Proposed 24-inch-diameter pipe
- Proposed 12-inch-diameter pipe

Figure 6-5
Problem F3 Solution
Alternative 1

Thornton Creek Watershed Plan
City of Shoreline

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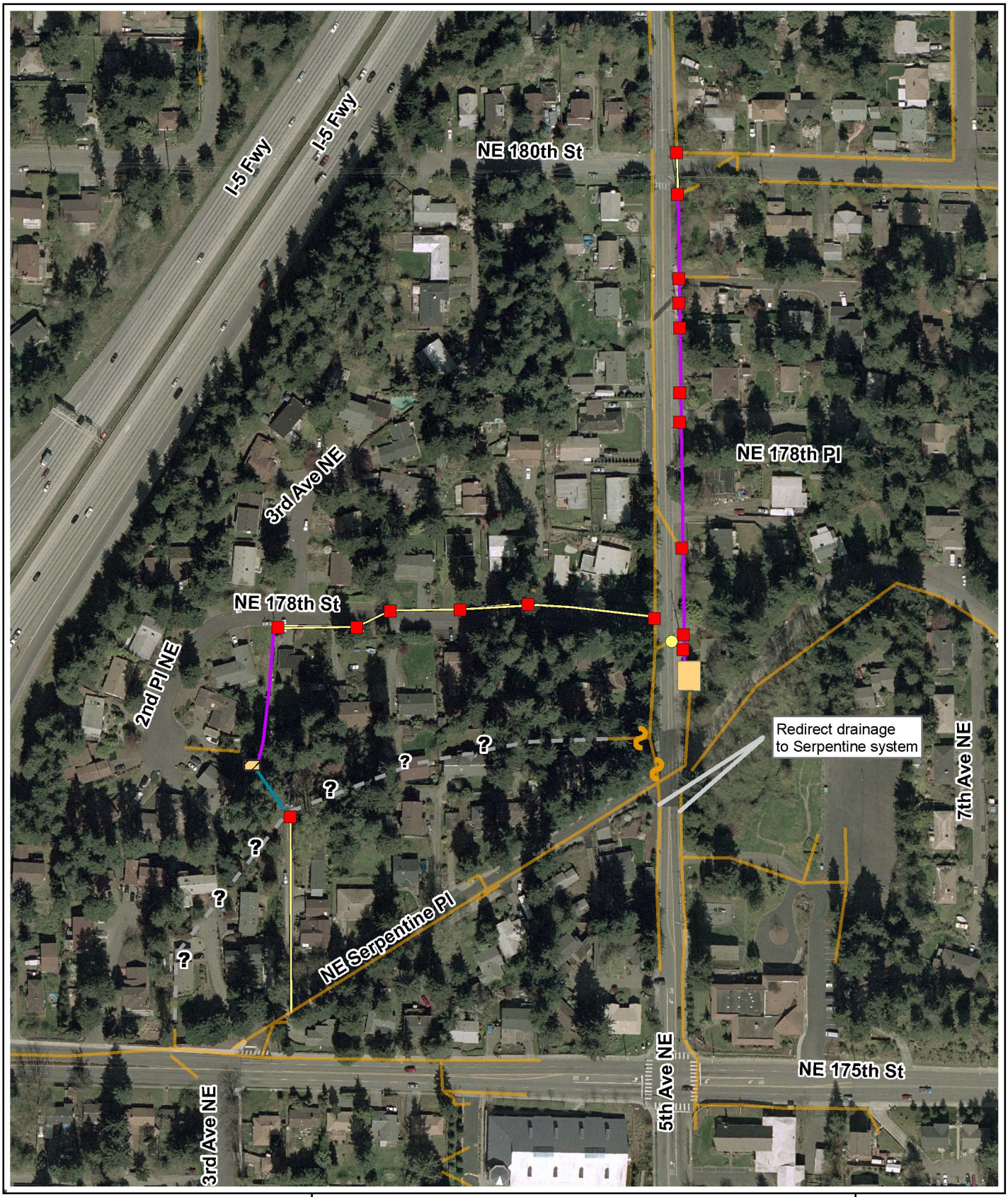

N

0 100 200 400 Feet

Legend

- Proposed catch basin/manhole
- Control structure
- Cap existing pipe
- Storm drain/road side ditch-culvert system
- Ditch
- Proposed Updated Pump Station 25
- Existing Serpentine Pump Station
- Proposed 18-inch-diameter pipe
- Proposed 24-inch-diameter pipe
- Proposed 18-inch-diameter force main
- Storm drain system (location not verified)

Figure 6-6
Problem F3 Solution
Alternative 2
Thornton Creek Watershed Plan
City of Shoreline

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6.2.4 Problem F4: Culvert Near 14849 12th Avenue NE

The recommended solution for this flooding problem (see Figure 4-1, p. 4-3, for location) is to excavate the channel to improve capacity, using the recommendations in Alternative 2 of the *Preliminary Study of Flooding Problems at 14849 12th Avenue NE* (Otak 2001). Currently, the average channel slope is approximately 0 percent between 12th Avenue NE and the upstream end of the surface water management facility in Paramount Park. By excavating for approximately 450 feet downstream from 12th Avenue NE, the channel slope could be increased to an average of 0.1 percent (see Figure 6-7). Although this is not a salmonid-bearing stream reach, the improvements would include habitat-friendly improvements including a small stream meander in the yards of 14849 and 15021 and plantings with native vegetation in the 35-foot Type IV stream buffer. Approximately 150 feet of rock wall will be maintained, and 150 additional feet of rock wall may be constructed, not immediately adjacent to the channel, but at the edge of the flood "bench" along the channel. This would require land acquisition or easements, as well as cooperation with the property owners. Finally, a 20-foot-long by 8-foot-wide by 5-foot-deep sump is proposed at the exit of the culvert at 12th Avenue NE to allow for sedimentation; the sump would be cleaned out as necessary to prevent sedimentation in the channel between 12th Avenue NE and the surface water management facility in Paramount Park.

Permitting Considerations

Littles Creek is likely to be considered a Type IV stream by the City of Shoreline. Type IV streams require a standard buffer width of 35 feet. Alterations (including dredging) to Type IV streams are not authorized by the City of Shoreline and thus a Critical Areas Special Use Permit exception would likely be required to allow for the proposed dredging. Any relocation of the Type IV stream would be allowed pursuant to SMC 20.80.480(G) which states, "Relocation of a Type IV stream shall be allowed only when the proposed relocation will result in equal or better habitat and water quality and will not diminish the flow capacity of the stream." Additionally, permits from the Corps, Ecology and WDFW would likely also be necessary if any alterations to Littles Creek are proposed.

Cost: $212,000

Alternative Solution Hydraulic Analysis

No hydraulic analysis was performed for this alternative.

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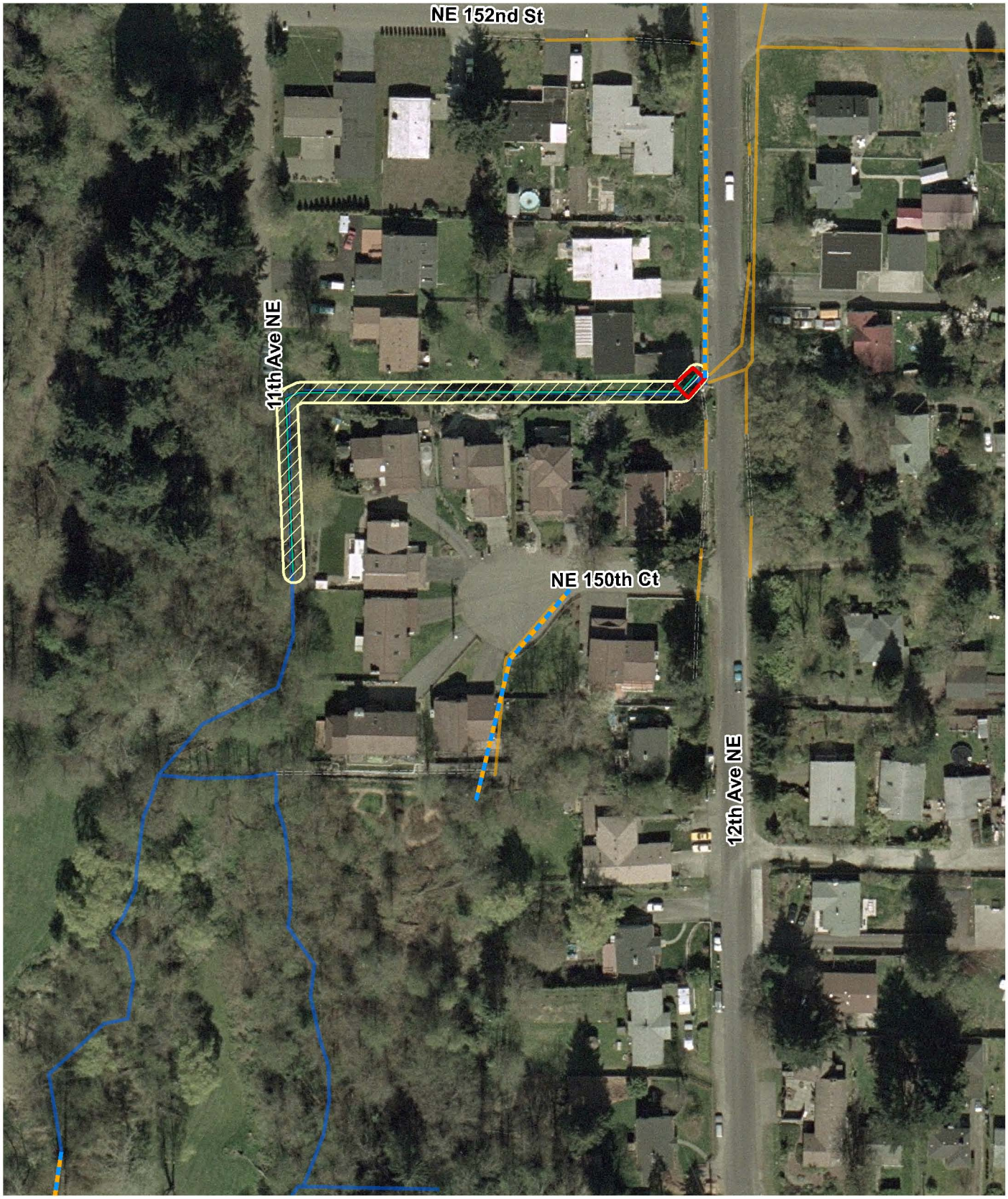

N

0 50 100 200 Feet

Legend

- Storm drain/road side ditch-culvert system
- Ditch
- Proposed sediment sump
- Proposed buffer restoration
- Proposed channel excavation
- Open water course
- Piped Water Course

Figure 6-7
Problem F4 Solution

Thornton Creek Watershed Plan
City of Shoreline

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6.2.5 Problem F5: Local Flooding near 1237 NE 148th Street

The alternative solutions to these problems include a traditional engineered solution and an LID solution. (See Figure 4-1, p. 4-3, for problem location.)

Alternatives

Alternative 1

Alternative 1 is shown in Figure 6-8. The solution includes construction of new 12-inch-diameter storm drain pipe from the inlet location near 1237 NE 148th Street to the storm drain on 15th Avenue NE. The catch basin of NE 148th Street is located in a depression, and there is a non-functional, plugged outlet pipe from the catch basin that is lower than the invert of the nearest storm drain manhole on 15th Avenue NE. To provide positive drainage, 200 feet of 12-inch-diameter pipe would need to be installed along NE 148th Street to 15th Avenue NE and 140 feet of 12-inch-diameter pipe would need to be constructed south along 15th Avenue NE. This conveyance improvement may increase downstream flows slightly, so it is recommended that a downstream analysis be performed before implementing this solution.

Cost: $107,000

Alternative 2

Alternative 2 includes the installation of an infiltration pipe/trench in the roadway shoulder(s) and connecting them to this catch basin. The infiltration trenches could be on the south side or north side or both. No soils or groundwater depth information is available to size the length of the trench. However, since the tributary area is small, the length of required trench would be relatively short. For cost estimating purposes, it was assumed that 100 feet of trench would be required and that the first section of pipe would be oversized and used similar to a wet vault to provide some water quality treatment (sedimentation) prior to infiltration. Alternative 2 is shown on Figure 6-9.

In addition to this improvement, the City could also work with the property owners who contribute runoff to this area to implement LID techniques which would further reduce runoff directed toward the low area. LID techniques such as rain gardens could be used by private property owners to help infiltrate roof, driveway, or sidewalk runoff. An allowance ($5,000) was included in the cost estimate for LID in addition to the infiltration pipe.

Cost: $49,000

Permitting Considerations

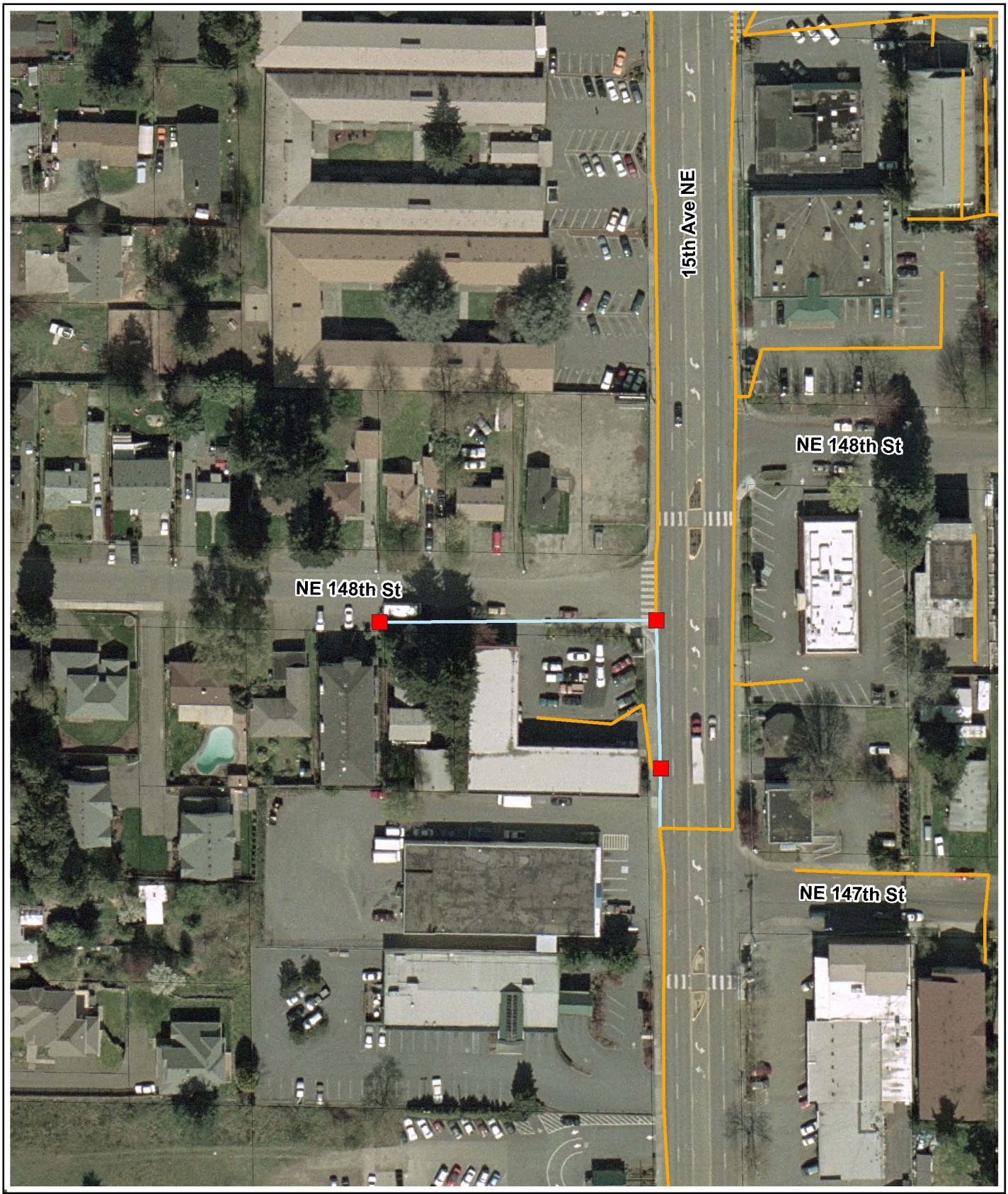
There are no environmental permit requirements for these alternatives.

Alternative Solution Hydraulic Analysis

No hydraulic modeling was performed for this solution.

Recommendation for Problem F5

Implementation of Alternative 2 is recommend along with investigating the use of LID techniques. The City will need to assess the capability of the soils to infiltrate runoff to confirm this alternative will solve the problem and to confirm length of trench required. Should Alternative 2 not be feasible, Alternative 1 should be pursued.



N

0 50 100 200 Feet

Legend

- Proposed catch basin/manhole
- Existing storm drain/roadside ditch-culvert system
- Proposed 12-inch-diameter pipe

Figure 6-8
Problem F5 Solution
Alternative 1
Thornton Creek Watershed Plan
City of Shoreline

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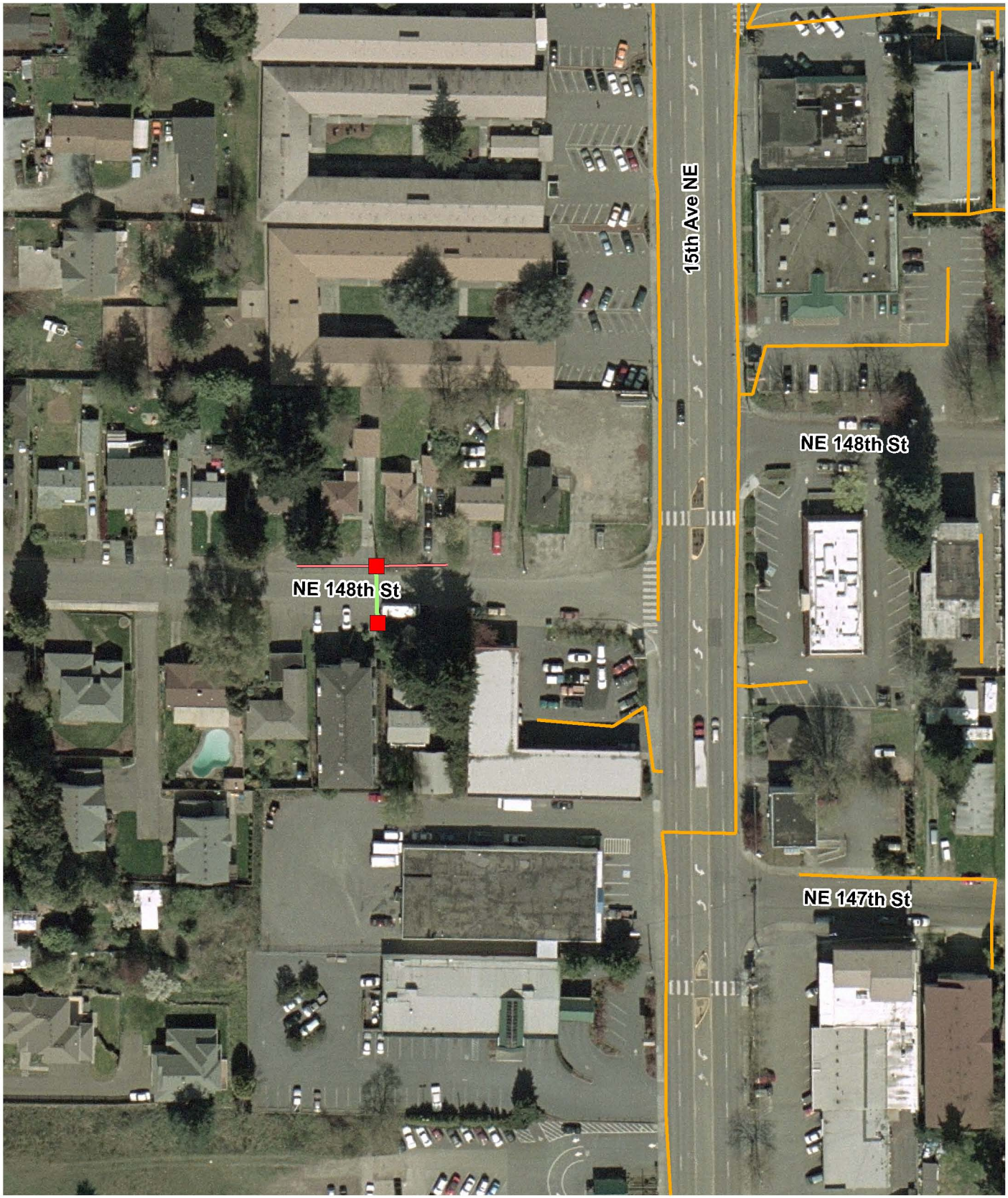

N

0 50 100 200 Feet

Legend

- Proposed catch basin/manhole
- Proposed 24-inch-diameter "dead" storage pipe for treatment
- Proposed 12-inch-diameter infiltration pipe
- Storm drain/road side ditch-culvert system

Figure 6-9
Problem F5 Solution
Alternative 2

Thornton Creek Watershed Plan
City of Shoreline

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6.2.6 Problem F6: NE 175th Street and 10th Avenue NE

To address this flooding problem, three alternatives were developed. (See Figure 4-1, p. 4-3, for problem location.) Alternatives 1 and 2 include detention and conveyance improvements. Alternative 3 includes conveyance improvements only. Refer to Figures 6-10 through 6-12.

Alternatives

Alternative 1

Alternative 1 includes detention and conveyance improvements. For purposes of this report, the solution includes purchasing three properties on the south side of NE 175th Street between 10th and 11th Avenues NE in order to construct a 1.6-acre-foot detention pond. The two lots on the southwest corner of the intersection of NE 175th Street and 10 Avenue NE were also considered, but there is not enough surface area in these lots for a pond of this size. The proposed detention facility would be off-line in a similar manner to the small existing pond in this location. Computer simulations of this facility indicate that this detention facility would reduce downstream flows such that there would be no overflow from the system heading south on 10th Avenue NE for the 25-year storm event.

Even with no contributing flow from NE 175th Street, the system along 10th Avenue NE south of NE 175th Street is still undersized and floods during the 25-year storm event. The proposed solution to address this flooding is to replace the existing storm drain system with an 18-inch-diameter drainage system from about 530 feet south of NE 174th Street to just north of the intersection of NE 165th Street.

Cost: $1,830,000

Alternative 2

Alternative 2 includes the same features as Alternative 1, except instead of a detention pond, a concrete vault would be used to provide detention. For purposes of this report, the vault was located in two lots that are currently being used as a park and ride in the southwest corner of the intersection of 10th Avenue NE and NE 175th Street. Using a vault would be much more expensive than constructing a pond, but it allows the site to continue to be used as a parking lot. These lots are barely large enough to fit the size of vault required and construction easements will likely be needed on adjacent properties in order for it to be constructed.

Cost: $3,250,000

Alternative 3

Alternative 3 includes conveyance improvements only. The solution includes replacing almost 2900 feet of pipe with 24-inch-diameter pipe from the low spot on NE 175th Street about 160 feet east of the intersection with 10th Avenue NE, down 10th Avenue NE to NE 165th Street, and along NE 165th Street, about 80 feet from

the intersection with 10th Avenue NE. The pipe replacement needs to be extended to the low spot on NE 175th Street in order to alleviate the flooding at this location.

Cost: $960,000

Permitting Considerations

None of the alternatives would require environmental permits. However, Alternative 3 would increase downstream flows, which would have the potential to be detrimental to fish and wildlife habitat. Alternative 1 would require the acquisition of 3 homes. Alternative 2 would require acquisition of permanent easements for the underground vault.

Alternative Solution Hydraulic Analysis

In order to evaluate these alternatives, the XP-SWMM model developed for the Littles Creek existing conditions was updated to incorporate the proposed improvements. The alternative conditions computer models indicate that downstream flows at NE 165th Street would increase from about 2.6 cfs under existing conditions to about 5.5 cfs for Alternatives 1 and 2 and 17.6 cfs for Alternative 3 for the 25-year storm event. The detention proposed for Alternatives 1 and 2 eliminates any overflows from NE 175th Street and does not cause any increase in downstream peak flows. However, the improvements along 10th Avenue NE increase the conveyance, which increases downstream flows for all three alternatives.

Recommendation for Problem F6

A comparison of the three alternatives is presented in Table 6-5. Alternative 1 is the recommended solution. While it appears to be more costly than Alternative 3, Alternative 3 significantly increases downstream flows. As a result, it is likely that Alternative 3 would require additional costly improvements downstream to accommodate the increase in flow. The downstream system, including Thornton Creek, has a history of flooding and fish and wildlife habitat issues. The increase in peak flows would exacerbate flooding at other locations downstream. In addition, erosion would likely be detrimental to fish and wildlife habitat.

It should be noted that Alternative 1 also results in an increase in downstream flows, albeit a much less significant increase. A downstream analysis is recommended prior to implementing this solution to determine the extents of the impacts resulting from the flow increase and to evaluate the improvements required to mitigate the impacts.

Table 6-5
Evaluation of 10th Avenue Alternatives (Problem F6)

Alternative	Cost	Effectiveness in Solving Problem	Impacts to Neighborhoods	Ease of Permitting	Downstream Impacts	
					Flows	Water Quality
Alternative 1 – Pond plus 1570' of 18" storm drain	$1,830,000	▪ Provides flood protection for 25-year event. ▪ Also reduces peak flow to the Serpentine System.	▪ Requires acquisition of three properties. ▪ The pond will be visible to the neighborhood.	▪ Few permits necessary	▪ Increases downstream flows from 2.6 cfs to 5.5 cfs for the 25-year storm event. An assessment of downstream impacts would be required prior to implementation.	▪ This alternative could incorporate water quality treatment at the pond.
Alternative 2 – Vault plus 1570' of 18" storm drain	$3,250,000	▪ Provides flood protection for 25-year event. ▪ Also reduces peak flow to the Serpentine system.	▪ Requires an easement for at least 2 properties. ▪ A parking lot can be rebuilt over top of the vault. ▪ The vault may not fit under just 2 properties and more land may be required. At a minimum, construction easements would be needed from neighboring properties.	▪ Few permits necessary	▪ Increases downstream flows from 2.6 cfs to 5.5 cfs for the 25-year storm event. An assessment of downstream impacts would be required prior to implementation.	▪ This alternative could incorporate a wet pool volume in the vault.
Alternative 3 – 2872' of 24" storm drain	$960,000 (1)	▪ Could be designed to provide flood protection for 100-year storm event.	▪ Lower impact to neighborhood since work is primarily within the 175th Street and 10th Avenue rights-of-way.	▪ Few permits necessary	▪ Increases downstream flows from 2.6 cfs to 17.6 cfs for the 25-year storm event. An assessment of downstream impacts would be required prior to implementation. It is highly likely that additional downstream improvements would be necessary if this solution is implemented.	▪ This alternative provides little opportunity for water quality treatment. ▪ Could increase erosion of downstream channels due to higher flows.

1 Does not include cost of possible downstream improvements needed to accommodate the increase in peak flows.

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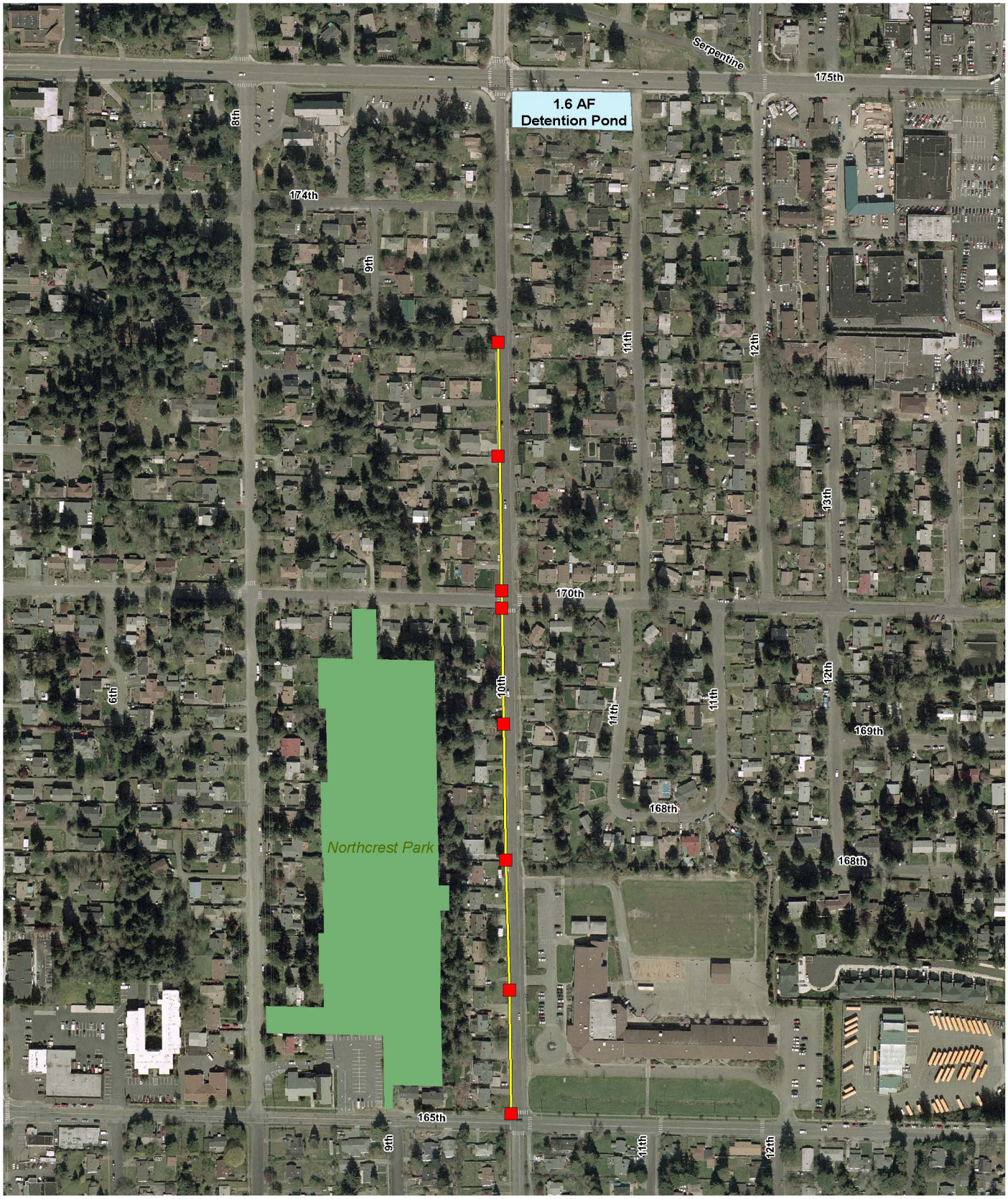

N

0 175 350 700 Feet

Legend

- Proposed catch basin/manhole
- Proposed 18-inch diameter storm drain
- Proposed detention pond
- Parks

Figure 6-10
Problem F6 Solution
Alternative 1
Thornton Creek Watershed Plan
City of Shoreline

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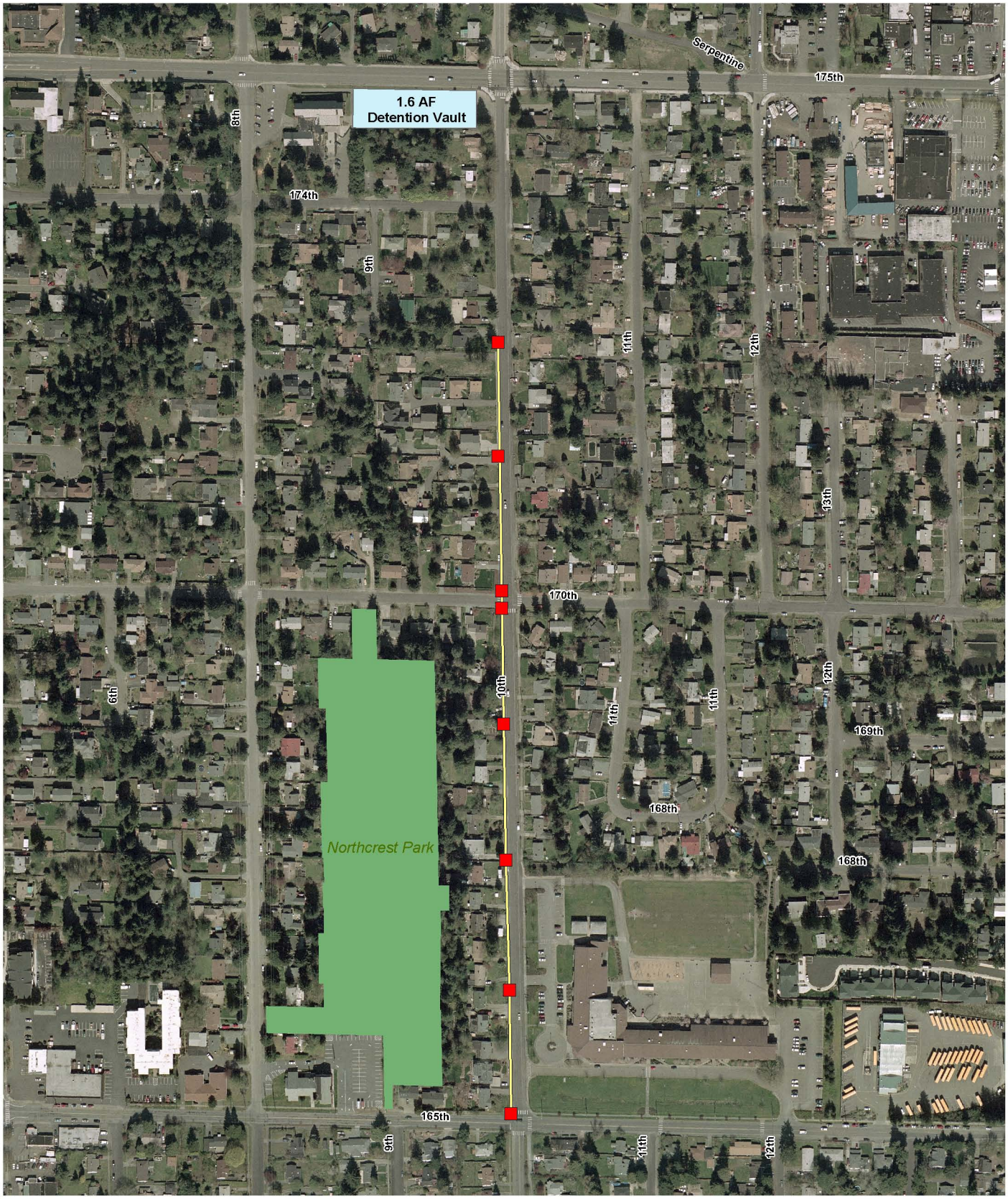

N

0 175 350 700 Feet

Legend

- Proposed catch basin/manhole
- Proposed 18-inch-diameter storm drain
- Proposed detention vault
- Parks

Figure 6-11
Problem F6 Solution
Alternative 2

Thornton Creek Watershed Plan
City of Shoreline

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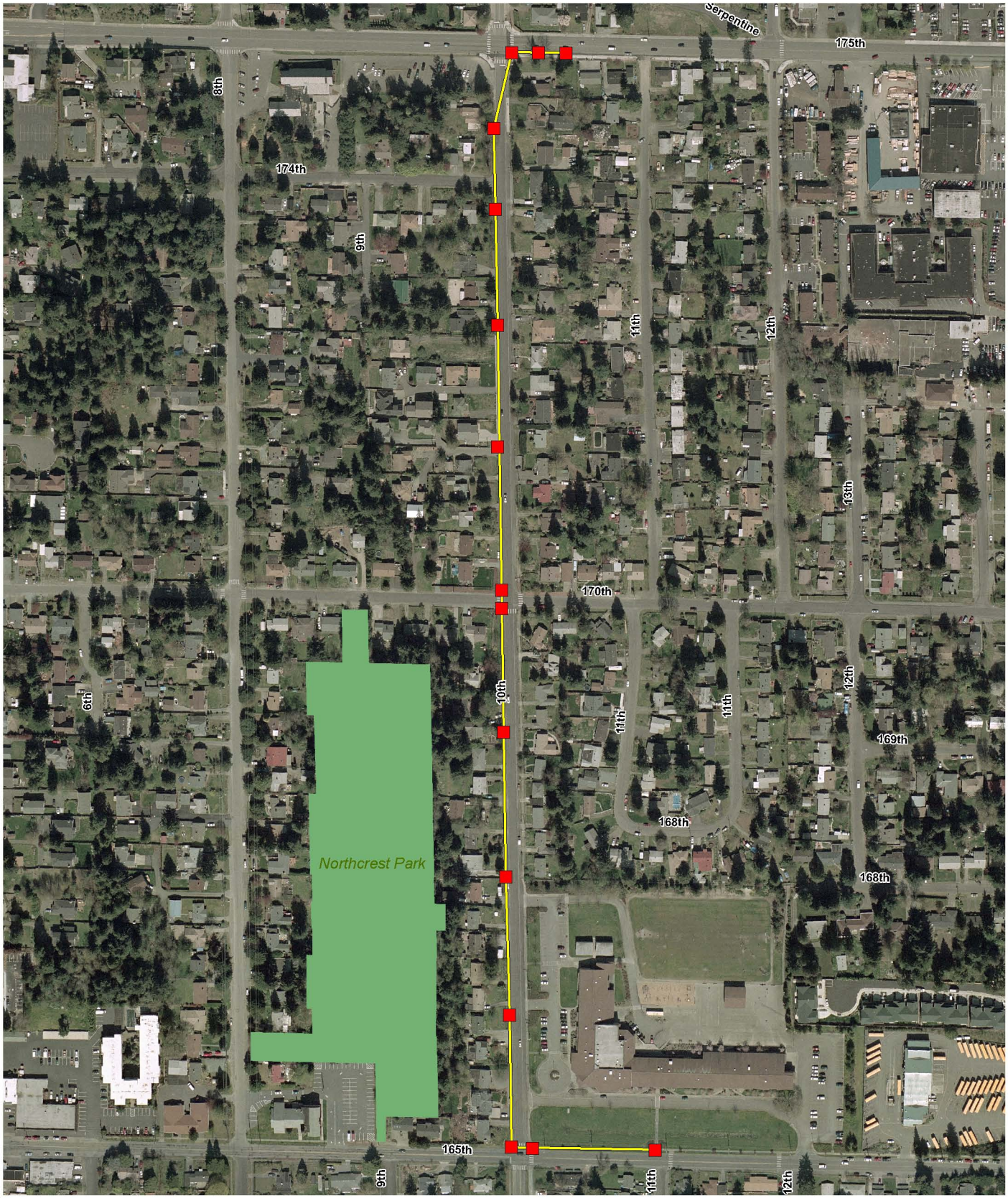

N

0 175 350 700 Feet

Legend

- Proposed catch basin/manhole
- Proposed 18-inch-diameter storm drain
- Parks

Figure 6-12
Problem F6 Solution
Alternative 3
Thornton Creek Watershed Plan
City of Shoreline

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6.2.7 Problem F7: N 167th Street and Wallingford Avenue N

To address this flooding problem, three alternatives were developed. (See Figure 4-1, p. 4-3, for problem location.) Alternative 1 upgrades the existing system. Alternative 2 includes replacing under-capacity pipe with open channel sections. Alternative 3 includes replacing a portion of the system with open channel. Note that no analysis was performed for these alternatives. Information on the alternatives and costs was developed with information provided by the City.

Alternatives

Alternative 1

This alternative includes replacing both the low- and high-flow pipe systems from the open channel section behind the property at 16533 Wallingford Avenue N to the ditch in Wallingford Avenue N with 12- to 18-inch-diameter pipe.

Cost: $86,000

Alternative 2

This alternative includes replacing the low- and high-flow pipe systems with open channel instead of larger pipe. This has the advantage of providing the potential for more fish habitat and, therefore, WDFW would likely permit this alternative.

Cost: $81,000

Alternative 3

Alternative 3 includes replacing the high-flow system with a lower open channel with a small section of larger pipe across a driveway. This would leave the main line low-flow route in place but would make that active only during higher flow events.

Cost: $66,000

Permitting Considerations

An HPA from WDFW would likely be required. As noted above, WDFW may have a preference for Alternative 2.

Alternative Solution Hydraulic Analysis

No hydraulic modeling was performed for this solution.

Recommendation for Problem F7

Alternative 2 is recommended because it would provide more fish habitat and be easier to permit.

6.2.8 Regulatory Measures to Address Flooding Problems

Regulatory measures can sometimes be used to help solve flooding problems by reducing runoff rates and volumes of stormwater runoff. Such measures are applied to new development and redevelopment. Examples include:

- More stringent stormwater detention standards that store runoff volumes on-site.
- Requiring low impact development (LID) techniques where practical. LID includes measures that increase the percentage of precipitation that is infiltrated on the site in order to reduce runoff rates and volumes, which will reduced flooding potential and protect water quality. Minimum levels of LID are included in the recently adopted standards where practical and additional LID measures are encouraged by the City. Examples of LID include rain gardens and bioretention; rooftop gardens; vegetated swales, buffers, and strips; tree preservation; roof leader disconnection and infiltration systems; rain barrels and cisterns; permeable pavers; soil amendments; impervious surface reduction; and impervious surface disconnection.
- Administrative Orders in the Engineering Development Guide such as the restrictions on filling of drainage ditches within the right-of-way that could result in the loss of the infiltration capability and increase system flows. Regulations for development in the floodplains are another measure to reduce flooding in areas in the future.

To achieve these goals for reducing stormwater impacts from development, protection of water resources, and compliance with state and federal stormwater requirements including the Phase II NPDES permit, these types of regulatory measures are being implemented city-wide with the adoption of a new stormwater code in 2009. The new code adopts the 2005 *Ecology Stormwater Management Manual for Western Washington*, which includes stricter water quality and detention standards for development than were previously required, LID and emerging water quality technologies for handling stormwater runoff.

The watershed plan considered a recommendation that the City adopt more stringent stormwater standards, which go beyond the state requirements, in frequently flooded areas such as Ronald Bog. However, because the City is mostly built out, benefits resulting from these more stringent standards would not be apparent for many years, as they would occur along with the long-term redevelopment in the basin. At the same time, basin management is a lifelong endeavor, and the City acknowledges that it may consider such recommendations in the future. For this reason, it was not included as a solution to any of the specific flooding problems discussed above.

6.2.9 Programmatic Measures to Address Flooding Problems

Programmatic measures are activities such as maintenance of stormwater infrastructure, water quality monitoring, and public outreach.

The City's existing maintenance activities include: clearing catch basins, drainage ditches and pipes to maintain conveyance capacity; sweeping streets and cleaning catch basins to remove solids and associated metals that become bound to these solids; maintaining regional and residential stormwater facilities to make sure they are functioning properly; and inspecting commercial and residential water quality stormwater facilities to ensure they are maintained to achieve their objectives.

Through events, workshops, and field activities, the City promotes recycling; natural yard care and sustainability; storm drain stenciling; green remodeling; and habitat restoration. The City reminds owners of private stormwater systems that they are responsible for their maintenance. The City encourages voluntary actions by, for example, informing the public of the benefits of using LID techniques and natural yard care on private property.

Programmatic measures also include proper planning for the replacement of existing infrastructure. Replacement of existing infrastructure provides an opportunity to incorporate LID measures to reduce runoff, improve water quality and provide for a more healthy watershed. For example, this could include using LID in the right-of-way to improve water quality treatment and bioretention or removing pipes and creating open channels where possible. The City's 2010 CIP includes a green infrastructure program to develop a plan to implement LID measures.

In addition, the City has also adopted an Illicit Discharge Detection and Elimination (IDDE) Program in order to meet the conditions of the NPDES permit. The IDDE program will look for and eliminate illicit discharges via direct connections (e.g., wastewater piping either mistakenly or deliberately connected to the storm drains) or indirect connections (e.g., infiltration into storm drains or creeks from cracked sanitary systems, spills collected by drain outlets, or paint or used oil dumped directly into a drain).

This watershed plan makes the following specific programmatic recommendations:

- The City should encourage home and business owners to keep catch basin grates free of leaves and debris.
- The City should develop more watershed-specific outreach activities within the Thornton Creek watershed. One possible example may be an outreach program to streamside residents on natural yard care practices and encouragement of native riparian planting; both can locally improve stream habitat and water quality.
- Existing and future water quality and stream monitoring activities on Thornton Creek will allow the City to monitor stream health; the monitoring results may be used to guide the capital projects, outreach activities, and regulations accordingly to improve watershed conditions. In addition, monitoring could be

used to assess performance of improvements made in the watershed to determine if adaptive management measures are appropriate.

- One specific maintenance activity worth noting involves the 30-inch-diameter outlet pipe and downstream channel system from Ronald Bog, which is very flat and subject to sediment accumulation. Built-up sediments can reduce system conveyance capacity and result in higher water surface elevations in Ronald Bog during flood periods. The 30-inch pipe is aging and eventually needs to be replaced; but currently, annual maintenance to remove sediment and prevent root intrusion is recommended. In addition, an annual maintenance program for the open channel system between N 171st Street and N 167th Street is strongly recommended.

6.3 Projects to Protect and Enhance Wetlands and Habitat

6.3.1 Problem AQ1: Ronald Bog Outlet Pipe and Catch Basin

Problem: As identified in Otak 2001 and Tetra Tech/KCM 2004, the 650-foot-long, 30-inch-diameter outlet pipe from Ronald Bog and associated catch basin have been postulated to be a barrier or partial barrier to upstream-bound fish movements. (See Figure 4-1, p. 4-3, for problem location.) However, as described previously in Section 3.4.3, this problem may have been overstated. WDFW's *Design of Road Culverts for Fish Passage* (WDFW 2003, chapter 5), requires that velocities be at or below 2 feet per second at the fish passage design flow for longer culverts to allow for the upstream passage of 6-inch trout and larger salmonid fish. Recent calculations (NHC 2008) have indicated that velocities through the pipe are lower than the 2 feet per second which would be required. Cutthroat trout and other salmonid fish are known to be able to pass fairly readily through very long, dark culverts where velocities are low (Holser, personal communication, 2008). Though the existing Ronald Bog outlet pipe would not meet all current WDFW design standards for new culvert placement, it does not appear to present a velocity barrier to upstream fish movement, and therefore may only present a partial barrier or hindrance to upstream fish movement. Furthermore, the present need for providing fish passage at this location in the basin is not great, as it lies well upstream of any anadromous fish use and near the upstream extent of fish use of any kind within the basin.

Solution: The proposed solution to this partial fish passage problem is to make improvements with respect to fish passage on the existing system as opportunities allow through the course of maintenance, repair, and upgrades. Ultimately, some years hence, the entire Ronald Bog piped outfall system will likely need to be significantly upgraded and/or replaced, at which time it could (or may be required to) be brought up to fish passage design standards for new construction. Such an upgrade would likely include some combination of a larger culvert size (such as a concrete box culvert or possibly a larger-diameter pipe), possible short or moderate-length daylighted sections, a gravel substrate, roughness elements within the channel or culvert sections, and some level of streamside planting for any daylighted sections. It may also be possible to work with WDFW and replace this pipe system using an

alternative fish passage approach, hydraulic design method, which would result in a smaller size system. In the meantime, repairs to and/or maintenance of the existing system should be conducted in a manner which will maintain or reduce existing low velocities.

Cost: $4.5 million to $5 million (but could be less if the City were to negotiate a smaller conveyance system size)

6.3.2 Problem AQ2: Wetland Fringe Areas Around Ronald Bog Park

Problem: Wetland fringe and buffer habitat areas around Ronald Bog Park are in need of enhancement. Specifically, wetland and buffer areas along the east edge of the park are infested with invasive Himalayan blackberry, lack a diverse native plant assemblage, and habitat structures. (See Figure 4-1, p. 4-3, for problem location.)

Solution: The project as envisioned would include excavation as needed to provide wetland hydrology to approximately an additional acre of area that is now upland or only marginal wetland; enhance and restore the inlet stream channel as fish and wildlife habitat, including the placement of log structures; remove existing non-native vegetation including Himalayan blackberry, knotweed, and nightshade; supplement topsoils; and implement a native revegetation plan.

Permitting: Enhancement of wetland fringe areas around Ronald Bog, including extensive excavation and stream channel improvements, would require permits from the Corps, Ecology, WDFW, and the City of Shoreline, as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: $580,000

6.3.3 Problem AQ3: Flow Splitter Upstream of Twin Ponds

Problem: The flow splitter upstream of Twin Ponds has previously been identified as a fish passage barrier (Tetra Tech 2004, Appendix C). (See Figure 4-1, p. 4-3, for problem location.) Pipe slope information for this assessment was taken from a memorandum from R. W. Beck to the City of Shoreline dated May 14, 2007 (R. W. Beck 2007b), which evaluated the peak flows in this flow split. It appears that this flow splitter may not be as definitive a fish migration barrier as stated. Slopes within the piped system are less than 1 percent with no drops or plunges. Similarly to the discussion regarding the outlet pipes from Ronald Bog, the WDFW design velocity criteria for long culverts in excess of 200 feet is 2 feet per second at and below the 10 percent exceedance flow. Even if this fish passage velocity criterion for culvert design is not strictly met, it is unlikely that the flow splitter and associated pipe system are a definitive migration barrier for all fish all the time. Subject to confirmation, velocities through the pipes associated with the splitter may be at or below 2 feet per second for much of the time, and some fish may be able to pass at marginally higher velocities.

A somewhat related problem is the quantity of flow that passes through the low flow path. An existing agreement was recorded in 1963 between the Washington State

Department of Transportation (WSDOT) and the property owner (Surface Drainage Agreement Property) that defines the maximum flow allowed to enter the low flow pipe system to be 17 cfs. The storm event is not specified in the agreement, but it is reasonable to assume for this evaluation that the 17 cfs maximum flow limitation should apply to the 100-year storm. Recent modeling done for the FEMA floodplain study estimates that the peak discharge to the low flow path at approximately 22 cfs (personal communication, NHC 2009), which exceeds the agreed upon flow. Since the agreement is between WSDOT and the property owner, detailed recommendations are not presented in this report.

Solution: The migration barrier and other habitat impacts associated with the flow splitter are essentially the same as would be at issue with any other piped section of stream channel. As such, the best project to propose at and in the vicinity of the splitter would be to daylight and restore as much of this piped stream system as is feasible, preferably all of it. Survey information accompanying the R. W. Beck memo (2007b) shows that low flow is piped beneath the open channel for nearly 250 feet before turning, still piped, to the west. That section of pipe, at least, could be eliminated, replacing the diversion structure at or much closer to the point where the low flows are directed to the west. Any modifications to the size and shape of the diversion pipe inlet to control diverted flows should also be designed to accommodate fish passage.

Stream restoration is recommended to include 1) the demolition and removal of at least portions of the existing pipe and concrete channel system and replacement with an open stream channel, 2) the removal of non-native invasive vegetation, 3) placement of in-stream log structures and spawning gravels, and 4) native riparian revegetation for bank stabilization, shading, eventual woody debris recruitment, and general wildlife habitat.

Cost: $257,000

6.3.4 Problem AQ4: Log Structures in Twin Ponds Park

Problem: In Twin Ponds Park (see Figure 4-1, p. 4-3, for location), log structures have been placed below a culvert upstream of the ponds to effectively backwater it and eliminate a previously described (Tetra Tech/KCM 2004; R. W. Beck 2005) plunge at its outfall. Hence, it is now passable. As can be seen in Photo 6-1, however, a moderate plunge now occurs at the lower log structure. While not ideal fish passage conditions, this is not a definitive or complete fish passage barrier. However, it could stand some improvement as described below.

No other barriers to fish passage in the vicinity of Twin Ponds were found.

Photo 6-1. *Facing north (upstream) along the North Branch channel upstream of Twin Ponds, 12/27/08.*

Photo 6-2. *View of the same culvert on 12/3/08.*

Solution: In-stream work is recommended immediately below the log structure pictured above to 1) raise the channel profile slightly (one foot or slightly less) to reduce the plunge height over the logs and 2) form a plunge pool below the logs. These changes will reduce plunges to fish-passable heights. Additional enhancement work which could be done in this vicinity includes lining the culvert with spawning sized gravel and adding additional native vegetation along the streambank proceeding upstream to NE 155th Street (especially along the left bank). The addition of interpretive signs to the park could benefit public education.

