Delta

2026

SHAW CREEK INTEGRATED STORMWATER MANAGEMENT PLAN

Delta

Corporation of Delta

CITY OF SURREY
the future lives here.

Final Report

Boundary/Shaw Creek ISMP

January 201

Submitted by:

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January 30, 2012

Rob Racine
The Corporation of Delta
4500 Clarence Taylor Crescent
Delta, B.C. V4K 3E2

Dear Mr..Racine:

RE: **BOUNDARY/SHAW CREEK ISMP**
Final Report Submission
Our File 0323.059-300

We are pleased to submit 14 copies (10 to Delta and 4 to Surrey) and a digital copy of our Final Report for the above-captioned project. This submission incorporates the comments made on the 90% report. It consists of:

- **Hydrotechnical Improvements** including addressing creek erosion and culvert upgrades.
- **Lowlands Drainage Improvement** namely making more efficient use of the East Oliver Bypass.
- **Water Quality Treatment** including education of residents, considering bylaw changes to require WQ treatment of pavement runoff, two wetlands, and WQ monitoring.
- **Volumetric Reduction** including considering bylaw changes to require stormwater capture for impervious surfaces, considering options for disconnected roof leaders in Delta, and a parkette rain garden in Surrey.
- **Flow Rate Control** including requiring detention to pre-development levels for all new development, roadways, and redevelopment.
- **Riparian Protection** including continuing implementation of riparian bylaws and regulations, considering options for relocating a stream away from railway/highway embankments, and improving existing riparian.
- **Instream Restoration and Enhancement** including improving fish passage and enhancing fish habitat.
- **Further Studies and Monitoring** including geotechnical investigation and monitoring, water quality and benthic monitoring and sediment sampling, and fish presence and fish passage investigations.

It was our pleasure to complete this interesting ISMP on behalf of the Corporation of Delta and City of Surrey.

Yours truly,

KERR WOOD LEIDAL ASSOCIATES LTD.

Original Signed By:

David Zabil, P.Eng.
Project Manager

DZ/
Encl.
cc: Jeannie Lee, City of Surrey

Statement of Limitations

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This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author

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Executive Summary

Executive Summary

The Corporation of Delta (Delta) together with the City of Surrey (Surrey) initiated an integrated stormwater management plan (ISMP) for the Boundary/Shaw Creek watershed, located near the south end of the border between Delta and Surrey. The 930 ha study area includes a largely urbanized upland area, agricultural areas in the lowlands, and a large park (Watershed Park) on the slope between the urban and agricultural areas. The study area includes tributaries Watershed Creek, Briarwood Creek, Shaw Creek, Oliver Slough, and a number of lowland ditches. The area drains generally from north to south into Mud Bay.

The Delta and Surrey Official Community Plans (OCPs) show minimal new development areas, however, redevelopment densification is expected. There are valuable environmental resources within the creek system, and riparian corridors are strong in Watershed Park.

Key Issues in Watershed

Delta and Surrey identified a number of key issues in the Boundary/Shaw Creek Watershed. The filed investigation program and stakeholder consultation process expanded and confirmed the key issues. Table 1 summarizes the key issues requiring resolution (in no order of importance).

Table 1: Summary of Key Issues

Key Issues
• Effectiveness of Existing Detention Facilities and Hydraulic Structures • Lowland Flooding • Delta Golf Course Flooding at South End • Flooding in Low-lying Portions of Watershed Park near BNSF Railway • Backwatered Storm Sewer Outfall near 63 Ave and 109A St • Erosion in the Stream Channels • Ravine Instabilities and Hazards • Sediment and Debris Accumulation and Potential Blockage of Shaw Creek Highway 10 Culvert • Fish Passage Barriers • Limited Fish Habitat • Poor Water Quality in Streams • Irrigation Water Supply in Farmland during Growing Season

The Integrated Stormwater Management Plan for Boundary/Shaw Creek

The Boundary/Shaw Creek ISMP strives to resolve the above issues through the following strategies:

- Detention facility assessment and recommendations.
- Culvert capacity assessment and upgrade program.
- Flooding assessment and improvements to culvert capacity, flow splitter adjustments, pump capacity increase, and East Oliver Bypass connection to Mud Bay.
- Erosion assessment and stabilization projects.
- Ravine stability assessment and proposed future detailed investigations.
- Debris interception and culvert inlet improvement at Shaw Creek Highway 10 culvert.
- Fish habitat and passage improvements.
- Water quality monitoring program and improvements.

- Improve water quality from non-point sources through the medium and long term implementation of stormwater source controls.
- Maintain base flows and low flows into the farmland channels for irrigation.
- Mitigate hydrologic impacts from future development through source controls and stormwater bylaws.

ISMP Performance Monitoring and Accountability of Plan

In order to measure and track the levels and changes in the health of a watershed, and to provide accountability to the ISMP, a suite of performance parameters has been developed that match the key issues identified above. Table E-2 lists the parameters or "indicators" that should be measured and tracked over time.

The proposed schedule for review of the watershed health indicators should be once every five years. It is suggested that indicators be measured every two years.

Table 2: Boundary/Shaw Creek Watershed Adaptive Management Indicators

Performance Indicator		Method of Analysis	2010	2015
1.	Total Impervious Area (% of Watershed Area)	GIS Analysis of Aerial Photos and Assessment Data	26%	Small increase expected due to development
2.	Effective Impervious Area (% of Watershed Area)	Estimated from surface cover type and source controls implemented	Flow monitoring required to quantify	decrease when source controls implemented
3.	Riparian Forrest Integrity (% of Riparian Area)	GIS Analysis of Aerial Photos	31%	Same or Increase
4.	Watershed Forest Cover (% of Watershed Area)	GIS Analysis of Aerial Photos	23%	Same or Increase
5.	Benthic Invertebrates	B-IBI scores based on methods used in this study	mean = 17.0	18
6.	Fish Populations	Density, species composition	No data	Collect Data
7.	Fish Passage Barriers	City/Streamkeepers Records	Full Barriers 1 Partial Barriers 4	Progressive Removal of Non-natural Barriers
8.	Average Summer Water Temperature (°C)	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 10.6 - 18.3 Mean: 15.0	Same or Decrease
9.	Dissolved Oxygen (DO, mg/L)	Field Measurement (during spring/summer baseflow)	Range: 1.5 – 10.8 Mean: 7.1	Same or Increase
10.	Water pH	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 5.7 – 7.5 Mean: 6.8	Same or Trend Toward Neutral
11.	Water Conductivity (μS)	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 83 – 7,590 Mean: 505	Same or Decrease
12.	Turbidity (NTU)	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 0 – 160 Mean: 15	Same or Decrease
13.	Water Quality Fecal Coliforms (MPN/100mL)	Field Sample at Oliver Slough near 112 Street & Lab Testing	1,600	< 200
14.	Sediment Quality	Metals in sediment	See Section 2.4	Same or Decrease
15.	No. of Erosion Sites	Field Assessment and Designation as Low, Medium, or High Severity and Consequence	See Table 2-2	Same or Decrease
16.	Lineal km of Roadside Ditches/Swales/Rain Gardens (km)	As-Constructed Drawings / GIS	16 km	18 km

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Section 1

Introduction

1. Introduction

The Corporation of Delta (Delta) together with the City of Surrey (Surrey) initiated an integrated stormwater management plan (ISMP) for the Boundary/Shaw Creek watershed, located near the south end of the border between Delta and Surrey (see Figure 2-1 in next section). The 930 ha study area includes a largely urbanized upland area, agricultural lowlands, and a large park (Watershed Park) on the slope between the urban and agricultural areas. The study area includes tributaries Watershed Creek, Briarwood Creek, Shaw Creek, Oliver Slough, and a number of lowland ditches. The area drains generally from north to south into Mud Bay.