Permitting: In-stream improvements would require permits from the Corps, Ecology, WDFW and the City of Shoreline as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: $60,000

6.3.5 Problem AQ5: Culvert Beneath 1st Avenue NE

Problem: The culvert beneath 1st Avenue NE may be a low-flow fish blockage (Tetra Tech/KCM 2004; R. W. Beck 2005). (See Figure 4-1, p. 4-3, for problem location.)

Solution: Modify culvert and adjoining channel to conditions that result in adequate water depth within the culvert, as feasible, for fish passage at low flows.

Permitting: In-stream improvements would require permits from the Corps, Ecology, WDFW and the City of Shoreline as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: $19,000

6.3.6 Problem AQ6: Outfall from Peverly Pond

Problem: The outfall from Peverly Pond is a barrier to upstream fish migration as the water plunges out of the pond and into the concrete-lined, canal-like ditch conveying flow southward along the west side of Interstate 5. (See Figure 4-1, p. 4-3, for problem location.) Three alternatives for solving this problem are described as follows:

- **Alternative 1.** Install a series of grade controls, increasing in elevation and with intervening pools and woody cover, along the concrete channel leading up to the outlet of Peverly Pond such that the plunge from the pond is reduced to a fish-passable height of 0.8 foot or less. The resulting “dammed” section of the concrete channel extending upstream of the pond outlet could be supplemented with additional woody cover and would serve to provide a significant amount of off-channel, beaver-dam-like rearing habitat for coho and/or cutthroat juveniles. WSDOT could be encouraged to implement this project as mitigation to offset impacts elsewhere.
- **Alternative 2.** Drain the pond and provide a fish-passable channel in its place (as may have been the natural condition). The restored channel section would be approximately 230 feet in length. This solution has a disadvantage in that

draining the pond would incur significant wetland impacts, though at least partially compensated for by improved stream channel habitat.

- **Alternative 3.** Build a concrete fish ladder connecting the pond outlet to the concrete channel extending downstream.

Alternative 1 is recommended because Alternative 2 may not be feasible due to wetland impacts and the loss of Peverly Pond; and because while Alternative 3 provides nuts and bolts fish passage, it provides few if any other habitat benefits.

Permitting: In-stream improvements would require permits from the Corps, Ecology, WDFW and the City of Shoreline as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: $257,000

6.3.7 Problem AQ7: Culvert under I-5

Problem: The approximately 1,950-foot-long culvert under I-5 is a fish passage barrier (Tetra Tech 2004, Appendix C). (See Figure 4-1, p. 4-3, for problem location.)

Solution: Action by the City of Shoreline is not indicated. Encourage WSDOT to provide a fish-passable culvert under I-5 at this location.

Permitting: In-stream improvements would require permits from the Corps, Ecology, WDFW, and the City of Shoreline as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: N/A, would be estimated as part of a WSDOT project.

6.3.8 Problem AQ8: Channel from Twin Ponds Upstream to Meridian Avenue N

Problem: Salmonid fish use becomes doubtful proceeding upstream to Meridian Avenue N from Twin Ponds due to the cumulative effects of the stagnant, weed-choked channel. (See Figure 4-1, p. 4-3, for problem location.)

Solution: Restore the channelized stream sections, approximately 600 feet in length, from Twin Ponds upstream to Meridian Avenue N near the Evergreen School. Add spawning-sized gravel and in-stream structure for substrate/habitat improvement. Add native vegetation for bank stabilization and stream canopy cover. Maintain or thin existing alders currently on-site to accommodate vegetative diversity.

Permitting: In-stream improvements would require permits from the Corps, Ecology, WDFW, and the City of Shoreline as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: $278,000

6.3.9 Problem AQ9: Restoration Project in Paramount Park Open Space

Problem: Invasive plant species are invading the restoration project in the Paramount Park Open Space (Tetra Tech/KCM 2004; R. W. Beck 2005). (See Figure 4-1, p. 4-3, for problem location.)

Solution: Eradicate invasive plant species, such as Himalayan blackberry and Japanese knotweed (Tetra Tech/KCM 2004; R. W. Beck 2005). The estimated area to be cleared is 120,000 square feet (2.75 acres). Plant additional native riparian vegetation including native conifers and deciduous trees.

Permitting: No state or federal permitting would be necessary. Local permits would likely be required to remove existing invasive species and implement restoration plantings.

Cost: $544,000

6.3.10 Problem AQ10: Hamlin Creek Habitat Problems

Problem: Habitat problems identified or confirmed for Hamlin Creek in the 2000 *Thornton Creek Watershed Characterization Report* (SPU 2000) focus on the high proportion of piped stream length and the poor habitat with little vegetative cover along the ditched and piped sections extending southward from the campus along 20th Avenue NE. (See Figure 4-1, p. 4-3, for problem location.)

Solution: The Washington Department of Social and Health Services (DSHS) is in the process of preparing a master plan for the portions of the Fircrest Campus (located in the City of Shoreline) not used by the Fircrest School or the Department of Health (DOH). One element of the master plan is a proposal to daylight and/or restore sections of upper Hamlin Creek which are now conveyed in piped and ditched systems across the property. The proposed daylighting and enhancement of the drainage system is intended to largely restore natural stream headwater functions including biofiltration, water infiltration and storage, wetland and wildlife habitats, and, in general, to provide high-quality, less flashy flows to downstream fish and wildlife habitat areas (AHBL Inc. 2008.)

Habitat function would be improved by daylighting some presently piped sections as well as enhancing some existing, open-channel ditched sections. Biologically diverse, well-vegetated stream buffer areas would be created as space allows, also contributing to improved in-stream habitat, especially where new channel sections are created in place of piped conveyances. The proposed new channel alignment has been chosen (on a conceptual level) to provide improved channel characteristics and sinuosity without excessive grading or clearing. Nearly all of the area proposed for the creation of the new, daylighted channel has been disturbed by previous development, now largely removed. Dense planting of the stream corridor with native species, along with planned maintenance and monitoring efforts, will help prevent encroachment by Himalayan blackberry and other non-native species

Permitting: Drainage improvements would require permits from the Corps, Ecology, WDFW, and the City of Shoreline as discussed in Section 6.2.1 for Flooding Problem F1.

Cost: $500,000

6.3.11 Problem AQ11: Lack of Coarse-Grained Sediment

Problem: Much of the length of the Thornton Creek channel lacks coarse-grained sediment and much of the watershed lacks sufficient access to floodplain sediment and in-stream structure to trap and accumulate sediment. While this shortcoming tends to be more prevalent in the lower channel segments in the basin that carry more flow, primarily those downstream of Shoreline in the City of Seattle, it also applies to certain stream segments higher in the basin within the City of Shoreline. It should be noted, however, that lower-gradient, headwater stream segments such as those that flow through marshy areas would not naturally be lined with such coarse-grained sediments (gravel) and it would not be appropriate to artificially supply gravel to those areas. An application of a combination of the solutions listed below is intended to address sediment-starved channel sections on a reach-specific basis within Shoreline. It is not intended to address the problem basin-wide, i.e. extending downstream through stream segments within the City of Seattle. Supplying gravel to these lower stream sections by increasing gravel supply to headwater reaches within the City of Shoreline is largely impractical due to the presence of existing in-stream waterbody impoundments approaching the city limits. In-stream gravels cannot be expected to pass through Twin Ponds and Peverly Pond to supply downstream channel sections since such gravels would just accumulate in these impoundments instead.

Solution 1: Reduce bank armoring and streambed grade controls where feasible; allow stream access to floodplain gravel through channel migration.

Solution 2: Provide in-stream structure to catch and accumulate sediment, particularly where channel downcutting is noted as occurring.

Solution 3: Introduce additional gravel supply to the upstream portions of sections of the stream that are sediment-starved and/or at locations where such gravel would be effectively distributed downstream. Examples of such locations are *downstream* of in-stream ponds or low-gradient reaches. It would be inappropriate to supply gravel immediately upstream of such low-gradient stream sections because they tend to accumulate course sediments and prevent, rather than accommodate, their movement farther downstream.

Permitting: In-stream improvements would require permits from the Corps, Ecology, WDFW, and the City of Shoreline as discussed in Section 6.2.1 under Alternative 1 for Flooding Problem F1.

Cost: $30,000 – $60,000

6.3.12 Problem AQ12: Coho Prespawn Mortality Rates

Problem: Coho prespawn mortality rates are high, averaging 79% throughout Thornton Creek (in comparison to Fauntleroy [39%], Piper's [56%] and Longfellow [71%] Creeks [City of Seattle 2007]). The causes are not fully understood, but are likely closely linked to water quality issues associated with streams in highly urbanized basins, epitomized by Thornton Creek. As headwater areas, the portions of the Thornton Creek basin within the City affect the habitat quality and suitability of the entire length of channel downstream through water quality and quantity, and related issues such as sediment transport. Without contributions in the form of suitable water quality—in particular, from the headwater, City of Shoreline portions of the Thornton Creek basin—improvements in coho prespawn mortality rates may not be realized. Habitat issues in Thornton Creek, especially as they relate to anadromous salmonid fish, are essentially basin-wide issues that do not relate to political boundaries such as city limits. Salmonid fish production is a regional heritage and a hallmark of stream health. By doing its share to improve Thornton Creek water and habitat quality in the headwater areas within the City, the City of Shoreline contributes to the overall health of the watershed.

Solution: Contribute to projects that improve water quality with the expectation of decreasing coho prespawn mortality downstream. Implementation of LID and best management practices are likely to improve water quality through increase infiltration and bioretention. Improvements in the City of Shoreline water quality may improve spawning success further downstream in lower Thornton Creek. It is also possible that the same cause(s) for coho prespawn mortality may also be adversely affecting coho juveniles and other fish and aquatic biota throughout the watershed. Investment in water quality projects may prove beneficial to multiple species and life stages.

Cost: $200,000

6.4 Projects to Improve Water Quality

Proposed measures to improve water quality in Thornton Creek include a combination of structural, non-structural, and programmatic solutions. As discussed below, these include projects and programs proposed in the *2005 Surface Water Master Plan* (R. W. Beck 2005) and several new measures proposed in this report specifically for Thornton Creek.

As stated in Section 3.5, Ecology included portions of Thornton Creek in Seattle (downstream of the City of Shoreline) on the 303(d) list, indicating impaired water quality conditions for fecal coliforms, temperature, and dissolved oxygen. Ecology has not yet completed a TMDL study for Thornton Creek, and Thornton Creek is not included in any TMDL studies or plans scheduled for 2009.

Ecology allows for implementation of a qualifying action plan by Shoreline and Seattle prior to implementation of a TMDL, which would allow Thornton Creek to be re-categorized as "polluted waters that do not require a TMDL" (Water Quality Assessment Category 4b). Ecology (2009a) states that "communities do not have to wait for a formal TMDL planning process and can grab the initiative to create

programs to clean up polluted waters. Because these programs are locally controlled, there is an opportunity to reduce overall costs and for the communities to exert greater control over the cleanup process." Department of Ecology staff (Lee 2009) indicate that the kind of actions described below could satisfy the expectations for re-categorizing sections of Thornton Creek in Seattle.

Ecology's guidance (Ecology 2009b) also states, "while pollution control programs are not TMDLs, they must have many of the same features and there must be some legal or financial guarantee that they will be implemented." This likely means that a 4b Plan would require more formal commitments by the City of Shoreline, as well as coordination with Seattle.

A voluntary action plan would be preferable to potentially rigid TMDL requirements that Ecology could include as conditions in the City of Shoreline's NPDES Permit. However, regardless of whether the actions are compulsory or voluntary, undertaking these actions now would provide real benefits to Thornton Creek, and coordination between the cities of Shoreline and Seattle on monitoring, projects, and programs would make more effective use of both cities' resources

The Master Plan recommends a number of water quality projects and programs that are applicable to the Thornton Creek Watershed (Table 6-6). All of the programs have city-wide applicability and are ongoing, and therefore are not discussed in detail within this Watershed Plan. The two projects include adding water quality features for the proposed Cromwell Park detention facility as well as adding a wetpond to the existing detention pond in the Ridgecrest neighborhood in the vicinity of 10th Avenue NE.

The proposed Cromwell Park detention facility, being constructed in 2009, has many associated water quality attributes, including one acre of infiltration area with amended soils, wetland enhancement, and wetland creation.

The improvements to the detention pond in the Ridgecrest neighborhood are not currently scheduled but may be proposed in the future based upon project priorities and available funding.

Table 6-6
2005 City of Shoreline Surface Water Master Plan
Water Quality Projects and Programs
for Thornton Creek Watershed

Master Plan Level 1 Projects and Programs	Currently Being Implemented?
2005 Master Plan Projects:	
Wetpond addition to detention pond in the Ridgecrest neighborhood in vicinity of 10th Ave NE	As funds become available
Wetpond addition to Cromwell Park Detention Pond	2009
2005 Master Plan Programs:	
Operation and Maintenance	Ongoing
No-Spray Zone Project	Ongoing
Clean Car Wash Program	Ongoing
Natural Lawn and Garden Care	Ongoing
Storm Drain Stenciling Program	Ongoing
Community Involvement Restoration Program	Ongoing
Compost Facility	Constructed 2004
Regional Road Maintenance/ESA/NPDES Program	Ongoing
Water Quality Monitoring	Ongoing
Participation in Regional Committees	Ongoing
Surface Water Monitoring and Source Control Program	Ongoing
Retention and Detention Facility Inspection	Ongoing

Described below are specific solutions to address the three most significant water quality problems in the Thornton Creek Watershed identified in Section 3.5: elevated water temperature, decreased dissolved oxygen, and bacteria. Some solutions, such as buffer improvements, apply to all three water quality problems, while other solutions are specific to each one. Solutions that apply to more than one problem are discussed for the first problem and then referenced for the other problems to which the solution applies.

6.4.1 Problem WQ1: Elevated Water Temperatures

The most effective solution for reducing water temperatures would be to improve buffers by planting shade-producing vegetation in open channel reaches with little or no vegetation. Most of these reaches are on private property (e.g., see Photo 3-4). The most effective and politically feasible buffer program would rely more heavily on incentives for homeowners and coordination with other public entities (e.g., for stream channels near I-5 and the Metro Base). To help address this problem, the City is enforcing its critical areas codes for buffers when redevelopment occurs on individual parcels. Improved buffers would provide shade to reduce stream temperatures, in turn

increasing DO concentrations during warm periods. Buffer restoration is recommended as an element of aquatic habitat solutions (Section 6.3). Costs for this solution are assumed to be included in these aquatic habitat projects.

Additional temperature monitoring is recommended at the downstream-most accessible point in each tributary; this would require only one new monitoring probe. A temperature monitoring probe should be installed downstream of Twin Ponds in Thornton Creek. Monitoring in Littles Creek already occurs near the city limits. Monitoring in Hamlin Creek does not appear to be applicable due to the fact that the stream is nearly completely piped. Costs for the additional monitoring are assumed to be only around $230 – only a monitoring probe is needed, with staff time for maintaining and downloading the probe; equipment costs are summarized in Appendix D.

6.4.2 Problem WQ2: Reduced Dissolved Oxygen Concentrations

Improved soils and ground vegetation in buffers – on private and public property – would provide filtering and infiltration of runoff from areas adjacent to the riparian zone, helping to control nutrient input. In some areas, mature canopy conditions are generally satisfactory around the streams and open water areas, while understory conditions could be improved (e.g., Photo 3-8 in Hamlin Park; similar conditions exist around Twin Ponds and other parks). In other areas, both the overstory and ground conditions are in need of improvement. As stated in Section 6.4.1, buffer restoration projects and costs are included as an element of aquatic habitat solutions.

Education, outreach, and incentive programs can be undertaken to reduce fertilizer use. This would reduce nutrient inputs to the stream, helping to reduce oxygen demand. These programs are included in the Master Plan; the City should review these programs to ensure that that they are ongoing and effective.

Fertilizer use at public facilities (e.g., parks) should also be reviewed with consideration for reducing fertilizer application or using alternative methods such as compost topdressing or soil amendments. This is assumed to be a virtually cost-neutral solution.

Habitat improvements, as described in the solutions for problems AQ10 and AQ11, would increase channel roughness, improving turbulence and increasing DO concentrations. As with buffer improvements, these costs are assumed to be included as an element of aquatic habitat solutions.

6.4.3 Problem WQ3: Bacterial Contamination

As stated above, improved buffers would provide filtering and infiltration of runoff from areas adjacent to the riparian zone, reducing the direct input of bacteria-contaminated runoff to Thornton Creek and its tributaries. Education and outreach programs can also be aimed at pet waste control. Signage and pet waste bags are already in place in public parks; this program should be reviewed for effectiveness (ensure that the bags are re-stocked and there are sufficient stations placed at high-use areas).

Section 7
RECOMMENDED WATERSHED PLAN

7.1 Introduction

In Section 6, a wide array of solutions was considered to solve watershed problems. The array of solutions included: capital projects, which are constructed improvements; regulatory measures, such as development standards that can reduce surface drainage and water quality impacts; and programmatic measures, including routine maintenance or public outreach. In general, capital projects are best suited for addressing acute site-specific problems, while regulatory or programmatic measures affect the entire basin. This section provides a summary of these recommendations and prioritizes the recommended capital projects.

The priority levels for capital projects are similar to the levels identified in the City of Shoreline Surface Water Master Plan (Master Plan; R. W. Beck 2005). The Master Plan identified three priority levels for flood protection with specific time frames. Because this plan only includes the projects for the Thornton Creek watershed, specific time frames for the priorities were not included. Specific time frames for implementation require a prioritization of all the projects city-wide not just in Thornton Creek. Therefore, the projects in this plan are divided into three priority levels with relative rather than specific time frames: short term, mid term and long term. The City will determine when exactly to implement each project based on the priorities of projects throughout the City.

7.2 Summary of Recommendations

A summary of specific watershed plan recommendations is presented in Tables 7-1, 7-2 and 7-3. These tables indicate whether the recommendation is a regulatory measure, programmatic, or a capital improvement, and also identifies costs and priority. The development of project priorities is discussed later in this section. The following paragraphs discuss the basin-wide regulatory and programmatic recommendations.

7.2.1 Regulatory Measures

To achieve goals for reducing stormwater impacts from development, protection of water resources, and compliance with state and federal stormwater requirements including the Phase II NPDES permit, the City adopted new stormwater code in 2009. The new code adopts the 2005 *Ecology Stormwater Management Manual for Western Washington*, which includes stricter water quality and detention standards for development than were previously required, LID and emerging water quality technologies for handling stormwater runoff. This city-wide action will help reduce

runoff rates and volumes of stormwater runoff from new development and redevelopment.

Additional regulatory recommendations include:

- Encourage low impact development (LID) techniques. LID includes measures that increase the percentage of precipitation that is infiltrated on the site in order to reduce runoff rates and volumes, which will reduced flooding potential and protect water quality. Minimum levels of LID are included in the recently adopted standards where practical. Examples of LID include rain gardens and bioretention; rooftop gardens; vegetated swales, buffers, and strips; tree preservation; roof leader disconnection and infiltration systems; rain barrels and cisterns; permeable pavers; soil amendments; impervious surface reduction; and impervious surface disconnection.
- Continue to apply Administrative Orders in the Engineering Development Guide such as the restrictions on filling of drainage ditches within the right-of-way that could result in the loss of the infiltration capability and increase system flows.
- Continue to pursue preferred options for floodplain management and regulations for the area south of Ronald Bog. As previously noted, a floodplain mapping study will be completed in winter 2009. Options include submitting the floodplain study to FEMA for incorporation in the national flood insurance database, regulating the floodplain through the use of City building permits, or simply distributing maps of the floodplain to educate and prepare the neighbors of the North Branch Thornton Creek.

Table 7-1. Prioritization of Solutions to Flooding Problems

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Estimated Cost	Permitting Needs
1	F1	Ronald Bog @ NE 175th St. & Meridian Ave.	Combination of Capital/Regulatory/ Programmatic	Given its outlet capacity, Ronald Bog does not provide enough water storage and over tops its southern bank, flooding up to 11 homes near the pond's outlet along Corliss Ave. between N 172nd St. and N 171st St.	A combination of flood barrier in combination with selective property acquisition and flood proofing (Alternatives 1 and 4)	A berm along the southern edge of the pond will prevent neighborhood surface water flooding. Property acquisition and/or floodproofing will prevent property damage to individual homes.	$650,000 to $1.4 million	Based on wetland recon. , berm appears possible w/o wetland fill, thereby avoiding state and federal permits. No critical area permits should be required for the flood proofing and property acquisition.
2	F2	Residential flooding from NE 170th St. to NE 175th St. between 13th Ave. NE and 12th Ave. NE (17021, 17029, 17042 11th Ave. NE)	Capital	Detention pond @ 17021 11th Ave. NE floods during storm events because it has no outlet. The pond overflows, flooding the neighbor @ 17029. Flooding also occurs upstream across the street in back yard of 17042.	Construct ditch with a control structure along 12th Ave NE as a first phase (Alternative 1). If this proves to be insufficient, Alternative 3 (rain garden swales and pipe improvements) could be implemented.	Flood reduction/prevention	$61,000 for Alt. 1 $247,000 for Alt. 3	No critical area permits should be required.
3	F3	Residential flooding on 5th Avenue NE just north of NE Serpentine Pl.	Capital	Flooding due to maximum capacity at the Serpentine Pump Station is not capable of handling the 25-year storm and the pipe system on 5th Ave. NE is insufficient.	Two alternatives were evaluated. The City will determine the preferred alternative based on criteria to be established during project feasibility studies/design and downstream analysis. For planning purposes, the estimated cost for Alternative 1 is shown.	Flood prevention.	$880,000 for Alt. 1	No critical area permits should be required.
1	F4	Littles Creek flooding between 14849 & 15021 12th Ave. NE	Capital	Littles Creek exits a culvert & turns west 90 degrees between two properties toward the Paramount Park Open Space.	Excavate the channel to improve conveyance capacity with a sump to trap sediment.	Flood reduction/prevention, stream/habitat restoration and enhancement. Improvement of neighborhood aesthetic.	$212,000	HPA, Corps permit, mitigation may be required
3	F5	Non-functional catch basin/1237 NE 148th St.	Capital and Programmatic	The catch basin in front of apartment building 1237 has no outlet, creating ponding each time the catch basin is full.	Work with property owners to implement an LID solution.	Flood reduction/prevention.	$49,000	No critical area permits should be required.
3	F6	Roadway storm drain overflow/along 10th Ave. NE south of NE 175th St	Capital	Homes on the east side of 10th Ave. NE are in a 4- to 10-foot depression relative to the road. The drainage system has insufficient capacity in a 25-year storm so that water will flow out of catch basins and down the driveways of properties along this street.	Add a detention pond at NE 175th Street and 10th Avenue NE and upgrade a portion of the existing conveyance system along 10th Avenue NE between NE 175th and NE 165th Streets.	Flood prevention.	$1,830,000	No critical area permits should be required.
2	F7	N 167th St and Wallingford Ave N	Capital	The pipe under N 167th St and the pipe immediately downstream are undersized. In addition, the pipe system on the western side of 16533 Wallingford Ave N is also undersized. The undersized system has resulted in property flooding during high flow events.	Replacing low- and high-flow pipe systems with open channel.	Flood reduction/prevention, stream/habitat restoration and enhancement.	$81,000	HPA

Table 7-2. Prioritization of Solutions to Wetland and Aquatic Habitat Problems

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Problems Addressed	Estimated Cost	Permitting Needs
2	AQ1	Fish passage of the outlet pipe system from Ronald Bog.	Capital	Partial fish passage barrier of pipe system at pond outlet.	Long-term solution is to replace the system to meet fish passage design standards for new construction.	Brought up to WDFW fish passage standards.	Fish Passage	$4.5 million - $5 million (but could be less if the City were to negotiate a smaller conveyance system size)	Army Corps, HPA, SEPA, local grading and environmental permitting.
3	AQ2	Enhancement of wetland fringe areas around Ronald Bog.	Capital		See text in Section 6.3.1			$580,000	Army Corps, HPA, SEPA, local grading and environmental permitting.
2	AQ3	Daylighted stream channel and partial fish passage barrier removal at the flow splitter upstream of Twin Ponds between Corliss Ave. N. and I-5.	Capital	The flow splitter upstream of Twin Ponds has been identified as a fish passage barrier according to previous reports (Tetra Tech 2004, Appendix C). More recent work has classified it as a partial fish passage barrier.	Reconstruct the stream channel up- and downstream of the flow splitter based on site-specific information to daylight piped stream sections as feasible and improve fish-passage. Provide revegetation, bank stabilization, log structures, non-native vegetation removal and other habitat features to the localized area as appropriate.	Daylight piped stream sections to improve in-stream and riparian habitat and improve stream function. Improve fish passage through the area that is reported to be a barrier, ultimately expanding the geographic habitat availability for salmonid fish.	Improve fish passage at a man-made flow control feature. Restore natural stream function by daylighting piped stream sections.	$257,000	Army Corps, HPA, local permitting.
2	AQ4	Reported fish passage barriers w/in Twin Ponds Park/culvert north of the north pond & culvert beneath a pedestrian trail.	Capital	Reports indicated 2 possible fish passage barriers in Twin Ponds Park. No obvious barriers were observed on site visits on 12/3/08 and 12/27/08. The culvert flowing into the park under N. 155th St. was small, but appeared fish passable. A larger culvert under a footpath just upstream of the north pond was fish passable, but could be made more fish friendly and aesthetically pleasing.	In-stream work to re-grade the channels and modify or supplement structures such that plunge pools will definitely allow fish passage. Line the culvert just upstream of the north pond with spawning sized gravel. Add native vegetation along the stream bank between the two culverts mentioned upstream of the north pond (especially along the left bank).	Stream/wetland/habitat enhancement. Create a more natural park for the public to enjoy.	Habitat function. Park aesthetic.	$60,000	HPA, possible Army Corps (if disturbing wetlands), local permitting.
2	AQ5	Low flow fish passage barrier/culvert under 1st Ave. NE (from Twin Ponds Park to Pevely Pond).	Capital	Reports document this culvert as a low flow fish barrier. Vegetation and mud present in culvert inhibit but do not prevent passage.	Clear mud and vegetation from within the culvert. Replace with gravel.	Defined fish passage.	Potential fish impassable culvert.	$19,000	HPA, possible Army Corps permit, local permitting.
2	AQ6	Fish Passage Barrier/Outfall of Peverly Pond east of 1st Ave. NE along I-5 and north of N. 149th St.	Capital	A concrete ramp channels outflow from Peverly pond down ~5 feet to a straight channel adjacent to 1-5.	Install a series of grade controls along the concrete channel leading up to the outlet of Peverly Pond such that the plunge from the pond is reduced to a fish-passable height. The resulting grade-controlled section of the concrete channel extending upstream of the pond outlet would provide a significant amount of off-channel, beaver-dam-like rearing habitat.	Fish passable stream. Stream/wetland/habitat enhancement.	Fish passage.	$257,000	HPA, possible Army Corps permit, local permitting.
WSDOT Project	AQ7	Culvert under I-5, downstream of Peverly Pond.	Capital	Fish passage barrier.	Replace / improve culvert	Fish passable stream.	Fish blockage.	Funded by others. Would be estimated as part of a WSDOT project	HPA, local permitting.
2	AQ8	Weed Choked Meridian Creek, upstream to Meridian Ave. N. from the south pond in Twin Ponds Park.	Capital	Fish passage barrier due to the cumulative effects of the stagnant, weed-choked channel. Some Himalayan blackberry has been removed and native plants have been added by community volunteers. Reed canary grass dominates some interior channel segments.	Construct better defined stream channel, add LWD, gravel, and stabilize banks. Replant with native wetland vegetation.	Fish passable stream. Stream/wetland/habitat enhancement.	Fish passage. Habitat function. Improve park aesthetic.	$278,000	HPA, local permitting.

Table 7-2 (continued)

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Problems Addressed	Estimated Cost	Permitting Needs
3	AQ9	Maintain previous restoration site in Paramount Park Open Space/along Little's Creek stream bank	Programmatic	Past restoration site work does not appear to be maintained	Grub out Himalayan blackberry and spray/remove reed canary grass. Replant with native wetland vegetation and increase native shrub densities to shade out reed canary grass.	Maintain/restore past improvement efforts.	Removal of non-native vegetation in past restoration site.	$544,000	local permitting
3	AQ10 - A	Lack of habitat and stream function along Hamlin Creek, south from the Fircrest campus along 20th Ave. NE.	Capital	Hamlin Creek flows through a roadside ditch with no in-stream structure, no canopy cover and no native vegetation.	Construct better defined channel, add LWD, gravel, and stabilize banks. Replant with native riparian vegetation.	Habitat enhancement.	Habitat function. Neighborhood aesthetic.	$500,000	HPA, local permitting.
State Project	AQ10 - B	Much of Hamlin Creek is piped and/or has poor habitat	Capital	Most of the length of two forks of Hamlin Creek on the state-owned Fircrest Campus is piped and would benefit from daylighting.	Daylight and/or restore sections of upper Hamlin Creek which are now conveyed mostly in piped systems across the Fircrest Campus property.	On-site habitat improvements for terrestrial and amphibious wildlife, downstream water quality and quantity benefits for fish and other aquatic wildlife in Thornton Creek farther downstream in perennial reaches.	Virtually all stream functions are lost in the presently-piped sections; daylighted and restored sections will provide headwater stream functions of infiltration, biofiltration, storage and flow attenuation, and providing water to support riparian and wetland habitats.	To be developed as part of the state's Master Planning process for the Fircrest Campus site.	HPA, local permitting.
3	AQ11	Thornton Creek is lacking coarse-grained sediment.	Capital	Much of the watershed lacks sufficient access to floodplain sediment and in-stream structure to trap and accumulate sediment.	Reduce bank armoring and streambed grade controls where feasible; allow stream access to floodplain gravel through channel migration. Provide in-stream structure to catch and accumulate sediment. Introduce additional gravel supply to sections of the stream that are sediment-starved and/or at locations where such gravel would be effectively distributed downstream. Examples of such locations are downstream of in-stream ponds or low-gradient reaches because such areas tend to accumulate course sediments and prevent their movement farther downstream.	Stream/ habitat enhancement.	Habitat function. Neighborhood aesthetic.	$30,000 – $60,000	HPA, possible Army Corps permit, local permitting.
Citywide Project	AQ12	Coho prespawn mortality.	Programmatic	Coho prespawn mortality rates are high, averaging 79% throughout Thornton Creek.	Contribute to projects that improve water quality with the expectation of decreasing coho prespawn mortality downstream. Increase biofiltration of stormwater with more stringent treatment standards.	Improvements to water quality will contribute to decreasing prespawn mortality downstream.	Salmonid prespawn mortality in urban streams.	$200,000	

Table 7-3. Prioritization of Solutions to Water Quality Problems

Priority Level	Project ID	Title/Location	Solution Type	Description	Preferred Solution	Benefit Provided	Problems Addressed	Estimated Cost
2	WQ1	Reduce temperature in Thornton Creek	Programmatic/Capital	Elevated temperatures in Thornton, Littles, and Hamlin Creeks and reduced groundwater inputs.	Plant shade-producing vegetation in open channel reaches and monitor temperature at the downstream of each tributary.	Shade and monitoring of conditions	High temperature	Cost included in applicable Stream Habitat projects
2	WQ2	Improve dissolved oxygen concentrations	Programmatic	Reduced dissolved oxygen concentrations and elevated nutrient levels.	Improve soils and ground vegetation in buffers. Implement education, outreach and incentive programs to reduce fertilizer use.	Increased dissolved oxygen	Low dissolved oxygen	Cost included in applicable Stream Habitat projects
2	WQ3	Reduce bacterial contamination.	Programmatic	Bacterial contamination	Improve soils and ground vegetation in buffers. Implement education, outreach and incentive programs to control pet waste.	Reduced bacterial contamination	High fecal counts	Cost included in applicable Stream Habitat projects

7.2.2 Programmatic Measures

Programmatic measures are activities such as maintenance of stormwater infrastructure, water quality monitoring, proper planning for the replacement of existing infrastructure and public outreach.

Recommended programmatic measures include:

- The City should encourage home and business owners to keep catch basin grates free of leaves and debris.
- The City should develop more watershed-specific outreach activities within the Thornton Creek watershed. One possible example may be an outreach program to streamside residents on natural yard care practices and encouragement of native riparian planting; both can locally improve stream habitat and water quality.
- Continue existing water quality and stream monitoring activities on Thornton Creek, and possibly expand these activities in the future, to allow the City to monitor stream health. Monitoring results may then be used to guide the capital projects, outreach activities, and regulations accordingly to improve watershed conditions. In addition, monitoring could be used to assess performance of improvements made in the watershed to determine if adaptive management measures are appropriate.
- Perform a stream typing (i.e., classification) study to specifically define streams according to the City's definition. The current system of classification, which tends to rely on independent study and observation, has created some confusion with respect to permitting.
- One specific maintenance activity involves the 30-inch-diameter outlet pipe and downstream channel system from Ronald Bog, which is very flat and subject to sediment accumulation. Built-up sediments can reduce system conveyance capacity and result in higher water surface elevations in Ronald Bog during flood periods. The 30-inch-diameter pipe is aging and eventually needs to be replaced; but currently, annual maintenance to remove sediment and prevent root intrusion is recommended. In addition, an annual maintenance program for the open channel system between N 171st Street and N 167th Street is recommended.

7.3 Priority Levels

Due to the divergent nature of flood protection, stream habitat and water quality projects, the priority levels for these types of project are defined slightly differently as noted in the following sections. Related programs and program costs are discussed in Chapter 8, and more detailed cost estimates for projects and programs are provided in Appendix D.

7.3.1 Flood Protection Priority Levels

This section describes the three priority levels for flood protection projects and the recommended projects, along with estimated project costs. The priority levels reflect their relative implementation horizon:

- Priority Level 1: Short Term
- Priority Level 2: Mid Term
- Priority Level 3: Long Term

Prioritization of the projects was based whether the problem:

- Causes property damage
- Impedes traffic
- Is cost effective/affordable
- Is permittable
- Has public interest/acceptance

A qualitative evaluation of each problem for priority level is contained in Table 7-4. Table 7-1 (p. 7-3) provides summary descriptions of each of the identified flood protection projects for the Thornton Creek watershed within the City of Shoreline and also summarizes the benefits, costs, and their priority.

Table 7-4
Flooding Problem Priority Levels

	Problem	Safety and Property Damage			Impedes Traffic	Cost-Effective/Affordable	Permittable	Public Interest/Acceptance	Known to be Recurrent	Priority Level
		1–5 Homes	6–10 Homes	11+ Homes						
F1	Ronald Bog – Corliss Ave N Thornton Creek			X	X	X	X	X	X	1
F2	NE 170th to NE 175th between 13th Ave. NE & 12th Ave. NE	X				X[1]	X		X	2
F3	5th Ave. NE north of NE Serpentine Place		X				X		X	3
F4	Littles Creek near 14849 12th Ave. NE	X				X	X		X	1
F5	Non-functional catch basin/1237 NE 148th St.	X					X		X	3
F6	Roadway storm drain overflow/10th Ave. NE south of NE 175th St		X				X		X	3
F7	N 167th St. and Wallingford Ave. N	X			X	X	X		X	2

1. Cost-effective for Alternative 1.

7.3.2 Stream Habitat Priority Levels

The priority levels for stand-alone stream habitat projects were defined as follows:

- **Stream Habitat Priority Level 1: Critical Projects and Programs.** Stream Habitat Priority Level 1 projects include meeting regulatory requirements. There are no stand-alone habitat projects in the Thornton Creek watershed that the City must complete to meet regulatory requirement. The only habitat projects that must be completed to meet regulatory requirements are those associated with mitigation for flood protection projects, and are included under those flood protection projects.
- **Stream Habitat Priority Level 2: Enhance and Expand Habitat in Areas Where Wild Anadromous Fish are Present.** All fish barrier removal projects were classified as Stream Habitat Priority Level 2 projects are within the Thornton Creek watershed (with the exception of the culvert under Interstate 5 which is under WSDOT purview). While stream sections in the Thornton Creek watershed within the City do not reliably support anadromous salmonid fish due to a migration barrier at Interstate 5 near the city limits, as well as possible additional barriers farther downstream in the City of Seattle, WDFW has proposed that mitigation for not making a culvert project fish-passable is the removal of another fish barrier in the system.
- **Stream Habitat Priority Level 3: Provide Additional Benefits to Stream Habitat.** Level 3 projects and programs are intended to provide additional benefits to stream habitat such as enhancing sections of streams with habitat potential for salmonid fish as well as non-salmonid fish. All projects listed in Table 7-2 (p. 7-5) are Stream Habitat Priority Level 3 projects within the Thornton Creek watershed.

Table 7-2 (p. 7-5) provides summary descriptions of each of the identified aquatic projects for the Thornton Creek watershed within the City of Shoreline and also summarizes benefits, costs, and other attributes. A column in that table also lists the priority level for each project, based on applying the ranking protocol described above. In general, the listed projects not involving fish passage do not rank particularly high since anadromous fish use of Thornton Creek or its tributaries within the City is rather limited, and benefit to anadromous fish is a primary ranking criteria.

The correction of fish passage barriers can directly benefit anadromous fish by increasing their range within the watershed; however, the benefit of correcting any given barrier cannot fully accrue as long as barriers remain downstream. Several barriers along Thornton Creek are downstream, outside of the City of Shoreline, in the City of Seattle and/or under WSDOT jurisdiction. Thus, the benefits of correcting any fish migration barrier along Thornton Creek within the City of Shoreline could not be fully realized until or unless downstream barriers beyond the City's control were also corrected.

The costs for Project AQ1 depend greatly on what will be required by WDFW. For example, the City may be able to negotiate environmental mitigation elsewhere in the

watershed as opposed to replacing the 30-inch pipe system with a much larger conveyance system.

Replacing the culvert carrying the North Branch under Interstate 5 or otherwise making it fish-passable, Project AQ7, is not a responsibility of the City of Shoreline and so calculating its costs is outside the scope of this report. Though direct action with respect to this project by the City is not indicated, the City should strongly encourage WSDOT to provide a fish-passable culvert to carry Thornton Creek under Interstate 5. Such a fish-passable culvert would validate the City's addressing the various other fish passage barriers upstream of the freeway, such as at the outlet of Peverly Pond and at the flow splitter upstream of Twin Ponds.

Project AQ10 would involve the daylighting of sections of Hamlin Creek on state property as part of the master planning process for the Fircrest Campus. As such, a cost estimate will likely eventually be developed as part of that process, and implementation would be financed as part of the redevelopment of the campus and so should not require funding from the City of Shoreline.

Costs listed for Project AQ12 are not a set amount needed to address the causes and solutions of coho prespawn mortality in the Thornton Creek watershed, but rather a suggested general cost that could be used to improve water quality in the basin where high benefit to costs can be achieved. .

7.3.3 Water Quality Priority Levels

The priority levels for Water Quality Projects, with some overlap, were defined as follows:

- **Water Quality Priority Level 1: Critical Projects and Programs.** Water quality Priority Level 1 includes activities that need to be implemented to meet minimum regulatory requirements, particularly for the NPDES Phase II municipal stormwater permit. These programs are already being implemented city-wide, so there are no water quality regulatory requirements specified for Thornton Creek. At some time in the future, Ecology may include water quality sampling data in their updated 303(d) list for upper Thornton Creek, which then may result in some future TMDL study and subsequent requirements to reduce pollution from stormwater.
- **Water Quality Priority Level 2: Enhance the Ability of the System to Improve Water Quality.** Water quality Priority Level 2 includes both project and programmatic activities that would enhance the ability of the City's surface water system to improve water quality.

Note that for water quality, a third priority level was not used. Table 7-3 (p.7-9) provides summary descriptions of each of the identified water quality projects for the Thornton Creek watershed within the City of Shoreline and also summarizes benefits, costs, and other attributes. A column in that table also lists the Priority Ranking level for each project, based on applying the ranking protocol described above.

Section 8
FINANCIAL ANALYSIS

8.1 Introduction

This financial analysis describes financial considerations anticipated in the implementation of this watershed plan. This watershed plan will be implemented within the City's Surface Water Management (SWM) utility. The financial consideration of this plan will be incorporated into the City's ongoing financial planning efforts for its SWM utility.

This section first describes some of the potential funding sources for the capital projects in this plan. Next, the capital funding strategy for the Ronald Bog improvements is discussed, which includes the City's efforts to date to obtain funding and anticipated milestones for obtaining funding. The last part of this section describes potential rate impacts associated with a range of potential city-wide SWM capital spending.

Not included in this financial analysis is a discussion of how the improvements in this Thornton Creek Watershed Plan compare in priority to other SWM activities. As a result, this financial analysis does not include a schedule for the improvements because a schedule can only be developed after the relative priorities of this watershed plan and other SWM activities are established.

8.2 Potential Funding Sources

There are several potentially available sources of grant and loan funding for the projects described in this plan. A brief description of some of these funding sources is provided in the following paragraphs without reference to their potential applicability to specific projects. This list is not exhaustive, but is considered to represent the most likely sources of funding.

King County Flood Control Zone District – Opportunity Fund

The King County Flood Control Zone District (King County FCZD) was formed in April 2007 with the mission to protect public health and safety, regional economic centers, public and private properties, and transportation corridors. Through its Opportunity Fund, the King County FCZD makes certain funds available on an annual basis to each city in King County, based on the city's assessed taxable value. Eligible uses of the funds include stormwater comprehensive plans and capital projects. The City must apply annually and the uses of funds must be consistent with the application. Unused funds in any given year are available in the following year. The City of Shoreline is currently allocated approximately $80,000 annually.

King County Flood Control Zone District – Capital Projects Fund

The King County FCZD's Capital Project Fund provides approximately $30 million per year to local jurisdictions. This is a competitive process where capital projects are evaluated against flood risk reduction criteria, and then evaluated and prioritized by a 15-member Advisory Committee comprised of elected officials from throughout the county. Ultimately, a project must be approved by the District Board of Supervisors in order to receive funding. The average amount funded is approximately $2 million to $3 million per project, and the fund is operated on a reimbursement basis.

Flood Control Assistance Account Program (FCAAP)

Any public entity that belongs to the National Flood Insurance Program (NFIP) throughout the state may apply for this cost reimbursement biennium grant. Entities generally must complete a Comprehensive Flood Hazard Management Plan to receive assistance. Eligible projects include: developing a Comprehensive Floodplain Management Plan, flood hazard reduction technical studies, flood damage reduction projects, acquisition projects, mapping projects including channel mitigation zone delineations, fish habitat protection/enhancement projects associated with flood damage reduction benefits, and others such as a flood warning system. The maximum amount available in one county, including all jurisdictions, is $500,000 per biennium. FCAAP will fund up to 50 percent of the cost of an eligible Flood Damage Construction Project. FCAAP grant applications for the current two-year funding cycle are due July 30, 2009.

FEMA – Hazard Mitigation Grant Program

Hazard Mitigation Grant Program (HMGP)[5] funding becomes available following a presidential disaster declaration. These funds originate from FEMA and are administered in Washington by the Washington Military Department Emergency Management Division. The program is designed to reduce or eliminate the effects and costs of future disaster damage. There is a lengthy application process, which includes a detailed cost-benefit analysis of the project. If funds are awarded, the HMGP covers 75 percent of the project cost as quoted in the application. The FEMA funding program does not fund projects that eliminate a floodplain from FEMA management.

FEMA – Pre-Disaster Mitigation

Another program is FEMA Pre-Disaster Mitigation (PDM). PDM grants are also administered by the Emergency Management Division. PDM grants fund certain mitigation planning and mitigation projects. Eligibility requirements exist, including cost-effectiveness and conformance with a FEMA-approved State Hazard Mitigation Plan.

[5] Authorized under Section 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), 42 U.S.C. 5121-5206

Public Works Trust Fund

The Washington State 2009-2011 Biennial Budget does not include funding for the 2010 Public Works Trust Fund (PWTF) Loan Program; the following details are provided as potential information for use in future years. The PWTF provides construction, pre-construction, planning, and emergency loans. The largest of the four loan programs is the construction loan program, with an annual application cycle. Loans are typically for 20 years. The interest rate is between 0.5 percent and 2 percent, depending on the local match of 5 percent to 15 percent of the project cost. PWTF loans are administered by the Washington State Public Works Board.

Revenue Bonds

The City could also issue revenue bonds to fund capital improvements. Revenue bonds would be repaid by revenues of the SWM utility. Interest rates vary with market conditions but are typically higher than government loan programs.

8.3 Ronald Bog Improvements Funding Strategy

As described in Section 7, the City has not yet determined the recommended solution for the flooding problem downstream from Ronald Bog. The estimated cost for the various alternatives ranges from approximately $650,000 to $1.4 million.

Additionally, the City is considering applying for FEMA funding (HMGP or PDM).

Because the specific alternative is not yet chosen and the amount of grant funding, if any, is not yet known, this financial analysis is based on the $650,000 to $1.4 million range of project costs for Ronald Bog improvements.

8.4 Financial Analysis

8.4.1 Summary of Capital Improvements

Table 8-1 summarizes available capital improvement information, from the following sources:

- This Thornton Creek Watershed Plan
- The City's most recently approved 6-Year SWM Capital Improvement Program, 2010-2015

The City's most recently approved 6-year SWM capital improvement program (CIP) was adopted in 2009 during the development of the 2010 budget. The Other SWM CIP Projects contained in Table 8-1 include projects that are part of the 6-year SWM CIP, excluding the Thornton Creek watershed. Some of the projects from the 6-year CIP are discrete projects and others (such as CIP formulation and engineering) are annual expenses that the City considers capital expenses.

The total estimated project cost of the Thornton Creek Watershed Plan improvements is anticipated to range between $11.0 million and $12.5 million, depending on the

selected wetland/aquatic habitat project alternatives, the selected Ronald Bog alternative, and the amount, if any, of grant funding that is received.

The total estimated cost of projects outside the Thornton Creek Watershed in the City's 6-year SWM CIP is $8.6 million in 2009 dollars. Not yet included in the City's SWM financial planning is the Boeing Creek Watershed Plan (scheduled to be completed in 2013). Some of the improvements in the City's 6-year SWM CIP are from within the Boeing Creek watershed, and the scope and cost of improvements in the Boeing Creek watershed are likely to change following completion of the Boeing Creek Watershed Plan.

Table 8-1
Summary of Estimated Capital Improvement Project Costs

Project IDs	Description	Estimated Cost[1]
Thornton Creek Watershed Plan Projects		
Thornton Creek Watershed Plan - Priority 1 Projects		
F1.	Ronald Bog flood prevention at NE 175th & Meridian	$650,000 - $1,400,000
F4.	Littles Creek flood prevention at 14849 - 15021 12th Ave NE	$212,000
Subtotal Priority 1		$862,000 - $1,612,000
Thornton Creek Watershed Plan - Priority 2 Projects		
F2.	Flood prevention at NE 170th-NE175th between 12th and 13th Ave NE	$61,000 - $247,000
F7.	Flood prevention at N 167th St and Wallingford Ave N	$81,000
AQ1.	Fish passage of the outlet pipe systems from Ronald Bog	$4,500,000 - $5,000,000
AQ3.	Daylighted stream channel and partial fish barrier removal	$257,000
AQ4.	Reported fish passage barriers w/in Twin Ponds Park	$60,000
AQ5.	Low flow fish passage barrier under 1st Ave NE	$19,000
AQ6.	Fish passage barrier/outfall of Peverly Pond	$257,000
AQ8.	Weed choked Meridian Creek	$278,000
Subtotal Priority 2		$5,513,000 - $6,199,000
Thornton Creek Watershed Plan - Priority 3 Projects		
F3.	Upgrade pipe system on 5th Ave NE and NE 178th and Pump Station No 25	$880,000
F5.	Flood prevention at 1237 NE 148th St for non-functional catch basin	$49,000
F6.	Flood prevention roadway storm drain overflow along 10th Ave NE	$1,830,000
AQ2.	Enhancement of wetland fringe areas around Ronald Bog	$580,000
AQ9.	Maintain restoration site in Paramount Park Open Space	$544,000
AQ10-A.	Lack of habitat and stream function along Hamlin Creek	$500,000
AQ11.	Thornton Creek coarse-grained sediment	$30,000 - $60,000
AQ12.	Coho prespawn mortality	$200,000
Subtotal Priority 3		$4,613,000 - $4,643,000
Thornton Creek Watershed Plan Projects, Total[2]		$10,988,000 - $12,454,000
Other SWM CIP Projects, Total[3]		$8,553,080
Total SWM Projects		$19,541,080 - $21,007,080

Notes:

(1) Estimated costs in $2009s.

(2) Source: This Watershed Plan. Excludes projects funded by others: AQ7. Replace/remove culvert under I-5 downstream of Peverly Pond; AQ10-B. Daylight and/or restore Hamlin Creek

(3) Source: City of Shoreline 2010-2015 Capital Improvement Plan projects. Additional SWM projects excluding those accounted for by the Thornton Creek Watershed Plan Projects

The intent of this financial analysis is to identify the levels of city-wide SWM capital improvements that can be funded over the next six years given certain SWM fee scenarios. This financial analysis does not specify the relative priorities of these capital improvements, or which capital improvements should be funded within the next six years.

The City has a SWM financial planning model that has been used since 2004 to develop SWM fee recommendations and project SWM utility revenues and expenses. The SWM financial planning model was used in this financial analysis, with the following key assumptions:

- SWM operation and maintenance expenses per the 2009 budget
- Annual inflation of 3 percent per year except salaries and wages inflation of approximately 3.4 percent year (per 2008 City projections)
- Capital expenditure inflation of 4 percent per year
- Customer growth of 0.25 percent per year
- January 2010 SWM fund balance of approximately $3.2 million
- Minimum SWM fund balance of at least 15 percent of operating expenses
- For scenarios involving future debt, debt terms are 5.5 percent interest, and levelized principal and interest payments over 20 years
- Minimum Debt Service Coverage Ratio of 2.0
- King County FCZD revenues of $80,000 per year and interest income of $25,000 per year.

8.4.2 Results

Several different scenarios were evaluated. Each scenario is defined by the amount of SWM fee increases over the next six years and whether additional debt is issued to pay for capital improvements. The output of each scenario is the amount of funds available over the next six years for capital improvements.

Table 8-2 indicates that without issuing debt, the City has between $11 million and $13.5 million available for capital improvements over the next six years (depending on the size of SWM fee increases). Table 8-3 shows that this amount would cover the combined cost of the other projects of the City's 6-year SWM CIP that are not in the Thornton Creek Watershed and Priority 1 and a portion of the Priority 2 projects in Thornton Creek Watershed. Without issuing debt, the remaining Priority 2 and Priority 3 projects cannot be afforded.

Table 8-2
Funds Available for Capital Improvements Through 2015

Scenario	Amount of New Debt Issued through 2015	Annual SWM Fee Per Household in 2015	$ Available for Capital Improvements, $M (1)
No SWM Fee Increases through 2015	None	$130	$11M
No 2010 Increases. Then 3%/Year Through 2015	None	$146	$12.5M
No 2010 Increases. Then 5%/Year Through 2015	None	$158	$13.5M
No SWM Fee Increases through 2015	$8M	$130	$16.5M
No 2010 Increases. Then 3%/Year Through 2015	$10.5M	$146	$20M
No 2010 Increases. Then 5%/Year Through 2015	$11.5M	$158	$21.3M

(1) Inflation adjusted total. Estimated amount, to be refined in the City's upcoming SWM Rate Study.

Table 8-3
Capital Projects Afforded Without Issuing Debt

	Estimated Available $[1]
Funds Available for CIP through 2015 (without issuing debt)[2]	$11,000,000 - $13,500,000
Priority 1 Thornton Creek Watershed (All projects)	$862,000 - $1,612,000
Priority 2 Thornton Creek Watershed (25-57% of projects)[3]	$1,542,000 - $3,168,000
Priority 3 Thornton Creek Watershed (0% of projects)[3]	$0
Other SWM CIP Projects (All projects)	$8,553,080
Total	$10,957,080 - $13,333,080

Notes:

(1) Estimated project costs in $2009s

(2) Amount dependent on SWM fee increases: no 2010 increases and a range of 0% to 5% through 2015.