The Delta and Surrey Official Community Plans (OCPs) show minimal new development areas, however, redevelopment densification is expected. There are valuable environmental resources within the creek system, and riparian corridors are strong in Watershed Park.

This report fulfills the goals of the ISMP process including:

- document the existing condition of the drainage system and the ecological health of the watershed;
- define how development can proceed with minimal effects on flooding, erosion, water quality, and ecological health;
- identify required remedial and new capital work items; and
- provide a sustainable plan with minimal operational and maintenance costs.

The ISMP process strives to preserve watershed health as a whole, while meeting community needs and allowing development and redevelopment to occur. It allows for trade-offs so that environmental losses in one area within a watershed can be offset by gains in others, thereby meeting the regulatory guiding principle of no-net-loss.

1.1 Goals and Objectives

The goal of the Boundary/Shaw Creek study is to develop a comprehensive ISMP that will seek to improve the overall watershed system by minimizing the risk of flooding, preserving aquatic and riparian habitats, and develop effective and affordable watercourse improvements.

Delta and Surrey have developed the following objectives for this study:

- Protect aquatic ecosystems and water resources (surface and ground water) for their fish, wildlife, and ecological values.
- Minimize the risk to life and property associated with flooding.
- Provide or recommend pollution prevention and water quality control approaches.
- Involve the local stakeholders, agencies and public in a consultation process that will provide information on the current system and fully explore a range of options for improving the management of the watershed.
- Develop a comprehensive and cost effective strategy for municipal capital improvements, projects for streamkeeper groups, and improve community awareness of watershed issues.
- Meet Metro Vancouver criteria for ISMP acceptance. Obtain municipal commitment to ISMP implementation and maintenance program.
- Review appropriate streamside setbacks and address any existing or potential conflicts with existing riparian regulations.
- Develop functional preliminary designs for any structural/hydraulic improvements that are required.

The plan is to be cost-effective, scientifically defendable, supported by the public, and endorsed by the environmental agencies.

1.2 ISMP Key Issues

The following key issues for the watershed were identified. Refer to Figure 2-1 for orientation.

Existing Flooding

Sediment/debris issue in Shaw Creek potentially plugging Highway 10 culvert resulting in road overtopping and flooding;

Sediment/debris in Shaw Creek at upstream end of Highway 10 culvert

Sediment/debris in Shaw Creek between 120 Street and Highway 10

Debris Jams in Shaw Creek between 120 Street and Highway 10

Debris Jams in Shaw Creek between 120 Street and Highway 10

- Flooding of the south portion of Delta Golf Course (causes may include: located in floodplain, lack of pump station on the golf course);
- Storm sewer near 63 Ave and 109A St backwatered by Watershed Creek water levels;
- Flooding of farmlands west of Highway 91 (causes may include: located in floodplain, runoff from uplands, hydraulic constrictions in conveyance system); and

- Lower part of Watershed Park (located in floodplain, inadequate flood conveyance to Oliver Pump Station, runoff from uplands).

Irrigation

- Desire to increase irrigation water supply to farmland in the growing season.

Existing Erosion

- Erosion and ravine instabilities and hazards;

Bank Erosion in Shaw Creek downstream of Highway 10 culvert

Bank Erosion in Shaw Creek downstream of Highway 10 culvert

- Severe erosion and unstable obstructions observed in Shaw Creek between 120 Street and Highway 10; and
- Erosion at the top end of Shaw Creek at storm sewer outfall and through the 6007 Scott Road property including bank stabilization needs.

Environmental

- Fish passage barriers;

- Limited spawning and rearing habitat capacity; and

- Poor water quality in upland creeks and lowland ditches and sloughs (high summer water temperatures, high turbidity/TSS, high nutrients in lowlands, fecal coliforms, high metals).

Poor Water Quality in Shaw Creek

Poor Water Quality in Watershed Creek

Effectiveness of Existing Infrastructure

- Capacity and condition assessment of hydraulic structures; and
- Performance evaluation of existing stormwater detention systems and possible improvement.