(3) The range displays the amount afforded to complete the Priority 2 and Priority 3 Thornton Creek Watershed Plan projects.

By issuing debt, the City can build more capital improvements, potentially up to approximately $21 million. The City may be able to complete substantially all of the capital improvements in Table 8-1 (after adjusting capital costs for inflation) by issuing debt and implementing 5 percent annual SWM fee increases from 2011 through 2015. The analysis shown in Table 8-2 is a preliminary estimate and it is anticipated that it would be refined during the City's SWM Rate Study and Implementation Plan, scheduled for 2010.

8.5 Next Steps

The City's next steps in evaluating SWM funding and the potential schedule for improvements in this Thornton Creek Watershed Plan are anticipated to include the following:

- Select preferred alternative for Ronald Bog improvements (Fall 2009/Winter 2010)
- The City may pursue FEMA grant funding. In this case, it would receive notification of FEMA grant funding (November 2009 – January 2010)
- As part of upcoming SWM Rate Study and Implementation Plan (2010), prioritize city-wide SWM improvements and revise the City's SWM financial plan. This Watershed Master Plan, and the financial plan it contains, is expected to include discussion of anticipated SWM fee increases and debt service issuance policies.

AHBL Inc. 2008. Fircrest Excess Property Report - Land Use Options and Recommendations. Report prepared for Washington State Department of Social & Health Services (DSHS).

Cowardin, L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. Publication No. FWS/OBS-79/31. Washington, D.C.: U.S. Fish and Wildlife Service.

Dinicola, R.S.. 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. U.S. Geological Survey, Water Resources Investigations Report 89-4052.

Ecology, Washington State Department of. 2009a. Water Quality Assessment Category 4b. http://www.ecy.wa.gov/programs/wq/303d/wqassescat4b.html

Ecology, Washington State Department of. 2009b. Water Quality Assessment Categories. http://www.ecy.wa.gov/programs/wq/303d/WQAssessmentCats.html

Entranco. 2000. Draft Thornton Creek Hydrologic and Hydraulic Modeling: Hydrologic and Hydraulic Model Plan.

Golder Associates, Inc. 2002a. Ecological Resources Assessment; Fisheries, Streams, and Wildlife for Fircrest School Site. Report prepared for DSHS.

Golder Associates, Inc. 2002b. Preliminary Geotechnical Assessment for Fircrest School Site. Report prepared for DSHS.

Golder Associates, Inc. 2002c. Wetland Delineation Report for Fircrest Campus. Report prepared for DSHS.

Holser, Ginger. 2008. Personal Communication with WDFW Area Habitat Biologist. 11/4/08 (Project meeting at City of Shoreline).

Interagency Advisory Committee on Water Data. March 1982. Guidelines for Determining Flood Flow Frequency, Bulletin 17B.

Kerwin, John. 2001. Washington Conservation Commission. Salmon and Steelhead Habitat Limiting Factors Report for the Cedar-Sammamish Basin (Water Resource Inventory Area 8).

Lee, Sinang. 2009. Department of Ecology staff, personal Communication with Kenneth Ludwa, R. W. Beck. Phone conversation and email. February 23, 2009.

NHC (Northwest Hydraulic Consultants). 2008. Internal communication produced hydraulic calculations and data.

NHC. 2009. Personal communication with Chris Long, email dated 7-06-09).

Otak. 2001. Ronald Bog Drainage Improvements, Phase 1: Thornton Creek Tributary Flood Reduction Study.

Pace Engineers, Inc.. 2008. Draft Stormwater Narrative for 60% Submittal: Cromwell Park Redevelopment.

R. W. Beck, Inc. 2005. City of Shoreline Surface Water Master Plan. Prepared for the City of Shoreline, Seattle, Washington.

R. W. Beck. 2007a. Thornton Creek Corridor Project: Preliminary Engineering Report, Final Report.

R. W. Beck. 2007b. Thornton Creek Flow Splitter Evaluation: Draft Technical Memorandum.

Rasmussen & Huse, Consulting Engineers, Inc. 1987. Ronald Bog Drainage Study. Prepared for King County Department of Public Works Surface Water Management Division.

Seattle, City of. 2007. State of the Waters 2007, Volume I: Seattle Watercourses.

Seiler, D. 2000. Washington Department of Fish and Wildlife. Personal communication to K. Lynch, SPU. (Referenced in SPU 2000).

SPU (Seattle Public Utilities). 2000. Thornton Creek Watershed Characterization Report. Report prepared by Thornton Creek Watershed Management Committee under the direction of Seattle Public Utilities.

Tetra Tech. 2003. City of Shoreline: Stream and Wetland Inventory and Assessment, Appendices. Prepared for the City of Shoreline, Seattle, Washington.

Tetra Tech/KCM. 2004. Thornton Creek Basin Characterization Report. Prepared for the City of Shoreline, Seattle, Washington, as part of the City of Shoreline Stream and Wetland Inventory and Assessment.

U.S. Environmental Protection Agency. 1988. Hydrologic Simulation Program, FORTRAN, USEPA Environmental Research Laboratory, Athens, Georgia.

Washington Trout. 2000. Stream Typing Draft Report. Prepared for Seattle Public Utilities.

Watershed Company, The. 2001. Sensitive Areas Study, Evergreen School Property, Shoreline, Washington.

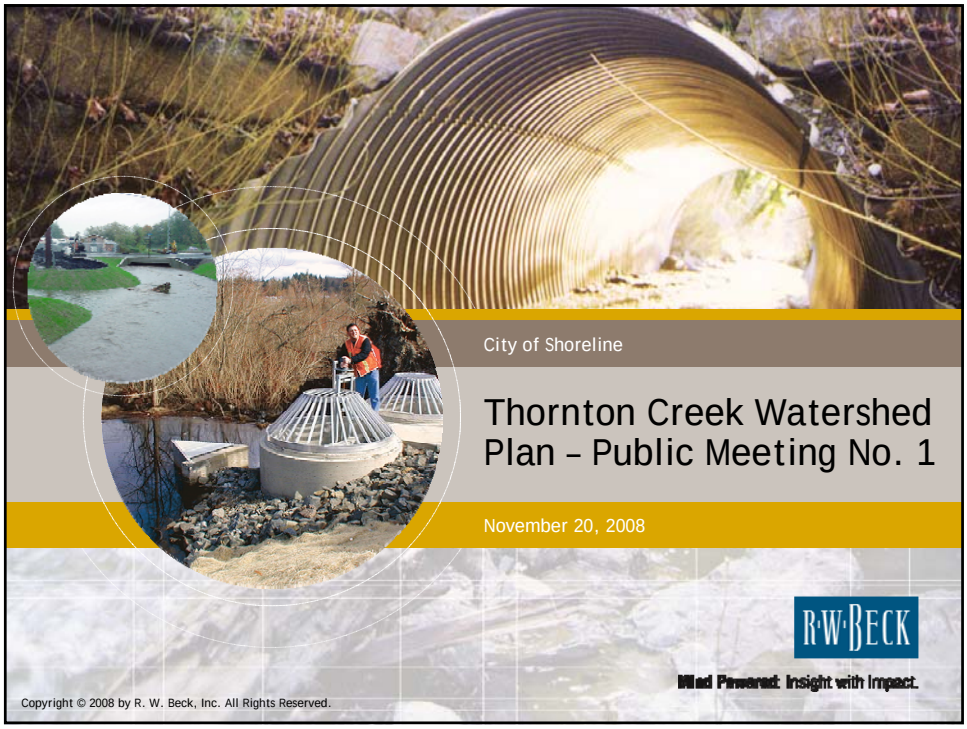
WDFW (Washington Department of Fish and Wildlife). 2003. Design of Road Culverts for Fish Passage.

Appendix A
PUBLIC INVOLVEMENT

R·W·BECK

An SAIC Company

A1. Public Meeting, November 20, 2008



City of Shoreline

Thornton Creek Watershed Plan – Public Meeting No. 1

November 20, 2008

R·W·BECK

Mind Powered: Insight with Impact.

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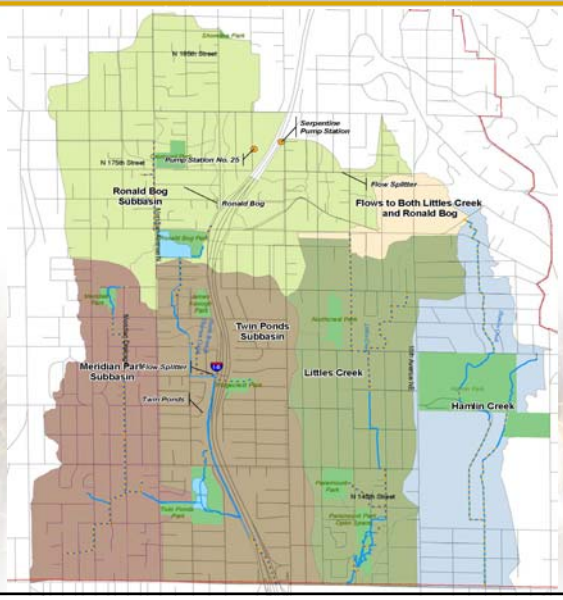
Purpose of this Meeting

- To discuss current City actions to address flooding and other issues with Thornton Creek
- To explain the community's role in this process
- Gather community input on evaluation criteria

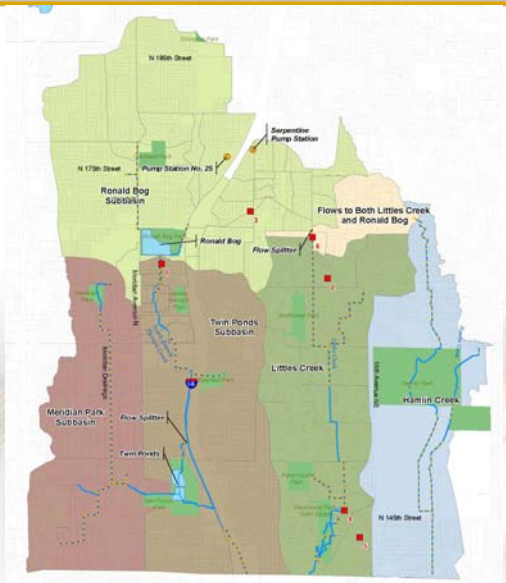
Thornton Creek Watershed Area



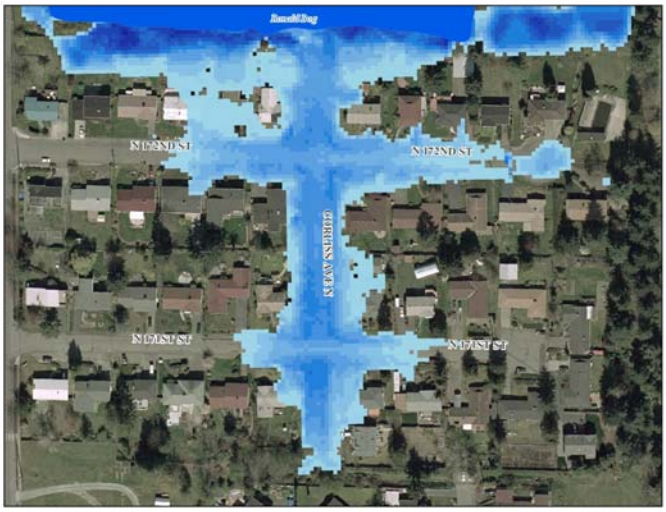
Cause of Flooding

- Drainage system includes
  - Pipes, channels, and natural streams to convey runoff
  - Ponds, lakes, bogs, and wetlands to store runoff
- Flooding occurs when storm runoff exceeds the conveyance and storage capacity of the system

Flooding Problem Areas



Flooding Problem – December 3, 2007



Just a Year Ago…

- Some 240 acre-feet of water passed through Ronald Bog in 24 hours
- Flood waters on Corliss = 25 acre-feet
- That water flooded more than a dozen family homes – many more were impacted
- Estimates ranged as high as $20 million to fix the system

Recent City Actions

- Continued on going maintenance of the aging system
- Preparing a Floodplain Mapping Study
- Completed improvements in 2008
- Preparing a Watershed Plan for Thornton Creek

Flood Plain Mapping

- Detailed scientific model
- Defines extent of impacts on the basin
- Tool for evaluating performance or effectiveness of alternatives
- May open up funding alternatives

Improvements in 2008

- Replaced downstream culverts
- Cleaned up the open channels
- Replaced failing pipes on Corliss Ave N
- Extended the street system on Corliss Place
- Installed the level monitor
- Purchased emergency pump

Improvements in 2008

Improvements in 2008

Improvements in 2008

Watershed Plan

- Refines projects and programs for the Thornton Creek Basin
- Performs engineering to define alternative solutions and costs
  - Flood protection
  - Habitat and Water Quality Improvement

Watershed Plan - continued

- Make recommendations
- Update prioritization
- Update Schedule
- Update funding analysis
- Engage the Community

Constraints and Challenges

- Flood protection alternatives
  - Determining effective solutions that are affordable
  - Meeting Permit requirements
  - Preventing downstream impacts
  - Minimizing neighborhood impacts

Constraints and Challenges

- Fish habitat improvement alternatives
  - Prioritizing solutions City wide
- Water quality improvement alternatives
  - NPDES compliance and incorporating water quality treatment into flood control capital projects

Community's Role

- Help evaluate alternatives
  - November 20 meeting – prioritize evaluation criteria
  - Early 2009 meeting – review and evaluate alternatives

Evaluation Criteria

- Permitable
- Manages downstream impacts
- Effective
- Affordable
- Minimizes impacts to neighborhoods
- What is most important to you?

Next Steps

- Public meeting to review and get input on specific alternatives – early 2009
- Watershed Plan with recommendations to City Council – end of 1st Quarter 2009
  - Including funding strategies
- Timeline for implementation – depends on solutions and funding

Stay In Touch

- Website - http://shorelinewa.gov/index.aspx?page=244
- Contact –
  Ross Heller, City of Shoreline
  (206) 801-2472
  rheller@ci.shoreline.wa.us

A2. Public Meeting, April 22, 2009

City of Shoreline

Ronald Bog Community Meeting

April 22, 2009

R·W·BECK

Mind Powered: Insight with Impact.

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Purpose of this meeting

- Provide status report on work to solve Ronald Bog flooding problem
- Answer questions
- Describe next steps

Presentation agenda

- 2009 construction
- Status of FEMA mapping
- Basin study and proposed improvements
- Interim Flood Plain Management

Improvements planned for 2009

- Construction of detention in Cromwell Park
- Paving on Corliss Place
- Drainage improvements on 171st east of Corliss Ave
- Drainage improvements at 172nd and Corliss Ave
- Connect foundation drains to street system & minor property restoration
- Improve the pump pad and street drainage system

FEMA mapping/computer modeling

- Computer modeling of 100 Year Event was performed according to FEMA standards
  - Accurately describes the December 3, 2007 Event (approximately equivalent to 100 Year Event)
  - Predicts 100 Year Event with 2008 improvements in place
  - Used to determine effectiveness of improvements

Computer simulation of floodplain

Before 2008 improvements

Criteria used to evaluate alternatives

- Provide 100 year flood protection
- Be affordable so it is implementable
- Does not increase downstream flows
- Minimize impacts to the neighborhood
- Be compatible with future habitat projects
- Ability to ultimately meet FEMA standards

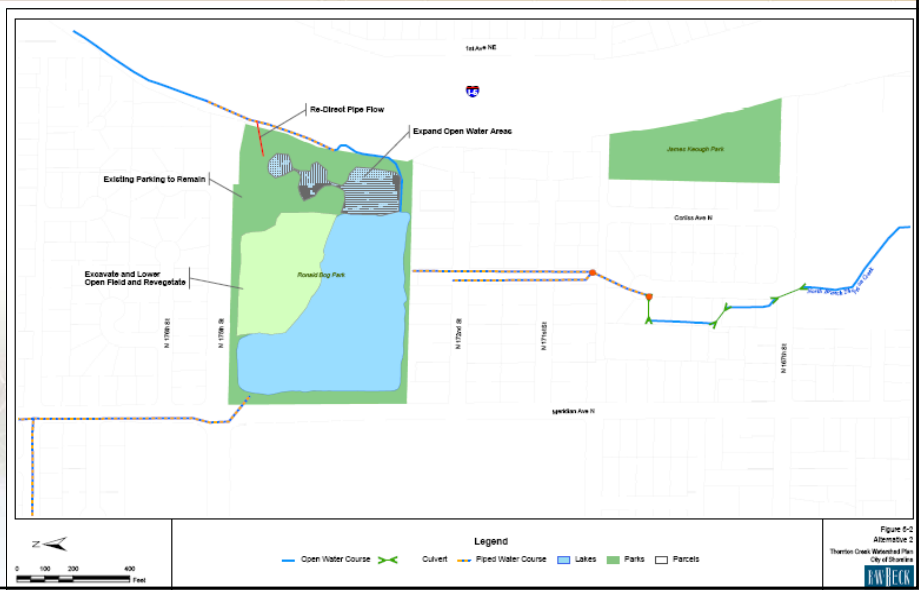
Why are FEMA standards important?

- Enables home owners and government agencies to have a consistent approach for evaluating flood risk & developing solutions
- FEMA standards apply to:
  - The technical computer analysis to prepare the 100 year floodplain area maps
  - The design of flood control structures that allow officials to revise the 100 year floodplain area
  - How lenders and assessors evaluate property

Screened nearly 30 potential alternatives

- Four categories of alternatives selected for detailed analysis
  1. Increased storage at Ronald Bog
  2. Increased conveyance capacity
  3. Flood berm or wall along the south edge of the Bog
  4. Property acquisition and flood proofing

Increased storage at Ronald Bog

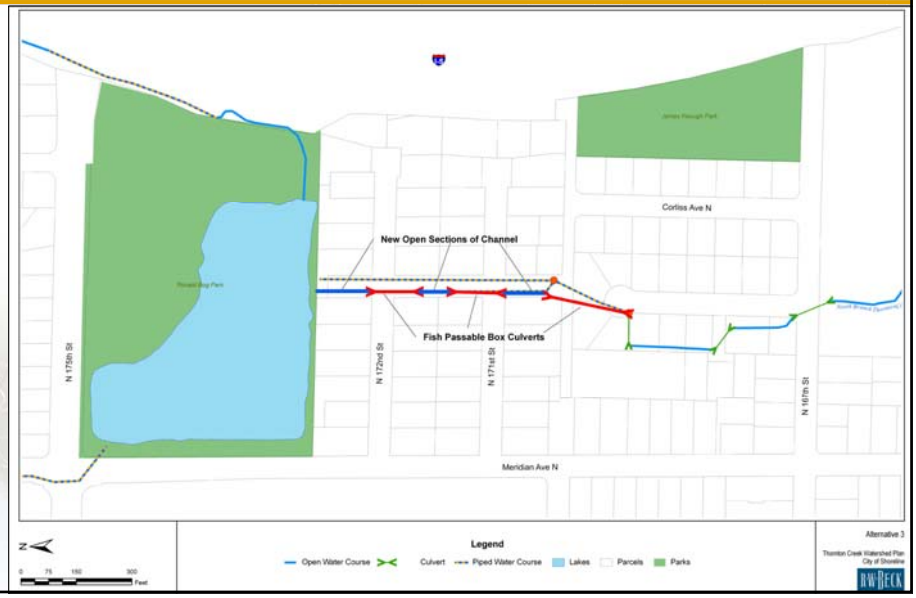


Increased storage at Ronald Bog

Evaluation Criteria	Yes	No	Comments
Provide 100 year flood protection		X	50 yr protection-doesn't solve groundwater problems
Be affordable/implementable		X	Funding more difficult
Does not increase downstream flows	X		
Minimize impacts to the neighborhood		X	Wetland and park impacts
Compatible with habitat projects	X		
Meet FEMA standards		X	Inadequate flood protection

DID NOT MOVE FORWARD

Increased conveyance capacity

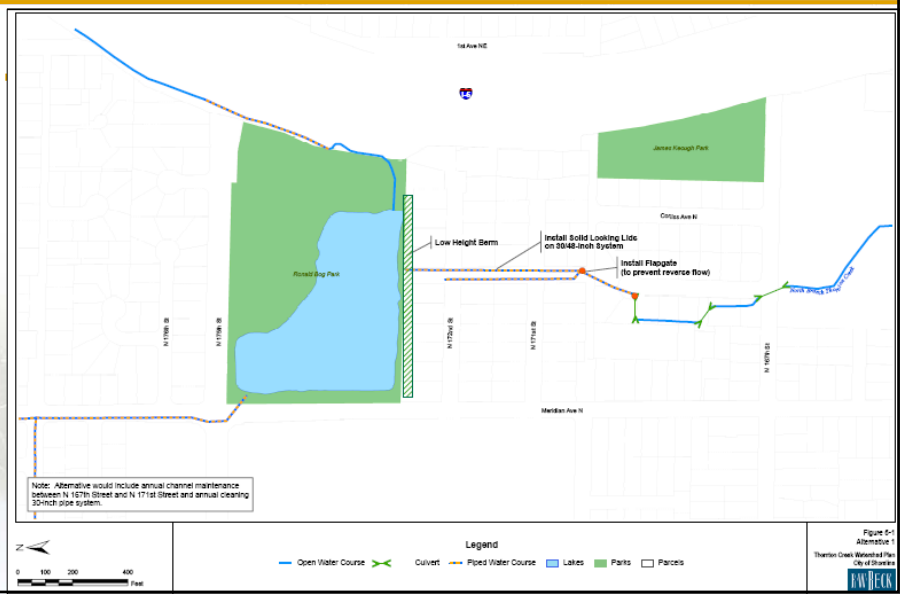


Increased conveyance capacity

Evaluation Criteria	Yes	No	Comments
Provide 100 year flood protection	X		Doesn't solve all groundwater problems
Be affordable/implementable		X	Funding more difficult
Does not increase downstream flows		X	Increases downstream flows
Minimize impacts to the neighborhood	X		
Compatible with habitat projects	X		Designed to be fish passable
Meet FEMA standards	X		

DID NOT MOVE FORWARD

Flood berm or wall along the Bog



Flood berm or wall along the Bog

Evaluation Criteria	Yes	No	Comments
Provide 100 year flood protection	X		Doesn't solve all groundwater problems
Be affordable/implementable	X		
Does not increase downstream flows	X		
Minimize impacts to the neighborhood	X		Design coordinated with neighborhood
Compatible with habitat projects	X		Add habitat projects
Meet FEMA standards	X		

- Street and home drainage systems must be isolated from Bog outlet pipe
- May need to pump local drainage in flood events

Property acquisition and flood proofing

- Acquire severely flooded properties
- Elevate properties with shallower flooding

Property acquisition and flood proofing

Evaluation Criteria	Yes	No	Comments
Provide 100 year flood protection	X		
Be affordable/implementable	X		
Does not increase downstream flows	X		
Minimize impacts to the neighborhood	X		Design coordinated with neighborhood
Compatible with habitat projects	X		Add habitat projects
Meet FEMA standards	X		

- Elevate homes 1 ft above 100-year flood level to be removed from floodplain
- Homes and roads would be elevated to provide access in a 100 year flood

Evaluation criteria eliminated two categories of alternatives

- Increased storage in the Bog is not affordable and does not provide 100 year level of protection to homes
- Additional conveyance capacity increases downstream peak flows and cost to provide downstream flood storage is not affordable

Alternatives for further evaluation

1. Flood berm or wall along the south edge of Ronald Bog
2. Property acquisition and flood proofing
3. Combination of both the above

Solutions Can Ultimately Meet FEMA Standards

Next steps

- Evaluate these alternatives using site specific data
  - Work with individual homeowners in the floodplain on floodproofing
  - Work with individual homeowners along the Bog on berm Solutions
- Develop more detailed costs
- Pursue funding alternatives
- Implement Interim Flood Management Plan
- Inform the community as work progresses

Interim Flood Management Plan (FMP)

The City will:

- Continue maintenance
- Provide early flood warning (Bog monitoring) system
  - Reverse 911 when Bog reaches a certain level
- Implement temporary pumping
- Assess feasibility of temporary berm in flood season
- 2009 construction improvements

Timeline

- Spring 2009
  - Meet with individual homeowners
- Summer 2009
  - Develop recommendations and detailed costs
  - Obtain Council review and approval
  - Submit grant applications
- Fall 2009
  - Meeting to discuss FMP and preparations for 2009 – 2010 wet season
- 2010 and 2011
  - Design and construction

Q & A

Questions?

Stay in touch

- Website - http://shorelinewa.gov/index.aspx?page=244
- Contacts –
  - Ross Heller, City of Shoreline

    (206) 801-2472

    rheller@shorelinewa.gov
  - Brian Landau, City of Shoreline

    (206) 801-2451

    blandau@shorelinewa.gov

A3. Homeowner Interview Summary

Thornton Creek Watershed Plan
Homeowner Interviews – Comment Matrix

July 22, 2009

Names and addresses have been removed to preserve privacy of homeowners

	NAME	Interview #1	Interview #2	Interview #3	Interview #4	Interview #5	Interview #6	Interview #7	Interview #8	Interview #9	Interview #10	Interview #11	Interview #12	Interview #13	Interview #14	Interview #15
	ADDRESS															
BACKGROUND	TIME @ ADDRESS	11 years	24 years	20 years	5 years; family owned for 35 years	20 years	8 years	owned 13 years	4 years	4 years	5 years	50 years	45 years	35 years	13 years	16 years
	HAVE BASEMENT															
	FLOOD INSURANCE	Y haven't used yet	would not consider	don't know		Y beneficial			N would consider	N would consider	N would consider	N would consider	N should not need if water is managed	N should not need if water is managed	N used to have; cancelled	Y purchased after 2007 flood
	FLOODING CONCERN (LOW, MED, HI / TYPE)	HI esp. when raining; safety	LOW water went away quickly	LOW not for us, but concerned for neighbors	HI flooding seems to be getting worse	HI inconvenience of clean up/ repairs	HI mold, health	LOW don't live at property	HI esp. when raining	HI esp. when raining; home equity, safety, health, mold	HI esp. when raining	MED esp. when raining; safety	MED esp. when raining	MED not frequent enough "to lose sleep over"	HI damaged collector car; house settling; foundation cracks	HI property value; mold; can't fully use basement until flooding stops
EXTENT OF FLOODING	HAVE FLOODED															
	MAIN LEVEL															
	BASEMENT															
	CRAWL SPACE															
	YARD															
	STREET FRONTAGE															
	OTHER					HVAC system; back yard flooding yearly								171st & Corliss underwater; no vehicular access		
	NOTES	Even homeowners who did not experience flooding in their own homes or on their property identified with and felt the impacts of being flooded. Many were out in the flooded streets or in neighbors' homes trying to help.														
KEY CONSIDERATIONS	FUNDING/ COST															
	TIME															
	LEVEL OF PROTECTION															
	ENVIRO.															
	OTHER			do it right the first time			not an easy solution	not a quick fix; do it right the first time	protecting home equity		make sure this project doesn't get lost in case of City staff turnover	fix street drainage	focus on properly managing what you already have	focus on properly managing what you already have		property values

Thornton Creek Watershed Plan
Homeowner Interviews – Comment Matrix

July 22, 2009

Names and addresses have been removed to preserve privacy of homeowners

		NAME	Interview #1	Interview #2	Interview #3	Interview #4	Interview #5	Interview #6	Interview #7	Interview #8	Interview #9	Interview #10	Interview #11	Interview #12	Interview #13	Interview #14	Interview #15
		ADDRESS															
FLOOD REDUCING STRATEGIES	GENERAL	CONVEYANCE					pump from the bog during off season										
		STORAGE			park south of 167th	Ronald Bog park	Ronald Bog park		Ronald Bog park	dredge the bog	Ronald Bog park		Ronald Bog park	dredge the bog	Ronald Bog park or other playfield		Ronald Bog park
		FLOOD PROOFING	sump pump, berm around yard					sump pump, sand bags									
		PLANNING															
		OTHER							no real preference					use common sense and low cost, existing tools - pump the bog and monitor to avoid downstream impacts			
	PROPERTY PURCHASE	CANDIDATE FOR PURCHASE	Y														
		SUPPORT PURCHASE															
		NOTES		thinks those who have been flooded might want to sell; top dollar from City		if market value or more; not attached to home		was unsure; didn't seem favorable		only fair solution; feels strongly that the City should buy flooded homes; wants to sell to City this year	house and neighborhood are irreplaceable	only if flooding could not be adequately reduced	would like to sell	better to purchase homes along bog than to spend $ on a solution that won't be maintained	could support the purchase of flooded homes if it will solve flooding		should be low on the list of options
	BERM @ BOG	BOG ADJACENT															
		SUPPORT BERM															
		NOTES				won't help; water came from street into home; maybe better than nothing	won't help; need more storage than that				don't want to lose view of wild life	don't want view obstruction		just one more thing for the City to maintain; won't be maintained	just one more thing for the City to maintain; won't be maintained	would support depending on size and appearance	
POTENTIAL FUNDING SOURCES		LID															
		RATE INCREASE															
		NEW/REALLOCATED TAXES															
		RE-PRIORITIZE CAPITAL BUDGET															
		OTHER							tax or charge developers upstream	purchase flooded homes		Federal funding					
		NOTES	the flooding has cost us a lot already	don't know	okay to pay a little more to solve the problem (a few pennies on the dollar)	maybe rate increases, but depends on how much	would pay more to fix the problem; should be a priority over other projects (e.g. sidewalks)	would pay more only if problem will be fixed; reprioritize this project over others			depends on cost to residents; would rather pay upfront and be done; need to know what we are paying for	would pay if certain that for the next 50 years City is committed to fixing our flooding	if people want improvements they need to pay for them; a little at a time is better than asking for a lump sum		don't mind spending a dollar if you know what you're getting will work	don't care; whatever is the most beneficial to flooded residents	would support any/all

Thornton Creek Watershed Plan
Homeowner Interviews – Comment Matrix

July 22, 2009

Names and addresses have been removed to preserve privacy of homeowners

	NAME	Interview #1	Interview #2	Interview #3	Interview #4	Interview #5	Interview #6	Interview #7	Interview #8	Interview #9	Interview #10	Interview #11	Interview #12	Interview #13	Interview #14	Interview #15
	ADDRESS															
COST VS. LEVEL OF PROTECTION	COST															
	LEVEL OF PROTECTION															
	NOTES	this should be a priority for the City above other projects	flooding is infrequent; not a major issue	would support a reduced level of protection	would like the neighborhood to have the highest level of protection	would rather pay taxes to provide higher level protection for others	want highest level of protection (complete elimination of flooding); peace of mind	reduced level of protection ok - number of people impacted doesn't warrant highest level	would not support a reduced level of protection	if residents pay, it has to be for a solution that will work	undecided; 100 year protection is unrealistic; 25-50 is probably ok, but less than that is not ok	need to find a balance between the two	don't overreact to infrequent flooding	fix flooding before spending money on sidewalks or other improvements on Aurora		want the best protection for the cost; strike a balance
CONCERNS	ENVIRONMENTAL	open creek is not safe for kids, creates mosquito problem	don't know	like open creek	like open creek because it is park like; not concerned about salmon here	like open creek; support environmental protection, but need to use common sense	like open creek as long as maintained; environment should be a high priority	none	none; never should have built homes here	like open creek; does it create more blockages to flow?	like open creek; don't want project held up due to fish	don't like open creek, not safe for kids	none; don't believe there are salmon in the bog	none	open creek ok; trust the city will act responsibly	open creek ok; prioritize people over salmon
	COULD INTERFERE W/ PROJECT SUCCESS	open creek; impacting access on Corliss	can't please everyone; open creek	cost	people won't want to pay; impacts to driveway access on Corliss	others don't want to pay taxes; other's concern for fish, frogs	cost, maintenance, permits	others' concern for wetlands and wildlife	class action law suit	cost to homeowners	some are concerned about fish; turnover at the City	cost	can't please everyone	give us a concrete solution, not just a bunch of alternatives	don't know	Janet Way is protective of frogs

Appendix B
HYDROLOGIC AND HYDRAULIC MODELING MEMORANDUM
(Prepared by Northwest Hydraulic Consultants)

R·W·BECK

An SAIC Company

Memorandum

To: **nhc** file # 21629

From: Chris Long and David Hartley, northwest hydraulic consultants, inc.

Date: November 24, 2008

Re: Hydrologic and Hydraulic Modeling for the North Branch Thornton Creek Basin Plan

Introduction

Northwest Hydraulic Consultants (**nhc**) was contracted by R.W. Beck to provide hydrologic and hydraulic modeling support for the North Branch Thornton Creek Basin Plan. Combined with its tributary watersheds of Littles and Hamlin Creeks, the North Branch Thornton Creek watershed is the largest in the City, encompassing approximately 2,400 acres within the City of Shoreline. The North Branch first appears as a definable open channel stream just north of Ronald Bog. The creek exits to the south of the bog and generally flows south through primarily residential property before entering twin culverts underneath Interstate-5 and crossing Shoreline's boundary with the City of Seattle.

A focus of the Basin Plan was addressing the all too frequent flooding of the residential properties immediately south of Ronald Bog. Up to 20 homes located adjacent to Corliss Ave N. south of Ronald Bog and have experienced flood damage in recent large storms. Even though the bog has been the focus of multiple engineering studies in recent years, flood mitigation measures to date have been limited. Through a comprehensive hydrologic and hydraulic modeling approach, several alternatives to alleviate the flooding were investigated. This memorandum explains the approach taken to identify the flooding problem and evaluate mitigation alternatives.

Modeling Approach

The EPA's HSPF program (USEPA, 1988) was selected as the computer model to quantify the flooding problem at the Ronald Bog and to evaluate the effectiveness of the mitigation alternatives. HSPF is a sophisticated computer modeling program that simulates land surface and in-stream hydrologic processes on a continuous basis. The program is commonly used to transform long-time series of observed rainfall and evaporation data into concurrent time-series of streamflow data based on continuous accounting of soil moisture levels. This approach offers some distinct advantages over the more traditional event-based modeling approaches. Event-based models simulate streamflow for individual storm events and their accuracy depends on numerous assumptions including soil moisture levels at the start of the storm event being modeled. Also, event-based models cannot be used to simulate low flows and hence are of little value in characterizing the overall hydrologic regime for a given watershed.

Continuous hydrologic modeling is of particular value in studying a watershed such as that draining to Ronald Bog because it allows for close examination of the relationship between the flows into and out of a detention pond. Because the stage of Ronald Bog is the principal determinant in the extent of flooding, the metric used to quantify the flooding problem and to evaluate the effectiveness of the proposed

solutions was a stage-frequency analysis at the bog. The HSPF model enabled continuous calculation of the pond stage at 15-minute intervals for 60 years (water years 1949 through 2008). By extracting the peak annual stages and fitting a curve through the data, the annual exceedance probability associated with the entire range of bog stages, including high stages that cause flood damage, could be estimated. The development of probability curves for historic, existing, and proposed conditions at Ronald Bog provided a convenient method of comparing the modeled scenarios.

Modeled Scenarios

The HSPF model was used to simulate the function of Ronald Bog under six different conditions. The first condition, labeled the ***Prior Condition***, reflects the circumstances under which the bog operated prior to channel improvements that began in February 2008. The second condition, labeled the ***Current Condition***, characterizes the bog's present hydrologic and hydraulic response since a channel improvement project undertaken by the City of Shoreline was completed in October 2008. The ***Design Condition*** is similar to the ***Current Condition***, but assumes the open-channel portion of the North Branch is maintained per R.W. Beck's engineered design drawings. The three remaining conditions, labeled as ***Alternative 1***, ***Alternative 2***, ***and Alternative 3***, were flood mitigation scenarios that were defined through a collaborative effort involving City of Shoreline staff, R.W. Beck and **nhc**. Table 1 below itemizes significant characteristics of the modeled scenarios.

Table 1. Modeled Scenarios

Modeled Scenario	Brief Description
Prior Condition	• Based on Bog hydraulic conditions prior to Feb 2008 • Includes 3 old culverts, north & south channels geometry before cleaning/dredging • Bog stage vs. outflow based on SWMM model HYD_EXIST_26.xp • Bog stage vs. volume based on live storage above 363.7'
Current Condition	• Based on current hydraulic conditions (post Oct 2008) • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Bog stage vs. outflow based on SWMM model F-27.xp • Bog stage vs. volume based on live storage above 362.67'
Design Condition	• Based on RW Beck's designed hydraulic conditions • Includes 3 new culverts, dredged and maintained north & south channels geometry • Bog stage vs. outflow based on SWMM model F-29.xp • Bog stage vs. volume based on live storage above 362.67'
Alternative 1	• Based on proposed hydraulic conditions • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Includes approximate proposed Cromwell Park detention • Bog stage vs. outflow based on SWMM model F-27.xp • Bog stage vs. volume based on live storage above 362.67' only north of residential properties (represents the effect of a dividing berm at the south end of the bog)
Alternative 2	• Based on proposed hydraulic conditions • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Includes approximate proposed Cromwell Park & increased Ronald Bog detention • Bog stage vs. outflow based on SWMM model F-27.xp • Bog stage vs. volume based on an approximate 20% increase in storage

Alternative 3[2]	• Based on proposed hydraulic conditions • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Includes connection of existing 18" storm pipe to Ronald Bog • Bog stage vs. outflow based on SWMM model F-28.xp • Bog stage vs. volume based on live storage above 362.67' only north of residential properties (represents the effect of a dividing berm at the south end of the bog)

Notes: [1] All scenarios use current conditions land use. Future land use was not considered in the scenarios.

[2] The RW Beck report refers to this as a variant of Alternative 1; *Berm with 18-inch Pipe System Extension*

Hydrologic Modeling

As explained earlier, HSPF was chosen to evaluate the past and present frequency of flooding and the effectiveness of proposed flooding solutions. In general, the process of developing the HSPF model included the following steps:

- Collection of hydrometereological (precipitation and evaporation) data for the watershed.
- Segmentation of the watershed into smaller modeling subbasins.
- Analysis of soils and land use to determine the physical characteristics of each subbasin.
- Estimation of stage-area-storage-discharge relationships for routing flows through stream reaches, ponds, or conduits.
- Determination of appropriate hydrologic response parameters based on a calibration exercise.

The proceeding sections describe how these steps were accomplished for the North Branch Thornton Creek watershed.

Hydromet Data

Fifteen-minute precipitation data used in the hydrologic model was obtained from three sources. Preference was given to rain gages located nearest the basin; however the nearest rain gages have recorded data for the shortest periods. Table 2 summarizes the rainfall source, the period of record, and any adjustment factor. Only rain from the SeaTac gage was adjusted. The adjustment factor accounts for proximity of the gage to the project site and is based on mean annual rainfall trends in the Puget Sound. Pan evaporation data for the model were obtained from the Puyallup evaporation station at a daily interval. A pan constant of 0.75 is used to convert pan evaporation to potential evapotranspiration.

Subbasins

The North Branch Thornton Creek watershed was divided into fifty-three subbasins. Some of the subbasins were identified in the *Thornton Creek Tributary Flood Reduction Study* completed by Otak (2001) and others were identified in a study by Pace Engineers to evaluate the redevelopment of Cromwell Park (Pace, 2008). The remaining subbasins were delineated using a combination of topographic subbasin boundaries and drainage network linkages found in the City's GIS database. In general, subbasins were delineated from key basin features, principally road crossings and distinct elevation breaks. Figure 1 depicts the modeled subbasins and Figure 2 illustrates the routing sequence.

Soils

Soils mapping for the Thornton Creek basin was derived from USGS quadrangle geology maps that have been digitized and slightly modified by the Washington Department of Natural Resources. These maps identified only two soil units within the basin: Vashon Till and Advance Glacial Outwash Deposits. For this study, a third category, saturated (or "wetland") soils, was added in those areas defined as wetlands or open water in the City's GIS database. Figure 3 shows the location of the surface geology layers in the basin.

Land Use

Current land use categories and land cover conditions within the North Branch Thornton Creek basin were extracted from the City's GIS database. Total Impervious Area (TIA) ratios were previously assigned in the Thornton Creek and West Lake Washington Basins Characterization Report developed by Tetra Tech (Tetra-Tech, 2004). For residential properties, the TIA value was assigned based on a review of 1999 aerial photos. For non-residential properties, the TIA value was assigned based on the 2001 King County Assessors Database. Land use categories for future conditions were extracted from the zoning layer within the City's database. The future total impervious area ratio assumes that the basin will be fully built-out according to the maximum allowed impervious area as specified in the City's Development Code. Figures 4 and 5 depict the existing and future land uses in the basin.

For modeling purposes, HSPF differentiates between impervious and pervious surfaces. For each land use category, the total impervious area is calculated using the TIA ratios described above. From the total impervious area for each land use, a second fraction, the effective portion, is assumed to contribute runoff directly to the drainage system. The effective impervious area (EIA) for each land use class is computed by multiplying the total impervious area by the effective factor. The effective factors used in this study are based on experience modeling Puget Sound area watersheds with characteristics similar to the North Branch Thornton Creek. Tables 3 and 4 document the current and future land use categories and their assumed percent EIA. In addition, the tables identify the land cover characteristics assigned to each land use category.

Using a GIS, an overlay analysis was performed using the fifty-three subbasins, three soil types, and all land use categories to develop a matrix of spatially divided ground cover information. This matrix is a primary input to the HSPF model. Tables 5, 6, and 7 summarize some of the data processed by the overlay analysis. Table 5 identifies the total area and effective impervious area calculated for each subbasin. For ten of the subbasins, the GIS analysis calculated a future EIA slightly less than the current EIA. Because future reductions in effective impervious area are highly unlikely, those subbasins were assumed to maintain their current impervious characteristics in the future. Tables 6 and 7 tabulate the land use by subbasin for current and future conditions respectively.

Stage-Area-Storage-Discharge Relationships

HSPF uses user-defined stage-area-storage-discharge relationships, called FTABLEs, to simulate routing of runoff and estimate downstream flows. In general, FTABLEs are created for each subbasin based on pipe or open-channel hydraulics, as appropriate. In some cases, dummy storage FTABLEs may be used in HSPF when there is no significant storage in the subbasin.

For the North Branch model, the FTABLEs for all subbasins draining to Ronald Bog except one were estimated using simple equations that account for the size and average slope of the subbasin. This

simplified approach was accepted because all subbasins draining to the bog convey water through storm pipes that have negligible storage. The exception to this approach is an FTABLE that defines a flow splitter located at the intersection of NE 175th St. and 10th Ave NE. This splitter sends low flows directly to Ronald Bog, but at higher flows also sends discharge to Littles Creek. This FTABLE was estimated based on the size of pipes leaving the splitter and an assumed difference in pipe inverts.

Unlike the FTABLEs described above, the FTABLE describing the stage-area-storage-discharge behavior of Ronald Bog was critical for this study. In fact, significant effort went into establishing this FTABLE for each scenario because it is key to the accurate simulation of flood levels at the bog. The hydraulic relationships found in the FTABLE were extracted from two sources and were altered depending on the scenario being modeled.

The stage vs. storage portion of the FTABLE was generated using a GIS to analyze the elevation contours within and surrounding the bog. In previous work for the City of Shoreline (Otak, 2001), bathymetric contours of the bog were generated. These contours were combined with overbank elevations generated by the Puget Sound LiDAR Consortium in 2000 to develop a three-dimensional representation of the ground surface. Using this surface, storage volumes were computed at incrementally higher stages for the area within the bog's natural banks and the area south of the bog on the residential streets. Figure 6 charts the stage vs. storage curves that were extracted from the GIS for the six modeled scenarios.

The stage vs. discharge portion of the FTABLE was generated using a XP-SWMM model. The XP-SWMM model was first developed by R.W. Beck in 2007 as part of their Thornton Creek Corridor Project (R.W. Beck, 2007a). This model was modified to simulate a quasi-steady backwater analysis at discrete discharges; thereby establishing the bog stage corresponding to each modeled discharge. The intent of this approach was to develop a stage vs. discharge relationship that implicitly accounts for much of the hydraulic complexity that is considered in XP-SWMM. The geometry of the XP-SWMM model was changed as appropriate to reflect each of the scenarios being analyzed. The stage vs. discharge curves for the six modeled scenarios are depicted in Figure 7. Combined with a constant nominal area of 6 acres, the stage vs. storage and stage vs. discharge relationships define the Ronald Bog subbasin FTABLEs for each scenario.

Three other FTABLEs of note are those which describe the hydraulic interaction in Twin Ponds, a second flow splitter located approximately one mile downstream of Ronald Bog, and a proposed detention pond at Cromwell Park. The FTABLE that defines hydraulic routing through Twin Ponds was developed by Entranco and included in their work titled *Draft Thornton Creek Hydrologic and Hydraulic Modeling* (Entranco, 2000). The FTABLE that defines the flow splitter was studied in detail by R.W. Beck and documented in a memorandum titled *Thornton Creek Flow Splitter Evaluation, Draft Technical Memorandum* (R.W. Beck, 2007b). For Alternative 2, a FTABLE to describe the function of a proposed detention pond at Cromwell Park was estimated from specifications in a technical memorandum (Pace, 2008).

Model Calibration

Observed Bog Stages

The primary calibration source for the HSPF model was recorded pond elevations of Ronald Bog. Beginning in January 2005, volunteers noted the bog stage on an approximately every other day basis using a staff plate installed by the City. A pressure transducer was subsequently installed in the northwest

corner of the bog in May 2006. The transducer, which is maintained by City of Shoreline, has recorded pond stage at 15-minute intervals since its installation.

The transducer output was first adjusted for changes in barometric pressure since it is an absolute pressure recorder. Upon plotting the recorded bog stages, it was obvious that the sensor had steadily drifted from the time of its installation. Fortunately, the pond elevation on the staff plate was noted when the transducer output was downloaded, thereby providing a reference point to quantify the drift. Using eleven reference points distributed equally in time, the recorded stages were corrected. Figure 8 illustrates water surface elevations in Ronald Bog recorded via staff plate through May 2006 and those recorded with the pressure transducer (corrected and otherwise) since.

Note that the peak stage recorded at Ronald Bog occurred on the afternoon of December 3, 2007. In fact, according to the HSPF model, the bog reached its highest elevation since 1949 on this date. The survey of a high water mark recorded by a resident on N 171rst St. established the pond elevation at 369.64 feet NAVD 88. This independent check of the peak stage attained on December 3 confirmed the drift correction applied to the pressure sensor.

Hydrologic Response Parameters

The HSPF model uses a set of parameters to define the characteristics of a land surface's response to meteorologic inputs. These parameters represent the physical characteristics and boundary conditions, and can be adjusted (calibrated), as necessary, to allow the model to better match simulated flow data. The parameters initially used in the North Branch model were developed by the USGS based on a regional study of a number of basins in the Puget Sound area (Dinicola, 1990). These regional parameters have been found by many users in western Washington to provide a good basis for model application in the absence of good calibration data.

Using these regional parameters, the model simulated stages and rainfall volumes at Ronald Bog were compared to the observed stages and volumes (obtained through a conversion using the bog FTABLE). The comparison necessitated adjusting some of the parameters. The INFILT parameter was increased to 0.4 for all till soils because it was observed that the runoff pattern in the basin more closely matched that of an outwash soil rather than a till-derived soil. This significantly increased the infiltration rate of the tills. It is noted that a similar parameter adjustment was made by Entranco in their hydrology model of the Thornton Creek (Entranco, 2000).

Two parameters that characterize the groundwater response from the model were also modified. The AGWRC parameter was slightly decreased to 0.992, affecting the rate at which available groundwater is expressed. In addition, the parameter DEEPFR was set to 0.8, meaning that 80% of the active groundwater is diverted to a deeper aquifer and is not introduced into the stream reaches. This change had negligible affect on the storm event hydrographs but did decrease the streamflow volumes during the dryer periods. Figures 9 and 10 illustrate the correlation between the observed and simulated stages at Ronald Bog for the wet months of November and December of 2006 and 2007. Note that special consideration was given to matching the peak stage observed on December 3, 2007 since the primary purse of this study is to quantify flood events.

Model Verification

Verification of the HSPF simulated peak stages in Ronald Bog was performed using the XP-SWMM model. The process involved modifying the XP-SWMM model to include the available storage at the

Ronald Bog node and specifying the rainfall-runoff inflows to the bog for selected storms. Three of the four largest storms to rain on the bog since 1949 were simulated in the hydro-dynamic model: January 1990, February 1951, and December 2007. The results compared favorably as Table 8 summarizes. On average, XP-SWMM predicted an absolute peak stage approximately 0.5-foot lower than HSPF. This average difference in peak stage between the models is acceptable considering the HSPF model was calibrated to accurately simulate the pond stage hydrograph for the largest event in the period of record (December 2007) and the peak stage exactly reflects the observed data (Figure 10) and the independent HWM survey. Of note is the extremely close difference in the peak stage each model simulates for the conditions before and after construction of the Ronald Bog South Phase 1 project. For the three simulated storm events, the difference between the prior and design condition simulations respective to each model averaged less than 0.1-foot.

Results

A stage-frequency plot was used to quantify flooding for the previous and existing conditions at Ronald Bog and the degree of flood reduction possible via proposed mitigation measures. For each condition modeled, the peak annual stages were identified for water years 1949 through 2008. Following the procedures outlined in the IACWD Bulletin 17B (IACWD, 1982), a log-Pearson Type III distribution was used to assign bog water surface elevations to annual exceedance probabilities (also described as "average recurrence intervals" or "annual frequencies"). The stage-frequency curves for each scenario have been plotted against each other on Figures 11 and 12 to facilitate comparison of the scenarios. The bog stage for the most often quoted average recurrence intervals are listed in Table 9.

Current Condition Flooding

Figure 11 illustrates that a significant reduction in flood frequency was achieved with the Ronald Bog South Phase 1 construction project. This project, which commenced in the summer of 2008, encompassed dredging the open-channel portions of the North Branch located west of Corliss Ave. N. and replacing three undersized and deteriorating culverts that bracket the channels with larger fish-passable culverts. The benefit this project provided was the creation of a more hydraulically efficient outlet for the bog in addition to slightly increasing the amount of live storage. This project alone is responsible for decreasing the frequency of flooding, as identified by stages in excess of 367.5 ft, for present-day conditions from a 5-year frequency to approximately a 15-year frequency. Similarly, what would have been classified a 25-year stage prior to the construction project is now approximately an 85-year stage.

Design Condition Flooding

The Ronald Bog South Phase 1 project was based on a design that was investigated and engineered by R.W. Beck (R.W. Beck, 2007a). In addition to fish-passable box culverts, the design drawings specified dredging the open-channels to a constant slope that would connect the inverts of the culverts. Survey of this reach subsequent to the project revealed that dredging of the north and south channels to the design condition was not achieved. This was due to discovery by the contractor that portions of the side slopes and invert of the channels had been lined with brick and mortar, making excavation impossible within the permitted construction window. As such, the current condition of the north and south channels does not conform exactly to the design drawing specifications. The impact of this is shown in Figure 11. For any percent chance exceedance, the elevation of Ronald Bog under the design condition would be lower than the present-day condition; ranging from 0.1-foot to 0.2-foot.

Flood Mitigation Alternatives

The flood reduction benefits of the three modeled mitigation alternatives are all illustrated on Figure 12. Since all three incorporate elements of the Ronald Bog South Phase 1 project as designed by R.W. Beck, their benefits should be viewed relative to the design condition curve.

Alternative 1 proposes to add approximately two acre-feet of storage in a detention pond at Cromwell Park. Design of this facility, which is currently at the 60% level, is being investigated by Pace Engineers (Pace, 2008). As such, operation of the detention pond was estimated for this study. Alternative 1 also represents placement of a dividing berm along the southern edge of the bog. The effect of this berm reduces the flood storage volume that is currently available along Corliss Ave. N.. Compared to the design condition, Figure 12 shows the stages at Ronald Bog are slightly lowered up to the 10-year quantile, reflecting the benefit of the Cromwell Park detention pond. However, beyond the 10-year quantile the bog stage is negatively affected, reflecting the loss of storage volume due to the proposed dividing berm. It is noted that accurate performance of the Cromwell Park detention pond cannot be assessed until the design has progressed further.

The flood reduction benefit of Alternative 2 is more dramatic than Alternative 1. Alternative 2 includes the Cromwell Park detention pond but more significantly increases the live storage in Ronald Bog. The additional storage would be created by excavating portions of Ronald Bog Park to the north and east of the existing ordinary water surface of the bog. The percent increase in storage changes with stage, as Figure 6 shows, but may be roughly quantified as 20% overall. The stage-frequency plot illustrates that this alternative reduces the frequency of what design conditions classifies a 5-year flood to that of a 10-year flood. Similarly it transforms what is approximately a 35-year stage to a 100-year stage.

Alternative 3 demonstrates the effect of extending the newly replaced 18-inch storm drain running under the west side of Corliss Ave. N approximately 150 feet north and connecting it to Ronald Bog. This scenario does not incorporate the Cromwell Park detention option, however does reflect making unavailable the ponding volume on Corliss Ave. N resulting from the proposed dividing berm. Different than the first two alternatives, this option significantly changes the stage vs. discharge characteristics, as Figure 7 illustrates. The value of Alternative 3 is similar to upsizing the 30-inch outlet pipe, but has the added benefit of providing an independent conveyance path. This project would reduce the design condition 10-year flood level a 15-year flood level.

Flow Duration Analysis

A flow duration analysis of the discharge from Ronald Bog indicates that for current conditions, only 10% of the time is the outflow from the bog greater than 2.2 cfs. The full range of discharges from the bog and the related percent exceedance is graphed in Figure 13. The 10% exceedance flow of 2.2 cfs was simulated in the XP-SWMM model to determine the associated velocities. The water velocity in each of the five pipe segments that carry water from Ronald Bog to the first of the new fish-passable culverts are also listed on Figure 13. The velocities range from 0.9 fps to 1.6 fps.

References

- Dinicola, R.S.. 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. U.S. Geological Survey, Water Resources Investigations Report 89-4052.

- Entranco. 2000. Draft Thornton Creek Hydrologic and Hydraulic Modeling: Hydrologic and Hydraulic Model Plan.
- Interagency Advisory Committee on Water Data. March 1982. Guidelines for Determining Flood Flow Frequency, Bulletin 17B.
- Otak. 2001. Ronald Bog Drainage Improvements, Phase 1: Thornton Creek Tributary Flood Reduction Study.
- Pace Engineers, Inc.. 2008. Draft Stormwater Narrative for 60% Submittal: Cromwell Park Redevelopment.
- R.W. Beck. 2007a. Thornton Creek Corridor Project: Preliminary Engineering Report, Final Report.
- R.W. Beck. 2007b. Thornton Creek Flow Splitter Evaluation: Draft Technical Memorandum.
- Tetra-Tech/KCM, Inc.. 2004. Thornton Creek and West Lake Washington Basins Characterization Report.
- U.S. Environmental Protection Agency. 1988. Hydrologic Simulation Program, FORTRAN, USEPA Environmental Research Laboratory, Athens, Georgia.

Table 1. Modeled Scenarios

Modeled Scenario	Brief Description
Prior Condition	• Based on Bog hydraulic conditions prior to Feb 2008 • Includes 3 old culverts, north & south channels geometry before cleaning/dredging • Bog stage vs. outflow based on SWMM model HYD_EXIST_26.xp • Bog stage vs. volume based on live storage above 363.7'
Current Condition	• Based on current hydraulic conditions (post Oct 2008) • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Bog stage vs. outflow based on SWMM model F-27.xp • Bog stage vs. volume based on live storage above 362.67'
Design Condtion	• Based on RW Beck's designed hydraulic conditions • Includes 3 new culverts, dredged and maintained north & south channels geometry • Bog stage vs. outflow based on SWMM model F-29.xp • Bog stage vs. volume based on live storage above 362.67'
Alternative 1	• Based on proposed hydraulic conditions • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Includes approximate proposed Cromwell Park detention • Bog stage vs. outflow based on SWMM model F-27.xp • Bog stage vs. volume based on live storage above 362.67' only north of residential properties (represents the effect of a dividing berm at the south end of the bog)
Alternative 2	• Based on proposed hydraulic conditions • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Includes approximate proposed Cromwell Park & increased Ronald Bog detention • Bog stage vs. outflow based on SWMM model F-27.xp • Bog stage vs. volume based on an approximate 20% increase in storage
Alternative 3[2]	• Based on proposed hydraulic conditions • Includes 3 new culverts, north & south channels geometry after cleaning/dredging • Includes connection of existing 18" storm pipe to Ronald Bog • Bog stage vs. outflow based on SWMM model F-28.xp • Bog stage vs. volume based on live storage above 362.67' only north of residential properties (represents the effect of a dividing berm at the south end of the bog)

Notes: [1] All scenarios use current conditions land use. Future land use was not considered in the scenarios.
[2] The RW Beck report refers to this as a variant of Alternative 1; *Berm with 18-inch Pipe System Extension*

Table 2. Rainfall Records

Rainfall Gage	Period of Record	Adjustment Factor
Seattle-Tacoma International Airport	Oct 1949 – Sep 2000	0.94
King County Rain Gage 04U	Oct 2000 – Dec 2004	1
City of Shoreline Rain Gage	Jan 2005 – May 2008	1

Table 3. Current Land Cover by Land Use

Land Use	TIA %	Effective Factor	EIA %	Grass %	Forest %	Pasture %
Commercial	87	0.95	83	17	0	0
Institution	57	0.9	51	49	0	0
Open Space	0	0	0	100	0	0
Public Facilities	55	0.9	50	50	0	0
Parks and Cemeteries	12	0.95	11	69	20	0
Residential - Multi-Family	73	0.6	43	57	0	0
Residential (lots less than 5,000 SF)	57	0.25	14	86	0	0
Residential (lots 5,000 to 7,199 SF)	40	0.25	10	90	0	0
Residential (lots 7,200 to 10,890 SF)	36	0.2	7	93	0	0
Residential (lots 10,891 to 21,780 SF)	28	0.15	4	96	0	0
Residential (lots 21,781 to 43,560 SF)	19	0.15	3	87	10	0
Residential (lots more than 43,560 SF)	17	0.15	3	85	12	0
Transportation	70	0.95	67	33	0	0
Vacant	0	0	0	85	15	0
Open Water	0	0	0	0	0	0

Table 4. Future Land Cover by Land Use

Land Use	TIA %	Effective Factor	EIA %	Grass %	Forest %	Pasture %
Community Business	85	0.9	77	23	0	0
Contract Zone	85	0.8	68	32	0	0
Neighborhood Business	85	0.9	77	23	0	0
North Zone Business District	95	0.9	86	14	0	0
Office	85	0.9	77	23	0	0
Open Space	0	0	0	100	0	0
Planned Area or Mixed use	85	0.8	68	32	0	0
R6	50	0.25	12	88	0	0
R8	65	0.35	23	77	0	0
R12	75	0.6	45	55	0	0
R18	85	0.8	68	32	0	0
R24	85	0.8	68	32	0	0
R48	90	0.8	72	28	0	0
Regional Business	95	0.9	86	14	0	0
Parks and Cemeteries	15	0.95	14	66	20	0
Transportation	70	0.95	67	33	0	0
Open Water	0	0	0	0	0	0

Table 5. Effective Impervious Area by Subbasin

Subbasin	Total Area (ac)	Current EIA (ac)	Future EIA (ac)	Change (ac)
LN-A1	3.5	1.4	1.4	0
LN-B1	3.5	0.4	0.7	0.3
LN-B2	57.6	27.7	36.4	8.7
M-A1	164.4	52.9	56.8	3.9
M-A2	186.3	45.1	47.6	2.6
N-A1	43.5	12.6	14.5	1.9
N-A10	8.3	2.5	2.8	0.3
N-A11	8.1	2.1	2.4	0.2
N-A2	46.0	8.4	10.0	1.7
N-A3	225.2	71.9	71.9	0
N-A4	9.3	4.3	4.3	0
N-A5	8.0	3.1	3.1	0
N-A6	5.9	1.8	2.0	0.1
N-A7	3.9	0.7	0.8	0.1
N-A8	3.5	0.3	0.5	0.2
N-A9	1.1	0.2	0.2	0
R-00	16.8	2.2	2.5	0.3
R-A1	9.6	4.0	4.0	0
R-B1	74.6	15.8	18.1	2.3
R-B2	29.6	6.1	6.1	0
R-B3	9.0	2.2	2.4	0.2
R-B4	56.4	13.1	16.1	3.1
R-B5	1.8	1.5	1.5	0
R-B6	119.2	33.2	33.2	0
R-C1	10.6	3.1	3.2	0
R-C2	33.8	7.0	8.2	1.2
R-C3	80.8	23.9	23.9	0
R-D1	2.5	1.7	1.7	0
R-D2	3.0	2.0	2.0	0
R-D3A	1.6	0.6	0.6	0
R-D3B	9.2	6.1	6.1	0
R-D4	25.8	6.3	6.7	0.4
R-D5A	8.8	1.2	1.5	0.3
R-D5B	3.4	1.0	1.4	0.4
R-D5C	26.7	7.4	7.4	0
R-D5D	1.0	0.5	0.5	0
R-D5E	7.6	1.8	2.0	0.2
R-D5F	0.3	0.2	0.2	0
R-D5G	2.4	0.3	0.4	0.1
R-D5H	2.0	0.3	0.3	0.1
R-D5I	1.8	0.4	0.5	0
R-D5J	7.8	2.5	2.7	0.2
R-D5K	10.6	1.8	2.1	0.3
R-D5L	4.3	0.9	1.1	0.2
R-D5M	5.8	1.1	1.3	0.3
R-D5N	9.0	1.9	2.2	0.3
R-D5O	5.3	1.5	1.9	0.5
R-D6A	5.8	1.8	2.0	0.2
R-D6B	7.3	1.3	1.5	0.2
R-D6C	4.7	1.8	1.9	0.1
R-D7	14.0	4.4	5.1	0.8
R-E1	1.9	1.2	1.2	0
N-B1	97.3	32.4	32.9	0.5
Basin Total (ac)	**1490**	**429**	**462**	**32**
Basin Total (%)		**29%**	**31%**	

Table 6. Current Land Use Area (acres) by Subbasin

Subbasin	Commercial	Institution	Open Space	Public Facilities	Parks and Cemetaries	Residential - Multi-Family	Residential (lots less than 5,000 SF)	Residential (lots 5,000 to 7,199 SF)	Residential (lots 7,200 to 10,890 SF)	Residential (lots 10,891 to 21,780 SF)	Residential (lots 21,781 to 43,560 SF)	Residential (lots more than 43,560 SF)	Transportation	Vacant	Water	Total
LN-A1	0	1.45	0	0	0	0	0	0.31	0.64	0.15	0	0	0.93	0	0	3.47
LN-B1	0	0	0	0	0	0	0	0.13	1.7	1.35	0	0	0.34	0	0	3.53
LN-B2	16.59	2.75	0	0.71	0	9.35	0.23	1.87	8.48	3.14	3.7	0	10.65	0.17	0	57.63
M-A1	20.4	4.27	0	7.2	3.9	10.92	0.59	15.01	58.36	14.2	0.5	0	28.05	1.02	0	164.42
M-A2	0	1.32	0	7.23	3.13	0.49	0.54	19.13	93.05	11.85	2.62	0	46.52	0.46	0	186.34
N-A1	0	9.36	0	0	2.93	0	0.07	4.98	14.5	2.31	0.63	0	8.69	0.01	0	43.48
N-A10	0	0	0	0	0.75	0	0.05	0.45	2.12	1.41	0	0	3.19	0.32	0	8.29
N-A11	0	0.15	0	0	0	0	0	0	4.35	1.03	0	0	2.54	0.01	0	8.09
N-A2	0	1.61	0	0	10.92	0	0.1	2.7	16.04	3.72	0	0	7.12	0	3.83	46.03
N-A3	4.96	0.73	0	18.64	3.57	2.2	0.67	24.58	84.25	9.99	2.54	0	71.38	1.68	0	225.18
N-A4	0	0	0	8.09	0	0	0	0	0.66	0	0	0	0.31	0.23	0	9.28
N-A5	0	0	0	4.94	0	0	0	0.26	1.76	0	0	0	0.65	0.36	0	7.96
N-A6	0	0	0	0	2.35	0	0	0	1.4	0	0	0	2.19	0	0	5.94
N-A7	0	0	0	0	0	0	0	0.16	2.78	0.28	0	0	0.69	0	0	3.9
N-A8	0	0	0	0	0	0	0	0	2.18	0.25	0.93	0	0.12	0.03	0	3.51
N-A9	0	0	0	0	0	0	0	0	0.96	0	0	0	0.18	0	0	1.13
N-B1	0	3.18	0	1.5	0	0	0	4.37	43.73	3.07	0	0	39.39	2.08	0	97.32
R-00	0	0.12	0	0	7.33	0	0	0	0.58	0.89	0	0	1.86	0	6.02	16.79
R-A1	0	0	0	4.54	0.01	0	0	0	2.35	0.31	0	0	2.36	0.01	0	9.59
R-B1	0.14	0.09	0	0	0.05	0	0.06	4.1	42.63	8.87	0	0	17.78	0.91	0	74.63
R-B2	0.78	0.96	0	0	0.87	0	0.12	2.31	16.41	2.07	0.86	0	5.03	0.19	0	29.6
R-B3	0.09	0	0	0	2.94	0	0	0.44	3.01	0.22	0	0	2.28	0	0	8.98
R-B4	0.96	1.05	0.35	0	0.04	0.43	1.08	5.51	21.07	9.07	2.51	0	13.32	1.06	0	56.44
R-B5	1.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.76
R-B6	0.07	4.51	0	18.11	4.17	3.09	0.51	8.61	41.89	11.24	3.65	0	23.3	0.05	0	119.21
R-C1	0	0.7	0	0	0	0	0.04	0.78	3.56	1.84	0.13	0	3.53	0	0	10.57
R-C2	0	0.85	0	0.05	0	0	0	1.1	14.2	7.51	0.61	0	7.62	1.9	0	33.83
R-C3	0	2.66	0	20.69	5.39	0	0.37	5.42	27.92	5.17	0	0	13.19	0	0	80.8
R-D1	0	0	0	0	0	0	0	0.01	0	0	0	0	2.5	0	0	2.51
R-D2	0	0	0	0	0	0	0	0	0.04	0	0	0	2.9	0	0	2.95
R-D3A	0	0	0	0	0	0	0	0.14	0.61	0.09	0	0	0.79	0	0	1.63
R-D3B	0	0	0	0	0	0	0	0	0	0.08	0	0	9.08	0.03	0	9.19
R-D4	0	0	0.52	1.47	0	0	0.02	0.47	16.79	0	0	0	6.47	0.02	0	25.75
R-D5A	0	0	0	0	0	0	0.01	0.47	4.3	2.93	0	0	1.13	0	0	8.84
R-D5B	0	0	0	0	0	0.17	0.08	0	2	0.01	0	0	1.1	0	0	3.37
R-D5C	0	3.8	0	0.05	0	0	0.11	2	8.94	3.35	0.79	0	6.66	0.95	0	26.65
R-D5D	0	0	0	0	0	0	0	0.16	0	0.14	0	0	0.72	0	0	1.02
R-D5E	0	0	0	0	0	0	0.07	0.48	2.96	1.69	0.18	0	2.19	0	0	7.56
R-D5F	0	0	0	0	0	0	0	0	0	0	0	0	0.32	0	0	0.33
R-D5G	0	0	0	0	0	0	0	0.13	1.09	0.89	0	0	0.26	0.02	0	2.4
R-D5H	0	0	0	0	0	0	0	0.14	0.81	0.74	0	0	0.23	0.12	0	2.04
R-D5I	0	0	0	0	0	0	0.09	0	0.85	0.35	0	0	0.49	0	0	1.78
R-D5J	0	0	0	0	0	0	0	0.45	3.3	0.62	0	0	3.34	0.04	0	7.75
R-D5K	0	0	0	0	0	0	0	1.85	4.98	2.03	0	0	1.73	0	0	10.59
R-D5L	0	0	0	0	0	0	0	0.61	2.46	0.25	0	0	0.96	0.01	0	4.29
R-D5M	0	0	0	0	0	0	0	0.51	4.01	0.17	0	0	1.12	0	0	5.82
R-D5N	0	0	0	0	0	0	0.11	1.44	4.76	0.64	0	0	1.99	0.01	0	8.95
R-D5O	0	0	0	0	0	0	0	0.9	1.77	0.78	0	0	1.84	0	0	5.29
R-D6A	0	0	0	0	0	0	0.09	0.27	2.29	0.48	0.38	0	2.33	0	0	5.84
R-D6B	0	0	0	0	0	0	0	1.68	3.3	1.06	0	0	1.25	0	0	7.29
R-D6C	0	0	0	0	0	0	0	1.52	0.81	0.01	0	0	2.37	0	0	4.7
R-D7	0.36	0.3	0	0.73	0	0	0	1.28	5.88	0.95	0	0	4.42	0.04	0	13.97
R-E1	0	0	0	0	0	0	0	0	0.03	0	0	0	1.83	0	0	1.86
Basin Total	**46.11**	**39.86**	**0.87**	**93.95**	**48.35**	**26.65**	**5.01**	**116.73**	**582.56**	**117.2**	**20.03**	**0**	**371.23**	**11.73**	**9.85**	**1490.07**

Table 7. Future Land Use Area (acres) by Subbasin

Subbasin	Community Business	Contract Zone	Neighborhood Business	North City Business District	Office	Open Space	Planned Area	Residential 12 du/acre	Residential 18 du/acre	Residential 24 du/acre	Residential 48 du/acre	Residential 6 du/acre	Residential 8 du/acre	Regional Business	Parks and Cemetaries	Transporation ROW	Water	Total
LN-A1	0	0	0	0	0	0	0	0	0	0	0	0.24	2.3	0	0	0.93	0	3.47
LN-B1	0	0	0	0	0	0	0	0	0	0	0	2.55	0.63	0	0	0.34	0	3.53
LN-B2	0	0	0	22.47	0.3	0	0	3.13	2.82	2.96	4.28	9.93	1.34	0	0	10.4	0	57.63
M-A1	0	0	0	0	0	0	0	1.32	7.44	0	1.49	94.96	6.83	21.43	3.9	27.06	0	164.42
M-A2	0	0	0	0	0	0	0	0.53	0	0	0	137.15	0	0	3.13	45.53	0	186.34
N-A1	0	0	0	0	0	0	0	6.57	0	2.79	0	15.23	7.47	0	2.93	8.48	0	43.48
N-A10	0	0	0	0	0	0	0	0	0	0	0	4.34	0	0	0.75	3.19	0	8.29
N-A11	0	0	0	0	0	0	0	0	0	0	0	5.54	0	0	0	2.54	0	8.09
N-A2	0	0	0	0	0	0	0	0	0	1.61	0	22.67	0	0	10.92	7	3.83	46.03
N-A3	0	0	0	0	0	0	5.17	1.5	3.94	0.56	0	141.07	0	0	3.57	69.37	0	225.18
N-A4	0	0	0	0	0	0	0	0	0	0	0	8.97	0	0	0	0.31	0	9.28
N-A5	0	0	0	0	0	0	0	0	0	0	0	7.32	0	0	0	0.65	0	7.96
N-A6	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	2.35	2.19	0	5.94
N-A7	0	0	0	0	0	0	0	0	0	0	0	3.32	0	0	0	0.58	0	3.9
N-A8	0	0	0	0	0	0	0	0	0	0	0	3.41	0	0	0	0.1	0	3.51
N-A9	0	0	0	0	0	0	0	0	0	0	0	0.96	0	0	0	0.18	0	1.13
N-B1	0	0	0	0	0	0	0	0.76	0	0.05	0	58.48	0.01	0	0	38.02	0	97.32
R-00	0	0	0	0	0	0	0	0	0	0	0	1.59	0	0	7.33	1.86	6.02	16.79
R-A1	0	0	0	0	0	0	0	0	0	0	0	7.22	0	0	0.01	2.36	0	9.59
R-B1	0	0	0	0	0	0	0	0	0	0	0	57.88	0	0	0.05	16.7	0	74.63
R-B2	0	0	0	0	0	0	0	0	0	0	0	24.43	0	0	0.87	4.3	0	29.6
R-B3	0	0	0	0	0	0	0	0	0	0	0	3.76	0	0	2.94	2.27	0	8.98
R-B4	0	0	0	0	0	0.35	0	3.46	0.15	0	0	31.53	7.9	0.81	0.04	12.21	0	56.44
R-B5	0	0	0	0	0	0	0	0	0	0	0	1.76	0	0	0	0	0	1.76
R-B6	0	0	0	0	0	0	0	2.66	0	1.22	1.38	86.25	1.5	0.03	4.17	22.01	0	119.21
R-C1	0	0	0	0	0	0	0	0	0	0	0	7.1	0	0	0	3.46	0	10.57
R-C2	0	0	0	0	0	0	0	0	0	0	0	26.26	0	0	0	7.57	0	33.83
R-C3	0	0	0	0	0	0	0	0	0	0	0	62.82	0	0	5.39	12.59	0	80.8
R-D1	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	2.5	0	2.51
R-D2	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	2.9	0	2.95
R-D3A	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0	0	0.73	0	1.63
R-D3B	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0	0	9.08	0	9.19
R-D4	0	0	0	0	0	0.52	0	0	0	0	0	17.73	1.02	0	0	6.48	0	25.75
R-D5A	0	0	0	0	0	0	0	0	0	0	0	8.06	0	0	0	0.78	0	8.84
R-D5B	0	0	0	0	0	0	0	0.71	0	0	0	0.47	1.1	0	0	1.1	0	3.37
R-D5C	0	0	0	0	0	0	0	0	0	0	0	17.69	2.88	0	0	6.08	0	26.65
R-D5D	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.72	0	1.02
R-D5E	0	0	0	0	0	0	0	0	0	0	0	5.51	0	0	0	2.05	0	7.56
R-D5F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.33
R-D5G	0	0	0	0	0	0	0	0	0	0	0	2.14	0	0	0	0.26	0	2.4
R-D5H	0	0	0	0	0	0	0	0	0	0	0	1.88	0	0	0	0.16	0	2.04
R-D5I	0	0	0	0	0	0	0	0	0	0	0	1.34	0	0	0	0.44	0	1.78
R-D5J	0	0	0	0	0	0	0	0	0	0	0	4.45	0	0	0	3.3	0	7.75
R-D5K	0	0	0	0	0	0	0	0	0	0	0	9.16	0	0	0	1.42	0	10.59
R-D5L	0	0	0	0	0	0	0	0	0	0	0	3.32	0	0	0	0.97	0	4.29
R-D5M	0	0	0	0	0	0	0	0.08	0	0	0	4.62	0	0	0	1.12	0	5.82
R-D5N	0	0	0	0	0	0	0	0	0	0	0	6.82	0.14	0	0	2	0	8.95
R-D5O	0	0	0	0	0.14	0	0	0	0	0	0	1.07	2.33	0	0	1.74	0	5.29
R-D6A	0	0	0	0	0	0	0	0	0	0	0	3.51	0	0	0	2.33	0	5.84
R-D6B	0	0	0	0	0	0	0	0	0	0	0	6.16	0	0	0	1.13	0	7.29
R-D6C	0	0	0	0	0	0	0	0	0	0	0	2.33	0	0	0	2.37	0	4.7
R-D7	0	0	0	1.31	0	0	0	0.14	0	0	0	8.13	0	0	0	4.39	0	13.97
R-E1	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	1.83	0	1.86
Basin Total	**0**	**0**	**0**	**23.78**	**0.44**	**0.87**	**5.17**	**20.86**	**14.35**	**9.19**	**7.15**	**933.92**	**35.45**	**22.27**	**48.35**	**358.41**	**9.85**	**1490.07**

Table 8. Verification of HSPF Results with XP-SWMM

Storm	Model	Ronald Bog Stage Prior Condition	Ronald Bog Stage Design Condition	Difference
Dec 2007 event	HSPF	369.60	368.63	0.97
	SWMM	368.99	368.24	0.75
		0.61	0.39	
Feb 1951 event	HSPF	368.78	367.75	1.03
	SWMM	368.38	367.34	1.04
		0.40	0.41	
Jan 1990 event	HSPF	368.35	367.53	0.82
	SWMM	367.71	367.01	0.70
		0.64	0.52	

Note: [1] Elevations are based on the NAVD 88 vertical datum.

Table 9. Ronald Bog Stage-Frequency Quantiles

Average Annual	Modeled Condition					
Return Period	**Prior**	**Current**	**Design**	**Alternative 1**	**Alternative 2**	**Alternative 3**
2	366.6	365.7	365.6	365.5	365.2	365.4
5	367.5	366.5	366.4	366.4	366.0	366.2
10	368.0	367.1	367.0	367.0	366.4	366.7
25	368.7	367.8	367.6	367.7	367.0	367.3
50	369.2	368.3	368.1	368.2	367.5	367.8
100	369.7	368.8	368.6	368.7	367.9	368.3
500	370.8	369.9	369.7	369.9	368.9	369.3

Notes: [1] A brief description of the modeled conditions is found in Table 1.
[2] Elevations are based on the NAVD 88 vertical datum.
[3] Elevation 367.5 is generally accepted as the flood stage.

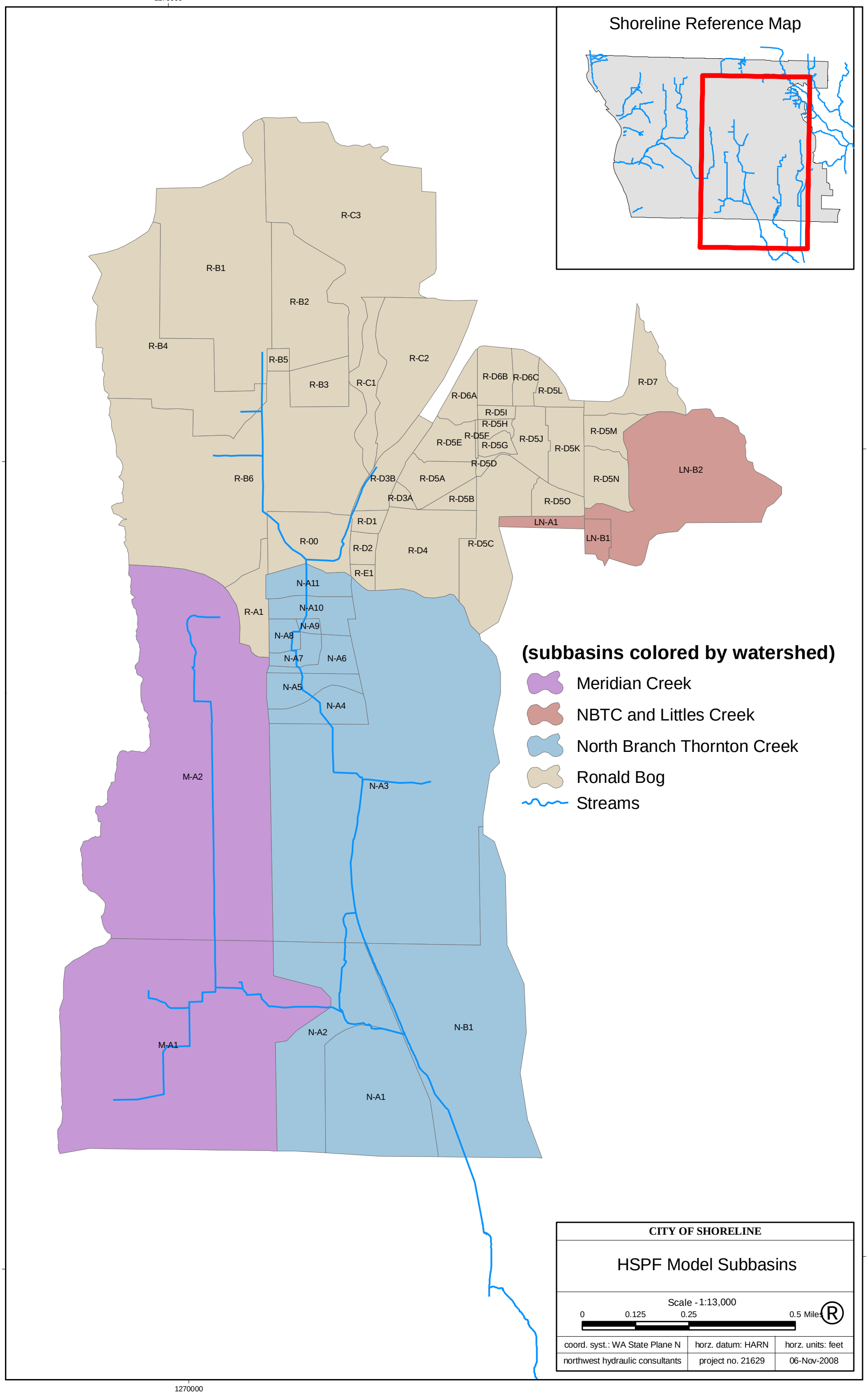

Shoreline Reference Map
1270000
280000
270000
R-C3
R-B1
R-B2
R-B4
R-B5
R-B3
R-C1
R-C2
R-D6B
R-D6C
R-D5L
R-D7
R-D6A
R-D5I
R-D5H
R-D5E
R-D5G
R-D5J
R-D5K
R-D5M
R-D5D
R-B6
R-D3B
R-D5A
R-D5N
LN-B2
R-D3A
R-D5B
R-D5O
R-D1
LN-A1
LN-B1
R-00
R-D2
R-D4
R-D5C
R-E1
N-A11
R-A1
N-A10
N-A9
N-A8
N-A7
N-A6
N-A5
N-A4
M-A2
N-A3
N-A2
N-B1
M-A1
N-A1
(subbasins colored by watershed)
Meridian Creek
NBTC and Littles Creek
North Branch Thornton Creek
Ronald Bog
Streams
CITY OF SHORELINE
HSPF Model Subbasins
Scale - 1:13,000
0
0.125
0.25
0.5 Miles
coord. syst.: WA State Plane N
horz. datum: HARN
horz. units: feet
northwest hydraulic consultants
project no. 21629
06-Nov-2008

Figure 1

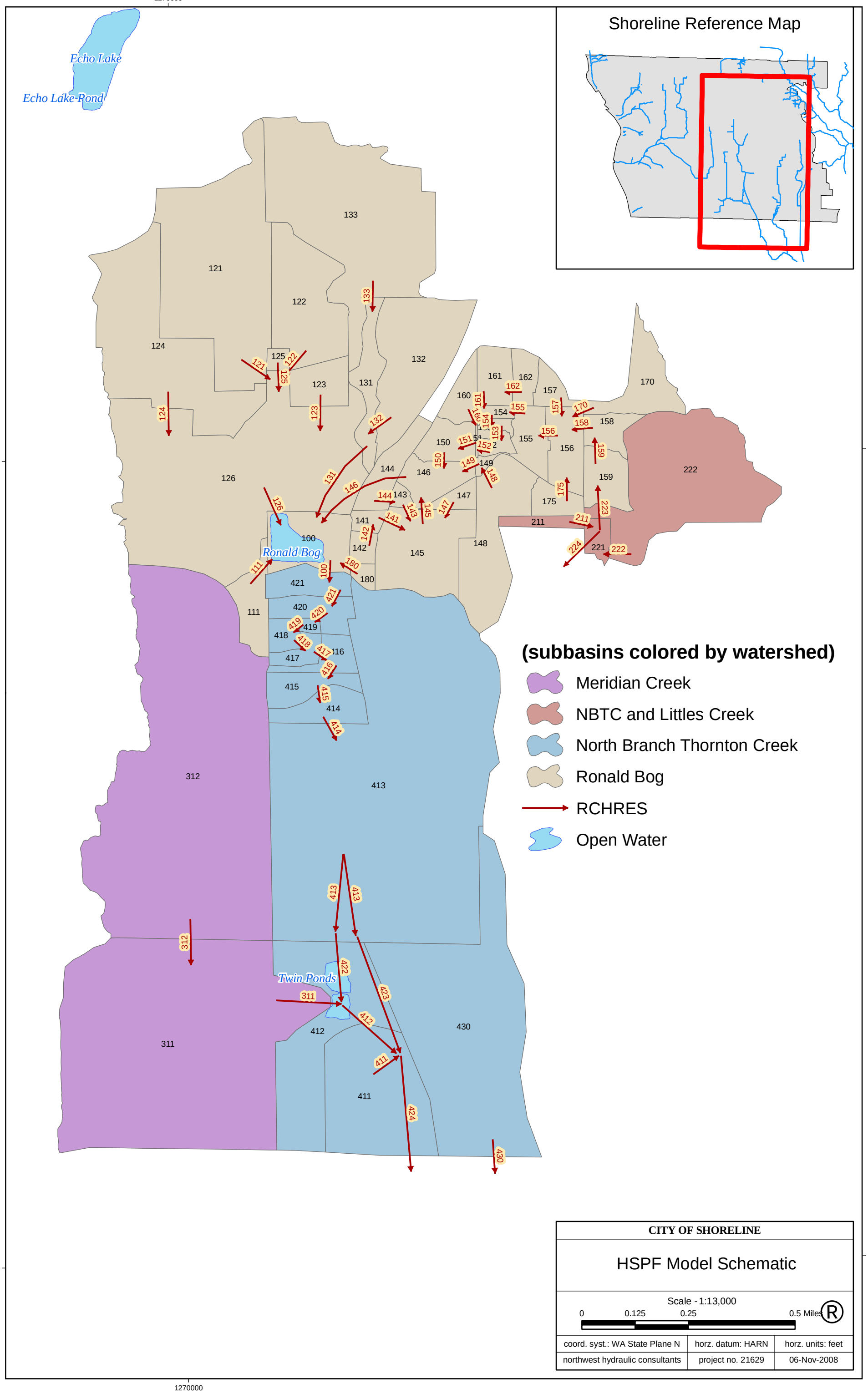

Shoreline Reference Map
Echo Lake
Echo Lake Pond
Ronald Bog
Twin Ponds
(subbasins colored by watershed)
Meridian Creek
NBTC and Littles Creek
North Branch Thornton Creek
Ronald Bog
RCHRES
Open Water
1270000
280000
270000
CITY OF SHORELINE
HSPF Model Schematic
Scale - 1:13,000
0
0.125
0.25
0.5 Miles
coord. syst.: WA State Plane N
horz. datum: HARN
horz. units: feet
northwest hydraulic consultants
project no. 21629
06-Nov-2008

Figure 2

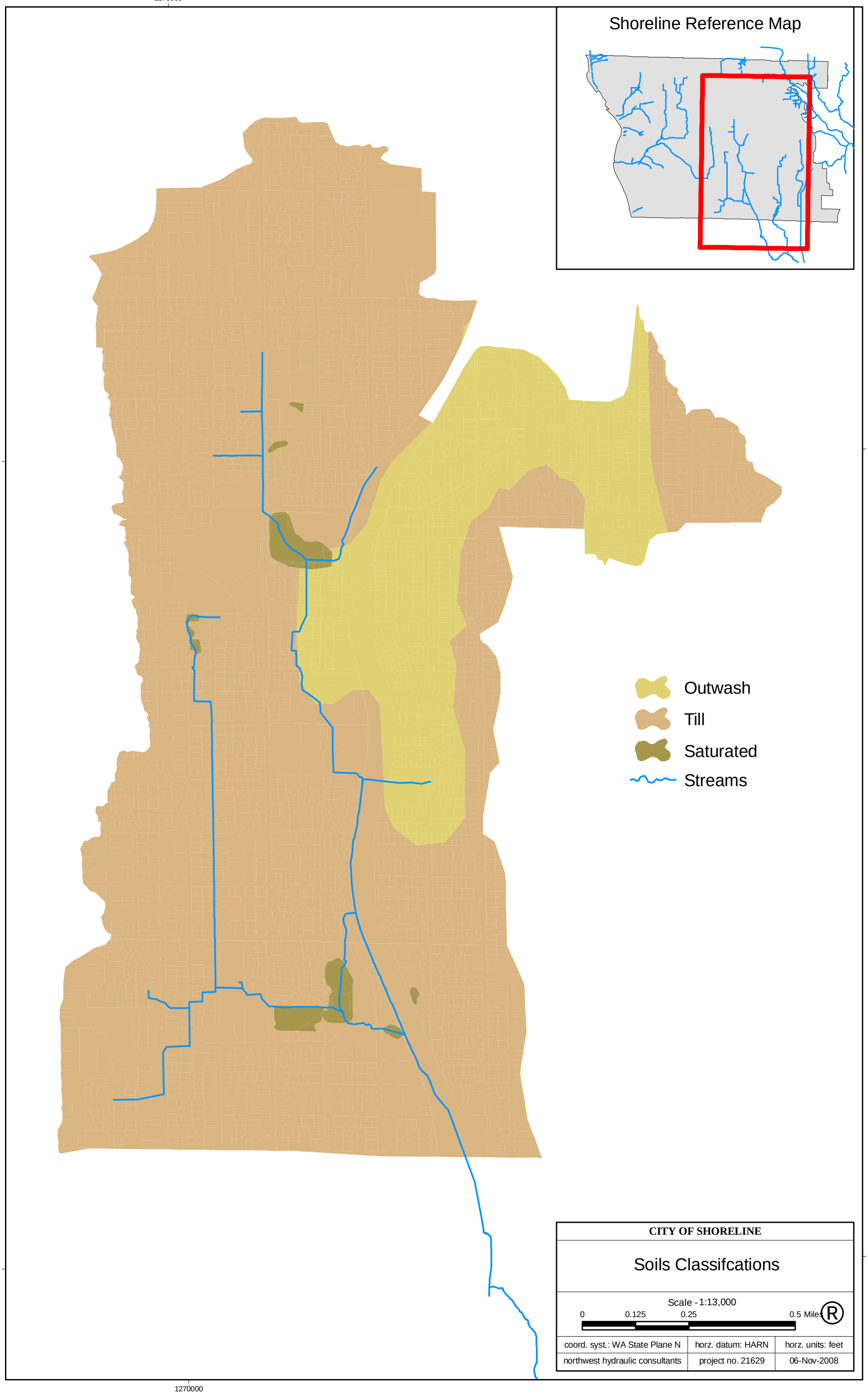

1270000
280000
270000
Shoreline Reference Map
Outwash
Till
Saturated
Streams
CITY OF SHORELINE
Soils Classifcations
Scale - 1:13,000
0
0.125
0.25
0.5 Miles
coord. syst.: WA State Plane N
horz. datum: HARN
horz. units: feet
northwest hydraulic consultants
project no. 21629
06-Nov-2008

Figure 3

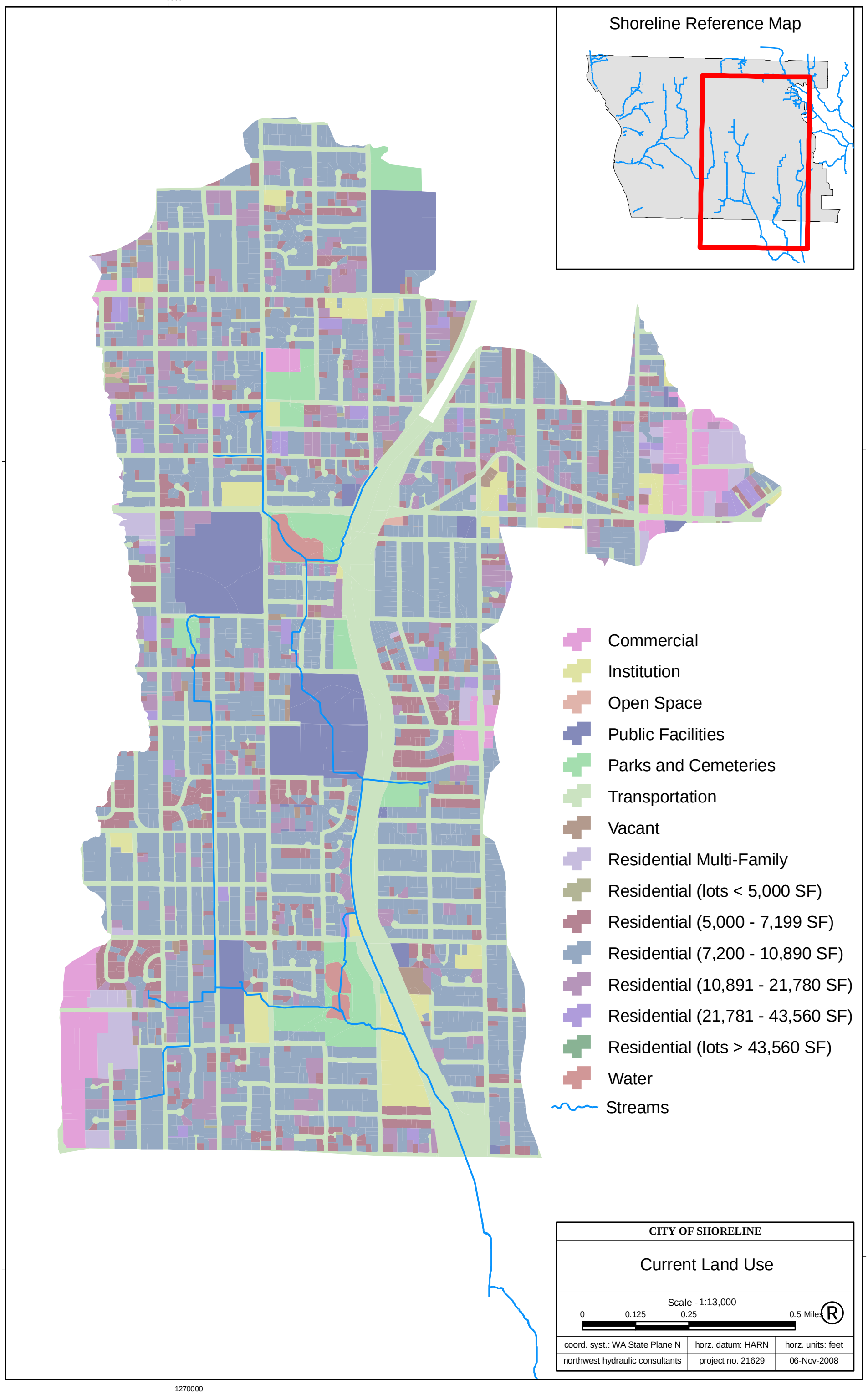

1270000
280000
270000
Shoreline Reference Map
Commercial
Institution
Open Space
Public Facilities
Parks and Cemeteries
Transportation
Vacant
Residential Multi-Family
Residential (lots < 5,000 SF)
Residential (5,000 - 7,199 SF)
Residential (7,200 - 10,890 SF)
Residential (10,891 - 21,780 SF)
Residential (21,781 - 43,560 SF)
Residential (lots > 43,560 SF)
Water
Streams
CITY OF SHORELINE
Current Land Use
Scale - 1:13,000
0
0.125
0.25
0.5 Miles
coord. syst.: WA State Plane N
horz. datum: HARN
horz. units: feet
northwest hydraulic consultants
project no. 21629
06-Nov-2008

Figure 4

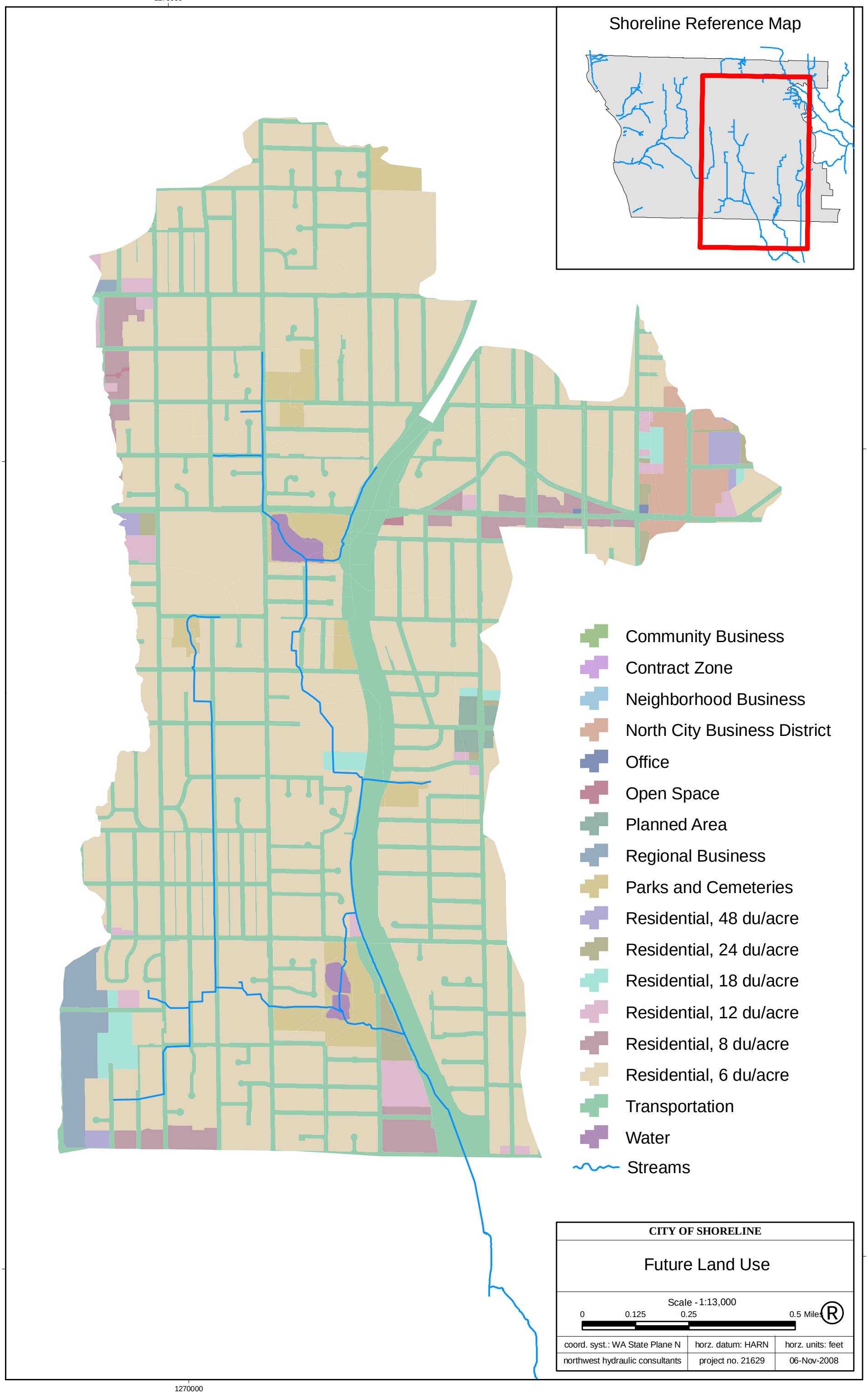

Shoreline Reference Map
Community Business
Contract Zone
Neighborhood Business
North City Business District
Office
Open Space
Planned Area
Regional Business
Parks and Cemeteries
Residential, 48 du/acre
Residential, 24 du/acre
Residential, 18 du/acre
Residential, 12 du/acre
Residential, 8 du/acre
Residential, 6 du/acre
Transportation
Water
Streams
CITY OF SHORELINE
Future Land Use
Scale - 1:13,000
0
0.125
0.25
0.5 Miles
coord. syst.: WA State Plane N
horz. datum: HARN
horz. units: feet
northwest hydraulic consultants
project no. 21629
06-Nov-2008
1270000
280000
270000

Figure 5

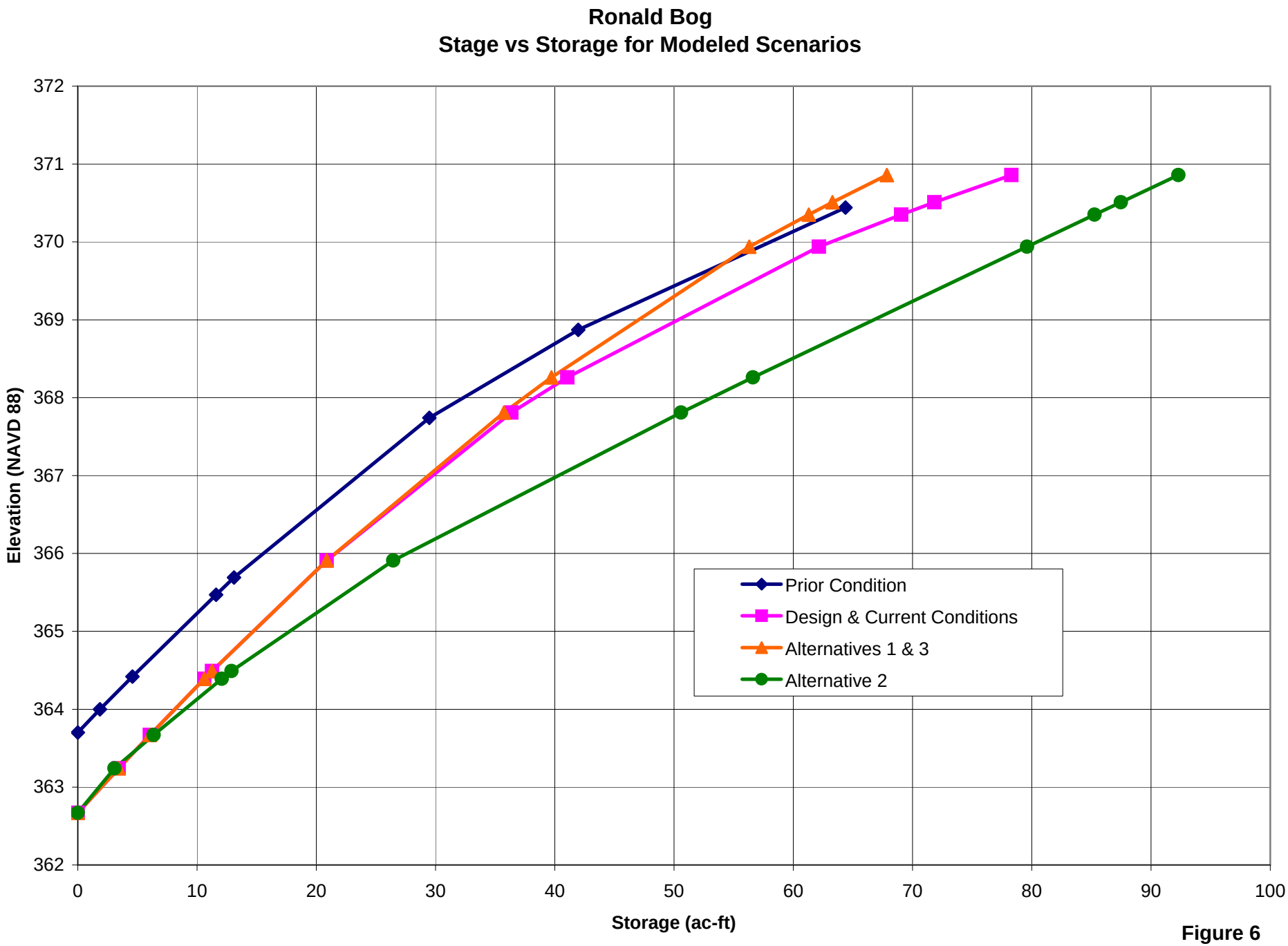

Ronald Bog
Stage vs Storage for Modeled Scenarios
Elevation (NAVD 88)
372
371
370
369
368
367
366
365
364
363
362
0
10
20
30
40
50
60
70
80
90
100
Storage (ac-ft)
Prior Condition
Design & Current Conditions
Alternatives 1 & 3
Alternative 2

Figure 6

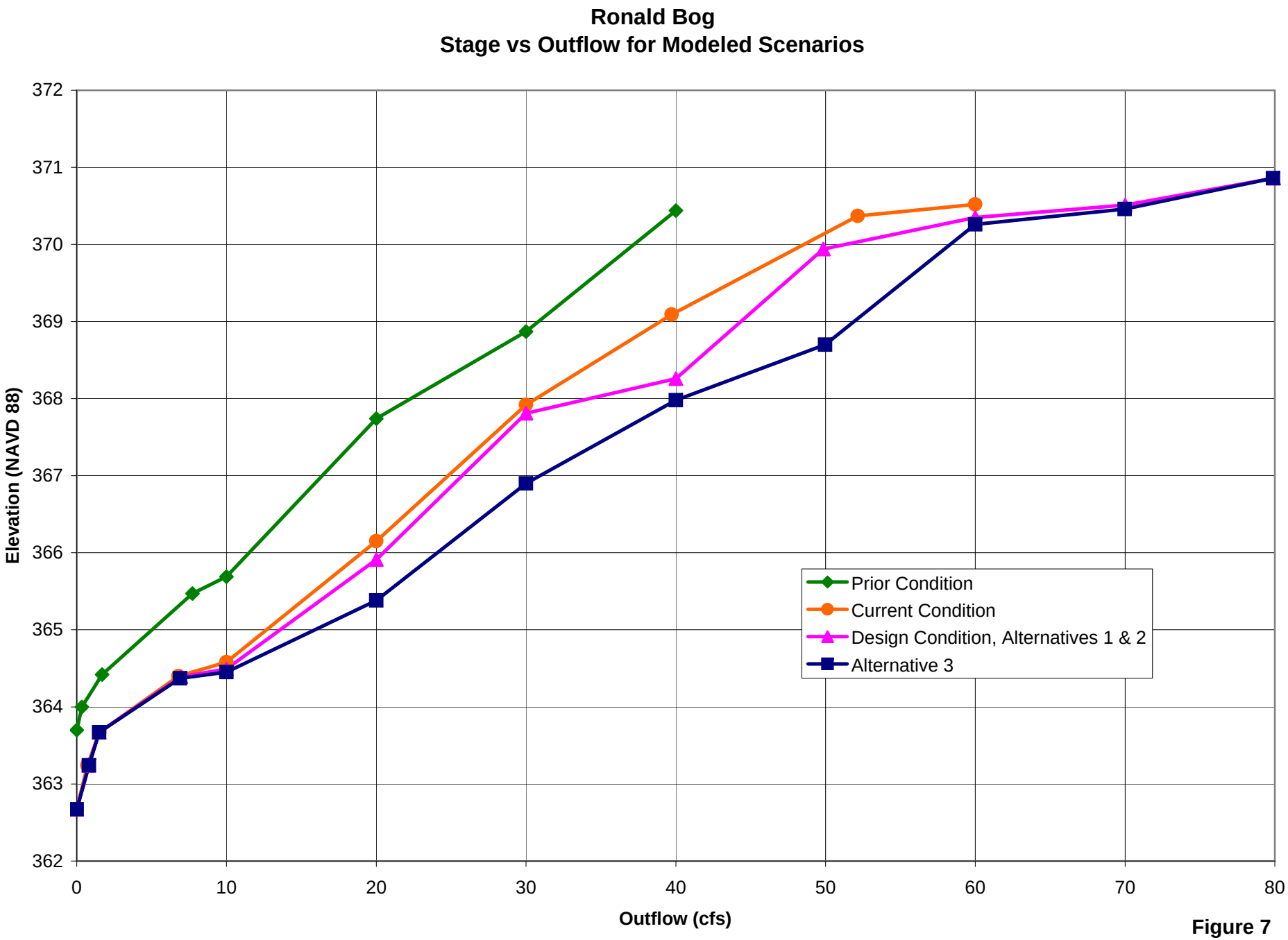

Ronald Bog
Stage vs Outflow for Modeled Scenarios
Elevation (NAVD 88)
372
371
370
369
368
367
366
365
364
363
362
0
10
20
30
40
50
60
70
80
Outflow (cfs)
Prior Condition
Current Condition
Design Condition, Alternatives 1 & 2
Alternative 3

Figure 7

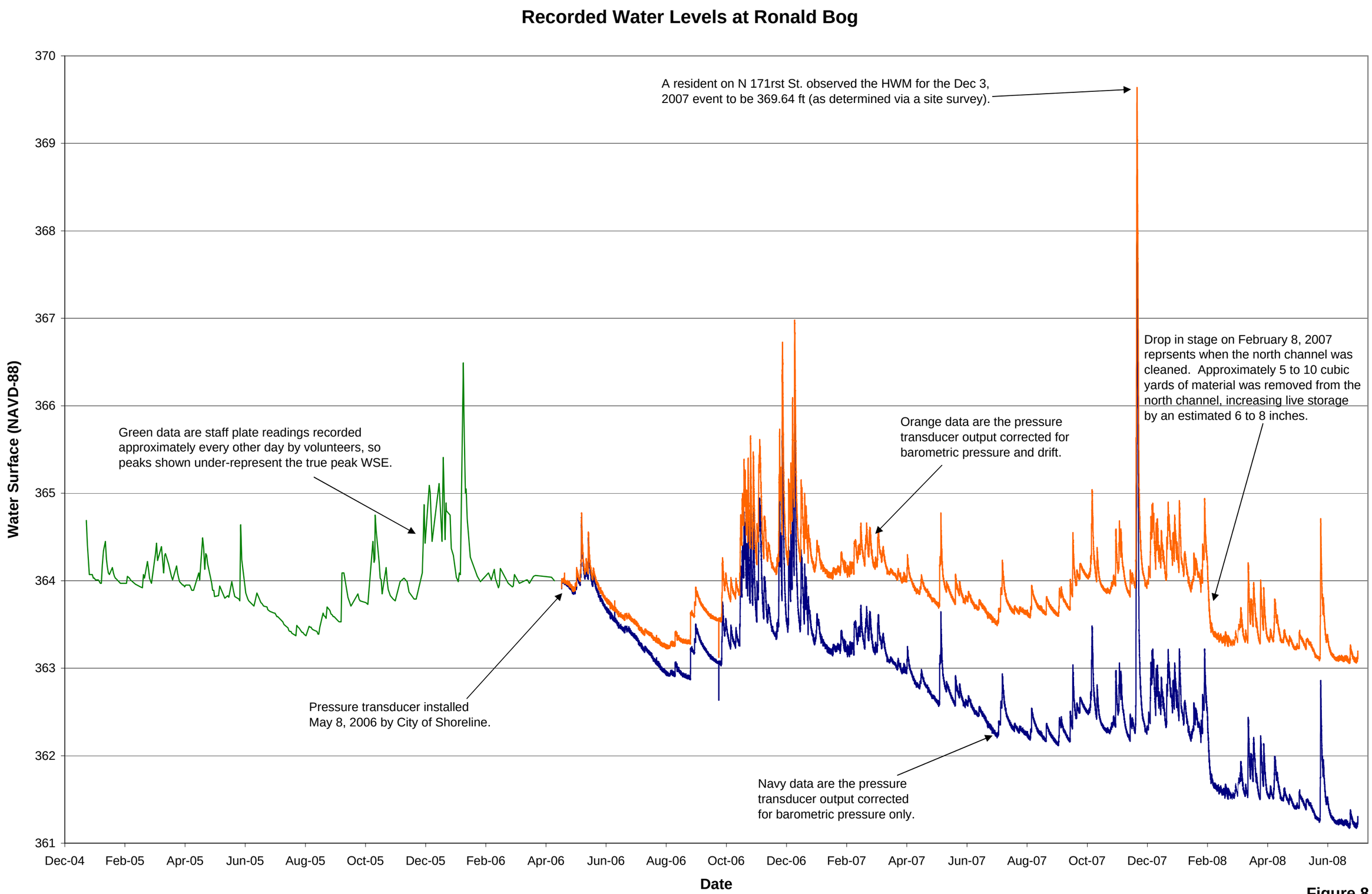

Recorded Water Levels at Ronald Bog
Water Surface (NAVD-88)
370
369
368
367
366
365
364
363
362
361
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Date
A resident on N 171rst St. observed the HWM for the Dec 3, 2007 event to be 369.64 ft (as determined via a site survey).
Drop in stage on February 8, 2007 reprsents when the north channel was cleaned. Approximately 5 to 10 cubic yards of material was removed from the north channel, increasing live storage by an estimated 6 to 8 inches.
Orange data are the pressure transducer output corrected for barometric pressure and drift.
Green data are staff plate readings recorded approximately every other day by volunteers, so peaks shown under-represent the true peak WSE.
Pressure transducer installed May 8, 2006 by City of Shoreline.
Navy data are the pressure transducer output corrected for barometric pressure only.