1.3 Scope of Assignment

The following table summarizes the major tasks involved in undertaking this study.

Table 1-1: Engineering Work Program

Major Tasks		
Phase 1	1.	Project Initiation
	2.	Background Information Review
Phase 2	3.	Hydrogeology and Geotechnical Assessment
	4.	Land Use Assessment
	5.	Drainage System and Erosion Inventory
	6.	Environmental Inventory and Assessment
Phase 3	7.	Hydrology/Hydraulic Analysis
	8.	Ecological Health Analysis
	9.	Project Summary and 50% Report
Phase 4	10.	Mitigation Alternatives
Phase 5	11.	Develop Strategy, Plan, and Report

1.4 Stormwater and Drainage Criteria

Table 1-2: Summary of Stormwater Criteria

Application		Criteria/Methodology
Flood and Erosion Protection	Minor drainage system	• 10-year return period design event typically.[1] • 5-year return period design event for low density residential areas; 25-year return period design event for high value commercial or industrial development.[1] • 5-year return period design event.[2]
Flood and Erosion Protection	Major drainage system (Rural, Urban, Commercial Industrial)	• 100-year return period design event for floodway routing.[1, 2] • 25-year return period design event for dyked or reclaimed land.[1] • 100-year return period design event for culverts with less than 3 meter span on BC Ministry of Transportation roads.[3]
Agricultural Criteria	ARDSA Criteria	• Limit flooding to 5 days during a 10-year 5-day winter storm. • Limit flooding to 2 days during a 10-year 2-day growing season storm. • Provide 1.2 m of freeboard during baseflows between storm events.
Erosion & Environmental Protection	Volume Reduction (Source Controls)	• On-site rainfall capture (runoff volume reduction) for 6-month 24-hour storm (72% 2-year 24-hour storm).[4]
Erosion & Environmental Protection	Water Quality Treatment	• 6-month 24-hour storm (72% 2-year 24-hour storm).[4]
Erosion & Environmental Protection	Rate Control (Detention / Diversion)	• Control post-development flows to pre-development levels for 6-month, 2-year, and 5-year 24-hour event.[4] • On fish bearing streams restrict post-development flows to pre-development levels for all storms up to and including the 10-year storm.[1] • Limit flows to more stringent of the following criteria: Control the 5-year post-development flow to: 50% of the 2-year post development rate; or the 5-year pre-development rate.[2]
Erosion & Environmental Protection	Riparian	• Establish riparian setbacks to comply with Delta Streamside Protection and Enhancement Areas Bylaw[5] and Riparian Areas Regulation.

1 Corporation of Delta Stormwater Management Design Manual, February 1989, Revised January 1994.
2 City of Surrey Design Criteria Manual, May 2004.
3 BC Ministry of Transportation supplement to TAC Geometric Design Guide, 2007.
4 DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat, 2001.
5 Corporation of Delta Development Permit Area to Establish Streamside Protection and Enhancement Areas Bylaw No. 6349, 2005.

1.5 Stakeholder Consultation Program

The stakeholder consultation included meetings with the municipalities, an Open House public meeting, and questionnaires seeking input on the key issues and potential solutions. Stakeholders included:

- municipal advisory committees;
- streamkeeper volunteer groups;
- residents;
- Burlington Northern Santa Fe (BNSF) Rail;
- Ministry of Transportation and Infrastructure (MOT);
- Metro Vancouver;
- Ministry of Agriculture and Lands;
- Fisheries and Oceans Canada (DFO);
- BC Ministry of Environment (MOE);
- Delta Farmers' Institute; and
- Delta Golf Course.

This ISMP was developed under of the direction the Corporation of Delta and the City of Surrey. The contents of the final report including the alternatives and the projects proposed in the Plan were selected in consultation with the municipalities.

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Section 2

Boundary/Shaw Creek Watershed

2. Boundary/Shaw Creek Watershed

2.1 Background Material

Table 2-1 summarizes the background information reviewed as part of this study.