Figure 8

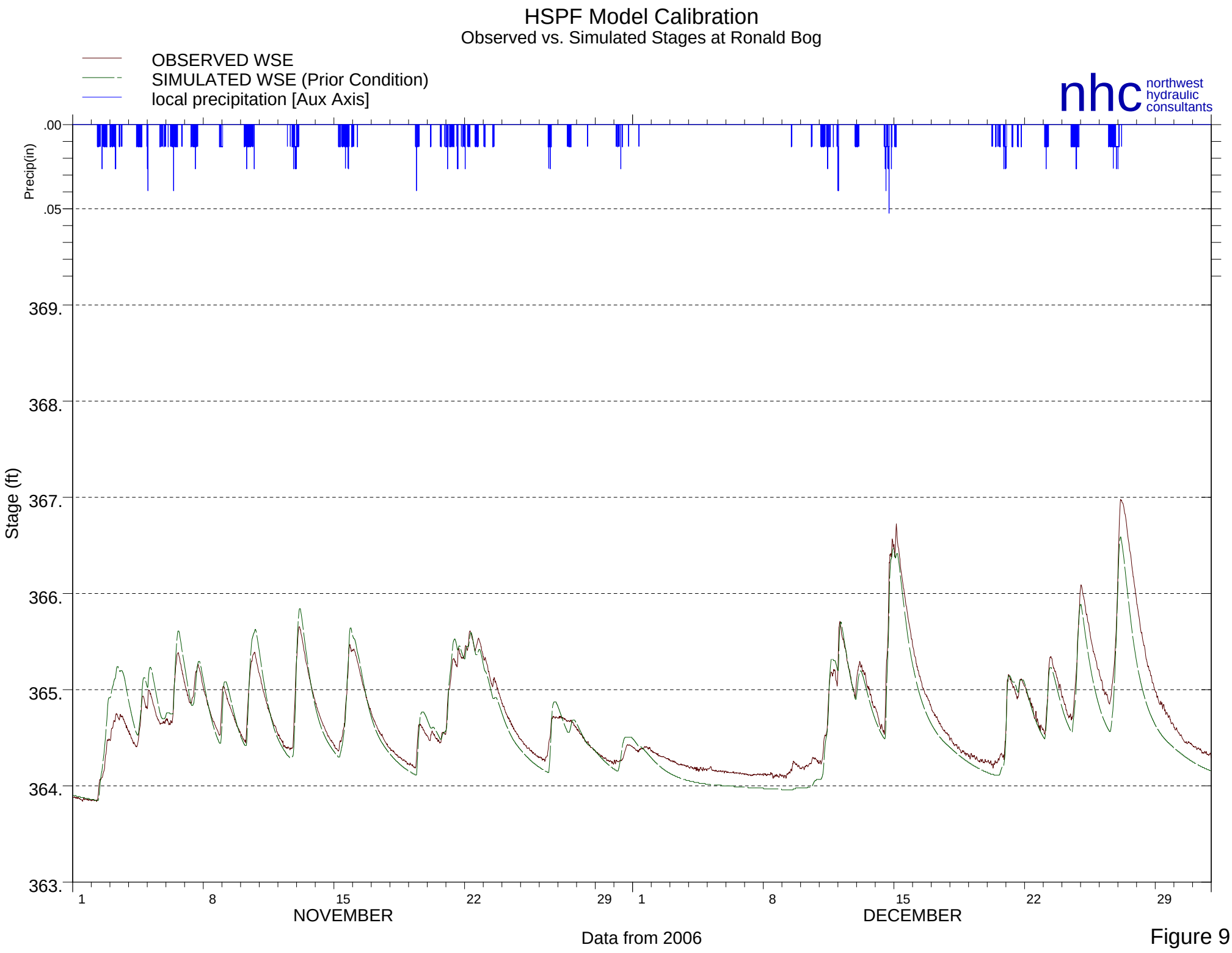

HSPF Model Calibration
Observed vs. Simulated Stages at Ronald Bog
OBSERVED WSE
SIMULATED WSE (Prior Condition)
local precipitation [Aux Axis]
nhc
northwest
hydraulic
consultants
Precip(in)
.00
.05
Stage (ft)
369.
368.
367.
366.
365.
364.
363.
1
8
15
22
29
1
8
15
22
29
NOVEMBER
DECEMBER
Data from 2006

Figure 9

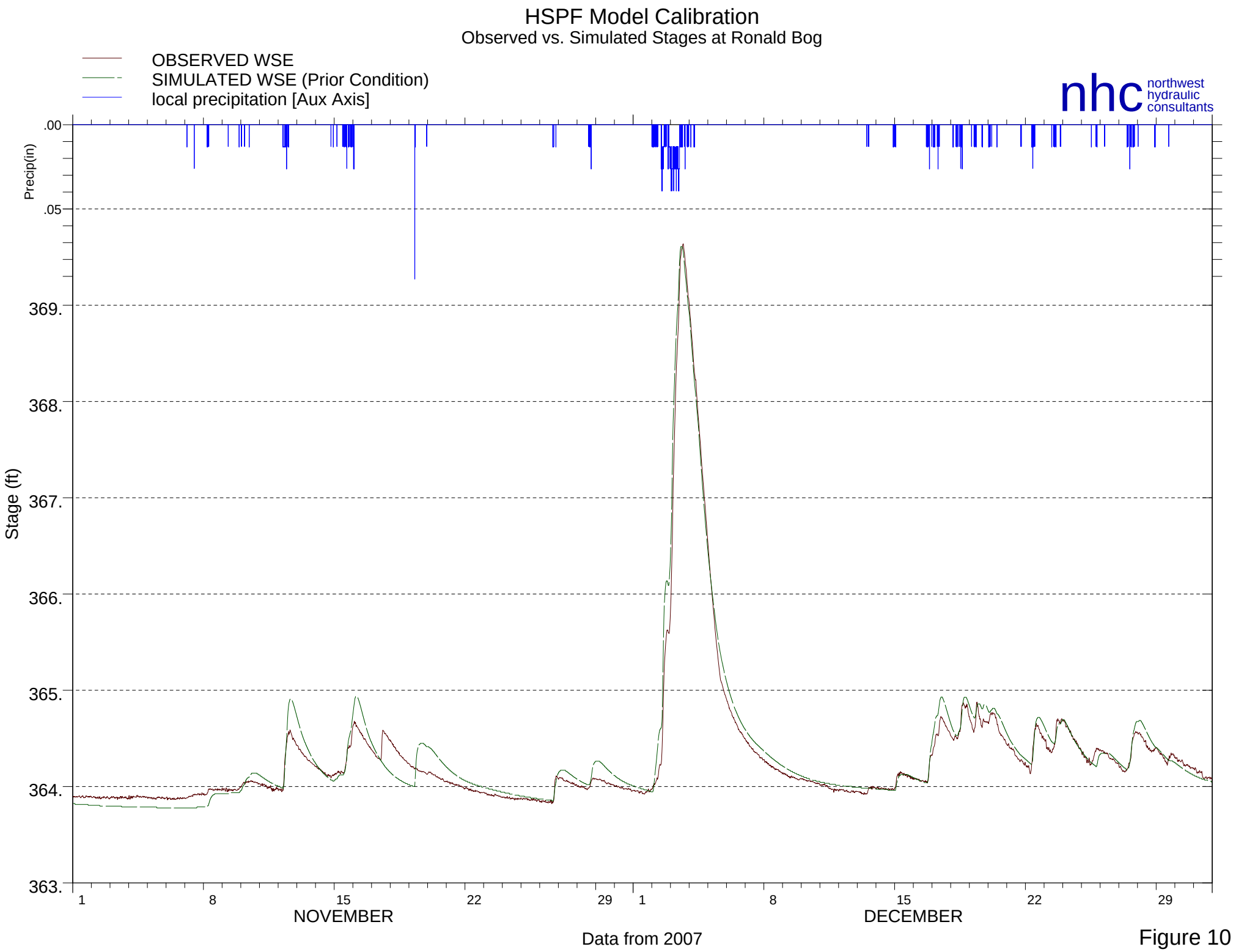

HSPF Model Calibration
Observed vs. Simulated Stages at Ronald Bog
OBSERVED WSE
SIMULATED WSE (Prior Condition)
local precipitation [Aux Axis]
nhc
northwest
hydraulic
consultants
Precip(in)
.00
.05
Stage (ft)
369.
368.
367.
366.
365.
364.
363.
1
8
15
22
29
1
8
15
22
29
NOVEMBER
DECEMBER
Data from 2007

Figure 10

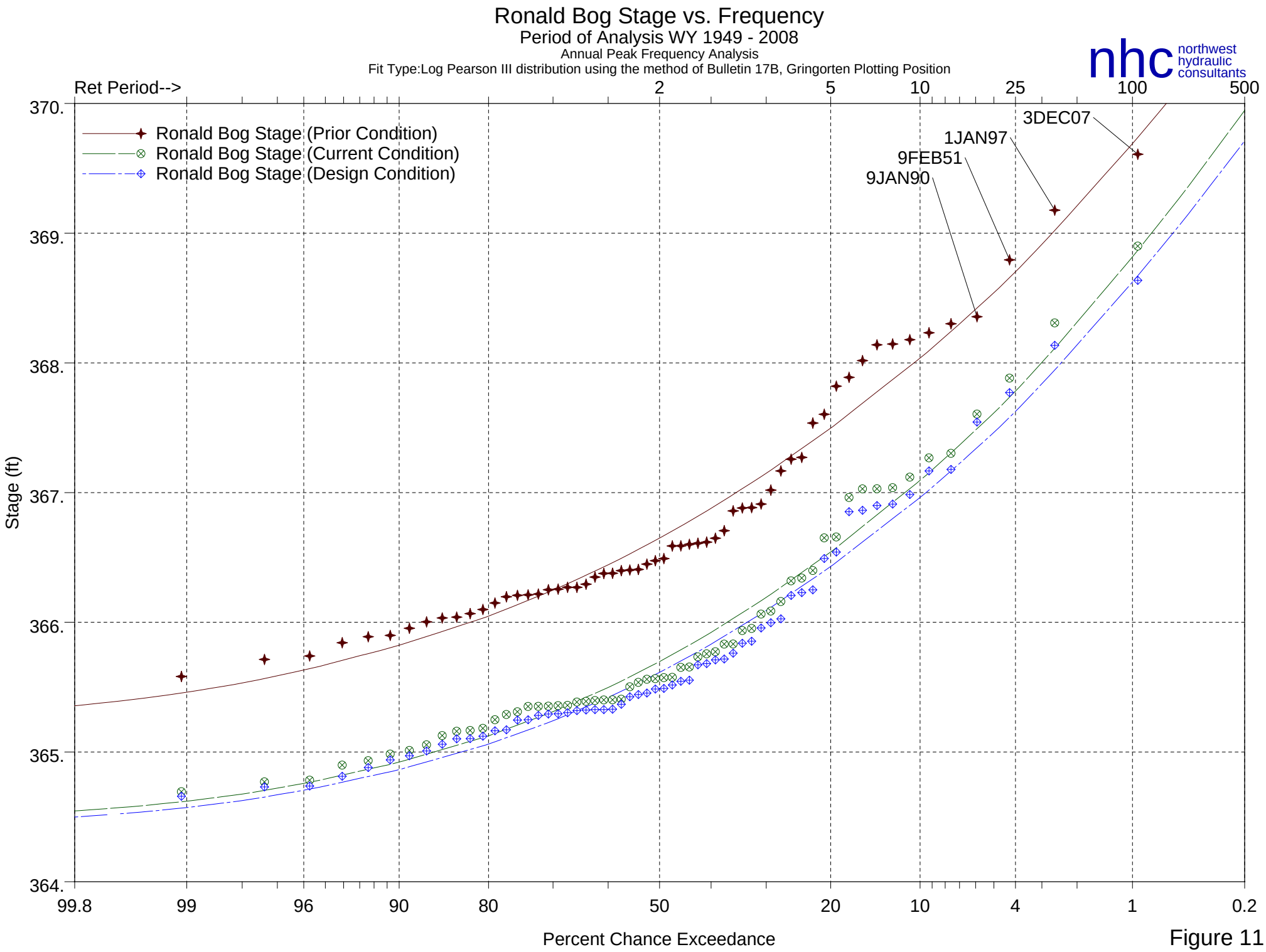

Ronald Bog Stage vs. Frequency
Period of Analysis WY 1949 - 2008
Annual Peak Frequency Analysis
Fit Type:Log Pearson III distribution using the method of Bulletin 17B, Gringorten Plotting Position
nhc northwest hydraulic consultants
Ret Period-->
2
5
10
25
100
500
370.
369.
368.
367.
366.
365.
364.
Stage (ft)
Ronald Bog Stage (Prior Condition)
Ronald Bog Stage (Current Condition)
Ronald Bog Stage (Design Condition)
3DEC07
1JAN97
9FEB51
9JAN90
99.8
99
96
90
80
50
20
10
4
1
0.2
Percent Chance Exceedance

Figure 11

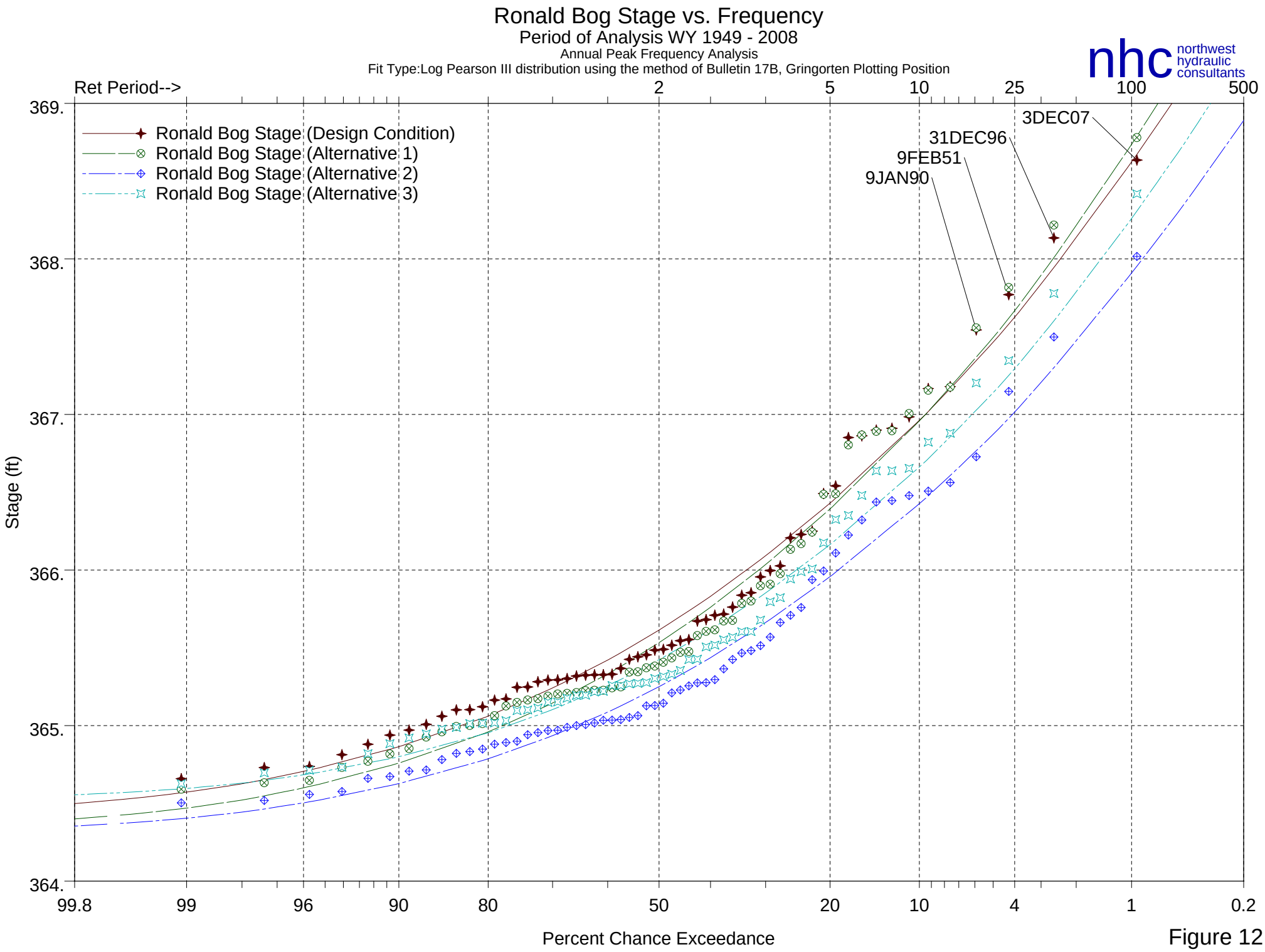

Ronald Bog Stage vs. Frequency
Period of Analysis WY 1949 - 2008
Annual Peak Frequency Analysis
Fit Type:Log Pearson III distribution using the method of Bulletin 17B, Gringorten Plotting Position
nhc northwest hydraulic consultants
Ret Period-->
2
5
10
25
100
500
369.
368.
367.
366.
365.
364.
Stage (ft)
Ronald Bog Stage (Design Condition)
Ronald Bog Stage (Alternative 1)
Ronald Bog Stage (Alternative 2)
Ronald Bog Stage (Alternative 3)
3DEC07
31DEC96
9FEB51
9JAN90
99.8
99
96
90
80
50
20
10
4
1
0.2
Percent Chance Exceedance

Figure 12

Ronald Bog Outflow Duration Analysis

Period of Analysis WY 1949 - 2008

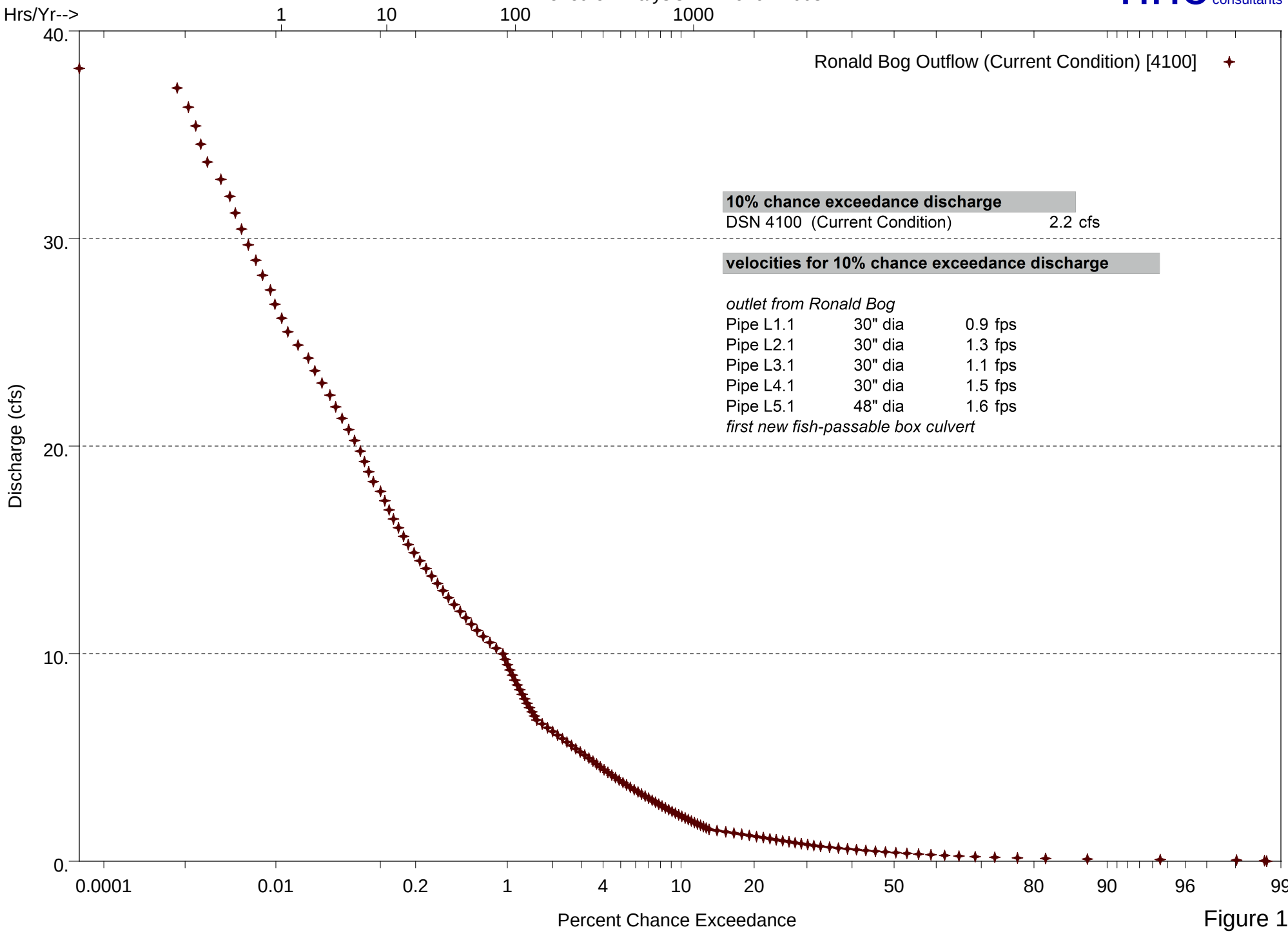


Figure 13

Appendix C
WATER QUALITY INDEX PARAMETERS

R·W·BECK

An SAIC Company

C1. Water Quality Index Data, 2007-2008

PROJECT: 421874-100

Locator:	TH1					Locator:	TH1					Locator:	TH1			
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE			
Client Loc:	Thornton Creek TH1-012907					Client Loc:	Thornton Creek TH1					Client Loc:	Thornton Creek TH1			
Sampled:	Jan 29, 2007					Sampled:	Feb 26, 2007					Sampled:	Mar 27, 2007			
Lab ID:	L41610-4					Lab ID:	L41829-4					Lab ID:	L42264-4			
Matrix:	FRESH WTR					Matrix:	FRESH WTR					Matrix:	FRESH WTR			
% Solids:						% Solids:						% Solids:				
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
		-Wet Weight Basis					-Wet Weight Basis						-Wet Weight Basis			
COMBINED LABS																
M=CV SM2540-D (03-01-009-002)																
Total Suspended Solids	0.8	<RDL	0.5	1	mg/L	10.5		0.5	1	mg/L		2.75		1	2	mg/L
M=CV SM4500-N-C (03-03-013-003)C																
Total Nitrogen	1.78		0.05	0.1	mg/L	1.22		0.05	0.1	mg/L		1.34		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C																
Total Phosphorus	0.0332		0.005	0.01	mg/L	0.0694		0.005	0.01	mg/L		0.0389		0.005	0.01	mg/L
M=ES NONE																
Field Personnel	JWilliams				none	JW				none		J.Williams				none
Sample Start Time	920				hr	820				hr		845				hr
M=MC SM-9222 D ed.17																
Fecal Coliform	2				CFU/100ml	250				CFU/100ml		63				CFU/100ml

PROJECT: 421874-100															
	Locator:	TH1				Locator:	TH1				Locator:	TH1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	Thornton Creek WQ monitoring site				Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ monitoring sta			
	Sampled:	Apr 24, 2007				Sampled:	May 29, 2007				Sampled:	06/26/07 8:50:00 AM			
	Lab ID:	L42450-4				Lab ID:	L42718-4				Lab ID:	L42966-4			
	Matrix:	FRESH WTR				Matrix:	FRESH WTR				Matrix:	FRESH WTR			
	% Solids:					% Solids:					% Solids:				
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
		-Wet Weight Basis					-Wet Weight Basis					-Wet Weight Basis			
COMBINED LABS															
M=CV SM2540-D (03-01-009-002)															
Total Suspended Solids	1.9		0.5	1	mg/L	1.7		0.5	1	mg/L	2		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C															
Total Nitrogen	1.52		0.05	0.1	mg/L	1.26		0.05	0.1	mg/L	2.03		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C															
Total Phosphorus	0.0356		0.005	0.01	mg/L	0.0417		0.005	0.01	mg/L	0.0281		0.005	0.01	mg/L
M=ES NONE															
Field Personnel	Jessica Williams				none	Jessica Williams				none	Jessica Williams				none
Sample Start Time	910				hr	800				NONE					
M=MC SM-9222 D ed.17															
Fecal Coliform	560				CFU/100ml	47				CFU/100ml	270				CFU/100ml

PROJECT: 421874-100

	Locator:	TH1				Locator:	TH1				Locator:	TH1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	site				Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ monitoring sta			
	Sampled:	07/31/07 8:55:00 AM				Sampled:	08/28/07 8:40:00 AM				Sampled:	09/24/07 6:25:00 AM			
	Lab ID:	L43137-4				TimeSpan:					TimeSpan:				
	Matrix:	FRESH WTR				Lab ID:	L43487-4				Lab ID:	L43788-4			
	% Solids:					Matrix:	FRESH WTR				Matrix:	FRESH WTR			
						% Solids:					% Solids:				
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
		-Wet Weight Basis					-Wet Weight Basis					-Wet Weight Basis			
COMBINED LABS															
M=CV SM2540-D (03-01-009-002)															
Total Suspended Solids	1.63		0.5	1	mg/L	0.7	<RDL	0.5	1	mg/L	0.8	<RDL	0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C															
Total Nitrogen	2		0.05	0.1	mg/L	2.16		0.05	0.1	mg/L	1.82		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C															
Total Phosphorus	0.0311		0.005	0.01	mg/L	0.0321		0.005	0.01	mg/L	0.0327		0.005	0.01	mg/L
M=ES NONE															
Field Personnel	Jessica Williams				none	Jessica Williams				none	Jessica Williams				none
Sample Start Time															
M=MC SM-9222 D ed.17															
Fecal Coliform	110				CFU/100ml	510				CFU/100ml	620				CFU/100ml

PROJECT: 421874-100

	Locator:	TH1				Locator:	TH1				Locator:	TH1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ monitoring sta			
	Sampled:	10/30/07 9:38:00 AM				Sampled:	11/27/07 8:30:00 AM				Sampled:	12/18/07 12:00:00 AM			
	TimeSpan:					Lab ID:	L44198-4				Lab ID:	L44656-4			
	Lab ID:	L43959-4				Matrix:	FRESH WTR				Matrix:	FRESH WTR			
	Matrix:	FRESH WTR													
	% Solids:					Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
Parameters							-Wet Weight Basis					-Wet Weight Basis			
	Value	Qual	MDL	RDL	Units										
COMBINED LABS		-Wet Weight Basis													
M=CV SM2540-D (03-01-009-002)															
Total Suspended Solids	0.8	<RDL	0.5	1	mg/L	1.1		0.5	1	mg/L	9.86		0.7	1.4	mg/L
M=CV SM4500-N-C (03-03-013-003)C															
Total Nitrogen	1.55		0.05	0.1	mg/L	1.01		0.05	0.1	mg/L	0.998		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C															
Total Phosphorus	0.025		0.005	0.01	mg/L	0.0329		0.005	0.01	mg/L	0.0568		0.005	0.01	mg/L
M=ES NONE															
Field Personnel	Jessica Williams				none	Jessica Williams				none	Jessica Williams				none
Sample Start Time															
M=MC SM-9222 D ed.17															
Fecal Coliform	910				CFU/100ml	280				CFU/100ml	510				CFU/100ml

PROJECT: 421874-100

	Locator:	TH1				Locator:	TH1				Locator:	TH1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	station				Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ monitoring sta			
	Sampled:	01/22/08 9:50:00 AM				Sampled:	02/26/08 10:05:00 AM				Sampled:	04/22/08 9:10:00 AM			
	Lab ID:	L44842-4				Lab ID:	L44957-4				Lab ID:	L45258-4			
	Matrix:	FRESH WTR				Matrix:	FRESH WTR				Matrix:	FRESH WTR			
	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
Parameters		-Wet Weight Basis					-Wet Weight Basis					Wet Weight Basis			
COMBINED LABS															
M=CV SM2540-D (03-01-009-002)															
Total Suspended Solids	0.7	<RDL	0.5	1	mg/L	1.9		0.5	1	mg/L	1.8		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C															
Total Nitrogen	1.4		0.05	0.1	mg/L	1.73		0.05	0.1	mg/L	1.01		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C															
Total Phosphorus	0.0279		0.005	0.01	mg/L	0.027		0.005	0.01	mg/L	0.0321		0.005	0.01	mg/L
M=ES NONE															
Field Personnel	Jessica Williams / City of Shoreline				none	Jessica Williams				none	Jessica Williams / Shoreline				none
Sample Start Time															
M=MC SM-9222 D ed.17															
Fecal Coliform	5				CFU/100ml	19				CFU/100ml	15				CFU/100ml

PROJECT: 421874-100

	Locator:	TH1				Locator:	TH1				Locator:	TH1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ station				Client Loc:	Thornton Creek WQ monitoring sta			
	Sampled:	05/27/08 8:25:00 AM				Sampled:	06/24/08 8:30:00 AM				Sampled:	07/22/08 8:40:00 AM			
	Lab ID:	L45483-4				Lab ID:	L45661-4				Lab ID:	L45905-4			
	Matrix:	FRESH WTR				Matrix:	FRESH WTR				Matrix:	FRESH WTR			
	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
Parameters		Wet Weight Basis					Wet Weight Basis					Wet Weight Basis			
COMBINED LABS															
M=CV SM2540-D (03-01-009-002)															
Total Suspended Solids	1.6		0.5	1	mg/L	2		0.5	1	mg/L	8.1		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C															
Total Nitrogen	1.39		0.05	0.1	mg/L	2.17		0.05	0.1	mg/L	2.4		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C															
Total Phosphorus	0.0392		0.005	0.01	mg/L	0.0252		0.005	0.01	mg/L	0.0279		0.005	0.01	mg/L
M=ES NONE															
Field Personnel	Jessica Williams / Shoreline				none	Jessica Williams / Shoreline				none	Jessica Williams				none
Sample Start Time															
M=MC SM-9222 D ed.17															
Fecal Coliform	1000				CFU/100ml	1000				CFU/100ml	210				CFU/100ml

PROJECT: 421874-100

	Locator:	TH1				Locator:	TH1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	Thornton Creek WQ monitoring sta				Client Loc:	Thornton Creek WQ monitoring station			
	Sampled:	08/26/08 10:53:00 AM				Sampled:	09/23/08 9:00:00 AM			
	Lab ID:	L46040-4				Lab ID:	L46273-4			
	Matrix:	FRESH WTR				Matrix:	FRESH WTR			
	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
Parameters		Wet Weight Basis					-Wet Weight Basis			
COMBINED LABS										
M=CV SM2540-D (03-01-009-002)										
Total Suspended Solids	6.3		0.5	1	mg/L	0.25	<MDL	0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C										
Total Nitrogen	1.38		0.05	0.1	mg/L	2.09		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C										
Total Phosphorus	0.0837		0.005	0.01	mg/L	0.0272		0.005	0.01	mg/L
M=ES NONE										
Field Personnel	Jessica Williams/Shoreline				none	Jessica Williams / Shoreline				none
Sample Start Time										
M=MC SM-9222 D ed.17										
Fecal Coliform	150				CFU/100ml	200				CFU/100ml

PROJECT: 421874-100

Locator:	LT1					Locator:	LT1					Locator:	LT1			
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE			
Client Loc:	Littles Creek LT1-012907					Client Loc:	Littles Creek LT-1					Client Loc:	Littles Creek LT-1			
Sampled:	Jan 29, 2007					Sampled:	Feb 26, 2007					Sampled:	Mar 27, 2007			
Lab ID:	L41610-3					Lab ID:	L41829-3					Lab ID:	L42264-3			
Matrix:	FRESH WTR					Matrix:	FRESH WTR					Matrix:	FRESH WTR			
% Solids:						% Solids:						% Solids:				
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
		-Wet Weight Basis					-Wet Weight Basis						-Wet Weight Basis			
COMBINED LABS																
M=CV SM2540-D (03-01-009-002)																
Total Suspended Solids	0.25	<MDL	0.5	1	mg/L	1.5	<RDL	1	1.9	mg/L		1.4		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C																
Total Nitrogen	1.5		0.05	0.1	mg/L	1.16		0.05	0.1	mg/L		1.46		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C																
Total Phosphorus	0.0335		0.005	0.01	mg/L	0.0357		0.005	0.01	mg/L		0.0425		0.005	0.01	mg/L
M=ES NONE																
Field Personnel	JWilliams				none	JW				none		J.Williams				none
Sample Start Time	860				hr	850				hr		915				hr
M=MC SM-9222 D ed.17																
Fecal Coliform	14				CFU/100ml	17				CFU/100ml		29				CFU/100ml

PROJECT: 421874-100

Locator:	LT1					Locator:	LT1					Locator:	LT1			
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE			
Client Loc:	Littles Creek WQ monitoring site					Client Loc:	Littles Creek WQ monitoring statio					Client Loc:	Littles Creek WQ monitoring statio			
Sampled:	Apr 24, 2007					Sampled:	May 29, 2007					Sampled:	06/26/07 8:25:00 AM			
Lab ID:	L42450-3					Lab ID:	L42718-3					Lab ID:	L42966-3			
Matrix:	FRESH WTR					Matrix:	FRESH WTR					Matrix:	FRESH WTR			
% Solids:						% Solids:						% Solids:				
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
		-Wet Weight Basis					-Wet Weight Basis						-Wet Weight Basis			
COMBINED LABS																
M=CV SM2540-D (03-01-009-002)																
Total Suspended Solids	0.9	<RDL	0.5	1	mg/L	2		0.5	1	mg/L		1.8	<RDL	1	2	mg/L
M=CV SM4500-N-C (03-03-013-003)C																
Total Nitrogen	1.32		0.05	0.1	mg/L	1.55		0.05	0.1	mg/L		1.77		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C																
Total Phosphorus	0.0357		0.005	0.01	mg/L	0.0413		0.005	0.01	mg/L		0.0445		0.005	0.01	mg/L
M=ES NONE																
Field Personnel	Jessica Williams				none	Jessica Williams				none		Jessica Williams				none
Sample Start Time	845				hr	745				NONE						
M=MC SM-9222 D ed.17																
Fecal Coliform	5				CFU/100ml	230				CFU/100ml		760				CFU/100ml

PROJECT: 421874-100

Locator:	LT1					Locator:	LT1					Locator:	LT1			
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE			
Client Loc:	Littles Creek WQ monitoring site					Client Loc:	Littles Creek WQ monitoring statio					Client Loc:	Littles Creek WQ monitoring statio			
Sampled:	07/31/07 9:15:00 AM					Sampled:	08/28/07 9:05:00 AM					Sampled:	09/24/07 7:40:00 AM			
Lab ID:	L43137-3					TimeSpan:						TimeSpan:				
Matrix:	FRESH WTR					Lab ID:	L43487-3					Lab ID:	L43788-3			
% Solids:						Matrix:	FRESH WTR					Matrix:	FRESH WTR			
						% Solids:						% Solids:				
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
		-Wet Weight Basis					-Wet Weight Basis					-Wet Weight Basis			
COMBINED LABS															
M=CV SM2540-D (03-01-009-002)															
Total Suspended Solids	0.53	<RDL	0.5	1.1	mg/L	0.25	<MDL	0.5	1	mg/L	1.2		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C															
Total Nitrogen	1.91		0.05	0.1	mg/L	1.68		0.05	0.1	mg/L	1.64		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C															
Total Phosphorus	0.0485		0.005	0.01	mg/L	0.041		0.005	0.01	mg/L	0.0402		0.005	0.01	mg/L
M=ES NONE															
Field Personnel	Jessica Williams				none	Jessica Williams				none	Jessica Williams				none
Sample Start Time															
M=MC SM-9222 D ed.17															
Fecal Coliform	59				CFU/100ml	600				CFU/100ml	2400				CFU/100ml

PROJECT: 421874-100

Locator:	LT1					Locator:	LT1					Locator:	LT1				
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE				
Client Loc:	Littles Creek WQ monitoring statio					Client Loc:	Littles Creek WQ monitoring statio					Client Loc:	Littles Creek WQ monitoring statio				
Sampled:	10/30/07 9:20:00 AM					Sampled:	11/27/07 8:55:00 AM					Sampled:	12/18/07 12:00:00 AM				
TimeSpan:						Lab ID:	L44198-3					Lab ID:	L44656-3				
Lab ID:	L43959-3					Matrix:	FRESH WTR					Matrix:	FRESH WTR				
Matrix:	FRESH WTR																
% Solids:						Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
Parameters						-Wet Weight Basis						-Wet Weight Basis				
	Value	Qual	MDL	RDL	Units											
COMBINED LABS	-Wet Weight Basis															
M=CV SM2540-D (03-01-009-002)																
Total Suspended Solids	0.25	<MDL	0.5	1	mg/L	0.5	<RDL	0.5	1	mg/L		9.4		1	2	mg/L
M=CV SM4500-N-C (03-03-013-003)C																
Total Nitrogen	1.64		0.05	0.1	mg/L	1.15		0.05	0.1	mg/L		1.28		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C																
Total Phosphorus	0.0278		0.005	0.01	mg/L	0.0288		0.005	0.01	mg/L		0.0551		0.005	0.01	mg/L
M=ES NONE																
Field Personnel	Jessica Williams				none	Jessica Williams				none		Jessica Williams				none
Sample Start Time																
M=MC SM-9222 D ed.17																
Fecal Coliform	410				CFU/100ml	420				CFU/100ml		180				CFU/100ml

PROJECT: 421874-100

Locator:	LT1					Locator:	LT1					Locator:	LT1			
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE			
Client Loc:	station					Client Loc:	Littles Creek WQ monitoring statio					Client Loc:	Littles Creek WQ monitoring statio			
Sampled:	01/22/08 9:30:00 AM					Sampled:	02/26/08 9:50:00 AM					Sampled:	04/22/08 8:50:00 AM			
Lab ID:	L44842-3					Lab ID:	L44957-3					Lab ID:	L45258-3			
Matrix:	FRESH WTR					Matrix:	FRESH WTR					Matrix:	FRESH WTR			
	Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
Parameters		-Wet Weight Basis						-Wet Weight Basis						Wet Weight Basis			
COMBINED LABS																	
M=CV SM2540-D (03-01-009-002)																	
Total Suspended Solids	1.4		0.5	1	mg/L		1	RDL	0.5	1	mg/L		2.1		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C																	
Total Nitrogen	1.57		0.05	0.1	mg/L		1.46		0.05	0.1	mg/L		1.28		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C																	
Total Phosphorus	0.0309		0.005	0.01	mg/L		0.0312		0.005	0.01	mg/L		0.0261		0.005	0.01	mg/L
M=ES NONE																	
Field Personnel	Jessica Williams / City of Shoreline				none		Jessica Williams				none		Jessica Williams / Shoreline				none
Sample Start Time																	
M=MC SM-9222 D ed.17																	
Fecal Coliform	240				CFU/100ml		110				CFU/100ml		73				CFU/100ml

PROJECT: 421874-100

Locator:	LT1					Locator:	LT1					Locator:	LT1			
Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE					Descrip:	CITY OF SHORELINE			
Client Loc:	Littles Creek water quuality monito					Client Loc:	Littles Creek WQ station					Client Loc:	Littles Creek WQ monitoring statio			
Sampled:	05/27/08 8:05:00 AM					Sampled:	06/24/08 8:10:00 AM					Sampled:	07/22/08 8:25:00 AM			
Lab ID:	L45483-3					Lab ID:	L45661-3					Lab ID:	L45905-3			
Matrix:	FRESH WTR					Matrix:	FRESH WTR					Matrix:	FRESH WTR			
	Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
Parameters		Wet Weight Basis						Wet Weight Basis						Wet Weight Basis			
COMBINED LABS																	
M=CV SM2540-D (03-01-009-002)																	
Total Suspended Solids	2.5		0.5	1	mg/L		1.4		0.5	1	mg/L		3.5		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C																	
Total Nitrogen	1.56		0.05	0.1	mg/L		1.7		0.05	0.1	mg/L		2.31		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C																	
Total Phosphorus	0.0497		0.005	0.01	mg/L		0.0437		0.005	0.01	mg/L		0.112		0.005	0.01	mg/L
M=ES NONE																	
Field Personnel	Jessica Williams / Shoreline				none		Jessica Williams / Shoreline				none		Jessica Williams				none
Sample Start Time																	
M=MC SM-9222 D ed.17																	
Fecal Coliform	610				CFU/100ml		150				CFU/100ml		3200				CFU/100ml

PROJECT: 421874-100

	Locator:	LT1				Locator:	LT1			
	Descrip:	CITY OF SHORELINE				Descrip:	CITY OF SHORELINE			
	Client Loc:	Littles Creek WQ monitoring statio				Client Loc:	Littles Creek WQ monitoring station			
	Sampled:	08/26/08 11:10:00 AM				Sampled:	09/23/08 8:45:00 AM			
	Lab ID:	L46040-3				Lab ID:	L46273-3			
	Matrix:	FRESH WTR				Matrix:	FRESH WTR			
	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
Parameters		Wet Weight Basis					-Wet Weight Basis			
COMBINED LABS										
M=CV SM2540-D (03-01-009-002)										
Total Suspended Solids	5.6		0.5	1	mg/L	2.8		0.5	1	mg/L
M=CV SM4500-N-C (03-03-013-003)C										
Total Nitrogen	1.45		0.05	0.1	mg/L	1.76		0.05	0.1	mg/L
M=CV SM4500-P-B,F(03-03-013-003)C										
Total Phosphorus	0.0578		0.005	0.01	mg/L	0.0403		0.005	0.01	mg/L
M=ES NONE										
Field Personnel	Jessica Williams/Shoreline				none	Jessica Williams / Shoreline				none
Sample Start Time										
M=MC SM-9222 D ed.17										
Fecal Coliform	150				CFU/100ml	310				CFU/100ml

C2. Ambient Monitoring Data, 2002-2008

Ambient Water Quality Monitoring **Ronald Bog, RB-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Milli volts	NTU's	Lake HT ft. 10ths	Samplers	Comments
1/4/2002	RB-1	11:10 AM									0.8	JK	
1/7/2002	RB-1	4:00 PM									2.48	AL	Raining
1/8/2002	RB-1	2:15 PM									2.32	AL	Partly Cloudy
1/9/2002	RB-1	10:37 AM	10.04	8.4	42.2	61.6	0	6.75	11.5	5.58	1.56	AL	Partly Cloudy
1/24/2002	RB-1	1:45 PM	10.95	4.8	55.5	90.2	0	6.93	4.6	28.93	0.7	AL	Cloudy and cold
2/14/2002	RB-1	2:38PM	9.68	7.5	64.3	97.1	0	6.73	13.4	0.00	0.72	AL	Sunny
3/1/2002	RB-1	4:30 PM	9.38	7.8	64.2	95.5	0	6.91	3.7	n/t	0.68	AL	Partly sunny
3/13/2002	RB-1	10:15 AM	10.41	6.7	62.8	96.5	0	6.88	3.8		1.02	AL/JC	Jay GPS in pt.
3/27/2002	RB-1	11:00 AM	9.73	9.1	72.7	104.3	0	6.95	2.6	mf	0.62	Al	Took photos
4/3/2002	RB-1	3:11 PM	11.74	12.9	81.9	106.9	0.1	mf*	mf*	n/t	0.58	AL	mf* pH was reading very low see notes. pH meter recorded 5.83
4/19/2002	RB-1	11:10 AM	8.28	11.4	73	98.6	0	6.79	4.3	clr	0.64	AL	Overcast
4/29/2002	RB-1	3:50 PM	11.54	16	86.9	104.9	0.1	7.28	-21.3		0.64	AL	Sunny
5/13/2002	RB-1	11:20 AM	9.92	15.6	84.9	103.4	0.1	7.24	-17.2	clr	0.54	AL/JK	Overcast skies
5/24/2002	RB-1	10:00 AM	12.5	16.5	87.9	105	0.1	7.2	-15.1	Clr	0.56	AL/JK	Hazy and sunny
6/26/2002	RB-1	10:00 AM	7.74	23.9	115.5	118	0.1			clr	0.46	AL/JK	pH meter on the fritz.
7/17/2002	RB-1	3:05 PM	7.49	26.9	118	113.5	0.1	7.59	-33.4		0.5	AL	dry weather pattern
Aug-02	RB-1	No sample											
Sep-02	RB-1	No sample											
10/10/2002	RB-1	12:15 PM	4.55	14.9	110.2	136.5	0.1	7.07	-1.2		0.48	AL	Overcast periods of rain, lake turn-over?
10/28/2002	RB-1	4:20 PM	4.28	11.9	105.6	141	0.1	6.91	6.5		0.38	AL	Partly cloudy.
11/12/2002	RB-1	2:35 PM	7.38	7.8	94.8	129.5	0.1	7.23	-6.6		0.9	AL	light drizzle
11/27/2002	RB-1	3:10 PM	3.86	8.8	84.2	122	0.1	7	6.3		0.5	AL	clear and cold.
12/17/2002	RB-1	3:50 PM	8.25	7	54.4	83	0	6.85	14.2		1.3	AL	Overcast and cool air temps.
1/2/2003	RB-1	12:30 PM	9.75	7.6	26.3	67.2	0	7	7.1		1.85	JK	H2O level up on the beach.
2/6/2003	RB-1	11:30 AM	8.82	7.9	49.2	72.9	0	6.69	18.4	fairly clear	0.64	JK	Parly sunny and cold
3/10/2003	RB-1	11:00 AM	9.62	7.8	52.6	78.2	0	6.54	29	13.60	0.88	AL	Overcast with mild to cool temperatures
5/27/2003	RB-1	9:25 AM	8.97	18.9	79.7	90.2	0			NA	0.6	JK	Partly cloudy with highs in the mid to low 60's.