Table 2-1: Summary of Background Material

Date	Title
January 1987	East Delta Drainage and Irrigation Study, K. Wilson, P.Eng., Ministry of Environment and Parks
May 1993	Corporation of Delta East Delta Drainage and Irrigation Study Design Report, Dayton and Knight Consulting Engineers
December 1994	Proposed West Newton Plan, Land Use Map, City of Surrey
February 1999	Panorama Ridge Drainage and Slope Stability Assessment, Volumes 1 to 3, Stanley Consulting Group
November 1999	Panorama Ridge Functional Review of Existing Drainage Concerns (54 Avenue), Stantec Consulting
February 2000	Drawings of East Oliver Bypass Ponds, Kerr Wood Leidal Associates
May 2000	Update to Panorama Ridge Drainage and Slope Assessment Final Report, Stantec Consulting
July 2001	Tender Drawings of East Oliver Bypass Ponds, Kerr Wood Leidal Associates
July 2002	Corporation of Delta Long Range Drainage Plan, New East Consulting Services
June 2004	Assessment of a Well to Supply a Public Fountain, Gartner Lee Ltd.
April 2005	Eugene Creek 90% Design Submission Drawings Package, McElhanney Consulting Services
September 2008	Preliminary Report to the City of Surrey for Eugene Creek Channel Diversion, McElhanney Consulting Services

2.2 Drainage

The Boundary/Shaw Creek study area is located in both the Delta and Surrey, with approximately 75% of the watershed within Delta (see Figure 2-1). The study area is approximately bounded by 68 Avenue to the north, Mud Bay to the south, 112 Street to the west and 128 Street to the east. The Cougar Creek and the Eugene Creek watersheds are immediately north and east of the study area, respectively.

- Study area is approximately 930 ha with the Surrey area (220 ha) largely developed and the Delta area (710 ha) mostly undeveloped or agricultural land.
- Drainage direction is generally toward the south, via storm sewers, culverts, creeks, and ditches.
- Study area drainage discharges into Mud Bay via the Oliver Pump Station.
- Uplands rate controls includes two detention facilities in Surrey (Boundary Park Pond and 6455 121 Street tank).

- Lowland flow control includes the East Oliver Bypass series of lowland storage ponds/wetlands with a flow splitter (see photo to right) that regulates the flows into the farmlands west of Highway 91 (other irrigation control structures exist in the lowlands outside the study area).

Refer to Figures 2-1 and 2-2 for the study area extents and drainage system overview.

Field Inventory

Field inventories were completed between May 20 and June 8, 2010 for Watershed Park as well as the area south of Highway 10 and north of Ladner Trunk Road. The creek bed was traversed on foot and locations of interest were identified and recorded with a Trimble GeoXT handheld global positioning system (GPS) receiver. Measurements, photographs and additional observations were recorded as attributes associated with these positions to create a comprehensive geographical information system (GIS) database. Figure 2-3 shows the field inventory and locations of interest.

Field inventory work included gathering information on creek crossings, channel cross-sections, erosion, deposition, obstructions and a condition assessment of hydraulic structures. Sites of significant erosion were identified and assigned a relative severity level of low, moderate or high, based on a visual assessment that took into account the following parameters:

- total height of eroded bank;
- apparent rate of erosion; and
- apparent capacity of bank material to resist further erosion.

In addition to rating the severity of these sites, the potential consequences of the erosion activity was also evaluated and assigned a relative risk level of low, medium or high. This was based on a visual assessment that took into account the perceived level of risk to human life, property damage or destruction and wildlife habitat. Tables 2-2 and 2-3 summarize the erosion and obstruction locations. In general, the following observations were made:

- Severe erosion was noted along Shaw Creek between 120 Street and Old Highway 10 (Delta Golf Course access road).
- Consequences of the most severe erosion site were low as there are no nearby structures.

- One major erosion site noted adjacent to Highway 10 embankment which if left unaddressed would threaten the highway in the future (E-11).
- Erosion at the toe of the ravine southeast of Highway 10 may undermine toe increasing likelihood of slope instability and pose a risk to homes on Panorama Ridge.

- Unstable obstructions such as debris jam, large woody debris, and sediment was noted in Shaw Creek upstream of Highway 10. These pose the risk of culvert blockage and should be monitored, anchored, or removed.




See Appendix A for photo overviews of the field inventory.

Table 2-2: Summary of Observed Severe Erosion Sites

ID	Location	Severity	Consequence	Length (m)	Depth (m)	Comment
E-1	RIGHT BANK	MODERATE	LOW	26	0.5 - 0.75	
E-2	BOTH	LOW	LOW	15	0.5-1	
E-3	LEFT BANK	MODERATE	LOW	10	0.5-1	MULTIPLE SITES WITHIN 50 m
E-4	LEFT BANK	MODERATE	MODERATE	6	2-4	
E-5	LEFT BANK	MODERATE	LOW	10	1-2	
E-6	LEFT BANK	HIGH	LOW	15	2-4	
E-7	LEFT BANK	HIGH	LOW	40	4-8	
E-8	RIGHT BANK	HIGH	LOW	20	1.5-4	
E-9	RIGHT BANK	MODERATE	HIGH	15	2-4	
E-10	LEFT BANK	LOW	LOW	10	.5-1	
E-11	RIGHT BANK	HIGH	HIGH	20	2-5	ALSO DEBRIS BARRIER & GRAVEL DEPOSITION
E-12	RIGHT BANK	MODERATE	HIGH	40	2-5	LEFT BANK EROSION 1M DEPTH

Severity Ratings based on erosion area: Low = less than 10 m^2, Moderate = 10 to 50 m^2; High = greater than 50 m^2
Consequence Ratings: High = roads or buildings at risk, Moderate = private property at risk, Low = all others

Refer to Figure 2-3 for location of sites

O:\0300-0399\323-059\300-Report\Final Report\[Table 2-2 ErosionSites.xls]wk-Table_Combined

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Table 2-3: Summary of Observed Major Channel Obstructions

ID	Cause	Stability	Type	Downstream Drop (m)	Comment
O-1	NATURAL	STABLE	FALLEN TREE	0	.5 m DIAMETER
O-2	NATURAL	STABLE	FALLEN LOGS	0	
O-3	NATURAL	UNSTABLE	BRANCHES/DEBRIS	0	CAUSES CREEK DIVERSION
O-4	NATURAL	UNSTABLE	BRANCHES/DEBRIS	0	
O-5	NATURAL	STABLE	BOULDERS	0.3	DEPOSITION/PROTECTION
O-6	ANTHROPOGENIC	STABLE	950 CONC BARREL	0	
O-7	NATURAL	STABLE	BOULDERS	0.5	BOULDERS & LOG
O-8	NATURAL	UNSTABLE	LOGS & DEBRIS	1	MODERATE EROSION LEFT & RIGHT BANK 1-2.5M
O-9	NATURAL	STABLE	BOULDERS	0.5	
O-10	NATURAL	UNSTABLE	DEBRIS	0	
O-11	NATURAL	UNSTABLE	FALLEN TREE/DEBRIS	0	MODERATE EROSION BOTH BANKS
O-12	NATURAL	STABLE	DEBRIS	1	
O-13	NATURAL	UNSTABLE	LOGS	.5	
O-14	ANTHROPOGENIC	FIXED	TIMBER DAM	0	
O-15	ANTHROPOGENIC	STABLE	OLD DAM?	.5	
O-16	NATURAL	STABLE	BOULDERS	.25	

Refer to Figure 2-3 for location of sites

O:\0300-0399\323-059\300-Report\Final Report\[Table 2-3 ObstructionSites.xls]wk-Table_Combined

2.3 Land Use

The historic, existing, and future land uses were identified in the study area in order to estimate imperviousness values and how they have changed and how they are predicted to change in the future. Aerial photographs and land use information were received from Surrey and Delta.