Ambient Water Quality Monitoring **Ronald Bog, RB-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Milli volts	NTU's	Lake HT ft. 10ths	Samplers	Comments
6/17/2003	RB-1	2:20 PM	7.8	26.2	103.5	101.5	0.1	7.42	-15.5		0.45	JK/AN	Sunny high 70's
7/10/2003	RB-1	4:00 PM	7.24	26.8	111.6	108.1	0.1	7.84	-41	7.20	0.4	AL/AN	Sunny highs mid to upper 80's
8/15/2003	RB-1	11:00 AM	9.27	24.1	115	116.8	0.1	n/c	n/c		0.1	AL	ph meter on fritz
9/17/2003	RB-1	2:08 PM	7.4	19.1	115	129.6	0.1	7.4	-21.2		0.38	AL	
10/9/2003	RB-1	2:30 PM	6.95	17.1	109.9	129.9	0.1	6.86	8.1		0.44	JK	overcast sprinkles
10/21/2003	RB-1										4.15	AL	
10/24/2003	RB-1	10:20 AM	3.55	13.7	66	84.1	0	6.55	25.9	8.06	0.92	AL	
11/13/2003	RB-1	3:10 PM	9.49	9.6	66.1	94.1	0	7	4.7		0.54	AL	Clear and sunny
12/5/2003	RB-1	11:10 AM	9.26	7.3	45.5	68.9	0	6.36	35.1	11.87	1.44	AL	Raining
12/22/2003	RB-1	2:50 PM	8.84	7.5	51.9	77.9	0	6.42	31.8	4.14	n/a	AL/AN	partly sunny
1/8/2004	RB-1	11:20 AM	12.26	1.6	27.9	error		5.88	61.2	13.15	2.34	AL	maybe to cold for SC meter, layer of 1" ice covers 60% of lake
1/28/2004	RB-1	3:50 PM	9.68	6.4	61.5	95.5	0	6.64	25.8	6.52	1.02	AL	drizzle rain
2/11/2004	RB-1	3:30 PM	9.74	8.3	64	93.3	0	6.8	1.59	7.60	0.94	AN	sunny
3/10/2004	RB-1	3:35 PM	10.46	11.4	73.7	99.5	0	7.6	-28.8	10.70	0.94	AN	sunny mild air temps
3/26/2004	RB-1	3:40 PM	10.05	10.03	70.2	97.6	0	7.26	-9.3	5.36	1.24	AL	Overcast cool temps
4/14/2004	RB-1	2:25 PM	9.44	17	89.6	105.8	0.1	8.28	-57.7	16.07	0.81	AN	Raining, 50's
4/28/2004	RB-1	11:15 AM	6.58	17.1	91.9	108.3	0.1	7.15	-3.1	3.30	0.8	AN/AL	sunny mild air temps
6/17/2004	RB-1	10:55 AM	9.39	21.4	98.8	106.1	0.1		-34.8	13.60	0.7	AN	Sunny upper 70s to low 80's
7/28/2004	RB-1	1:40 PM	10.62	28	113.5	107.3	0.1			47.50	0.26	AL	Sunny, hot. Green algae bloom in full swing.
8/19/2004	RB-1	8:23 AM	7.32	22.4	46	100.4	0.1			29.00	0.5	AN/WSC	Sunny and hot, 80s
9/27/2004	RB-1	2:20pm	3.86	17.8	79.5	92.5	0.0	7.12	6.0	8.64	0.76	AL/AN	Sunny, low 70's
10/12/2004	RB-1	10:30am	3.79	15.7	75.0	91.0	0.0	6.87	8	7.25	0.80	AL	high clouds; mild air temps
11/2/2004	RB-1	2:20pm	6.47	10.3	55.2	77.0	0.0	7.19	-26	15.20	2.38	AL/WSC	cloudy skies; no rain
12/13/2004	RB-1	1:38pm	7.88	8.1	59.5	2.1	0.0	6.53	35	8.64	1.4	AN	rainy, 40's
1/5/2005	RB-1	2:30pm	6.28	4.2	46.1	76.7	0.0	6.43	42	4.11	0.9	AN	Cold; upper 30's but clear
1/28/2005	RB-1	3:15pm	6.84	9.1	54.3	77.9	0.0	6.59	19	Not sampled		AL/WC	Overcast grey skies

Ambient Water Quality Monitoring **Ronald Bog, RB-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Milli volts	NTU's	Lake HT ft. 10ths	Samplers	Comments
2/2/2005	RB-1	3:00pm	10.78	10.7	27.1	36.9	0.0	6.98	-1.0	2.83	0.88	AN/AL/WSC	Sunny, very nice; mild air temps
2/22/2005	RB-1	12:35pm	9.45	7.8	55	82	0	6.5	20	5.85	0.88	AN	Clear, sunny, upper 50s - low 60s
3/9/2005	RB-1	1:30	11.87	13.3	63.2	81.5	0	NT	NT	4.07	NA	AN	Overcast cloudy about 60
3/30/2005	RB-1	3:15 PM	9.78	12.9	53.4	69.7	0	6.76	2	8.01	1.34	AN	Sunny, 60s
4/21/2005	RB-1	2:30 PM	8.92	18.6	57.9	66.2	0	7.31	-25	2.33	0.94	AL	Sunny warm temps
5/26/2005	RB-1	2:25 PM	9.85	22.2	63.6	67.4	0	7.08	-15	n/a	0.8	AL	Sunny, hot, 70s
6/28/2005	RB-1	11:10	9.03	19.2	59.7	67.5	0	6.93	-4	5.81	0.74	AL & TH	Blue/green algae blooming. 3 1/2 feet from shore. Put water sample under microscopeobserved only "fannie" cyanobacteria…The green/blue filaments …noted. Some curving to the strands. Saw zooplankton diatons in sample too.
7/20/2005	RB-1	2:32 PM	4.58	28.1	80.8	76.4	0	6.99	-9	4.80	0.57	AL & TH	Sunny, high clouds
8/17/2005	RB-1	10:40 AM	5.07	21.1	74.2	80.1	0	6.87	-4	n/a	0.4	AL	Overcast, cloudy. Tlamentous green algae observed.
10/19/2005	RB-1	2:00 PM	7.2	14.2	65.7	82.8	0.00	6.79	-5	6.60	0.68	AL & TH	Overcast and cool
11/8/2005	RB-1	2:00 PM	7.15	10.2	47.4	65.9	0.00	6.68	21	8.33	0.94	AL	Mostly cloudy
12/30/2005	RB-1	10:10 AM	8.18	7.2	46.3	70.4	0.00	6.25	49	17.64	1.36	AL	Overcast periods of light drizzle
1/19/2006	RB-1	3:25 PM	8.32	6.8	47.1	72	0.00	6.58	2.6	10.56	1.1	AL	cloudy cool
2/16/2006	RB-1	3:30 PM	8.22	9	56.1	81.3	0.00	6.63	24	12.35	0.92	AL	sunny cold
3/24/2006	RB-1	9:10 AM	10.72	9.7	62	87.7	0.00	7	2	meter out	1.16	AL	partly cloudy rain last night
4/25/2006	RB-1	2:15 PM	9.98	19.7	83.7	93.4	0.00	7.47	-24	n/a	n/a	AL	Sunny, warm
5/31/2006	RB-1	2:45 PM	5.18	20	88.1	97.6	0.00	6.99	0	n/a	0.8	AL	Filtered sun, warm
7/3/2006	RB-1	8:41 AM	1.99	22.4	43.7	48.7	0.00	7.28	n/a	n/a	0.4	TH, EG	Cool, cloudy
8/2/2006	RB-1	1:45 PM	0.75	23	45.5	54.5	0.00	6.7	2	n/a	0.22	TH, CB	Partly cloudy, warm

Ambient Water Quality Monitoring **Ronald Bog, RB-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Milli volts	NTU's	Lake HT ft. 10ths	Samplers	Comments
9/8/2006	RB-1	10:05 AM	5.2	19.5	79	93.9	0.00	6.88	5	n/a	0.08	JW, TH	overcast skies, cool, 60's
10/13/2006	RB-1	11:05 AM	9.55	14.8	91.7	113.8	0.10	7.2	-14	6.00	0.33	JW, TH	cloudy, cool
11/14/2006	RB-1	11:00 AM	9.8	8.7	22.3	32.4	0.00	6.44	34	3.90	1.38	JW	High 40's, cloudy
12/22/2006	RB-1	11:05 AM	9.46	7.4	74.1	111.4	0.10	6.49	29	2.30	1.48	JW	overcast, mid 40s
1/30/2007	RB-1	1520	7.86	6	71.2	111.5	0.10	6.55	26	7.60	0.78	JW	40's, cool, sunny
2/26/2007	RB-1	1530	10.5	8	75.1	110.7	0.10	6.91	3	2.90	1.08	JW	partly sunny, high 40s
3/28/2007	RB-1	1550	6.52	13.1	85.8	110.7	0.10	7.04	-2	3.20	0.9	JW	High 50's, sunny. Minimal algae growth visible on the bottom.
4/25/2007	RB-1	1115	7.46	14.2	94.5	117.2	0.00	7.32	-17	5.70	0.72	JW	Mid 50s, overcast.
5/30/2007	RB-1	1435	7.69	22.6	107.4	111.7	0.10	7.24	-14	3.58	0.67	JW	clear and sunny, about 75
6/27/2007	RB-1	815	5.28	19.7	99.2	110.4	0.10	7.03	-2	1.98	0.52	JW	overcast, mid 50s
8/2/2007	RB-1	850	5.7	21.5	105.7	112.7	0.10	7.09	-4	1.71	0.48	JW	clear, sunny, upper 60s. Small (1.5") dead fish observed on the bottom of the bog by the gauge.
8/28/2007	RB-1	1435	5.36	21.7	107.1	114.5	0.10	7.29	-16	5.90	0.5	JW	clear, sunny, upper 60s. Mats of green algae near shore. Frogs and tiny fish observed in area.
9/24/2007	RB-1	1555	4.95	19.8	106.5	117.4	0.10	7.4	-22	9.00	0.52	JW	Clear, sunny, upper 50s
10/30/2007	RB-1	1500	4.33	12.6	70.7	92.6	0.00	6.86	4	4.70	0.76	JW	clear, sunny, mid 50s
11/28/2007	RB-1	1510	5.63	5.9	54.5	85.9	0.00	6.77	8	3.10	0.8	JW	overcast, low 40s, raining
12/18/2007	RB-1	1340	7.7	6.5	35.1	54.5	0.00	6.18	40	24.20	1.56	JW	rainy, low 40s. STORM EVENT. Water flowing in at sampling station from field too (about 10 gpm). Unusally high turbidity?
1/23/2008	RB-1	1540			48.7	82.3	0	6.72	12	1.90	0.88	JW	sunny, low 40s
2/28/2008	RB-1	930			71.6	104.1	0	6.76	10	1.80	0.18	JW	overcast, drizzle, 50 degrees
3/24/2008	RB-1	1502			60.4	85.6	0	6.61	12	4.20		EG	clear, 50s
4/22/2008	RB-1	1500			64	82.5	0	7.16	-28	3.70	0.39	JW	partly cloudy, mid 50s
5/27/2008	RB-1	1300			94.4	101.8	0.1	7.77	44	0.70	0.18	JW	overcast, low 60s

Ambient Water Quality Monitoring **Ronald Bog, RB-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Milli volts	NTU's	Lake HT ft. 10ths	Samplers	Comments
6/24/2008	RB-1	1530			87.5	95.1	0	7.84	60	1.20	0.2	JW, KW	clear, sunny, 60s
7/23/2008	RB-1	1020			96.1	104.4	0.1	7.29	131	2.30	-0.04	JW	overcast, 60. work was done downstream this last spring to lower the natural level of the bog. The natural summer level is now below the "0" point ont the gauge.
8/28/2008	RB-1	1600			85.7	94.5	0	7.38	-2	3.70	0.55	JW	Clear, sunny
9/23/2008	RB-1	1440			87.1	100.9	0.1	6.91	82	1.50	0.4	JW	50s, partly cloudy
10/28/2008	RB-1	1415			72.2	96.7	0	7.03	132	6.60	0.06	JW	mid 50's, overcast, foggy. Algae visible in the water column. Weird jelly blob sighted

Ambient Water Quality Monitoring
City of Shoreline

Ronald Bog NE Inlet Stream by I-5 on-ramp, RB-2

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Sal. ppt	pH	Mill volts	NTU's	Flow Est. CFS	Samplers	Comments
1/9/2002	RB-2	10:45 AM	10.74	8.7	88.8	129	0.1	6.68	18.4	0	< .1	AL	Sluggish flow, area of back water from the Bog.
1/24/2002	RB-2	1:55 PM	12.45	6.3	82.7	128.8	0.1	6.54	23.3	0	< .1	AL	Cloudy cold air temps
2/14/2002	RB-2	2:45 PM	11.08	7.9	82.2	122.1	0.1	6.98	-1.1	0	<.1	AL	Sunny mild temps
3/1/2002	RB-2	4:20 PM	10.2	8	74.2	110	0.1	7	-1.8	n/t	<.1	AL	Partly sunny, water clear
3/13/2002	RB-2	10:30 AM	11.08	7	70.8	107.8	0.1	6.99	1.5	0.25	1gal/min	AL/JC	Jay GPS in monitoring pt.
3/27/2002	RB-2	11:20 AM	12.84	7.4	78.4	117.9	0.1	7.06	-3.5		.5 gal/min	AL	Took photos
4/3/2002	RB-2	3:30 PM	12.31	11	73	99.7	0	mf	mf	n/t	.5 gal/min	AL	See miscellanous notes, pH 5.26
4/19/2002	RB-2	11:15 AM	9.04	8.7	69.5	101	0	6.69	10.8	cldy	.5 gal/min	AL	Overcast skies
4/29/2002	RB-2	4:05 PM	9	13.3	87.4	112.8	0.1	6.81	4.7	clr	1pt./min	AL	Sunny mild temps
5/13/2002	RB-2	11:35 AM											Dry, pockets of pooled water.
5/24/2002	RB-2	10:15 AM											Dry, pockets of pooled water.
6/26/2002	RB-2	10:10 AM											Dry no visible pools
7/17/2002	RB-2	2:50 PM											Dry couple of stagnant pools.
Aug-02	RB-2												No site visits
9/27/2002	RB-2	4:30 PM											Dry
10/10/2002	RB-2	12:25 PM	5.9	12	74.5	99	0	6.71	18.4	34.8	trickle	AL	Overcast periods of rain.
10/28/2002	RB-2	4:11 PM											DRY
11/12/2002	RB-2	2:45 PM	9.11	11.3	40.5	54.7	0	7.09	1.9	32.8	3 gal/min	AL	light drizzle.
11/27/2002	RB-2	3:20 PM										AL	Dry, stagnant pools.
12/20/2002	RB-2	11:20 AM	3.03	5.8	105.2	166.4	0.1	6.17	52.6	4.6	trickle	JK	Fairly stagnant.
1/2/2003	RB-2	12:45 PM	10.96	8	3.6	4.3	0	7.08	-2	28	stagnant	JK	Cloudy, periods of rain.
2/6/2003	RB-2	11:40 AM	7.15	4.7	92.4	150.5	0.1	6.41	32.7	3.4	Slight	JK	Sunny and cold
3/10/2003	RB-2	10:45 AM	6.59	8.4	83.3	122.7	0.1	6.04	55	25.1	trickle	AL	Overcast with mild to cool temperatures
5/27/2003	RB-2	9:30 AM									Stagnant	JK	Partly cloudy with highs in the mid to low 60's. Stream disconnected on surface flow.
6/17/2003	RB-2	2:10 PM											Sunny high 70's. Dry, pockets of pooled water.
7/10/2003	RB-2	4:15 PM										AL	Dry
8/15/2003	RB-2	11:10 AM										AL	Dry
9/17/2003	RB-2	2:15 PM										AL	no flow pooled water
10/9/2003	RB-2	2:20 PM										JK	no flow pooled water

Ambient Water Quality Monitoring
City of Shoreline

Ronald Bog NE Inlet Stream by I-5 on-ramp, RB-2

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Sal. ppt	pH	Mill volts	NTU's	Flow Est. CFS	Samplers	Comments
10/24/2003	RB-2	10:30 PM	4.06	10.5	129.9	179.9	0.1	6	56.6	2.53	trickle	AL	sunny and cool
11/13/2003	RB-2	3:20 PM										AL	no flow pooled water
12/5/2003	RB-2	11:20 AM	11.87	7.6	16	24	0	6.4	32.5	29.8	.75 cfs	AL	Raining
12/22/2003	RB-2	3:00 PM	9.22	8	84.7	123.7	0.1	6.37	34.7	2.3	Trickle	AL/AN	Partly sunny
1/8/2004	RB-2	11:10 AM	11.73	3.5	52.9	89.9	0	6.34	40.4	54	10 gpm	AL	Bankful flow, but velocity low
1/23/2004	RB-2	3:40 PM	9.89	7.8	63.1	94	0	6.65	25.6	10.45	slight	AL	periods of drizzle
2/12/2004	RB-2	4:35 PM	9.86	8.1	90.7	134.1	0.1	7.41	-16.2	1.46	slight	AN	sunny
3/10/2004	RB-2	3:45 PM	8.53	9.7	36	48.9	0	6.33	42.7	29.1	slight	AN	sunny mild air temps
3/26/2004	RB-2	3:45 PM	9.62	9.5	33.4	47.4	0	7.14	0.9	20.5	slight	AL	Overcast cool temps
4/14/2004	RB-2	2:30 PM	9.09	11.7	35.7	48.5	0	7.55	-19.8	15.37	slight	AN	Raining, 50's
4/28/2004	RB-2	11:20 AM	7.51	10.5	48.9	68.2	0	6.81	15.1	10.94	slight	AN/AL	sunny mild air temps
6/17/2004	RB-2	11:02 AM	7.29	14.7	56.9	71	0		8.9	6.26	trickle	AN	sunny upper 70s to low 80s
7/28/2004	RB-2	2:00 PM	6.76	18.5	56.1	64.4	0			7.6	trickle	AL	Sunny, hot. Odd water being here.
9/27/2004	RB-2	2:30pm	6.39	15.3	51.5	63.9	0.0	7.11	-7.0	2.34	<1 gpm	AL/AN	Sunny, low 70's
10/12/2004	RB-2	10:40am	7.21	13.9	50.4	64.0	0.0	7.10	-5		1 gpm	AL	High clouds; mild air temps
11/2/2004	RB-2												Backwater from Bog, no samples
12/13/2004	RB-2	1:03pm	10.91	9.1	72.3	105.1	0.0	6.92	2	11.3	1.5 cfs	AN	40's, rainy
1/5/2005	RB-2	2:45pm	9.07	5.1	51.1	22.4	0.0	6.88	31	2.21	slight	AN	Cold, upper 30's but clear
1/28/2005	RB-2	2:52pm	9.46	9.3	30.4	87.8	0.0	6.88	6	0.84	2-3 gpm	AL/WC	Overcast grey skies
2/8/2005	RB-2	2:30pm	10.12	7.4	58.6	88.5	0.0	6.41	26	5.07	slight	AN	Sunny, warm, upper 50's
2/22/2005	RB-2	2:30pm	11.22	7.7	45.3	70.2	0	6.94	-2	1.22	slight	AN	Clear, sunny, upper 50s to low 60s
3/14/2005	RB-2	9:50AM	6.11	7.3	43.3	65.6	0	6.48	23	1.08	slight	AN	Overcast cloudy about 60
3/30/2005	RB-2	3:20PM	6.47	10.8	47.8	65.3	0	6.55	12	13.88	slight	AN	sunny, 60s
4/21/2005	RB-2	2:40 PM	9.98	11.8	72.3	96.8	0	7.22	-20	1.29	trickle	AL/WC	Sunny and warm
5/26/2005	RB-2	2:35 PM	7.12	15.2	57.7	71.2	0	6.67	8	n/a	trickle	AL	Sunny, hot, 70s
6/28/2005	RB-2	11:30	6.15	14.6	46	57.3	0	4.55	149	4.52	trickle	AL & TH	Cloudy, cool, 60s
7/20/2005	RB-2	2:42 PM	7.3	17	59.1	70.2	0	6.82	1	2.2	trickle	AL & TH	Sunny, high clouds

Ambient Water Quality Monitoring
City of Shoreline

Ronald Bog NE Inlet Stream by I-5 on-ramp, RB-2

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Sal. ppt	pH	Mill volts	NTU's	Flow Est. CFS	Samplers	Comments
8/17/2005	RB-2	10:35 AM	6.59	17.7	75	87.2	0	6.57	13	521	2 gpm	AL	Overcast, cloudy. Period of rain overmight and early morning. Sediment/turbidity was coming from N inlet. Pipe ot the one coming in from E. Checked new ret/det pond, E of 1-5, S of 175th bone dry. Spoke with Calvin, 1-5 site manager, found area, it w
10/19/2005	RB-2	2:10 PM	4.13	13.8	65.5	83.1	0	6.57	15	4.1	trickle	AL & TH	Overcast and cool
11/8/2005	RB-2	1:45 PM	9.19	10	59.7	83.5	0	6.67	21	2.03	Standing trickle	AL	Mostly cloudy
12/30/2005	RB-2	10:00 AM	9.99	7.7	40.9	60.9	0	6.49	19	12.4	5 gpm	AL	Overcast light drizzle
1/19/2006	RB-2	3:35 PM	9.96	8.1	84	123.9	0.1	6.9	0.8	4.63	trickle flow	AL	cloudy cool
2/16/2006	RB-2	3:40 PM	9.07	8.5	81.9	119.7	0.1	6.92	7	5.41	trickle flow	AL	sunny cold
2/26/2006	RB-2	1515	7.53	8	59.2	87.8	0	6.49	26	3.9	not flowing	JW	partly sunny, high 40s
3/24/2006	RB-2	9:00 AM	9.38	8.8	24.6	35.7	0	6.55	25	57.4	10 gpms	AL	partly cloudy rain last night
4/25/2006	RB-2	2:00 PM	1.02	13.4	75.6	96.5	0	6.47	33	37.7	no flow	AL	Sunny, warm
5/31/2006	RB-2	2:55 PM	No flow. Pool of water									AL	Filtered sun, warm
7/3/2006	RB-2	8:35 AM	No flow. Puddle of water									TH, EG	Cool, cloudy
8/2/2006	RB-2	1:38 PM	Creek is dry.									TH, CB	Partly cloudy, warm
9/8/2006	RB-2	10:00 AM	Creek is dry.									JW, TH	overcast skies, cool, 60's
10/13/2006	RB-2	11:00 AM	Creek is dry.									JW, TH	Cloudy, cool, 60s
11/14/2006	RB-2	10:45 AM	7.7	8.3	70.4	103.3	0	6.02	56	2.55	not flowing	JW	high 40's, cloudy
12/22/2006	RB-2	11:25 AM	8.25	5.5	45	72.2	0	6.33	36	1.6	not flowing	JW	overcast, mid 40s
1/23/2007	RB-2	1520	10.2	4.4	72.1	119	0.1	6.62	19	0.8	1 gpm	JW	sunny, low 40s
1/30/2007	RB-2	1500	4.21	4.4	101	166.6	0.1	6.48	28	9.8	not flowing	JW	40's, cool, sunny
3/28/2007	RB-2	1535	4.81	13.2	98.4	129.3	0.1	6.48	27	16	0.5 gpm	JW	High 50's, sunny. Water looked brown and silty
4/25/2007	RB-2	1120	Creek mostly dry with a few puddles. No data colleccted.								no flow	JW	Mid 50s, overcast.
5/30/2007	RB-2	1425	1.19	15.8	50.4	61.4	0	6.16	42	5.12	no flow	JW	clear and sunny, about 75. larger puddles than last time. Taken from large puddle at the bend.
6/27/2007	RB-2	810	Creek is dry. No sample taken.								dry	JW	overcast, low 50s
8/2/2007	RB-2	840	Creek is dry. No sample taken.								dry	JW	clear, sunny, upper 60s
8/28/2007	RB-2	1425	Creek is dry. No sample taken.								dry	JW	clear, sunny, upper 60s

Ambient Water Quality Monitoring
City of Shoreline

Ronald Bog NE Inlet Stream by I-5 on-ramp, RB-2

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Sal. ppt	pH	Mill volts	NTU's	Flow Est. CFS	Samplers	Comments
9/24/2007	RB-2	1545	Creek is dry. No sample taken.								dry	JW	Clear, sunny, upper 50s
10/30/2007	RB-2	1440	2.48	8.6	44.6	65	0	6.5	-29	4.9	pool	JW	clear, sunny, mid 50s
11/28/2007	RB-2	1440	6.48	5.7	30.7	48.7	0	6.4	29	8.1	2 gpm	JW	water was a pool and then a slug of stormwater pushed through and caused some flow. Overcast. Low 40s, raining
12/18/2007	RB-2	1330	10.92	6.2	11.7	18	0	6.64	16	57.5	10 cfs	JW	rainy, low 40s. STORM EVENT. Unusally high turbidity?
2/28/2008	RB-2	915			69.6	102.8	0	6.5	27	9.8	0.25 gpm	JW	overcast, drizzle, 50 degrees
3/24/2008	RB-2	1450			68.4	96.4	0	6.79	-3	2	no flow	EG	clear, 50s
4/22/2008	RB-2	1525			79.1	111.5	0.1	6.67	8	1.5	1 gpm	JW	partly cloudy, mid 50s
5/27/2008	RB-2	1250									dry	JW	Overcast, low 60s
6/24/2008	RB-2	1515									dry	JW, KW	clear, sunny, 60s
7/23/2008	RB-2	1010									dry	JW	overcast, 60
8/28/2008	RB-2	1545			47.3	57.3	0	5.51	165	4	ponding	JW	clear, sunny. Had rained earlier in the week
9/23/2008	RB-2	1420			34.6	45.7	0	6.18		2.4	ponding	JW	50s, partly cloudy. Meter would't read mV. Mostly dry with puddles
10/28/2008	RB-2	1410									dry	JW	mid 50's, overcast, foggy

Ambient Water Quality Monitoring

City of Shoreline

Meridian Park Outlet C, MD-C

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Spec Cond *25 C*	Salinity ppt	pH	Milli volts	NTUs	Flow EST CFS	Samplers	Comments
1/9/2002	C	9:45 AM	2.42	7.4	65.4	98.5	0	6.12	46.5	5.44	none	AL	Partly cloudy
1/31/2002	C	1:50 PM	3.75	4.3	75.6	125.2	0.1	6.35	34.1	0	< .1	AL	Cold Temps, snow early in the week.
2/14/2002	C	2:10 PM	2.72	6.1	96.6	151.1	0.1	6.43	29.2	0	no	AL	sunny and warming temps
3/1/2002	C	4:10 PM	1.47	6.8	101.5	155.4	0.1	6.46	27.5	n/t	<.01	AL	partly sunny
3/13/2002	C	10:05 AM	4.21	5.8	80	126.2	0.1	6.32	36.3	5.68	slight	AL/JC	Jay GPS in points.
3/27/2002	C	10:30 AM	2.42	7.1	114	173.6	0.1	6.57	26		slight	AL	Photos taken
4/3/2002	C	2:40 PM	2.05	14.4	147.7	185.1	0.1	mf*	mf*	n/t	slight	AL	see miscell notes
4/19/2002	C	11:00 AM	1.62	7.7	111.7	166.7	0.1	6.49	21.5	cldy	no	AL	Overcast skies
4/29/2002	C	3:35 PM	3.36	16.2	162.9	196	0.1	6.71	10		no	AL	sunny and warming temps
5/13/2002	C	11:00 AM	1.42	12.3	147.4	194.6	0.1	6.81	5.7			AL	Overcast skies
5/24/2002	C	11:30 AM	1.07	12.9	164.6	213.9	0.1	6.62	16.1	clr		AL	Hazy and sunny.
6/25/2002	C	3:00 PM											Wetland completely dry.No sample
7/17/2002	C	2:00 PM											DRY. Some patches of pooled water 5' x 5'
8/12/2002	C	4:00 PM											Completely dry.
9/27/2002	C												Completely dry.
10/28/2002	C	3:45 PM											Completely dry.
11/12/2002	C	2:10 PM											Dry some patches of pooled water in the north end.
11/27/2002	C	3:00 PM											Dry some patches of pooled water in the north end.
12/17/2002	C	3:30 PM	2.65	6.4	70.2	109.2	0.1	6.35	42.9		slight	AL	overcast follows a week of heavy rains.
1/3/2003	MD-C	2:25 PM						6.13	62.1	10.25	Stagnant	JK	DO meter off rescrewed battery plate recalibrate
1/16/2003	C	3:50 PM	2.18	5.3	76.4	122.7	0.1	6.52	40.9	6.12	none	AL/JK	overcast skies
2/6/2003	MD-C	11:10 AM	1.8	3.5	77.6	131.8	0.1	6.24	41.2	13.4	Stagnant	JK	Overcast and cold
3/10/2003	MD-C	10:30 AM	2.11	7.8	92.7	137.7	0.1	5.91	61.5	13.3	Trickle	AL	Overcast with mild to cool temperatures. Saw male and female mallard ducks at staff gage
5/27/2003	MD-C	9:05 AM	0.39	12.7	112.1	146.1	0.1			41.5	Stagnant	JK	Partly cloudy with highs low to mid 60's. Extreamly rusty colored water.

Ambient Water Quality Monitoring
City of Shoreline

Meridian Park Outlet C, MD-C

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Spec Cond *25 C*	Salinity ppt	pH	Milli volts	NTUs	Flow EST CFS	Samplers	Comments
6/17/2003	MD-C	2:00 PM									Dry		Sunny high 70's. Dry at staff gage and WQ monitoring area
7/10/2003	MD-C										Dry		Sunny high mid to upper 80's. Dry at staff gage and WQ monitoring area
10/24/2003	MD-c	10:00 AM	0.96	9.6	113.9	161.9	0.1	6	56.1	2.3	Slight	AL	Sunny and cool
11/13/2003	MD-C	3:00 PM	1.32	6.2	146.6	230.8	0.1	6.12	45.8	0.91	no flow	AL	Clear and sunny
12/5/2003	MD-C	11:00 AM	3.04	6.3	87.2	135.8	0.1	6.17	43.3	3.15	slight	AL	Rain
12/22/2003	MD-C	2:30 PM	1.4	5	86.5	146.6	0.1	6.13	45.2	4.26	n/c	AL/AN	Partly sunny
1/8/2004	MD-C	2:35 PM	6.25	0.4	46.6	n/r	0	6.01	56.8	4.45	slight	AL	light rain at times
1/28/2004	MD-C	3:15 PM	1.42	7	94.5	144	0.1	5.96	59.3	4.66	slight	AL	drizzle at times
2/11/2004	MD-C	3:10 PM	4.76	5.8	79.9	97.5	0.1	6.38	42.1	4.88	slight	AN	sunny
3/11/2004	MD-C	3:35 PM	5.37	9.7	133.5	189	0.1	6.66	24.3	6.69	slight	AN	sunny
3/26/2004	MD-C	3:40 PM	3.67	9	115	165.5	0.1	6.7		9.51	slight	AL	Overcast cool temps
4/14/2004	MD-C	3:25 PM	2.55	12.7	147.8	193.3	0.1	6.73	18.2	11.6	slight	AN	Raining at times with overcast skies and 50's F
11/2/2004	MD-C	2:45pm	6.52	9.1	41.9	60.1	0.0	6.23	37.0	15.12	N/A	AL	Cloudy skies, no rain
12/13/2004	MD-C	3:00pm	1.49	7.2	102.1	157.5	0.1	5.64	8.5	6.3	slight	AN	40's, rainy
1/28/2005	MD-C	2:30pm	0.65	6.7	120.4	185.5	0.1	6.43	33	6.07	slight/none	AL/WC	Overcast grey skies
2/22/2005	MD-C	1:45pm	3.9	4.8	126	209.7	0.1	6.51	20	6.32	slight/none	AN	Clear, sunny upper 50s to low 60s
3/14/2005	MD-C	11:00AM	1.47	7.6	134.9	202.2	0.1	6.72	9	7.37	slight/none	AN	Sunny, warm 60s
3/30/2005	MD-C	4:10PM	1.75	8.4	76.1	112.7	0.1	6.12	37	17.8	slight/none	AN	Sunny 60s
4/26/2005	Md-C	10:30 AM	0.76	13.3	157.3	202.7	0.1	2.93	214	10.03	no flow noted	AL/WC	Overcast grey skies
5/26/2005	MD-C	2:10 PM	2.14	16.7	146.7	174.9	0.1	6.64	9	N/A	0	AL	Sunny, hot, 70s
6/28/2005	MD-C	10:40 AM	1.18	13.8	120.6	155.3	0.1	2.54	242	10.2	standing water	AL & TH	Cloudy, cool, 60s
7/20/2005	MD-C	2:15 PM	Dry today. No water anywhere in wetland.									AL & TH	Sunny, high clouds
8/17/2005	MD-C				Dry no water								
10/19/2005	MD-C	1:45 PM			Dry, with some standing water at the north edge of the wetland.							AL & TH	Overcast cool

Ambient Water Quality Monitoring
City of Shoreline

Meridian Park Outlet C, MD-C

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Spec Cond *25 C*	Salinity ppt	pH	Milli volts	NTUs	Flow EST CFS	Samplers	Comments
11/10/2005	MD-C	3:10 PM	2.02	8.4	83.7	122.7	0.1	6	59	3.03	trickle	AL	Partly cloudy, chilly, breezy
12/30/2005	MD-C	9:40 AM	1.5	6.7	72.4	111	0.1	5.29	55	7.55	.2 cfs	AL	Cloudy rain beginning
1/25/2006	MD-C	11:10 AM	1.08	5	75.5	122.4	0.1	6.07	56	4.97	no visible flow	AL	partly sunny
2/16/2006	MD-C	3:20 PM	1.16	4.9	71.6	116.5	0.1	6.07	53	4.31	trickle flow	AL	sunny cold
3/23/2006	MD-C	11:00	2.2	8.3	107.5	159.9	0.1	6.5	31	7.13	none	AL	partly sunny mild air temps
4/27/2006	MD-C	10:15 AM	1.76	11	124.8	170.6	0.1	6.76	14	n/a	None	AL	Sunny, warm.
5/24/2006	MD-C	11:30 AM	No data, creek was dry									AL	Cloudy, period of light drizzle and rain showers.
6/30/2006	MD-C	11:45	No data, creek was dry									TH, EG, CI	Sunny, warm.
8/2/2006	MD-C	3:45 PM	No data, creek was dry									TH, CB	partly cloudy, warm
9/8/2006	MD-C	10:30 AM	No data, creek was dry									TH, JW	
10/13/2006	MD-C	10:50 AM	No data, creek was dry									TH, JW	Cloudy, cool, 60s
11/14/2006	MD-C	1:10 PM	4.69	7	30.5	47.1	0	5.97	56	1.91	not flowing	JW	high 40's, cloudy
12/22/2006	MD-C	10:55 AM	1.52	5.4	58.2	93.3	0	5.93	60	1.97	trickle flow	JW	overcast, mid 40s
1/23/2007	MD-C	1140	Water was frozen over with thick ice.								not flowing	JW	sunny, low 40s
1/30/2007	MD-C	1630	1.68	1.5	73.9	error	0.1	6.18	45	4.9	not flowing. Ice covered.	JW	mid 30's, very cold (frozen), clear. Had to break ice 1/4" thick to take measurements. Suspect cold temperatures is why it would not read the specific conductivity.
2/26/2007	MD-C	1440	2.42	6.4	108.2	168.3	0.1	6.38	31	3.4	not flowing.	JW	partly sunny, high 40s
3/28/2007	MD-C	1445	2.14	9.2	114.1	164.8	0.1	6.99	1	5.2	not flowing.	JW	High 50's, sunny
4/25/2007	MD-C	1025	0.8	9.9	126.2	178.2	0	6.78	11	5.7	not flowing.	JW	Mid 50's, overcast. No flow with stagnant water. Decaying organic material and bacteria sheen visible.

Ambient Water Quality Monitoring
City of Shoreline

Meridian Park Outlet C, MD-C

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Spec Cond *25 C*	Salinity ppt	pH	Milli volts	NTUs	Flow EST CFS	Samplers	Comments
5/29/2007	MD-C	1310	1.08	13.6	109.4	139.2	0.1	6.36	35	*	not flowing.	JW	clear and sunny, about 65. Water was very low (stagnant) so no accurate WQ turbidity could be obtained.
6/27/2007	MD-C	725	No data, creek was dry								no water	JW	overcase, low 50s
8/2/2007	MD-C	810	No data, creek was dry								no water	JW	clear, sunny. Upper 60s
8/28/2007	MD-C	1400	No data, creek was dry								no water	JW	clear, sunny. Upper 60s
9/24/2007	MD-C	1500	No data, creek was dry								no water	JW	clear, sunny. Upper 50s
10/30/2007	MD-C	850	No data, creek was dry									JW	clear, sunny, 50s
11/27/2007	MD-C	1325	1.8	5	87.4	142.4	0.1	6.19	40	2.8	ponding	JW	overcast, low 40s, raining
12/18/2007	MD-C	1445	3.58	4.9	59.3	96.5	0	6.15	41	2.2	none evident	JW	rainy. Low 40s. STORM EVENT.
2/28/2008	MD-C	1030	1.12	7.7	129.2	192.9	0.1	6.63	19	3.2	not flowing	JW	overcast, drizzle, 50 degrees
3/24/2008	MD-C	1444	4.18	7.7	69.4	103.9	0	6.41	27	5.4	not flowing	EG	clear, 50s
4/22/2008	MD-C	1425	6.7	9.4	114.2	163	0.1	6.55	17	2.3	not flowing	JW	partly cloudy, mid 50s
5/27/2008	MD-C	1230	No data, creek was dry								no water	JW	overcast, low 60s. Ground was wet with little standing water.
6/24/2008	MD-C	1453	No data, creek was dry								no water	JW, KW	clear, sunny, 60s
7/23/2008	MD-C	930	No data, creek was dry								no water	JW	overcast, 60
8/28/2008	MD-C	1500	No data, creek was dry								no water	JW	clear, sunny
9/23/2008	MD-C	1355	No data, creek was dry								no water	JW	50s, partly cloudy
10/28/2008	MD-C	1335	No data, creek was dry								no water	JW	mid 50's, overcast, foggy

Ambient Water Quality Monitoring **Meridian Creek, upstream 50' from confl to Twin Ponds, MRD-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
1/9/2002	MD-1	11:10 AM	8.42	8.3	99	145.3	0.1	6.56	24.4	0.15	.2 to .5	AL	Partly cloudy
1/24/2002	MD-1	2:20 PM	6.28	6.6	129.6	199.5	0.1	6.65	17	6.42	< .1	AL	Cloudy cold air temps
2/14/2002	MD-1	3:30 PM	6.38	6.8	128.4	197.0	0.1	6.64	17.8	0	< .1	AL	Sunny, mild to cool air temps
3/1/2002	MD-1	11:47 AM	6.45	6.3	129.6	201.6	0.1	6.8	9.5	n/t	<.1	AL	Overcast skies, water clear. Observed adult stlhead in south pond of Twins pond. Had bruised lower jaw, deformed caudal (Rounded) and dorsal. Assume hatchery broodstock plant.
3/13/2002	MD-1	11:00 AM	7.66	7.2	103.6	157.1	0.1	6.76	13.8	0.02	2.5 gal/min		Jay GPS in point
3/27/2002	MD-1	11:40 AM	6.06	7.5	147.1	220.7	0.1	6.61	21.8		1 gal/ min		Overcast skies.
4/3/2002	MD-1	4:30 PM	4.68	10.3	167.9	233.5	0.1	mf*	mf*	n/t	1 gal/min		See pH miscell notes, pH was 5.01
4/19/2002	MD-1	10:45 PM	4.64	8.9	144.1	208	0.1	6.62	14.4	CLr	1 gal/min		Overcast skies.
4/29/2002	MD-1	3:15 PM	4.05	13.7	172.6	219.9	0.1	6.76	5.5	Clr	1 gal/min		Sunny
5/13/2002	MD-1	10:40 AM	3.29	10.7	184.4	254.6	0.1	6.74	10	rust	.25 gal/min		Overcast skies.
5/24/2002	MD-1	11:10 AM	3.06	10.6	162.5	224	0.1	6.68	12.5	rust	.5 gal/min		Hazy and sunny
6/25/2002	MD-1	10:25 AM	0.42	15.5	257.8	315.1	0.2			rust	.25 gal/min		Partly sunny warm
7/17/2002	MD-1	2:30 PM	0.47	16	265.4	319.8	0.2	6.95	6.7	8.2	trickle < .25 gal/min		
8/12/2002	MD-1	4:00 PM											Dry
9/24/2002	MD-1	2:25 PM											Dry
10/8/2002	MD-1	4:10 PM	1.25	12.8	155.4	208	0.1	6.75	16.2	2.55	trickle < .25 gal/min		periods of lite drizzle
10/21/2002	MD-1	4:10 PM	0.94	11.2	215.7	293.1	0.1	6.78	14.3	1.53	trickle < .25 gal/min		overcast skies stale air
11/13/2002	MD-1	11:30 AM	1.29	10.3	92.1	128.2	0.1	6.6	27.9	3.62	1 gal/min		overcast skies strong storm last night
11/27/2002	MD-1	3:48 PM	0.9	5.3	170.8	274.1	0.1	6.53	31.3	1.8	1 gal/min		clear and cold
12/20/2002	MD-1	11:50 PM	4.44	7.8	132.2	197.2	0.1	6.65	25	4.25	1 to 2 gal/min		partly cloudy
1/3/2003	MD-1	10:15 AM	8.6	8.2	95	140	0.1	6.54	31	4.3	.1 cfs	JK	cloudy hard rains last night
2/6/2003	MD-1	4:20 PM	5.19	7.2	139.3	210.7	0.1	6.71	17.1	2.2	slight	JK	Sunny and cold
3/10/2003	MD-1	11:25 AM	6.49	8.6	115.2	167.8	0.1	6.47	32.9	6.8	3 gpm	AL	Overcast with mild to cool temperatures
4/14/2003	MD-1	11:30 AM	4.73	9.9	118.5	166.7	0.1	6.54	28	4.31	5 gpm	AL/JK	

Ambient Water Quality Monitoring **Meridian Creek, upstream 50' from confl to Twin Ponds, MRD-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
5/27/2003	MD-1	10:20 AM	2.95	12.4	156.4	206.2	0.1			4.45	trickle	JK	Partly cloudy with highs in the low to mid 60's
6/17/2003	MD-1	3:00 PM										JK/AN	Sunny high 70's. Pool of water with brown precipitate, no surface flow.
7/10/2003	MD-1										Dry	AL/AN	Sunny highs mid to upper 80's. Dry at WQ monitoring area.
9/17/2003	MD-1	11:40 AM									no flow	AL	pooled water only
10/9/2003	MD-1	2:20 PM									no flow	JK	pooled water
10/24/2003	MD-1	11:00 AM	3.35	12.5	154.2	202.8	0.1	6.31	39.3	7.02	2 gpm	AL	Sunny and cool
11/13/2003	MD-1	2:45 PM	1.76	7.2	168.1	255	0.1	6.59	23.6	0.81	trickle	AL	clear and sunny
12/4/2003	MD-1	10:45 AM	4.67	8.2	126.1	185.9	0.1	6.33	36.6	1.52	5 gpm	AL	Cloudy breezy
12/23/2003	MD-1	11:00 AM	4.77	7.4	132.7	200	0.1	6.25	40.3	1.44	4 gpm	AL/SS/AN	Overcast
1/8/2004	MD-1	1:55 PM	9.83	3.5	55	92.3	0	6.28	43.9	18.52	.25 cfs	AL	light rain, heavy rain and ice days before
1/30/2004	MD-1	3:45 PM	8.75	8.2	93.1	137.3	0.1	6.55	30.4		.25 cfs	AN	light drizzle
2/11/2004	MD-1	2:50 PM	8.55	7.1	60.1	114.2	0.1	7.15	0.4	2.2	4 gpm	AN	sunny
3/9/2004	MD-1	10:20 PM	7.84	9.4	52.5	74.7	0	6.55		19.03	7 gpm	AL	Parkwood Elementary school field trip
3/29/2004	MD-1	3:15 PM	4.23	11.5	142.4	191.8	0.1	6.86	14.5	5.2	slight	AN	Sunny 75 F
4/14/2004	MD-1	3:10 PM	4.59	11	78.2	243.1	0.1	6.82	13.9	6.16	slight	AN	Raining at times with overcast skies and 50's F
4/29/2004	MD-1	3:30 PM	1.91	11.6	168.6	227.2	0.1	6.57	25.4	2.33	slight	AL	Sunny hot
6/24/2004	MD-1	3:20 PM									Dry	AL/AN	Overcast grey skies
9/23/2004	MD-1	10:10am	0.84	12.6	137.8	180.6	0.1	6.59	24.0	0.61	5 gpm	AL	overcast / foggy; mild air temp
9/27/2004	MD-1										Dry	AL/AN	sunny, low 70's
10/5/2004	MD-1										Standing water, no flow, no sample		
11/18/2004	MD-1	11:20am	3.34	8.8	95.3	137.8	0.1	6.67	19.0	3.39	1 gpm	AL	windy, chilly temp
12/13/2004	MD-1	2:40pm	8.13	8.7	38.6	82.3	0.0	6.53	22	7.50	<5 gpm	AN	rainy, 40's
1/5/2005	MD-1	3:15pm	6.46	5.1	114.1	184.3	0.1	6.42	33	3.24	slight	AN	cold, upper 30's; clear
1/31/2005	MD-1	12:15pm	4.97	8.7	111.1	161.2	0.1	6.57	15	2.92	slight	AN	Clear, sunny blue skies; mid 50's
2/8/2005	MD-1	3:00pm	7.00	6.6	106.7	164.4	0.1	6.52	16	13.10	slight	AN	Sunny, warm, upper 50's
2/22/2005	MD-1	1:30pm	6.41	5.3	109.2	175.4	0.1	6.66	13	2.78	slight	AN	Clear, sunny upper 50s to low 60s
2/25/2005	MD-1	11:30am	6.62	6.00	113.00	177.60	0.10	6.57	20.00	4.65	1gpm	AL	Overcast mild air temps
3/14/2005	MD-1	10:20AM	4.28	6.8	71.6	106.4	0	6.68	12	10.13	slight	AN	Sunny, warm 60s

Ambient Water Quality Monitoring **Meridian Creek, upstream 50' from confl to Twin Ponds, MRD-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
3/30/2005	MD-1	3:45PM	7.67	9.5	95.8	136	0.1	6.62	10	6.15	1-2gpm	AN	Sunny, warm
4/26/2005	MD-1	11:30 AM	4.88	11.7	137.1	184.1	0.1	6.13	41	5.43	1	AL	Overcast filtered sun
5/26/2005	MD-1	3:10 PM	4.3	13.9	119.3	151.5	0.1	6.6	12	n/a	15	AL	Sunny, hot, 70's
6/28/2005	MD-1	3:08 PM	2.83	14.4	118.3	148.5	0.1	6.29	31	5.7	Trickle	AL & TH	Cloudy, cool, 60's
7/20/2005	MD-1	3:10 PM	No flow, water dry									AL & TH	Sunny, high clouds
8/17/2005	MD-1	10:10 AM	1.58	15.5	295.1	360.3	0.2	6.04	43	16.57	2 gpm	AL	Overcast, cloudy
10/19/2005	MD-1	2:40 PM	1.59	12.8	107.5	140.5	0.1			4.89	trickle	AL & TH	pH probe broke
11/15/2005	MD-1	10:45 AM	4.79	8.3	82.6	121.5	0.1	6.58	26	1.38	5 gpm	AL	Light drizzle, cool. Nice looking water at Meridian wetland. Finally is holding water like it normally does. Said hello to Dick Decker, he said lots of water flowed into Meridian Creek at Twin Ponds. It was up and over the path.
12/30/2005	MD-1	10:40 AM	9.03	7.5	43.5	65.5	0	6.14	51	7.72	20 gpm	AL	Overcast light drizzle
1/19/2006	MD-1	3:25 PM	7.07	8.3	106.2	156.2	0.1	6.56	27	4.92	10 gpm	AL	cloudy cool
2/16/2006	MD-1	10:00 AM	6.88	5.3	100.2	160.6	0.1	6.68	20	4.25	3 gpm	AL	sunny cold
3/23/2006	MD-1	10:50 AM	4.63	8.7	86	125.2	0.1	6.48	31	2.68	2 gpm	AL	Partly sunny mild air temps
4/21/2006	MD-1	3:55 PM	5.41	10.2	62.3	86.5	0	6.43	35	8.13	5 gpm	AL	Partly sunny, rain last night.
5/24/2006	MD-1	2:50 PM	3.05	13.1	85.4	111.5	0.1	6.66	19	n/a	2 gpm	AL	Cloudy, period of light drizzle and rain showers.
6/30/2006	MD-1	11:20 AM	dry, no water									TH, EG, C	Sunny, warm
8/2/2006	MD-1	3:55 PM	Creek was dry.									TH, CB	partly cloudy, warm
9/6/2006	MD-1	11:35 AM	Creek was dry.									JW, TH	clear skies, sunny, low 70's
10/13/2006	MD-1	10:30 AM	Creek was dry.									JW, TH	foggy, cool
11/14/2006	MD-1	10:30 AM	12.82	9	106.1	152.8	0.1	6.37	36	1.3	2 cfs	JW	high 40's, cloudy
12/22/2006	MD-1	10:30 AM	6.9	7.3	87.1	131.4	0.1	6.35	36	1.8	5 gpm	JW	overcast, 40s
1/30/2007	MRD-1	1720	3.6	4.5	62.6	104.1	0.1	6.61	20	15.6	3 gpm	JW	mid 30's, very cold, clear
2/26/2007	MRD-1	1455	4.48	7.5	70.9	103.5	0	6.51	26	1.98	10 gpm	JW	partly sunny, low 40s
3/28/2007	MRD-1	1420	2.98	9.8	110.6	155.9	0.1	6.75	13	6.3	5 gpm	JW	High 50's, sunny
4/25/2007	MRD-1	1040	3.35	10.1	143.8	200.5	0.1	6.85	7	3.5	3 gpm	JW	Mid 50s, overcast. Water was to low to sample. Data collected from downsteam of culvert.
5/29/2007	MRD-1	1245	2.45	12.2	144.5	192	0.1	6.69	17	3.62	1.5 gpm	JW	clear and sunny, about 65

Ambient Water Quality Monitoring **Meridian Creek, upstream 50' from confl to Twin Ponds, MRD-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
6/27/2007	MRD-1	740	Creek was dry. No sample taken.								dry	JW	overcast, low 50s. No water flowing from culvert
8/2/2007	MRD-1	830	Creek was dry. No sample taken.								dry	JW	clear, sunny, upper 60s
8/15/2007	MD-1	10:50 AM									Dry	AL	
8/28/2007	MRD-1	1410	Creek was dry. No sample taken.								dry	JW	clear, sunny, upper 60s
9/24/2007	MRD-1	1520	Creek was dry. No sample taken.								dry	JW	clear, sunny, upper 50s
10/30/2007	MRD-1	900	0.94	6.8	6.2	9.4	0	6.56	21	1.2	0.5 gpm	JW	clear, sunny, mid 50s
11/28/2007	MRD-1	1345	2.2	7.3	98.6	148.8	0.1	6.6	18	1.3	3 gpm	JW	overcast, low 40s, raining
12/18/2007	MRD-1	1435	10.62	6.3	12.9	20.1	0	6.47	30	20.5	10 cfs	JW	rainy. Low 40s. STORM EVENT. Unusually high turbidity?
1/23/2008	MRD-1	1120			113.1	189.4	0.1	6.62	19	2.02	3 gpm	JW	sunny, low 40s
2/28/2008	MRD-1	1000			133.2	197.8	0.1	6.73	12	2.8	10 gpm	JW	overcast, drizzle, 50 degrees
3/24/2008	MRD-1	1430			47.2	69.9	0	6.58	15	5.8	15 gps	EG	clear, 50s
4/22/2008	MRD-1	1435			90	128.1	0.1	6.57	14	2.5	8 gpm	JW	partly cloudy, mid 50s
5/27/2008	MRD-1	1220			153.2	198.1	0.1	6.85	106	2.4	5 gpm	JW	overcast, low 60s
6/24/2008	MRD-1	1500									0.25 gpm	JW, KW	. Clear, sunny, 60s. water present was filled with organic matter and iron bacteria
7/23/2008	MRD-1	945										JW	overcast, 60
8/26/2008	MRD-1	1530			102	125.5	0.1	6.48	127	1.9	0.10 gpm	JW	clear, sunny
9/23/2008	MRD-1	1415			108.8	145.8	0.1	6.48	44	1.2	0.10 gpm	JW	50s, partly cloudy. Mostly dry with small puddles. About 0.10 gpm flowing from culvert
10/28/2008	MRD-1	1400									0.10 gpm	JW	mid 50's, overcast, foggy. No standing water in creek. Tiny trickle of water flowing out of culvert.

Ambient Water Quality Monitoring **Thornton Creek, upstream of Twin Ponds by 50' on d/s side of culvert in park, TH-1**
City of Shoreline, 2001

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
1/9/2002	TH-1	11:00 AM	10.96	8.6	54.1	78.7	0	6.86	6.6	2.27	1.5	AL/JK	Partly cloudy
1/14/2002	TH-1	4:45 PM		8								AL	Installed temp logger
1/24/2002	TH-1	2:10 PM	13.07	6.3	98.2	152.8	0.1	7.31	-18.4	0	0.4	AL	Cloudy and cold
2/14/2002	TH-1	3:15 PM	11.49	7	99	150.8	0.1	7.31	-17.7	0	0.7	AL	Sunny mild air temps
3/1/2002	TH-1	11:35 AM	11.79	6.5	97.8	151.4	0.1	7.22	-14.3	N/T	0.75	AL	Light overcast skies, water was clear
3/13/2002	TH-1	10:45 AM	11.48	7	73.8	112.3	0.1	7.1	-5.4	1.55	0.75	AL/JC	Jay GPS in pts.
3/27/2002	TH-1	11:30 AM	11.84	8.2	123.2	181.4	0.1	7.47	-24.5		0.5	AL	Photos 11 &12
4/3/2002	TH-1	4:15 PM	10.93	10.9	145.6	199	0.1	mf*	mf*	n/t	0.75	AL	See miscellanous notes
4/19/2002	Th-1	10:30 AM	9.93	10.1	109.3	152.1	0.1	7.29	-21.9	clr	1	AL	Overcast skies
4/29/2002	TH-1	3:00 PM	9.9	13.8	127.3	162.3	0.1	7.58	-36.7	clr	0.75	AL	Sunny
5/13/2002	TH-1	10:30 AM	10.35	11.5	164.3	221.3	0.1	7.67	-39.9	clr	0.4	AL	Overcast skies
5/24/2002	TH-1	11:00 AM	10.41	11.8	148.5	199	0.1	7.58	-36	clr	0.2	AL	Hazy and sunny.
6/26/2002	TH-1	10:15 AM	9.51	14.6	211.7	264.4	0.1			Clr	3 gal/min	AL/JK	pH meter on the fritz.
7/16/2002	TH-1	2:50 PM	9.04	16.1	205.6	247.9	0.1	7.81	-44.7	5.2	5 gal/min	AL	sunny and nice
8/12/2002	TH-1	3:40 PM	8.93	17.2	227.4	267.2	0.1	8.07	-46.8	3.9	5gal/min	AL	sunny and hot
9/25/2002	TH-1	2:15 PM	8.85	13.5	212.4	271.8	0.1	7.94	-49.5	4.6	5gal/min	AL	sunny and warm
10/8/2002	Th-1	4:00 PM	9.37	12.4	204.6	269.4	0.1	7.89	-46.5	2.2	5gal/min	AL	overcast periods of drizzle
10/17/2002	TH-1	9:45 AM	9.57	10.4	116.8	161.8	0.1	7.64			5gal/min	AL	Parkwood school field trip.
11/13/2002	TH-1	11:45 AM	10.15	10.4	100.5	139.5	0.1	7.25	-7.5	7.45	.25 cfs	AL	overcast skies storm last night
11/27/2002	TH-1	3:36 PM	9.8	7.9	157.6	234.2	0.1	7.5	-21.9	1.09	5gal/min	AL	Clear and cold
12/9/2002	TH-1	11:45 AM	11.09	6.9	177.1	271.5	0.1	7.77	-36	2.04	5gal/min	AL	overcast skies low flows again
1/3/2003	TH-1	9:55 AM	11.65	6.7	51	78.4	0	7.13	-0.4	5.8	1.5 cfs	JK	cloudy rained hard last night.
2/6/2003	TH-1	4:10 PM	10.86	7.5	99.1	149	0.1	7.27	-11.8	2.3	10 gpm	JK	Sunny and cold
3/10/2003	TH-1	11:15 AM	11.34	8.2	69.2	102.1	0	6.74	18.6	7.1	.75 cfs	AL	Overcast with mild to cool temperatures
4/14/2003	TH-1	11:20	9.93	11.4	73.7	99.4	0	6.94	3	4.14	.1 to .25 cfs	AL	
5/27/2003	TH-1	10:10 AM	9.25	12.9	140.4	182.6	0.1			3.95	5 to 10 gpm	JK	Partly cloudy with highs in the mid to low 60's
6/17/2003	TH-1	3:05 PM	9.12	16.6	220.7	263	0.1	8	-48.4	4.2	5 to 10 gpm	JK/AN	Sunny high 70's
7/10/2003	TH-1	3:15 PM	7.76	7.8	229.3	266.3	0.1	7.93	-44	2.45	2 to 3 gpm	AL/AN	Sunny high mid to upper 80's
8/15/2003	TH-1	10:43 AM	8.36	15.7	223.6	271.7	0.1	n/c	n/c	1.37	2gal/min	AL	pH on fritz, partly sunny
9/17/2003	TH-1	11:34 AM	8.97	12.8	126.4	165.1	0.1	7.54	-27.7	4.66	3 gal/min	AL	

Ambient Water Quality Monitoring **Thornton Creek, upstream of Twin Ponds by 50' on d/s side of culvert in park, TH-1**
City of Shoreline, 2001

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
10/9/2003	TH-1	2:45 PM	8.66	12.2	195.1	257.8	0.1	7.57	-31.6	1	5 to 10 gal/mir	JK	overcast with sprinkles
10/24/2003	TH-1	10:50 AM	10.37	13.1	79.3	102.7	0.1	6.81	11.8	2.74	.5 cfs	AL	4-days after record rain event of 5" in 24 hrs
11/13/2003	TH-1	2:30 PM	9.81	8.3	184.9	271.6	0.1	7.51	-19.1	0.25	5gal/min	AL	clear and sunny
12/4/2003	TH-1	11:40 AM	11.41	6.6	76.4	117.8	0.1	6.92	9.2	3.37	.2 cfs	AL	Cloudy and breezy
12/23/2003	TH-1	10:50 AM	11.8	6.5	90	139.5	0.1	6.77	15.3	0.8	10 gpm	AL/SS/AN	
1/8/2004	TH-1	1:50 PM	12.05	2.6	46.8	81.7	0	6.78	18.9	13.3	1 cfs	AL	light rain,heavy rains and ice days before
1/30/2004	TH-1	3:35 PM	10.88	7.5	52.5	79	0	6.73	20.6		1 cfs	AN	light drizzle
2/11/2004	TH-1	2:40 PM	11.73	7.7	103.5	154.7	0.1	7.34	-12.8	2.23	.5 cfs	AN	Sunny
3/9/2004	TH-1	9:58 AM	12.41	9.5	67.5	99.2	0	7.34		21.3	20 gpm	AL	Parkwood Elementary school field trip
3/29/2004	TH-1	3:05 PM	8.38	13.6	116.4	148.9	0.1	7.57	-26.5	6	0.25 cfs	AN	Sunny 75 F
4/14/2004	TH-1	3:00 PM	9.89	11.6	171.1	229.6	0.1	8.36	-59.4	5.41	0.25 cfs	AN	Raining 50's
4/29/2004	TH-1	3:15 PM	9.48	13.7	159.1	203.1	0.1	7.35	-12.4	1.72	15 gpm	AL	sunny hot
6/24/2004	TH-1	3:10 PM	9.41	15.3	211.7	259.6	0.1	7.73	-45.7	6.25	5 gpm	AN/AL	Overcast grey skies
7/22/2004	TH-1	10:22 AM	8.34	16.4	167.5	199.3	0.1			2.85	3 gpm	AL	Sunny, hot warm nice.
8/19/2004	TH-1	9:26 AM	7.92	16.9	214.7	253.9	0.1			1.76	5 - 10 gpm	AN/WSC	Sunny and hot, 80s
9/23/2004	TH-1	10:00 AM	8.86	12.8	167.6	218.2	0.1	7.8	-45	1.5	5 gpm	AL	overcast foggy, brown substrate observed at sample location, usually substrate is black colored, observed crayfish at culvert outfall.
10/5/2004	TH-1	12:30 PM	9.58	12.5	194.9	255.9	0.1	7.89	-50	5.02	2 gpm	AL/WSC	Sunny
11/19/2004	TH-1	11:10 AM	9.94	8.6	76.8	112	0.1	7.15	-10	3.7	.5 cfs	AL	Partly cloudy
12/13/2004	TH-1	2:30 PM	10.72	7.9	49.4	73.8	0	7.17	-10	5.05	.75 cfs	AN	Rainy
1/5/2005	TH-1	3:00pm	12.23	4.1	78.4	130.0	0.1	6.14	18	1.08	0.5 cfs	AN	Cold, upper 30's but clear
1/31/2005	TH-1	12:05pm	10.24	9	103.1	148.2	0.1	7.48	-20	1.81	0.25 cfs	AN	Clear, sunny blue skies; mid 50's
2/8/2005	TH-1	2:45pm	11.70	7.2	63.1	95.7	0.0	7.15	-17	10.62	0.5cfs	AN	Sunny, warm, upper 50's
2/22/2005	TH-1	1:20pm	12.21	6.6	118.6	182.7	0.1	7.76	-48	0.79	50gpm	AN	Clear, sunny upper 50s to low 60s
2/25/2005	TH-1	11:15am	11.74	7.10	129.10	196.10	0.10	7.75	-48.00	1.42	5gpm	AL	Overcast, mild air temps
3/14/2005	TH-1	10:10AM	10.79	8.8	156.8	227.5	0.1	7.85	-53	0.65	~50gpm	AN	Sunny, warm 60s
3/30/2005	TH-1	3:40PM	11.41	10.1	59.1	82.6	0	7.2	-25	3.62	1cfs	AN	Sunny, warm 60s

Ambient Water Quality Monitoring **Thornton Creek, upstream of Twin Ponds by 50' on d/s side of culvert in park, TH-1**
City of Shoreline, 2001

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
4/26/2005	TH-1	11:00 AM	9.43	13.2	137.8	178.2	0.1	6.23	53	4.86	10	AL	overcast filtered sun
5/26/2005	TH-1	3:00 PM	9.43	16.7	127.5	151.8	0.1	7.39	-32	n/a	15	AL	Sunny, hot, 70's
6/28/2005	TH-1	2:52 PM	8.76	15.8	107.5	130.4	0.1	7.1	-17	9.26	10	AL & TH	Cloudy, cool, 60s
7/20/2005	TH-1	3:02 PM	8.44	16.6	214.2	255	0.1	7.92	-61	2.5	8 gpm	AL & TH	Sunny, high clouds
8/17/2005	TH-1	*Under construction for restoration. Flow diverted, and couldn't sample location.*											
10/19/2005	TH-1	2:30 PM	7.81	13.1	120.3	155.9	0.1			0.6	10 gpm	AL & TH	pH meter broke probe
11/15/2005	TH-1	10:30 AM	10.15	7.8	58.3	87	0	6.59	24	2.33	15 gpm	AL	Light drizzle, cool
12/30/2005	TH-1	10:30 AM	10.17	7.4	49	73.8	0	6.31	40	12.49	.6 cfs	AL	Overcast periods of light drizzle
1/19/2006	TH-1	3:00 PM	10.68	7.4	64.6	97.3	0.1	6.72	15	5.11	.25 cfs	al	cloudy cool
2/16/2006	Th-1	9:45 AM	11.54	5.3	82.7	132.2	0.1	7.03	0	4.85	20 gpm	AL	sunny cold
3/23/2006	TH-1	10:35 AM	9.17	9.5	85.9	122.2	0.1	7.08	-2	3.21	20 gpm	AL	partly sunny mild temps
4/21/2006	TH-1	3:45 PM	9.48	11.6	72.5	99.9	0	7.15	2	6.13	15 gpm	AL	partly sunny, rain last night.
5/24/2006	TH-1	2:40 PM	8.16	14.7	110.3	137.1	0.1	7.37	-22	n/a	20 gpm	AL	Cloudy, period of light drizzle and rain showers.
6/30/2006	TH-1	11:00 AM	3	15.1	206.2	235.5	0.1	7.65	n/a	n/a	5 gpm	TH, EG, CE	Sunny, warm
8/2/2006	TH-1	3:20 PM	1.3	16.4	214.7	252	0.1	7.67	-40	n/a	3 gpm	TH, CB	Partly cloudy, warm
9/8/2006	TH-1	11:25 AM	7.32	15.7	145.9	200.3	0.1	7.59	-35	1	5 gpm	JW, TH	overcast skies, cool, 60's
10/13/2006	TH-1	10:20 AM	8.68	11.2	192.5	261.5	0.1	7.66	-37	1.35	0.5 cfs	JW, TH	overcast skies, cool, 60's
10/30/2006	TH-1	938	8.1	9	130.3	187.5	0.1	7.33	-22	1.01	10 gpm	JW	clear, sunny, mid 50s
11/14/2006	TH-1	10:15 AM	15.54	8.9	53.7	77.5	0	6.69	18	1.96	10 cfs	JW	high 40's, cloudy
11/27/2006	TH-1	830	10.3	5.8	68.7	108.5	0.1	7.05	-5	1.3	5 cfs	JW	mostly sunny, low 40s
12/22/2006	TH-1	10:20 AM	10.93	5.8	53.5	84.3	0	6.63	19	1.5	20 cfs	JW	overcast, 40s
1/29/2007	TH-1	915	11.45	5.1	109.2	176.4	0.1	7.08	-5	1.07	10 cfs	JW	low 30's, cold, clear
2/26/2007	TH-1	820	10.68	6.7	82	125.9	0.1	7.8	-46	2.1	15 cfs	JW	overcast, low 40s
2/27/2007	TH-1	845	9.45	9.4	101.2	144.2	0.1	7.12	-7	1.37	8 cfs	JW	Low 50's, overcast
4/24/2007	TH-1	910	8.62	11.1	131.8	179.5	0.1	7.24	-13	0.68	8 cfs	JW	Mid 50's, overcast. Small ammount of algae present on bottom.
5/29/2007	TH-1	800	8.55	11.9	128.6	171.5	0.1	7.29	-15	0.5	9 cfs	JW	partly sunny,mid 50s
6/26/2007	TH-1	850	7.83	12.2	181.1	239.7	0.1	7.68	-37	1.4	10 gpm	JW	clear, sunny, mid 50s
7/31/2007	TH-1	855	7.73	14.3	198.3	249	0.1	7.55	-30	1.1	10 gpm	JW	clear, sunny, upper 60s
8/28/2007	TH-1	840	7.59	13.4	194.3	250.1	0.1	7.5	-28	0.9	10 gpm	JW	clear, cool, mid 50s
9/24/2007	TH-1	625	6.76	11.3	95.7	129.6	0.1	7.39	-21	0.7	10 gpm	JW	clear, cool, mid 50s

Ambient Water Quality Monitoring **Thornton Creek, upstream of Twin Ponds by 50' on d/s side of culvert in park, TH-1**
City of Shoreline, 2001

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
12/18/2007	TH-1	910	10.96	5.5	33.2	61.5	0	7.01	-3	13.8	10 cfs	JW	rainy, low 40s. STORM EVENT.
1/22/2008	TH-1	950			71.5	121.6	0.1	7.01	-9	0.85	5 cfs	JW	sunny, mid 30s
2/26/2008	TH-1	1005			123	185.1	0.1	7.39	-33	1.2	6 cfs	JW	sunny, low 50s. Brown, stringy algae present.
3/24/2008	TH-1	955			69.7	103.8	0	7.02	-17	1.5	7 cfs	JW	clear, low 50s
4/22/2008	TH-1	910			79.9	115.6	0.1	7.1	-24	0.9	5 cfs	JW	partly cloudy, mid 50s
5/27/2008	TH-1	825			126.8	163.8	0.1	6.93	80	1.9	45 gpm	JW	overcast, low 60s
6/24/2008	TH-1	830			186.9	249.6	0.1	7.8	47	0.7	45 gpm	JW, KW	clear, sunny, 60s
7/22/2008	TH-1	840			115.6	148.9	0.1	7.8	95	0.5	40 gpm	JW	overcast, 65
8/26/2008	TH-1	1053			115.8	136.8	0.1	7.45	118	3.4	4 cfs	JW	clear. People were playing in the creek just upstream of the sampling point
9/23/2008	TH-1	900			164.7	224.8	0.1	7.57	56	0.7	2 cfs	JW	50s, partly cloudy
10/28/2008	TH-1	845			173.1	249.2	0.1	7.59	107	0.5	35 gpm	JW	mid 50's, overcast, foggy

Ambient Water Quality Monitoring **Little's Creek: Sample location in Paramount Park, LT-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u s*	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
1/9/2002	LT-1	11:20 AM	9.92	9	106.5	153.5	0.1	6.72	13.6	0.00	0.5	AL	cleaned trash rack after sampling
1/24/2002	LT-1	2:35 PM	10.99	7.5	135.3	203.5	0.1	7.08	-6.2	0.00	0.4	AL	Cold air temps. Cloudy
2/14/2002	LT-1	3:50 PM	9.80	8.3	134.3	197.1	0.1	7.14	-10.4	0.00	0.3	AL	Sunny, mild air temps
3/1/2002	LT-1	11:20 AM	10.65	7.9	131.2	194.6	0.1	7.38	-21.7	n/t	0.75	AL	light overcast skies, water was clear
3/13/2002	LT-1	11:40 AM	10.24	8.1	116.4	173.3	0.1	7.23	-10.7	0.00	0.5	AL/JC	Jay GPS in pts.
3/27/2002	LT-1	1:20 PM	10.60	9.4	147	209.1	0.1	7.39	-20		0.5	AL	Overcast skies
4/19/2002	LT-1	10:00 AM	9.12	9.5	140.5	200.3	0.1	7.25	-19.3	Clr	1	AL	Overcast skies
4/29/2002	LT-1	2:35 PM	8.94	13.5	165.9	212.9	0.1	7.67	-41.5	clr	0.75	AL	Sunny, mild air temps
5/13/2002	LT-1	10:05	9.86	11.1	167.5	225.6	0.1	7.26	-17.8	clr	0.3	AL	Pulled temp logger.
5/24/2002	LT-1	10:45 AM	9.81	11.6	167.9	226.1	0.1	7.37	-23.2	clr	.5 gal/min	AL	Hazy and sunny
6/26/2002	LT-1	10:40 AM	8.52	14.6	190.8	239	0.1			clr	2.5 gal/min	AL	pH meter on the fritz.
7/16/2002	LT-1	2:40 PM	8.55	15	194.1	240.9	0.1	7.42	-21.1	6.70	1/8cfs	AL	Sunny and nice
8/15/2002	LT-1	3:20 PM	8.60	15.6	201.2	245.2	0.1	7.77	-24.2	6.00	5gal/min	AL	Sunny and hot
9/27/2002	LT-1	3:29 PM	8.76	13.4	187.6	240.7	0.1	7.6	-26.8	1.66	5gal/min	AL	Sunny and warm
10/8/2002	LT-1	4:40 PM	8.61	12.5	182.8	240.3	0.1	7.52	-26.3	1.50	5gal/min	AL	Overcast periods of lite drizzle.
10/21/2002	LT-1	4:00 PM	8.24	12.4	181.7	239.6	0.1	7.53	-26.6	1.07	10 gal/min	AL	overcast skies.
11/12/2002	LT-1	3:45 PM	7.89	11.1	78.8	107.5	0.1	6.7	23.5	6.50	0.2	AL	light drizzle.
12/9/2002	LT-1	11:35 AM	9.77	7.2	157.4	238.5	0.1	7.55	-23.7	2.19	5 gal/min	AL	overcast skies.
1/2/2003	LT-1	1:30 PM	9.65	8.6	91.5	153.5	0.1	6.95	8.9	5.60	.5 cfs	JK	cloudy rain most of day.
2/6/2003	LT-1	15:50	9.56	8.6	143	208.4	0.1	7.32	-13.9	11.30	5 gpm	JK	Sunny and cold
3/10/2003	LT-1	11:40 AM	10.37	9.8	133.3	187.7	0.1	6.98	6.8	4.70	10 to 20 gpm	AL	Overcast with mild to cool temperatures
4/14/2003	LT-1	11:05 AM	9.20	10.1	136.2	186.7	0.1	7.2	-12.7	4.50	8 to 10 gpm	AL	
5/8/2003	LT-1	4.45 PM	8.80	11.9	167.7	223.7	0.1			3.80	5 to 10 gpm	AL	Mostly sunny with mild air temps. Removed temp logger, looked fine.
5/27/2003	LT-1	9:45 AM	8.72	12	173	230.3	0.1			3.60	5 to 10 gpm	JK	Partly cloudy with highs in the low to mid 60's.
6/17/2003	LT-1	2:40 PM	8.50	14.5	186.4	232.8	0.1	7.69	-30.8	6.60	3 to 7 gpm	JK/AN	Sunny high 70's
7/10/2003	LT-1	3:05 PM	7.37	15.5	194.5	237.4	0.1	7.44	-16.7	8.50	2 to 3 gpm	AL/AN	Sunny high mid to upper 80's
8/15/2003	LT-1	10:30 AM	8.56	14.8	184.7	228.3	0.1	n/c	n/c	1.09	2 gpm	AL	Partly sunny, pH on fritz
9/17/2003	LT-1	11:20 AM	8.98	12.4	169.4	223.2	0.1	7.8	-41.1	1.08	5 gpm	AL	
10/13/2003	LT-1	3:30 PM	8.44	12.5	85.9	159.6	0.1	7.37	-19	1.00	5 to 10 gpm	JK	Overcast
10/24/2003	LT-1	11:15 AM	8.01	11.5	159.2	214.5	0.1	6.85	9.3	1.11	5 gpm	AL	sunny mild air temps

Ambient Water Quality Monitoring **Little's Creek: Sample location in Paramount Park, LT-1**

City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
11/13/2003	LT-1	2:15 PM	8.20	9.1	161.5	232.3	0.1	7.23	-6.1	0.93	5 gpm	AL	Clear sunny
12/4/2003	LT-1	11:30 AM	9.13	8.1	132.2	195.1	0.1	6.9	10.7	0.97	10 gpm	AL	Cloudy breezy
12/22/2003	LT-1	3:15 PM	8.58	8.8	140.7	203.4	0.1	6.5	26.7	1.32	10 gpm	AL/AN	Partly sunny
1/8/2004	LT-1	1:40 PM	10.27	4.7	70	114.5	0.1	6.94	11.4	6.58	.75 cfs	AL	Overcast
1/30/2004	LT-1	4:10 PM	9.27	8.6	100.8	146.8	0.1	6.77	19.4		.75 cfs	AN	Overcast and drizzle
2/11/2004	LT-1	2:30 PM	9.63	9.1	138	198.6	0.1	7.3	-10.4	1.30	.75 cfs	AL	Sunny
3/10/2004	LT-1	4:05 PM	8.32	10.4	149.2	206.7	0.1	7.19	-5	1.80	.1 to .2 cfs	AN	Sunny and mild air temps
3/29/2004	LT-1	3:30 PM	7.93	14.6	169.4	221.4	0.1	7.39	-15.5	2.90	0.2 cfs	AN	Sunny 75 F
4/14/2004	LT-1	2:40 PM	9.29	12.3	171	226	0.1	7.93	-35.4	1.51	0.25 cfs	AN	Raining, 50's
4/30/2004	LT-1	10:23 AM	8.63	11.9	172.8	230.3	0.1	7.5	-19.4	1.15	5 gpm	AL	sunny hot
6/17/2004	LT-1	11:25 AM	8.53	13.8	183.1	232.3	0.1		-24.3	5.50	7 gpm	AN	Sunny upper 70s to low 80s
7/28/2004	LT-1	2:15 PM	7.63	16.5	86.3	102.9	0.1			6.59	2 gpm	AL	Sunny, hot.
8/19/2004	LT-1	9:05 AM	8.01	15	83.5	145.6	0.1			0.76	10-15 gpm	AN/WSC	Sunny and hot, 80s
9/23/2004	Lt-1	9:40 AM	8.09	12.3	26.7	35.1	0	7.34	-20	1.42	5 gpm	AL	Overcast foggy
10/5/2004	LT-1	11:50 AM	8.73	12.2	161.4	213.7	0.1	7.47	-27	5.44	2 gpm	WSC/AL	Sunny
11/19/2004	LT-1	11:40 AM	8.38	8.8	128.9	186.4	0.1	7.01	-1	3.05	5 gpm	AL	Partly cloudy
12/13/2004	LT-1	2:10 PM	8.55	8.8	68.1	99.2	0	6.77	18	5.50	12 gpm	AN	rainy
1/13/2005	LT-1	11:30am	9.48	6.5	122.9	189.6	0.1	7.4	-22	3.32	5 gpm	AL	Cloudy, cold, just above freezing
1/28/2005	LT-1	3:40pm	8.40	9.7	134.9	190.7	0.1	7.17	15	0.76	10 gpm	AL/WC	Overcast grey skies
2/8/2005	LT-1	3:20pm	10.04	7.7	121.5	182.0	0.1	7.14	-12	11.10	25 gpm	AN	Sunny, warm, upper 50's
2/22/2005	LT-1	1:00pm	10.86	7.5	62.4	97	0	7.36	-31	0.72	20gpm	AN	Clear, sunny, upper 50s to low 60s
2/25/2005	LT-1	11:00am	11.60	7.80	132.00	196.30	0.10	7.39	-25.00	1.22	5gpm	AL	Overcast, mild air temps
3/14/2005	LT-1	10:40	11.15	8.9	141.4	205	0.1	7.46	-31	0.70	~20gpm	AN	Sunny, warm 60s
4/26/2005	LT-1	2:15 PM	8.54	12.9	153.8	200.8	0.1	7.36	-29	4.36	10	AL	overcast filtered sun
5/26/2005	LT-1	3:30 PM	8.25	14.6	116.7	208.5	0.1	7.15	-19	n/a	5	AL	Sunny, hot, 70's
6/28/2005	LT-1	3:38 PM	7.20	13.5	163.4	209.5	0.1	6.87	-3	2.45	8	AL & TH	Cloudy, cool, 60's
7/20/2005	LT-1	3:32 PM	7.52	14.9	172.2	213.8	0.1	7.44	-34	1.30	n/a	AL	Sunny, high clouds
8/17/2005	LT-1	9:50 AM	5.26	16.2	113.2	136.1	0.1	6.79	1	15.62	10 gpm	AL	Cloudy, overcast
10/20/2005	LT-1	8:30 AM	8.16	11.7	155.6	208.3	0.1			1.45	8 gpm	AL	Partly sunny
11/8/2005	LT-1	2:50 PM	8.89	9.7	137.8	195.7	0.1	7.01	2	2.02	10 gpm	AL	Mostly cloudy
12/29/2005	LT-1	3:10 PM	8.16	9	110.6	159.4	0.1	6.87	13	1.47	.5 cfs	AL	Overcast, mild air temps
1/19/2006	LT-1	2:35 PM	8.61	8.9	101.8	147.5	0.1	6.69	20	4.35	30 gpm	AL	cloudy cool
2/16/2006	LT-1	10:15 AM	9.97	6.2	115	179.5	0.1	6.92	7	6.71	15 gpm	AL	sunny cold

Ambient Water Quality Monitoring **Little's Creek: Sample location in Paramount Park, LT-1**
City of Shoreline

Date	Site	Time	DO mg/L	Temp. Deg C	Cond. *u* s	Specific Cond. *at 25 C*	Salinity ppt	pH	Millvolts	NTU's	Est. Flow CFS	Samplers	Comments
3/23/2006	LT-1	10:15 AM	8.11	10.2	124.1	173.3	0.1	7.03	-1	5.23	15 gpm	AL	partly sunny, mild air temps.
4/21/2006	LT-1	3:10 PM	8.74	11	112.6	152.2	7.1	6.99	3	5.59	20gpm	AL	Partly sunny, rain last night.
5/24/2006	LT-1	2:15 PM	7.54	12.7	139	182.3	0.1	7.14	-8	n/a	20 gpm	AL	Cloudy, period of light drizzle and rain showers.
6/30/2006	LT-1	10:50 AM	2.84	13.9	166.4	211.2	0.1	7.32	n/a	n/a	.25 cfs	TH, EG, CE	Sunny, warm
8/2/2006	LT-1	3:00 PM	1.03	14.6	171	214	0.1	7.2	-14	n/a	7 gpm	TH, CB	Partly cloudy, warm
9/6/2006	LT-1	11:10 AM	7.01	14.1	84.5	107.1	0.1	7.42	-26	0.70	10 gpm	JW, TH	clear skies, sunny, low 70's
10/13/2006	LT-1	10:05 AM	11.20	10.7	153	210.7	0.1	7.21	-10	0.73	3 cfs	JW, TH	foggy, cool
11/14/2006	LT-1	9:55 AM	10.53	8.9	120.7	174.3	0.1	6.73	15	0.50	5 cfs	JW	high 40's, cloudy
12/22/2006	LT-1	10:03 AM	8.52	7.2	106.3	161.5	0.1	6.75	13	0.60	12 cfs	JW	overcast, mid 40s
1/29/2007	LT-1	855	9.72	4.8	117.3	191.1	0.1	6.91	5	0.39	12 cfs	JW	low 40's, cold, clear
2/26/2007	LT-1	845	9.07	6.9	107	163.8	0.1	7.1	-5	0.90	10 cfs	JW	overcast, low 40s
3/27/2007	LT-1	915	8.77	9	126.6	182.4	0.1	7.19	-12	1.10	12 cfs	JW	Low 50's, overcast
4/24/2007	LT-1	845	8.62	11.1	131.8	179.5	0.1	7.24	-13	0.68	8 cfs	JW	Mid 50's, overcast. Small ammount of algae on bottom.
5/29/2007	LT-1	745	8.11	10.6	147.1	203.1	0.1	7.1	-6	0.80	9 cfs	JW	partly sunny, mid 50s
6/26/2007	LT-1	825	7.63	11.6	155.7	208.9	0.1	7.11	-6	1.30	5 cfs	JW	clear, sunny, mid 50s
7/31/2007	LT-1	915	7.68	12.8	162.3	211.5	0.1	7.2	-9	0.89	20 gpm	JW	clear, sunny, upper 60s
8/28/2007	LT-1	905	8.19	12.4	159	209.4	0.1	7.08	-5	0.50	25 gpm	JW	clear, cool, mid 50s
9/24/2007	LT-1	740	6.91	10.9	152.9	209.2	0.1	7.17	-10	0.20	25 gpm	JW	clear, cool, mid 50s
10/30/2007	LT-1	920	6.70	8.8	144.1	208.4	0.1	7.14	-12	0.37	20 gpm	JW	clear, sunny, mid 50s
11/27/2007	LT-1	855	8.40	5.4	115.2	183.7	0.1	7.04	-5	0.80	15 gpm	JW	mostly sunny, low 40s
12/18/2007	LT-1	850	9.35	6.8	69.6	107	0	7.01	-3	7.80	5 cfs	JW	rainy, low 40s. STORM EVENT.
1/22/2008	LT-1	930			112.5	191	0.1	7.15	-16	0.65	20 gpm	JW	sunny, mid 30s
2/26/2008	LT-1	950			133.5	196.9	0.1	7.05	-10	1.05	21 gpm	JW	sunny. Low 50s. Brown, stringy algae present.
3/24/2008	LT-1	930			112.2	173.2	0.1	6.96	-15	0.60	25 gpm	JW	clear, low 50s
4/22/2008	LT-1	8:50			121.5	183.9	0.1	7.05	-19	0.30	25 gpm	JW	partly cloudy, mid 50s
5/27/2008	LT-1	805			158.2	208.4	0.1	6.77	52	1.60	4 cfs	JW	overcast, low 60s
6/24/2008	LT-1	810			154	208.6	0.1	7.67	17	1.00	4 cfs	JW, KW	clear, sunny, 60s
7/22/2008	LT-1	825			161.5	211.9	0.1	7.61	-5	1.30	4 cfs	JW	overcast, 65
8/26/2008	LT-1	1110			152.4	194.2	0.1	7.34	50	2.40	4 cfs	JW	clear
9/23/2008	LT-1	845			120.8	166.9	0.1	7.16	32	0.70	3 cfs	JW	50s, partly cloudy
10/28/2008	LT-1	830			145.7	210.8	0.1	7.14	63	0.40	30 gpm	JW	mid 50's, overcast, foggy

Appendix D
COST ESTIMATES

R·W·BECK
An SAIC Company

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F1 Solution: Ronald Bog - Alternative 1 Non-Accredited Berm** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.46	ACRE	$ 3,300.00	$ 1,513
2	ACCESS	1.00	LS	$ 5,000.00	$ 5,000
3	EXCAVATION INCLUDING HAUL	850	CY	$ 15.00	$ 12,750
4	BERM CONSTRUCTION	2,400	CY	$ 25.00	$ 60,000
5	BERM LANDSCAPING	1,350	SY	$ 25.00	$ 33,750
6	CONTROL OF WATER	1	LS	$ 10,000.00	$ 10,000
7	EROSION & SEDIMENTATION CONTROL	1	LS	$ 10,000.00	$ 10,000
8	OVERFLOW WEIR	1	LS	$ 10,000.00	$ 10,000
9	TRAFFIC CONTROL	1	LS	$ 5,000.00	$ 5,000
10	SHORELINE STABILIZATION	1	LS	$ 20,000.00	$ 20,000
11	MISCELLANEOUS ITEMS	1	LS	$ 25,000.00	$ 25,000
				Subtotal	$ 193,013
	CONTINGENCY	30%			$ 57,904
				Subtotal	$ 250,917
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 25,092
				Construction Subtotal (Rounded)	$ 276,000
	STATE SALES TAX	8.5%			$ 23,460
	ENGINEERING/LEGAL/ADMIN	25%			$ 69,000
	CONSTRUCTION MANAGEMENT	10%			$ 27,600
	PERMITTING	10%			$ 27,600
				Project Subtotal (Rounded)	$ 424,000
	LAND ACQUISITION/EASEMENTS (2)	8	EA	$ 25,000.00	$ 200,000
	CONTINGENCY	10%			$ 20,000
				Total Estimated Project Cost (Rounded)	**$ 644,000**

Total Estimated Project Cost (Rounded) $ 644,000

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F1 Solution: Ronald Bog - Alternative 1 FEMA Accredited** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.64	ACRE	$ 3,300.00	$ 2,117
2	ACCESS	1.00	LS	$ 5,000.00	$ 5,000
3	EXCAVATION INCLUDING HAUL	1,000	CY	$ 15.00	$ 15,000
4	BERM CONSTRUCTION	4,200	CY	$ 25.00	$ 105,000
5	BERM LANDSCAPING	2,250	SY	$ 15.00	$ 33,750
6	CONTROL OF WATER	1	LS	$ 10,000.00	$ 10,000
7	EROSION & SEDIMENTATION CONTROL	1	LS	$ 20,000.00	$ 20,000
8	OVERFLOW WEIR	1	LS	$ 20,000.00	$ 20,000
9	TRAFFIC CONTROL	1	LS	$ 5,000.00	$ 5,000
10	SHORELINE STABILIZATION	1	LS	$ 25,000.00	$ 25,000
11	REMOVE SWIMMING POOL	1	LS	$ 15,000.00	$ 15,000
11	MISCELLANEOUS ITEMS	1	LS	$ 35,000.00	$ 35,000
				Subtotal	$ 290,867
	CONTINGENCY	30%			$ 87,260
				Subtotal	$ 378,127
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 37,813
				Construction Subtotal (Rounded)	$ 416,000
	STATE SALES TAX	8.5%			$ 35,360
	ENGINEERING/LEGAL/ADMIN	35%			$ 145,600
	CONSTRUCTION MANAGEMENT	10%			$ 41,600
	PERMITTING	15%			$ 62,400
				Project Subtotal (Rounded)	$ 701,000
	LAND ACQUISITION/EASEMENTS (2)	8	EA	$ 35,000.00	$ 280,000
	CONTINGENCY	10%			$ 28,000
				Total Estimated Project Cost (Rounded)	**$ 1,009,000**

Total Estimated Project Cost (Rounded) $ 1,009,000

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F1 Solution: Ronald Bog - Alternative 1 Wall** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.63	ACRE	$ 4,000.00	$ 2,516
2	ACCESS	1.00	LS	$ 5,000.00	$ 5,000
3	EXCAVATION INCLUDING HAUL	200	CY	$ 15.00	$ 3,000
4	SHEET PILE WALL	1	LS	$ 392,000.00	$ 392,000
5	LANDSCAPING	3,044	SY	$ 25.00	$ 76,111
6	CONTROL OF WATER	1	LS	$ 10,000.00	$ 10,000
7	EROSION & SEDIMENTATION CONTROL	1	LS	$ 10,000.00	$ 10,000
8	OVERFLOW WEIR	0	LS	$ 15,000.00	$ -
9	TRAFFIC CONTROL	1	LS	$ 5,000.00	$ 5,000
10	SHORELINE STABILIZATION	1	LS	$ 25,500.00	$ 25,500
11	MISCELLANEOUS ITEMS	1	LS	$ 50,000.00	$ 50,000
				Subtotal	$ 579,127
	CONTINGENCY	30%			$ 173,738
				Subtotal	$ 752,865
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 75,287
				Construction Subtotal (Rounded)	$ 828,000
	STATE SALES TAX	8.5%			$ 70,380
	ENGINEERING/LEGAL/ADMIN	25%			$ 207,000
	CONSTRUCTION MANAGEMENT	10%			$ 82,800
	PERMITTING	5%			$ 41,400
				Project Subtotal (Rounded)	$ 1,230,000
	LAND ACQUISITION/EASEMENTS (2)	8	EA	$ 15,000.00	$ 120,000
	CONTINGENCY	10%			$ 12,000
				Total Estimated Project Cost (Rounded)	**$ 1,362,000**

Total Estimated Project Cost (Rounded) $ 1,362,000

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of t project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F1 Solution: Ronald Bog - Alternative 2** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	6.48	ACRE	$ 3,500.00	$ 22,686
2	EXCAVATION INCLUDING HAUL	29,871	CY	$ 20.00	$ 597,417
3	EXCAVATION SORTING	11,948	CY	$ 15.00	$ 179,225
4	DISPOSAL IN LANDFILL (3)	10,081	TN	$ 80.00	$ 806,513
5	LANDSCAPING - WETLAND	1.49	ACRE	$ 50,000.00	$ 74,610
6	COMPOST (1' THICK)	2,407	CY	$ 35.00	$ 84,259
7	SEEDED LAWN INSTALLATION	24,149	SY	$ 2.50	$ 60,373
8	TOP SOIL (4" - REST FROM SALVAGE FROM EXISTING)	2,683	CY	$ 50.00	$ 134,161
10	CONTROL OF WATER	1	LS	$ 75,000.00	$ 75,000
11	EROSION & SEDIMENTATION CONTROL	1	LS	$ 50,000.00	$ 50,000
12	TRAFFIC CONTROL	1	LS	$ 31,200.00	$ 31,200
				Subtotal	$ 2,115,444
	CONTINGENCY	30%			$ 634,633
				Subtotal	$ 2,750,078
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 275,008
				Construction Subtotal (Rounded)	$ 3,025,000
	STATE SALES TAX	8.5%			$ 257,125
	ENGINEERING/LEGAL/ADMIN	25%			$ 756,250
	CONSTRUCTION MANAGEMENT	10%			$ 302,500
	PERMITTING	5%			$ 151,250
				Project Subtotal (Rounded)	$ 4,492,000
	LAND ACQUISITION (2)	0	LS	$ 50,000.00	$ -
	CONTINGENCY	30%			$ -
	Total Estimated Project Cost (Rounded)				**$ 4,490,000**
	Total Estimated Project Cost (Range)				**$4.5 to 5 Million**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of t project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

2. Land Acquisition unit costs include Administrative Costs.
3. Assues 50 percent fo the excavated material will require disposal at a landfill.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F1 Solution - Alternative 3 - System Replacment of Ronald Bog Pipe System with System that provides Fish Passage**
CHECKED BY: **MSG**
BY: **MW**
DATE: **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CONTROL STRUCTURE (4)	1	LS	$ 125,000.00	$ 125,000
2	CONTROL STRUCTURE FOUNDATION (ASSUME PILES)	1	LS	$ 35,000.00	$ 35,000
3	TEMP STREAM DIVERSION	1	LS	$ 25,000.00	$ 25,000
4	DEMOLITION AND REMOVAL OF ASPHALT	700	SY	$ 30.00	$ 21,000
5	NEW CHANNEL EXCAVATION	1,185	CY	$ 25.00	$ 29,630
6	STREAMBED GRAVEL	100	CY	$ 50.00	$ 5,000
7	RIPARIAN PLANTING	0.40	ACRE	$ 50,000.00	$ 20,000
8	REMOVE EXIST SD	870	LF	$ 30.00	$ 26,100
9	REMOVE CB	5	EA	$ 700.00	$ 3,500
10	8X5.5 CULVERT	573	LF	$ 3,000.00	$ 1,719,000
11	ASPHALT	110	TONS	$ 125.00	$ 13,745
12	BASE COURSE	175	TONS	$ 50.00	$ 8,741
13	CONTROL OF WATER	1	LS	$ 50,000.00	$ 50,000
14	EROSION & SEDIMENTATION CONTROL	1	LS	$ 40,000.00	$ 40,000
15	TRAFFIC CONTROL	1	LS	$ 30,000.00	$ 30,000
16	UTILITY RELOCATIONS	1	LS	$ 150,000.00	$ 150,000
				Subtotal	$ 2,301,715
	CONTINGENCY	30%			$ 690,514
				Subtotal	$ 2,992,229
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 299,223
				Construction Subtotal (Rounded)	$ 3,291,000
	STATE SALES TAX	8.5%			$ 279,735
	ENGINEERING/LEGAL/ADMIN	20%			$ 658,200
	CONSTRUCTION MANAGEMENT	10%			$ 329,100
	PERMITTING	5%			$ 164,550
				Project Subtotal (Rounded)	$ 4,723,000
	LAND ACQUISITIONS (3)	1	LS	$ 100,000.00	$ 100,000
	CONTINGENCY	30%			$ 30,000
	Total Estimated Project Cost (Rounded)				**$ 4,850,000**
	Total Estimated Project Cost (Range)				**$4.5 to 5 Million**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.
4. Control Structure must be fish passable.

Problem F1 Solution: Ronald Bog - Alternative 4 - Property Acquisition/Flood Proofing (Low Estimate Range)[1]

Resident (Last Name)	Resident (First Name)	Benefits (B)	Cost (C)	Net Benefit (B-C)	BCR	Address	Improvement Costs (Source: Roswold, 2009)	Additional Costs (e.g., Plan, Permits, Fees)	Short Description of Improvements	BCA Model Flood Mitigation	Existing: Finished Floor Elevation (ft)	Existing: FEMA Building Diagram	Existing: Square Footage for Model	Project: Flood Barrier or Elevation (ft)	Project: Elevation increase (ft)	Project: FEMA Building Diagram	Project: Square Footage for Model	Home Living Square Footage (Source: King County): Total Basement (C2a)	Finished Basement	1st Floor (C2.b)	Basement Garage	2nd Floor
Butay	Sam & Editha	**$49,101**	$16,820	$32,281	2.92	2305 N 171st St	$14,191.20	$2,628.68	Provide and install backflow preventers on exterior and interior grade level drains; provide and install floodgate/dam at garage door and back basement door.	Flood Barrier	368.14	1A	2,200	369.80	1.66	1A	2,200	1,100	290	1,100	300	
Crusoe	Mike & Charlotte (Option 1)	$499,297	$34,046	$465,251	14.67	2141 N 172nd St	$29,170.80	$4,875.62	Install backflow preventers on interior &exterior drains, approx. 110' of exterior concrete Floodwall at fence line w/ a Floogate at gate, re-install modified fence on Floodwall, re-landscape around new Floodwall	Flood Barrier	366.38	1A	3,140	369.80	3.42	1A	3,140	1,560	1,270	1,580		
Crusoe	Mike & Charlotte (Option 2)	$597,260	$439,600	$157,660	1.36	2141 N 172nd St	$439,600.00	$0.00	Acquisition (100 year project life)	Acquisition	366.38	1A	3,140	n/a	n/a	n/a	n/a	1,560	1,270	1,580		
Degrazia	Holly & Martin	**$55,839**	$11,676	$44,163	4.78	2310 N 172nd St.	$9,718.14	$1,957.72	Provide and install Floodgate/dam at garage door and at rear basement door	Flood Barrier	368.10	1A	2,400	369.80	1.70	1A	2,400	1,200	600	1,200	480	
Diffner	Jason & Sta	**$122,947**	$15,158	$107,789	8.11	2133 N. 172nd St.	$12,745.80	$2,411.87	Provide and install backflow preventers on exterior drains, provide and install Floodgate/dam at garage door and man door wall	Flood Barrier	368.00	1A	4,706	369.80	1.80	1A	4,706	1250	800	2476		980
Hall	Norman & Anjela	**$74,089**	$12,287	$61,802	6.03	2138 N 171st St	$10,249.20	$2,037.38	Provide and install backflow preventers on interior and exterior drains, provide and install Floodgate/dam at garage door and rear man door	Flood Barrier	367.84	1A	2,450	369.80	1.96	1A	2,450	1,100		1,350	300	
Khurana	Sonney	**$237,080**	$220,087	$16,993	1.08	2140 N 172nd St.	$187,902.00	$32,185.30	Provide and install floodvents within 12" of grade, vacate approx. 600 sq. ft. of basement living space and relocate on main floor level over garage replacing deck area, add replacement deck and stairs, relocate furnace, hot water heater, washer and dryer above BFE (approx. 3' above floor). Replace walls below BFE with PT 2x material and new siding	Elevation	367.40	1A	3,660	371.80	4.40	3	3,660	1,830	1,180	1,830		
Knox	Walter & Cynthia (Option 1)	**$87,685**	$197,610	-$109,925	0.44	2304 N 172nd St.	$168,356.25	$29,253.44	Provide and install floodvents within 12" of grade, vacate approx. 600 sq. ft. basement living area and add living space to main floor replacing rear deck area, add replacement deck and stairs, relocate furnace, hot water heater and washer & dryer above BFE (approx. 3' off floor).Replace walls below BFE with PT 2x material siding	Elevation	367.90	1A	2,500	371.80	3.90	3	2,500	1,250	600	1,250		
Knox	Walter & Cynthia (Option 2)	**$72,492**	$26,793	$45,699	2.71	2304 N 172nd St.	$22,863.60	$3,929.54	Provide and install backflow preventers on interior and exterior drains, provide and install Floodgate/dam at rear daylight basement wall/door and front garage door	Flood Barrier	367.90	1A	2,500	369.80	1.90	1A	2,500	1,250	600	1,250		
Nelson	Marcus & Annie	$77,999	$16,547	$61,452	4.71	2304 N 171st St	$13,953.59	$2,593.04	Provide and install Floodgate/dam at garage door and at rear basement door	Flood Barrier	368.01	1A	3,060	369.80	1.79	1A	3,060	1,520	1,120	1,540	300	
Widmark	Sonja	$61,131	$16,547	$44,584	3.69	2139 N 171st St	$13,953.59	$2,593.04	Provide and install Floodgate/dam at garage door and at rear basement door	Flood Barrier	368.06	1A	2,520	369.80	1.74	1A	2,520	1,100	500	1,420	300	
Yamane	Craig	**$68,873**	$165,537	-$96,664	0.42	2124 N 172nd St	$140,466.60	$25,069.99	Provide and install floodvents at basement/garage area within 12" of grade, vacate 400sq.ft. basement and add 400sq. ft. of living space at main floor level in place of existing deck, add replacement deck space, relocate furnace, washer & dryer, and hot water heater above the BFE (approx. 3' above floor).Replace walls below BFE with PT 2x material and siding	Elevation	368.42	3	2,580	371.80	3.38	3	2,580	970	400	1,610	540	
Total (Option 1)		**$1,334,041**	**$706,313**	**$627,728**	**1.89**		**$600,707**	**$105,606**														
Total (Option 2)		**$1,416,811**	**$941,050**	**$475,761**	**1.51**		**$547,495.63**	**$95,624.34**														

Assumptions:

30 year project life unless acquisition project

The "basement" of these houses is at grade and considered the "bottom floor", based on the contractor's building classification and looking at pictures of the houses.

Finished Floor Elevation and Building Diagrams that are designated in red are based on adjacent home characteristics

Square Footage and total basement values that are shown in red are based on the contractor's assessment of the type of building and a total basement area equal to the 1st floor area

Benefits and costs designated in red are based on the average cost of installing a Floodgate/dam, based on the contractors estimates of adjacent homes

Additional costs are based on permit costs of $500 (flood walls) or $4000 (additions), as well as a 15% mark-up for design

Streambed = 362.2 feet

1 foot above 100-year flood level = 369.8 feet

Floodgate/Floodwall overtops @ 369.8 feet

Variables used in table above (if any of these are changed, the BCA must be recalculated)

Dry floodprofing (permit)	$500
Additions (permit)	$4,000
Design Costs (% of improvements)	15%

[1] This cost estimate was prepared by the City of Shoreline.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F1 Solution: Ronald Bog - Alternative 4 - Property Acquisition/Flood Proofing (High Estimate Range)**
CHECKED BY: **MSG**
BY:
DATE: **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	PROPERTY PURCHASE	3	EACH	$ 400,000.00	$ 1,200,000
2	RELOCATION EXPENSES	3	EACH	$ 100,000.00	$ 300,000
3	DEMOLITION OF HOMES	3	EACH	$ 30,000.00	$ 90,000
4	FLOOD PROOFING	7	EACH	$ 94,500.00	$ 661,500
5	TEMP RELOCATION FOR FLOOD PROOFING	4	EACH	$ 10,000.00	$ 40,000
				Subtotal	$ 2,291,500
	CONTINGENCY	30%			$ 687,450
				Subtotal	$ 2,978,950
	MOBILIZATION (GENERAL REQUIREMENT)	0%			$ -
				Construction Subtotal (Rounded)	$ 2,979,000
	STATE SALES TAX	0.0%			$ -
	ENGINEERING/LEGAL/ADMIN	10%			$ 297,900
	CONSTRUCTION MANAGEMENT	5%			$ 148,950
	PERMITTING	0%			$ -
				Project Subtotal (Rounded)	$ 3,426,000
				Total Estimated Project Cost (Rounded)	**$ 3,430,000**

Notes:

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2. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F2 Solution: Alternative 1** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	1.00	LS	$ 500.00	$ 500
2	EXCAVATION INCLUDING HAUL	249	CY	$ 15.00	$ 3,733
3	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	0	LF	$ 50.00	$ -
4	FLOW CONTROL STRUCTURE, 48-INCH (4)	1	EA	$ 4,000.00	$ 4,000
5	EROSION CONTROL, HYDRO-SEEDING {1000 <= QTY < 5000}	3,500	SF	$ 0.75	$ 2,625
6	CONTROL OF WATER	1	LS	$ 5,000.00	$ 5,000
7	TRAFFIC CONTROL	1	LS	$ 2,000.00	$ 2,000
8	TEMPORARY EROSION AND SEDIMENT CONTRL	1	LS	$ 5,000.00	$ 5,000
9	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 27,858
	CONTINGENCY	30%			$ 8,358
				Subtotal	$ 36,216
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 3,622
				Construction Subtotal (Rounded)	$ 40,000
	STATE SALES TAX	8.5%			$ 3,400
	ENGINEERING/LEGAL/ADMIN	30%			$ 12,000
	CONSTRUCTION MANAGEMENT	10%			$ 4,000
	PERMITTING	5%			$ 2,000
				Project Subtotal (Rounded)	$ 61,000
	LAND ACQUISITION (0)	0	LS	$ -	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 61,000**

Total Estimated Project Cost (Rounded) $ 61,000

Notes:

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2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F2 Solution: Alternative 2** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	1.00	LS	$ 2,000.00	$ 2,000
2	EXCAVATION INCLUDING HAUL	133	CY	$ 15.00	$ 1,993
3	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	1,160	LF	$ 50.00	$ 58,000
4	WASHED DRAIN ROCK	804	TN	$ 25.00	$ 20,089
5	CATCH BASIN TYPE 2 48" (4)	2	EA	$2,940.00	$ 5,880
6	CATCH BASIN TYPE 2 54" (4)	4	EA	$3,780.00	$ 15,120
7	FLOW CONTROL STRUCTURE, 54-INCH (4)	1	EA	$ 6,100.00	$ 6,100
8	ROADSIDE PLANTING/LANDSCAPING		SY	$ 25.00	$ -
9	ASPHALT CONCRETE PAVEMENT PATCHING	161	TN	$ 100.00	$ 16,078
10	CONTROL OF WATER	1	LS	$ 15,000.00	$ 15,000
11	TRAFFIC CONTROL	1	LS	$ 8,000.00	$ 8,000
12	TEMPORARY EROSION AND SEDIMENT CONTRL	1	LS	$ 12,000.00	$ 12,000
13	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 165,260
	CONTINGENCY	30%			$ 49,578
				Subtotal	$ 214,838
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 21,484
				Construction Subtotal (Rounded)	$ 236,000
	STATE SALES TAX	8.5%			$ 20,060
	ENGINEERING/LEGAL/ADMIN	30%			$ 70,800
	CONSTRUCTION MANAGEMENT	10%			$ 23,600
	PERMITTING	5%			$ 11,800
				Project Subtotal (Rounded)	$ 362,000
	LAND ACQUISITION (0)	0	LS	$ -	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 362,000**

Total Estimated Project Cost (Rounded) $ 362,000

Notes:

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2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F2 Solution: Alternative 3** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	1.00	LS	$ 2,000.00	$ 2,000
2	EXCAVATION INCLUDING HAUL	688	CY	$ 15.00	$ 10,327
3	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	220	LF	$ 50.00	$ 11,000
4	WASHED DRAIN ROCK	110	TN	$ 25.00	$ 2,741
5	BIORETENTION SOIL MIX	74	CY	$ 75.00	$ 5,556
6	CATCH BASIN TYPE 2 54" (4)	4	EA	$ 3,780.00	$ 15,120
7	FLOW CONTROL STRUCTURE, 54-INCH (4)	1	EA	$ 6,100.00	$ 6,100
8	ROADSIDE PLANTING/LANDSCAPING	333	SY	$ 50.00	$ 16,667
9	ASPHALT CONCRETE PAVEMENT PATCHING	30	TN	$ 100.00	$ 3,049
10	CONTROL OF WATER	1	LS	$ 15,000.00	$ 15,000
11	TRAFFIC CONTROL	1	LS	$ 8,000.00	$ 8,000
12	TEMPORARY EROSION AND SEDIMENT CONTRL	1	LS	$ 12,000.00	$ 12,000
13	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 112,559
	CONTINGENCY	30%			$ 33,768
				Subtotal	$ 146,326
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 14,633
				Construction Subtotal (Rounded)	$ 161,000
	STATE SALES TAX	8.5%			$ 13,685
	ENGINEERING/LEGAL/ADMIN	30%			$ 48,300
	CONSTRUCTION MANAGEMENT	10%			$ 16,100
	PERMITTING	5%			$ 8,050
				Project Subtotal (Rounded)	$ 247,000
	LAND ACQUISITION (0)	0	LS	$ -	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 247,000**

Total Estimated Project Cost (Rounded) $ 247,000

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F4 Solution: Flooding at 12th Avenue** **CHECKED BY:**
BY: **K. Ludwa** **DATE:** **Apr-09**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.15	ACRE	$ 3,300.00	$ 511
2	EXCAVATION INCLUDING HAUL	200	CY	$ 15.00	$ 2,994
3	TEMP STREAM DIVERSION	1	LS	$ 25,000.00	$ 25,000
4	STREAMBED GRAVEL	150	CY	$ 50.00	$ 7,500
5	RIPARIAN PLANTING	0.31	ACRE	$ 50,000.00	$ 15,532
6	BOULDERS	56	TN	$ 50.00	$ 2,778
7	TRAFFIC CONTROL	1	LS	$ 12,000.00	$ 12,000
8	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 20,000.00	$ 20,000
9	MISCELLANEOUS ITEMS	1	LS	$ 10,000.00	$ 10,000
				Subtotal	$ 96,315
	CONTINGENCY	30%			$ 28,895
				Subtotal	$ 125,210
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 12,521
				Construction Subtotal (Rounded)	$ 138,000
	STATE SALES TAX	8.5%			$ 11,730
	ENGINEERING/LEGAL/ADMIN	30%			$ 41,400
	CONSTRUCTION MANAGEMENT	10%			$ 13,800
	PERMITTING	5%			$ 6,900
				Project Subtotal (Rounded)	$ 212,000
	EASEMENT (FOR ROCK WALL)	1	LS		$ -
	EASEMENT CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 212,000**

Total Estimated Project Cost (Rounded) $ 212,000

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F3 Solution: Alternative 2** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	12" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	0	LF	$ 40.00	$ -
2	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	900	LF	$ 60.00	$ 54,000
3	24" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	1,000	LF	$ 75.00	$ 75,000
4	CATCH BASIN TYPE 2 48" (4)	18	EA	$2,940.00	$ 52,920
5	CATCH BASIN TYPE 2 54" (4)	2	EA	$3,780.00	$ 7,560
6	ROADSIDE PLANTING/LANDSCAPING	2,111	SY	$ 25.00	$ 52,778
7	CAP 18-INCH	1	LS	$ 300.00	$ 300
8	ASPHALT CONCRETE PAVEMENT PATCHING	286	TN	$ 100.00	$ 28,644
9	PUMPS INSTALLED (AFP 2073 60HZ)	3	EA	$ 100,000.00	$ 300,000
10	PUMP STATION VAULT WITH HATCHES	1	LS	$ 50,000.00	$ 50,000
11	VARIABLE FREQUENCY DRIVE	3	LS	$ 5,000.00	$ 15,000
12	18-inch DI (AT PUMP STATION)	40	lf	$ 140	$ 5,600
13	24-inch DI	10	lf	$ 120	$ 1,200
14	18" Force Main (pvc)	100	lf	$ 90	$ 9,000
15	18-inch FITTINGS	6	ea	$ 3,000	$ 18,000
16	Misc., Restraints, Supports, Valve Boxes	1	LS	$ 5,000	$ 5,000
17	18-inch Check Valve	3	ea	$ 12,000	$ 36,000
18	18-inch Gate Valve	3	ea	$ 12,000	$ 36,000
19	MISCELLANEOUS MECHANICAL	1	LS	$ 15,000.00	$ 15,000
20	CONTROL PANEL AND MISC ELECTRICAL	1	LS	$ 30,000.00	$ 30,000
21	CONTOL OF WATER	1	LS	$ 15,000.00	$ 15,000
22	TRAFFIC CONTROL	1	LS	$ 8,000.00	$ 8,000
23	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 10,000.00	$ 10,000
24	MISCELLANEOUS ITEMS	1	LS	$ 10,000.00	$ 10,000
				Subtotal	$ 835,002
	CONTINGENCY	30%			$ 250,501
				Subtotal	$ 1,085,502
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 108,550
				Construction Subtotal (Rounded)	$ 1,194,000
	STATE SALES TAX	8.5%			$ 101,490
	ENGINEERING/LEGAL/ADMIN	30%			$ 358,200
	CONSTRUCTION MANAGEMENT	10%			$ 119,400
	PERMITTING	5%			$ 59,700
				Project Subtotal (Rounded)	$ 1,833,000
	LAND ACQUISITION (3)	0	LS	$ -	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 1,833,000**

Total Estimated Project Cost (Rounded) $ 1,833,000

Notes:

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2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs
3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F4 Solution: Flooding at 12th Avenue** **CHECKED BY:**
BY: **K. Ludwa** **DATE:** **Apr-09**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.15	ACRE	$ 3,300.00	$ 511
2	EXCAVATION INCLUDING HAUL	200	CY	$ 15.00	$ 2,994
3	TEMP STREAM DIVERSION	1	LS	$ 25,000.00	$ 25,000
4	STREAMBED GRAVEL	150	CY	$ 50.00	$ 7,500
5	RIPARIAN PLANTING	0.31	ACRE	$ 50,000.00	$ 15,532
6	BOULDERS	56	TN	$ 50.00	$ 2,778
7	TRAFFIC CONTROL	1	LS	$ 12,000.00	$ 12,000
8	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 20,000.00	$ 20,000
9	MISCELLANEOUS ITEMS	1	LS	$ 10,000.00	$ 10,000
				Subtotal	$ 96,315
	CONTINGENCY	30%			$ 28,895
				Subtotal	$ 125,210
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 12,521
				Construction Subtotal (Rounded)	$ 138,000
	STATE SALES TAX	8.5%			$ 11,730
	ENGINEERING/LEGAL/ADMIN	30%			$ 41,400
	CONSTRUCTION MANAGEMENT	10%			$ 13,800
	PERMITTING	5%			$ 6,900
				Project Subtotal (Rounded)	$ 212,000
	EASEMENT (FOR ROCK WALL)	1	LS		$ -
	EASEMENT CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 212,000**

Total Estimated Project Cost (Rounded) $ 212,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F5 Solution: Alternative 1** **CHECKED BY:**
BY: **K. Ludwa** **DATE:** **Mar-09**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	REMOVE CATCH BASIN	2.00	EA	$ 300.00	$ 600
2	REMOVE PAVEMENT	113.33	SY	$ 20.00	$ 2,267
3	12" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE	340.00	LF	$ 35.00	$ 11,900
4	CATCH BASIN TYPE 1	1	EA	$ 1,330.00	$ 1,330
5	CATCH BASIN TYPE 2 48"	2	EA	$ 2,940.00	$ 5,880
6	ASPHALT CONCRETE PAVEMENT PATCHING	51	TN	$ 100.00	$ 5,100
7	TRAFFIC CONTROL	1	LS	$ 12,000.00	$ 12,000
8	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 5,000.00	$ 5,000
9	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 49,077
	CONTINGENCY	30%			$ 14,723
				Subtotal	$ 63,800
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 6,380
				Construction Subtotal (Rounded)	$ 70,000
	STATE SALES TAX	8.5%			$ 5,950
	ENGINEERING/LEGAL/ADMIN	30%			$ 21,000
	CONSTRUCTION MANAGEMENT	10%			$ 7,000
	PERMITTING	5%			$ 3,500
				Project Subtotal (Rounded)	$ 107,000
				Total Estimated Project Cost (Rounded)	**$ 107,000**

Total Estimated Project Cost (Rounded) $ 107,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F5 Solution: Alternative 2** **CHECKED BY:**
BY: **K. Ludwa** **DATE:** **Mar-09**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CATCH BASIN TYPE 1	1.00	EA	$ 1,500.00	$ 1,500
2	24" DIA. PERFORATED POLYETHYLENE PIPE	100.00	LF	$ 40.00	$ 4,000
3	24" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE	40.00	LF	$ 75.00	$ 3,000
4	WASHED DRAIN ROCK	88	TN	$ 25.00	$ 2,193
5	TRAFFIC CONTROL	1	LS	$ 1,000.00	$ 1,000
6	TEMPORARY EROSION AND SEDIMENT CONTRL	1	LS	$ 500.00	$ 500
7	MISCELLANEOUS LID	1	LS	$ 5,000.00	$ 5,000
8	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 22,193
	CONTINGENCY	30%			$ 6,658
				Subtotal	$ 28,850
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 2,885
				Construction Subtotal (Rounded)	$ 32,000
	STATE SALES TAX	8.5%			$ 2,720
	ENGINEERING/LEGAL/ADMIN	30%			$ 9,600
	CONSTRUCTION MANAGEMENT	10%			$ 3,200
	PERMITTING	5%			$ 1,600
				Project Subtotal (Rounded)	$ 49,000
				Total Estimated Project Cost (Rounded)	**$ 49,000**

Total Estimated Project Cost (Rounded) $ 49,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F6 Solution: Alternative 1** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.65	ACRE	$ 3,300.00	$ 2,145
2	EXCAVATION INCLUDING HAUL	2,650	CY	$ 15.00	$ 39,750
3	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	1,570	LF	$ 60.00	$ 94,200
4	CATCH BASIN TYPE 2 48" (4)	8	EA	$2,940.00	$ 23,520
5	CATCH BASIN TYPE 2 54" (4)	1	EA	$3,780.00	$ 3,780
6	FLOW CONTROL STRUCTURE, 54-INCH (4)	1	EA	$ 6,100.00	$ 6,100
7	ROADSIDE PLANTING/LANDSCAPING	1,744	SY	$ 25.00	$ 43,611
8	HYDRO-SEEDING {QTY >= 5000}	28,314	SF	$ 0.15	$ 4,247
9	CHAIN LINK FENCE	810	LF	$ 12.00	$ 9,720
10	ASPHALT CONCRETE PAVEMENT PATCHING	218	TN	$ 100.00	$ 21,760
11	CONTOL OF WATER	1	LS	$ 25,000.00	$ 25,000
12	TRAFFIC CONTROL	1	LS	$ 15,000.00	$ 15,000
13	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 10,000.00	$ 10,000
14	MISCELLANEOUS ITEMS	1	LS	$ 10,000.00	$ 10,000
				Subtotal	$ 308,833
	CONTINGENCY	30%			$ 92,650
				Subtotal	$ 401,483
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 40,148
				Construction Subtotal (Rounded)	$ 442,000
	STATE SALES TAX	8.5%			$ 37,570
	ENGINEERING/LEGAL/ADMIN	30%			$ 132,600
	CONSTRUCTION MANAGEMENT	10%			$ 44,200
	PERMITTING	5%			$ 22,100
				Project Subtotal (Rounded)	$ 678,000
	LAND ACQUISITION (3)	1	LS	$ 886,600	$ 886,600
	CONTINGENCY	30%			$ 265,980
				Total Estimated Project Cost (Rounded)	**$ 1,830,580**

Total Estimated Project Cost (Rounded) $ 1,830,580

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F6 Solution: Alternative 2** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	ASPALT REMOVAL	3,721	SY	$ 8.00	$ 29,768
2	EXCAVATION INCLUDING HAUL	10,939	CY	$ 15.00	$ 164,081
3	1.6 ACRE-FOOT TANK	1	LS	$ 800,000	$ 800,000
4	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	1,570	LF	$ 60.00	$ 94,200
5	CATCH BASIN TYPE 2 48" (4) (4 FOR TANK)	12	EA	$ 2,940.00	$ 35,280
6	CATCH BASIN TYPE 2 54" (4)	1	EA	$ 3,780.00	$ 3,780
7	FLOW CONTROL STRUCTURE, 54-INCH (4)	1	EA	$ 6,100.00	$ 6,100
8	ROADSIDE PLANTING/LANDSCAPING	1,744	SY	$ 25.00	$ 43,611
9	HYDRO-SEEDING {QTY >= 5000}	0	SF	$ 0.15	$ -
10	CHAIN LINK FENCE	0	LF	$ 12.00	$ -
11	ASPHALT CONCRETE PAVEMENT PATCHING	991.1979	TN	$ 100.00	$ 99,120
12	CONTOL OF WATER	1	LS	$ 50,000.00	$ 50,000
13	TRAFFIC CONTROL	1	LS	$ 15,000.00	$ 15,000
14	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 10,000.00	$ 10,000
15	MISCELLANEOUS ITEMS	1	LS	$ 10,000.00	$ 10,000
				Subtotal	$ 1,360,939
	CONTINGENCY	30%			$ 408,282
				Subtotal	$ 1,769,221
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 176,922
				Construction Subtotal (Rounded)	$ 1,946,000
	STATE SALES TAX	8.5%			$ 165,410
	ENGINEERING/LEGAL/ADMIN	30%			$ 583,800
	CONSTRUCTION MANAGEMENT	10%			$ 194,600
	PERMITTING	5%			$ 97,300
				Project Subtotal (Rounded)	$ 2,987,000
	LAND ACQUISITION (3)	1	LS	$ 201,454	$ 201,454
	CONTINGENCY	30%			$ 60,436
				Total Estimated Project Cost (Rounded)	**$ 3,248,890**

Total Estimated Project Cost (Rounded) $ 3,248,890

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F6 Solution: Alternative 3** **CHECKED BY:** **MSG**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	EXCAVATION INCLUDING HAUL	0	CY	$ 15.00	$ -
3	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	0	LF	$ 60.00	$ -
4	24" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	2,872	LF	$ 75.00	$ 215,400
5	CATCH BASIN TYPE 2 48" (4)	15	EA	$ 2,940.00	$ 44,100
6	CATCH BASIN TYPE 2 54" (4)	0	EA	$ 3,780.00	$ -
7	FLOW CONTROL STRUCTURE, 54-INCH (4)	0	EA	$ 6,100.00	$ -
8	ROADSIDE PLANTING/LANDSCAPING	3,191	SY	$ 25.00	$ 79,778
9	HYDRO-SEEDING {QTY >= 5000}	0	SF	$ 0.15	$ -
10	CHAIN LINK FENCE	0	LF	$ 12.00	$ -
11	ASPHALT CONCRETE PAVEMENT PATCHING	464	TN	$ 100.00	$ 46,440
12	CONTOL OF WATER	1	LS	$ 15,000.00	$ 15,000
13	TRAFFIC CONTROL	1	LS	$ 15,000.00	$ 15,000
14	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 10,000.00	$ 10,000
15	MISCELLANEOUS ITEMS	1	LS	$ 10,000.00	$ 10,000
				Subtotal	$ 435,718
	CONTINGENCY	30%			$ 130,715
				Subtotal	$ 566,433
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 56,643
				Construction Subtotal (Rounded)	$ 623,000
	STATE SALES TAX	8.5%			$ 52,955
	ENGINEERING/LEGAL/ADMIN	30%			$ 186,900
	CONSTRUCTION MANAGEMENT	10%			$ 62,300
	PERMITTING	5%			$ 31,150
				Project Subtotal (Rounded)	$ 956,000
	LAND ACQUISITION (3)	0	LS	$ 886,600	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 956,000**

Total Estimated Project Cost (Rounded) $ 956,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F7 Solution: Alternative 1** **CHECKED BY:** **EG/MBW**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	DEMOLITION	1	LS	$ 4,600.00	$ 4,600
3	18" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	230	LF	$ 60.00	$ 13,800
4	EXCAVATION INCLUDING HAUL	20	TON	$ 30.00	$ 600
5	CONNECT TO EXISTING SYSTEM	3	LS	$ 1,500.00	$ 4,500
6	CATCH BASIN TYPE 2 54" (4)	0	EA	$ 3,780.00	$ -
7	HYDRO-SEEDING {QTY >= 5000}	1	LS	$ 3,000.00	$ 3,000
8	CONTOL OF WATER	1	LS	$ 5,000.00	$ 5,000
9	TRAFFIC CONTROL	1	LS	$ 3,000.00	$ 3,000
10	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 5,000.00	$ 5,000
11	MISCELLANEOUS ITEMS	0	LS	$ -	$ -
				Subtotal	$ 39,500
	CONTINGENCY	30%			$ 11,850
				Subtotal	$ 51,350
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 5,135
				Construction Subtotal (Rounded)	$ 56,000
	STATE SALES TAX	8.5%			$ 4,760
	ENGINEERING/LEGAL/ADMIN	30%			$ 16,800
	CONSTRUCTION MANAGEMENT	10%			$ 5,600
	PERMITTING	5%			$ 2,800
				Project Subtotal (Rounded)	$ 86,000
	LAND ACQUISITION (3)	0	LS	$ 886,600	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 86,000**

Total Estimated Project Cost (Rounded) $ 86,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F7 Solution: Alternative 2** **CHECKED BY:** **EG/MBW**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	EXCAVATION INCLUDING HAUL	150	TON	$ 30.00	$ 4,500
3	DEMOLITION	1	LS	$ 4,600.00	$ 4,600
4	CONNECT TO EXISTING SYSTEM	3	EA	$ 1,500.00	$ 4,500
5	ROADSIDE PLANTING/LANDSCAPING	409	SY	$ 25.00	$ 10,222
6	ASPHALT CONCRETE PAVEMENT PATCHING	0	TN	$ 150.00	$ 17
7	CONTOL OF WATER	1	LS	$ 5,000.00	$ 5,000
8	TRAFFIC CONTROL	1	LS	$ 3,000.00	$ 3,000
9	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 36,840
	CONTINGENCY	30%			$ 11,052
				Subtotal	$ 47,891
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 4,789
				Construction Subtotal (Rounded)	$ 53,000
	STATE SALES TAX	8.5%			$ 4,505
	ENGINEERING/LEGAL/ADMIN	30%			$ 15,900
	CONSTRUCTION MANAGEMENT	10%			$ 5,300
	PERMITTING	5%			$ 2,650
				Project Subtotal (Rounded)	$ 81,000
	LAND ACQUISITION (3)	0	LS	$ 886,600	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 81,000**

Total Estimated Project Cost (Rounded) $ 81,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem F7 Solution: Alternative 3** **CHECKED BY:** **EG?MBW**
BY: **DATE:** **Nov-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	EXCAVATION INCLUDING HAUL	110	TON	$ 30.00	$ 3,300
3	30" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE (5)	35	LF	$ 95.00	$ 3,325
4	CONNECT TO EXISTING SYSTEM	3	EA	$ 1,500.00	$ 4,500
5	SAW CUT	3	LF	$ 175.00	$ 525
6	ROADSIDE PLANTING/LANDSCAPING	187	SY	$ 25.00	$ 4,667
7	ASPHALT CONCRETE PAVEMENT PATCHING	4	TN	$ 150.00	$ 606
8	CONTOL OF WATER	1	LS	$ 5,000.00	$ 5,000
9	TRAFFIC CONTROL	1	LS	$ 3,000.00	$ 3,000
10	TEMPORARY EROSION AND SEDIMENT CONTROL	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 29,923
	CONTINGENCY	30%			$ 8,977
				Subtotal	$ 38,900
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 3,890
				Construction Subtotal (Rounded)	$ 43,000
	STATE SALES TAX	8.5%			$ 3,655
	ENGINEERING/LEGAL/ADMIN	30%			$ 12,900
	CONSTRUCTION MANAGEMENT	10%			$ 4,300
	PERMITTING	5%			$ 2,150
				Project Subtotal (Rounded)	$ 66,000
	LAND ACQUISITION (3)	0	LS	$ 886,600	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 66,000**

Total Estimated Project Cost (Rounded) $ 66,000

Notes:

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3. Land Acquisition unit costs include Administrative Costs.
4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ2: Enhancement of wetland fringe areas around Ronald Bog** **CHECKED BY:**
BY: **DATE:** **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	1.00	ACRE	$ 3,300.00	$ 3,300
2	ACCESS	1.00	LS	$ 1,000.00	$ 1,000
3	TRAFFIC CONTROL	1	LS	$ 500.00	$ 500
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 3,000.00	$ 3,000
5	CONTROL OF WATER	1	LS	$ 3,000.00	$ 3,000
6	EXCAVATION INCLUDING HAUL	1,500	CY	$ 15.00	$ 22,500
7	LOG STRUCTURE PLACEMENT	10	EA	$ 900.00	$ 9,000
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	60	CY	$ 50.00	$ 3,000
9	HAND REMOVAL OF NON-NATIVE VEGETATION	50,000	SF	$ 0.35	$ 17,500
10	TOPSOIL SUPPEMENTATION	150	CY	$ 45.00	$ 6,750
11	NATIVE REVEGETATION	85,000	SF	$ 2.00	$ 170,000
12	IRRIGATION	85,000	SF	$ 0.40	$ 34,000
13	INTERPRETIVE SIGNAGE	3	EA	$ 1,250.00	$ 3,750
14	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 282,300
	CONTINGENCY	30%			$ 84,690
				Subtotal	$ 366,990
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 36,699
				Construction Subtotal (Rounded)	$ 404,000
	STATE SALES TAX	8.5%			$ 34,340
	ENGINEERING/LEGAL/ADMIN	15%			$ 60,600
	CONSTRUCTION MANAGEMENT	10%			$ 40,400
	PERMITTING	5%			$ 20,200
	PERFORMANCE MONITORING	5%			$ 20,200
				Project Subtotal (Rounded)	$ 580,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 580,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ3: Daylighted stream channel and partial fish passage barrier removal at the flow splitter upstream of Twin Ponds/between Corliss Ave. N. and I-5.**

CHECKED BY:

BY:

DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.50	ACRE	$ 3,300.00	$ 1,650
2	ACCESS AND TRAFFIC CONTROL	1.00	LS	$ 5,000.00	$ 5,000
3	REINSTALL AND CALIBRATE OPEN-CHANNEL FLOW SPLITTER	1	LS	$ 8,000.00	$ 8,000
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 5,000.00	$ 5,000
5	CONTROL OF WATER	1	LS	$ 5,000.00	$ 5,000
6	EXCAVATION INCLUDING HAUL	750	CY	$ 15.00	$ 11,250
7	LOG STRUCTURE PLACEMENT	15	EA	$ 900.00	$ 13,500
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	175	CY	$ 50.00	$ 8,750
9	HAND REMOVAL OF NON-NATIVE VEGETATION	16,000	SF	$ 0.35	$ 5,600
10	TOPSOIL SUPPEMENTATION	200	CY	$ 45.00	$ 9,000
11	NATIVE REVEGETATION	16,000	SF	$ 2.00	$ 32,000
12	IRRIGATION	16,000	SF	$ 0.40	$ 6,400
13	DEMOLITION	1	LS	$ 6,000.00	$ 6,000
14	MISCELLANEOUS ITEMS	1	LS	$ 8,000.00	$ 8,000
				Subtotal	$ 125,150
	CONTINGENCY	30%			$ 37,545
				Subtotal	$ 162,695
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 16,270
				Construction Subtotal (Rounded)	$ 179,000
	STATE SALES TAX	8.5%			$ 15,215
	ENGINEERING/LEGAL/ADMIN	15%			$ 26,850
	CONSTRUCTION MANAGEMENT	10%			$ 17,900
	PERMITTING	5%			$ 8,950
	PERFORMANCE MONITORING	5%			$ 8,950
				Project Subtotal (Rounded)	$ 257,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 257,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ4: Fish barriers w/in Twin Ponds Park/culvert north of the north pond & culvert beneath a pedestrian trail**
BY:
CHECKED BY:
DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.50	ACRE	$ 3,300.00	$ 1,650
2	ACCESS	1.00	LS	$ 1,000.00	$ 1,000
3	RECONSTRUCTION OF ADJACENT CHANNEL SECTIONS TO BE FISH-PASSABLE	1	LS	$ 8,000.00	$ 8,000
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 2,000.00	$ 2,000
5	CONTROL OF WATER	1	LS	$ 2,000.00	$ 2,000
6	EXCAVATION INCLUDING HAUL	10	CY	$ 15.00	$ 150
7	LOG STRUCTURE PLACEMENT	3	EA	$ 900.00	$ 2,700
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	15	CY	$ 50.00	$ 750
9	HAND REMOVAL OF NON-NATIVE VEGETATION	1,000	SF	$ 0.35	$ 350
10	TOPSOIL SUPPEMENTATION	10	CY	$ 45.00	$ 450
11	NATIVE REVEGETATION	4,000	SF	$ 2.00	$ 8,000
12	IRRIGATION	0	SF	$ 0.40	$ -
13	INTERPRETIVE SIGNAGE	1	EA	$ 1,250.00	$ 1,250
14	MISCELLANEOUS ITEMS	1	LS	$ 1,000.00	$ 1,000
				Subtotal	$ 29,300
	CONTINGENCY	30%			$ 8,790
				Subtotal	$ 38,090
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 3,809
				Construction Subtotal (Rounded)	$ 42,000
	STATE SALES TAX	8.5%			$ 3,570
	ENGINEERING/LEGAL/ADMIN	15%			$ 6,300
	CONSTRUCTION MANAGEMENT	10%			$ 4,200
	PERMITTING	5%			$ 2,100
	PERFORMANCE MONITORING	5%			$ 2,100
				Project Subtotal (Rounded)	$ 60,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 60,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ5: Low flow fish passage barrier/culvert under 1st Ave. NE (from Twin Ponds Park to Peverly Pond)**
CHECKED BY:
BY:
DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	ACCESS	0.00	LS	$ 1,000.00	$ -
3	RECONSTRUCTION OF CHANNEL IN AND NEAR THE CULVERT TO BE FISH-PASSABLE	1	LS	$ 2,000.00	$ 2,000
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 1,000.00	$ 1,000
5	CONTROL OF WATER	1	LS	$ 1,000.00	$ 1,000
6	EXCAVATION INCLUDING HAUL	10	CY	$ 15.00	$ 150
7	LOG STRUCTURE PLACEMENT	2	EA	$ 900.00	$ 1,800
8	SUBSTRATE PLACEMENT	10	CY	$ 50.00	$ 500
9	HAND REMOVAL OF NON-NATIVE VEGETATION	500	SF	$ 0.35	$ 175
10	TOPSOIL SUPPEMENTATION	6	CY	$ 45.00	$ 270
11	NATIVE REVEGETATION	500	SF	$ 2.00	$ 1,000
12	IRRIGATION	0	SF	$ 0.40	$ -
13	INTERPRETIVE SIGNAGE	0	EA	$ 1,250.00	$ -
14	MISCELLANEOUS ITEMS	1	LS	$ 1,000.00	$ 1,000
				Subtotal	$ 8,895
	CONTINGENCY	30%			$ 2,669
				Subtotal	$ 11,564
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 1,156
				Construction Subtotal (Rounded)	$ 13,000
	STATE SALES TAX	8.5%			$ 1,105
	ENGINEERING/LEGAL/ADMIN	15%			$ 1,950
	CONSTRUCTION MANAGEMENT	10%			$ 1,300
	PERMITTING	5%			$ 650
	PERFORMANCE MONITORING	5%			$ 650
				Project Subtotal (Rounded)	$ 19,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 19,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ6: Fish Passage Barrier/Outfall of Peverly Pond east of 1st Ave. NE along I-5 and north of N. 149th St.**
BY:
CHECKED BY:
DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.50	ACRE	$ 3,300.00	$ 1,650
2	ACCESS	1.00	LS	$ 5,000.00	$ 5,000
	WEIR PLACEMENT ALONG EXISTING CHANNEL TO STEP UP TO POND				
3	OUTLET IN A FISH-PASSABLE MANNER	10	EA	$ 2,500.00	$ 25,000
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 5,000.00	$ 5,000
5	CONTROL OF WATER	1	LS	$ 5,000.00	$ 5,000
6	EXCAVATION INCLUDING HAUL	20	CY	$ 15.00	$ 300
7	LOG STRUCTURE PLACEMENT	15	EA	$ 900.00	$ 13,500
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	300	CY	$ 50.00	$ 15,000
9	HAND REMOVAL OF NON-NATIVE VEGETATION	16,000	SF	$ 0.35	$ 5,600
10	TOPSOIL SUPPEMENTATION	30	CY	$ 45.00	$ 1,350
11	NATIVE REVEGETATION	16,000	SF	$ 2.00	$ 32,000
12	IRRIGATION	16,000	SF	$ 0.40	$ 6,400
13	INTERPRETIVE SIGNAGE	1	EA	$ 1,250.00	$ 1,250
14	MISCELLANEOUS ITEMS	1	LS	$ 8,000.00	$ 8,000
				Subtotal	$ 125,050
	CONTINGENCY	30%			$ 37,515
				Subtotal	$ 162,565
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 16,257
				Construction Subtotal (Rounded)	$ 179,000
	STATE SALES TAX	8.5%			$ 15,215
	ENGINEERING/LEGAL/ADMIN	15%			$ 26,850
	CONSTRUCTION MANAGEMENT	10%			$ 17,900
	PERMITTING	5%			$ 8,950
	PERFORMANCE MONITORING	5%			$ 8,950
				Project Subtotal (Rounded)	$ 257,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 257,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ8: Restore and naturalize the channelized stream sections from Twin Ponds upstream to Meridian Avenue N. Add spawning-sized gravel and in stream log structures for substrate/habitat improvement. Add native vegetation for bank stabilization and stream canopy cover.**

BY:

CHECKED BY:

DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.50	ACRE	$ 3,300.00	$ 1,650
2	ACCESS	1.00	LS	$ 2,000.00	$ 2,000
3	TRAFFIC CONTROL	1	LS	$ 500.00	$ 500
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 5,000.00	$ 5,000
5	CONTROL OF WATER	1	LS	$ 5,000.00	$ 5,000
6	EXCAVATION OF MUCK FROM CHANNEL, ON-SITE DISPOSAL	300	CY	$ 5.00	$ 1,500
7	LOG STRUCTURE PLACEMENT	30	EA	$ 900.00	$ 27,000
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	300	CY	$ 50.00	$ 15,000
9	HAND REMOVAL OF NON-NATIVE VEGETATION	24,000	SF	$ 0.35	$ 8,400
10	TOPSOIL SUPPEMENTATION	100	CY	$ 45.00	$ 4,500
11	NATIVE REVEGETATION	24,000	SF	$ 2.00	$ 48,000
12	IRRIGATION	24,000	SF	$ 0.40	$ 9,600
13	INTERPRETIVE SIGNAGE	2	EA	$ 1,250.00	$ 2,500
14	MISCELLANEOUS ITEMS	1	LS	$ 5,000.00	$ 5,000
				Subtotal	$ 135,650
	CONTINGENCY	30%			$ 40,695
				Subtotal	$ 176,345
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 17,635
				Construction Subtotal (Rounded)	$ 194,000
	STATE SALES TAX	8.5%			$ 16,490
	ENGINEERING/LEGAL/ADMIN	15%			$ 29,100
	CONSTRUCTION MANAGEMENT	10%			$ 19,400
	PERMITTING	5%			$ 9,700
	PERFORMANCE MONITORING	5%			$ 9,700
				Project Subtotal (Rounded)	$ 278,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 278,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ9: Eradicate invasive plant species, such as Himalayan blackberry and Japanese knotweed. Plant additional native riparian vegetation including native conifers and deciduous trees.**

CHECKED BY:

BY:

DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	ACCESS	0.00	LS	$ 2,000.00	$ -
3	TRAFFIC CONTROL	0	LS	$ 500.00	$ -
4	EROSION & SEDIMENTATION CONTROL (coir on streambank planting areas etc.)	1	LS	$ 2,000.00	$ 2,000
5	CONTROL OF WATER	0	LS	$ 5,000.00	$ -
6	EXCAVATION	0	CY	$ 5.00	$ -
7	LOG STRUCTURE PLACEMENT (not included but suggest placing 15 in-stream logs as an optional or supplemental feature)	0	EA	$ 900.00	$ -
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	0	CY	$ 50.00	$ -
9	HAND REMOVAL OF NON-NATIVE VEGETATION	120,000	SF	$ 0.35	$ 42,000
10	TOPSOIL SUPPEMENTATION	50	CY	$ 45.00	$ 2,250
11	NATIVE REVEGETATION	120,000	SF	$ 2.00	$ 240,000
12	IRRIGATION	120,000	SF	$ 0.40	$ 48,000
13	INTERPRETIVE SIGNAGE	2	EA	$ 1,250.00	$ 2,500
14	MISCELLANEOUS ITEMS	1	LS	$ 8,000.00	$ 8,000
				Subtotal	$ 344,750
	CONTINGENCY	30%			$ 103,425
				Subtotal	$ 448,175
				Construction Subtotal (Rounded)	$ 448,000
	STATE SALES TAX	8.5%			$ 38,080
	PREPARE PLANTING PLAN	5%			$ 22,400
	IMPLEMENTATION MANAGEMENT	3%			$ 13,440
	PERMITTING	n/a			
	PERFORMANCE MONITORING	5%			$ 22,400
				Project Subtotal (Rounded)	$ 544,000
	LAND ACQUISITION/EASEMENTS (3)	0	EA	$ 5,000.00	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 544,000**

Notes:

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2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ10: Lack of habitat and stream function along Hamlin Creek, south from the Fircrest campus along 20th Ave. NE. Hamlin Creek is piped and/or flows through a roadside ditch with no in-stream structure, no canopy cover and no native vegetation. One patch of knot weed was observed on 12.3.08. Herbicide knot weed and plant native vegetation along the ditch. Land acquisition. Daylight stream sections as feasible. Dredge and define the stream channel, add LWD, gravel, and stabilize banks. Replant with native riparian vegetation.**

BY:

CHECKED BY:

DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	2.00	ACRE	$ 3,300.00	$ 6,600
2	ACCESS	1.00	LS	$ 10,000.00	$ 10,000
3	TRAFFIC CONTROL	1	LS	$ 10,000.00	$ 10,000
4	EROSION & SEDIMENTATION CONTROL	1	LS	$ 10,000.00	$ 10,000
5	CONTROL OF WATER	1	LS	$ 8,000.00	$ 8,000
6	EXCAVATION FOR STREAM DAYLIGHTING	800	CY	$ 5.00	$ 4,000
7	UTILITIES AND INFRASTRUCTURE - DRIVEWAYS, CULVERTS, STORM DRAINS , WATER SEWER, PHONE, ETC.	1	LS	$ 100,000.00	$ 100,000
8	LOG STRUCTURE PLACEMENT	20	EA	$ 900.00	$ 18,000
9	SUBSTRATE PLACEMENT/CHANNEL FORMATION	120	CY	$ 50.00	$ 6,000
10	HAND REMOVAL OF NON-NATIVE VEGETATION	15,000	SF	$ 0.35	$ 5,250
11	TOPSOIL SUPPEMENTATION	100	CY	$ 45.00	$ 4,500
12	NATIVE REVEGETATION	15,000	SF	$ 2.00	$ 30,000
13	IRRIGATION	0	SF	$ 0.40	$ -
14	INTERPRETIVE SIGNAGE	2	EA	$ 1,250.00	$ 2,500
15	MISCELLANEOUS ITEMS	1	LS	$ 20,000.00	$ 20,000
				Subtotal	$ 234,850
	CONTINGENCY	30%			$ 70,455
				Subtotal	$ 305,305
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 30,531
				Construction Subtotal (Rounded)	$ 336,000
	STATE SALES TAX	8.5%			$ 28,560
	ENGINEERING/LEGAL/ADMIN	15%			$ 50,400
	CONSTRUCTION MANAGEMENT	10%			$ 33,600
	PERMITTING	5%			$ 16,800
	PERFORMANCE MONITORING	5%			$ 16,800
				Project Subtotal (Rounded)	$ 482,000
	LAND ACQUISITION/EASEMENTS (3)	3	EA	$ 5,000.00	$ 15,000
	CONTINGENCY	30%			$ 4,500
				Total Estimated Project Cost (Rounded)	**$ 501,500**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **AQ11: Introduce additional gravel supply to sections of the stream that are sediment-starved and/or at locations where such gravel would be effectively distributed downstream. Examples of such locations are downstream of in-stream ponds or low-gradient reaches**

CHECKED BY:

BY:

DATE: **Dec-08**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	CLEARING AND GRUBBING	0.00	ACRE	$ 3,300.00	$ -
2	ACCESS	1.00	LS	$ 5,000.00	$ 5,000
3	TRAFFIC CONTROL	1	LS	$ 500.00	$ 500
4	EROSION & SEDIMENTATION CONTROL	0	LS	$ 5,000.00	$ -
5	CONTROL OF WATER	0	LS	$ 5,000.00	$ -
6	EXCAVATION INCLUDING HAUL	0	CY	$ 15.00	$ -
7	LOG STRUCTURE PLACEMENT	0	EA	$ 900.00	$ -
8	SUBSTRATE PLACEMENT/CHANNEL FORMATION	100	CY	$ 50.00	$ 5,000
9	HAND REMOVAL OF NON-NATIVE VEGETATION	0	SF	$ 0.35	$ -
10	TOPSOIL SUPPEMENTATION	0	CY	$ 45.00	$ -
11	NATIVE REVEGETATION	0	SF	$ 2.00	$ -
12	IRRIGATION	0	SF	$ 0.40	$ -
13	INTERPRETIVE SIGNAGE	0	EA	$ 1,250.00	$ -
14	MISCELLANEOUS ITEMS	1	LS	$ 1,000.00	$ 1,000
				Subtotal	$ 11,500
	CONTINGENCY	30%			$ 3,450
				Subtotal	$ 14,950
	MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 1,495
				Construction Subtotal (Rounded)	$ 16,000
	STATE SALES TAX	8.5%			$ 1,360
	ENGINEERING/LEGAL/ADMIN	15%			$ 2,400
	CONSTRUCTION MANAGEMENT	10%			$ 1,600
	PERMITTING	5%			$ 800
	PERFORMANCE MONITORING	10%			$ 1,600
				Project Subtotal (Rounded)	$ 24,000
	LAND ACQUISITION/EASEMENTS (3)	1	EA	$ 5,000.00	$ 5,000
	CONTINGENCY	30%			$ 1,500
				Total Estimated Project Cost (Rounded)	**$ 30,600**
				Total Estimated Project Cost (Range)	**$30,000 to $60,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT:	**AQ12: Contribute to projects that improve water quality with the expectation of decreasing coho prespawn mortality downstream. Contribute to the study efforts underway to more specifically determine the causes of and remedies for coho prespawn mortality basin-wide.**	**CHECKED BY:**		
BY:		**DATE:**	**Dec-08**	
	Earmark a set amount of funding to be contributed towards this purpose, suggested $200,000.		$	200,000
		Total Estimated Project Cost (Rounded)	**$**	**200,000**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.
3. Land Acquisition unit costs include Administrative Costs.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Problem WQ1 Solution** **CHECKED BY:**
BY: **DATE:**

ITEM NO.	BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	Temperature monitoring probe	1	LF	$ 150.00	$ 150
				Subtotal	$ 150
				Subtotal (Rounded)	$ 150
	STATE SALES TAX	8.5%			$ 13
	ENGINEERING/LEGAL/ADMIN	30%			$ 45
	CONSTRUCTION MANAGEMENT	10%			$ 15
	PERMITTING	5%			$ 8
				Project Subtotal (Rounded)	$ 230
	LAND ACQUISITION (3)	0	LS	$ -	$ -
	CONTINGENCY	30%			$ -
				Total Estimated Project Cost (Rounded)	**$ 230**

Total Estimated Project Cost (Rounded)	**$ 230**

Notes:

1. The above cost opinion is in 2008 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs
3. Land Acquisition unit costs include Administrative Costs.

4. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation
5. Cost includes trench excavation, trench box, bedding, disposal of unsuitable materials, pipe, and installation

Appendix E
RONALD BOG ALTERNATIVE SOLUTIONS

R·W·BECK

An SAIC Company

Preliminary Screening of Ronald Bog Alternative Solutions

ID	Alternative	Description	Flood Relief Benefits	Cost	Land Acquisition	Permitting Difficulty	Community Advocacy	Downstream Impacts	Constraints/Comments
1	Add Storage through Redevelopment	Adopt stringent storage requirements for all redevelopment and floodproofing for flooded homes	Over extended time, e.g., 50-100 years, enough storage may be provided in basin along with floodproofing to solve problem	low	none	low	low	none	- Flood proofing could be required for redevelopment within floodplain (raising structures, etc.)
2	Floodproofing	Use Floodproofing techniques to raise houses	Would benefit many homes.	moderate	none	low	low	none	
Ronal Bog Park Alternative Options									
3a	New Open Channel Outlet	Open Channel on Corliss. Lower outlet by 1'. Raising Intersections at 171st and 172nd	Provides some additional storage. Would need to be completed with other solutions to provide full protection	high	low	med	low	high (by itself)	- from Otak Option A
3b	Small Land Purchase	Purchase 4 homes on south side of bog and raise172nd and Corliss (to increase maximum allowable lake level)	same as above	med	med	med	?	med	- from Otak Option B
3c	Regrade East portion	Excavate very low quality wetlands and provide more storage	same as above but relatively small amount of added storage	low	none	high	?	med	- from Otak Option C
3d	Downstream conveyance Improvements	Use combination large culverts and open bottom box culverts. Lower bog outlet by one foot.	Provides significant benefit	high	med	high	high	high	- from Otak Option D
3e	Complete Park excavation	Excavate all of Park space available	Provides substantial flood storage	med	none	high	low?	low	- from Otak Option E
3f	Moderate Storage Expansion	Excavate open space area, but leave above elevation 364 +/_ to maintain park use	Provides some additional storage. Would need to be completed with other solutions to provide full protection	med	none	low	high	low	
3g	Moderate Storage Expansion with Underground Pipes	Excavate open space area and construct series on large (72") pipe gallery to maintain park use	Provides some additional storage. Would need to be completed with other solutions to provide full protection	higher than 3f	none	low	high	low	
3h	Pump Station	Construct pump station to draw down bog water levels during storm season and provide more storage	Provides some additional storage. Would need to be completed with other solutions to provide full protection	med	none	med-high	?	low	- from Otak 2001
3i	Berm/Floodwall	Provide floodwall on south side of bog and downstream improvements such as high flow bypass	Provides some additional storage. Would need to be completed with other solutions to provide full protection	med	none	med	?	low-med	- floodwall could be designed to be removable.
7d	Ronald Bog Engineered Control Outlet	Construction of an engineered control outlet structure at Ronald Bog. This would be in combination with one of the RB alternatives that lowers water levels.	Enable the City to better manage the water level/storage volume.	low	none	med-high	?		- Since Ronald Bog would effectively be lowered during the dry season because of replacing the existing downstream conveyance system with a positive slope, stop logs could be added during the summer to keep the water surface elevation similar to the existing (difference is less than one half foot).

Preliminary Screening of Ronald Bog Alternative Solutions

ID	Alternative	Description	Flood Relief Benefits	Cost	Land Acquisition	Permitting Difficulty	Community Advocacy	Downstream Impacts	Constraints/Comments
Cromwell Park Alternatives									
4a	Expand Wetland at Cromwell Park	Expand existing wetland at Cromwell Park (3 ac-ft of storage)	Provide some upstream storage	low-med	none	med	?	low	
4b	Underground Vault at Cromwell Park	Construct 2 ac-ft vault and bypass pipe system at north end of Cromwell Park	Provide some upstream storage	low-med	none	med	?	low	
4c	Underground Vault at Cromwell Park	Construct open pond and surface storage and bypass pipe system at north end of Cromwell Park (1.5 ac-ft)	Provide some upstream storage	less than 4b	none	med	low	low	
4d	Underground pipe gallery at Cromwell Park	Construct system of underground pipe (60" +/-) below play fields	Provide some upstream storage	low-med	none	med	?	low	
East of I-5									Assume 178th Street and 10th/175th Street Flooding problems are solved. These alternatives reflect ways to reduce downstream flows
5a	Pipe Detention in Pipe Improvements	Provide pipe detention where possible for the pipe system improvements	Provide limited upstream storage	low-med	none	low	?	low	Possible locations are 10th Ave NE from NE 175th to Ne 18th Street; NE 180th Street from 10th Avenue NE to 5th Ave NE and 5th Ave NE from NE 18th Street to NE Serpentine; and NE Serpentine from 5th Ave NE to NE 175th Street
5b	Incorporate Infiltration along new pipe systems	Incorporate perforated pipe system (possibly only in high flows) in outwash areas	Provide limited reduction in runoff volumes	low-med	none	low	?	low	
5c	Infiltration/detention system along 8th Ave Ne	Provide detention pipes (or open channels) and infiltration for section of road that has extra wide R/W width (130' for power lines). This area is in outwash soils	Provide limited reduction in runoff volumes	low-med	none	low	?	low	
5d	Infiltration	Maximize Opportunities for Infiltration in areas with Outwash soils							
6e	Prevent any further enclosing of roadside ditch system through ordinance	Much of this area is open ditch system. As some redevelopment occurs enclosing of open ditches input pipe systems will increase runoff rates and volumes.		low	none	low	low-med	low	

Preliminary Screening of Ronald Bog Alternative Solutions

ID	Alternative	Description	Flood Relief Benefits	Cost	Land Acquisition	Permitting Difficulty	Community Advocacy	Downstream Impacts	Constraints/Comments
Other Options to Reach downstream of Ronald Bog									
7a	Meridian Avenue Reroute	Redirect drainage from portion of Meridian to N 172nd Street system and West Branch.	Decreases flows to and from Ronald Bog.						- New Corliss Place North bypass would also be required. - Only accounts for about 1.3% of basin area. Impact likely minimal. Not modeled in XP-SWMM.
7b	Corliss Avenue Upgrades	Series of Pipe system upgrades as described in RW Beck 2007 report. Includes replace 18-inch West Branch with 30-inch system at positive grade. Replace 30-inch East Branch with new 36-inch at positive grade. Connecting East and West Branches at 172nd. Also includes culvert and channel upgrades and Corliss Place NE 36-inch bypass	Eliminates flooding throughout Project Area for the 25-year event.	med	low	high	high	high	- Flood benefits verified by XP-SWMM model. - After completion of Design Report, WDFW notified City that complete pipe system upgrade would not be approved as the regional solution.
7c	Ronald Bog to N 172nd Street Open Channel	Add open channel from the Ronald Bog outlet and connect to piped system along Corliss Avenue.	limited flooding benefit.	low	none	low	?	low	
7d	Detention west of Transfer Station	Add control structure to the pipe entrance about 500 feet south of 167th. Rough estimate is that this could provide up to 10 ac-ft of storage.	Could help reduce downstream flows from upstream conveyance improvements	low	med	med	?	low	
7e	Pump Station and Infiltration Gallery at James Keough Park	Construct pump station at 167th Street and pump to an infiltration gallery (several side by side 60" pipes) constructed in James Keough Park	Could help reduce downstream flows from upstream conveyance improvements	med	none	low	?	low	- Could make use of outwash soils for infiltration. Note that consideration of impacts to properties to the west would need to be considered. - Assuming 1-2 in/hr an infiltration rate of up to 1-2 cfs is estimated
7f	Pump Station and Pond at James Keough Park	Construct pump station at 167th Street and pump to a detention pond James Keough Park (roughly 6 ac-ft)	Could help reduce downstream flows from upstream conveyance improvements	med	none	low	?	low	- 6 ac-ft not likely adequate to solve flooding alone - lose park use of property
7g	Purchase Flooded Residences and create open channel	Use FEMA mapping and purchase frequently flooded homes and use these areas to provide excess storage.	Eliminates problem areas	high	high	med-high	?	low-med	- would need to design open channel systems so as not to significantly increase conveyance capacity (and increase downstream flows). '- lose some tax revenue.
Other Miscellaneous Options									
8a	Infiltration System at James Keogh Park to get downstream flow credit	Constructed an infiltration system (likely underground pipe gallery) in James Keogh Park (at I-5 and 167th Street). Route I-5 Runoff to infiltration facility to reduce overall flow to Thornton Creek.	Could help reduce downstream flows from upstream conveyance improvements	med	none	work with WSDOT		low	- would require boring under I-5 to route flows to pond. Would collect runoff from between1.8 and 3.6 acres impervious.
8b	Expand Pond at NE 175th I-5 SB offramp	Expand a small existing pond serving the SB I-5 offramp. There are currently 1 or 2 lots not currently developed that could be used for pond expansion.	Provide some upstream storage	med	land only	low		low	