Existing Land Use

Table 2-4: Existing Land Use

Delta	Surrey
Agricultural Parks/recreation Single family residential Some commercial along Scott Road Two schools	Mainly residential Some commercial along Scott Road
As per 2008 airphoto	

Refer to Figure 2-4 for existing land use and associated impervious percentages.

Future Land Use – OCP

- Very few zoning changes.
- Mainly redevelopment at higher impervious percentages.
- Potential for higher density along Scott Road.

Refer to Figure 2-5 for proposed land use. Table 2-5 summarizes the imperviousness values for each municipality and study area overall for the existing and future land uses.

Table 2-5: Existing and Future Total Impervious Areas

Existing Land Use			Future Land Use (Estimated 2030)		
Delta Area Only	Surrey Area Only	Total Study Area	Delta Area Only	Surrey Area Only	Total Study Area
18%	49%	26%	24%	58%	32%

Historic Land Use

Pre-development conditions were examined to assess how the stormwater flows have changed over the past three decades. The Terms of Reference noted a 1950 Delta and 1973 Surrey land use for this purpose. The 1974 for Delta and 1976 for Surrey aerial photography is shown on Figure 2-6 as those are the best quality photos provided by the municipalities. However, it was observed that there was little change in imperviousness between the 1950s and the 1970s. The aerial photography made available did not cover the entire study area and therefore a 5% imperviousness was assumed for the historic rural development.

2.4 Environmental Inventory and Assessment

An environmental inventory was undertaken to summarize watershed conditions and trends, and information on water and sediment quality, benthic invertebrate communities, aquatic species and habitats, vegetation and land cover patterns, and terrestrial habitats and wildlife use. In addition, habitat restoration sites and enhancement strategies were also identified.

Water Quality

Water quality sampling was undertaken on September 15, and 16, 2010. While one-time water quality sampling provides a limited snap-shot of parameter concentrations, it is a useful way to screen for issues of potential concern that should be managed as part of the ISMP. Because of a limited budget for sampling, water and sediment sampling did not include the replication (e.g., 5 samples in 30 days) or broader spatial sampling needed to more rigorously characterize environmental contaminants and for proper comparisons to appropriate federal or provincial guidelines. However, it is still useful to undertake such comparisons as a screening-level analysis to flag issues of concern, and as part of a weight-of-evidence approach used in ISMPs. Sampling consisted of:

1. in-situ measurements of general water quality parameters (temperature, specific conductivity, DO, pH, oxygen reduction potential (ORP), and turbidity) (28 sites in total);
2. discrete (grab) sampling for nutrients (nitrate, ammonia nitrogen, and orthophosphate), alkalinity, total suspended solids (TSS), fecal coliforms, and total metals (6 sites in total); and
3. continuous temperature monitoring at one site in the lowlands (downstream of 112th St near confluence with Big Slough) and one site in Shaw Creek (downstream of Old Highway 10) (operated June to September 2010).

Lab analyses were performed by ALS Environmental. Sampling sites are illustrated in Figure 2-7.

- General water quality parameter sampling results:
  - Water temperature: range = 10.63–18.32ºC, mean = 15.04ºC;
  - Dissolved oxygen: range = 1.53–10.76 mg/L, mean = 7.07 mg/L;
  - Specific conductivity: range = 83–7590 µS/cm, mean = 505 µS/cm;
  - pH: range = 5.72–7.49, mean = 6.81;
  - Total dissolved solids (TDS): range = 0.057–4.933, mean = 0.327;
  - Turbidity: range = -0.19–160.0 NTU; mean = 14.64 NTU; and
  - Oxygen reduction potential (ORP): range = -20.9–405.7, mean = 85.7.
- Watershed Creek and downstream ditches had lower water temperatures, likely due to the influx of groundwater from artesian wells in Watershed Park.
- Dissolved oxygen and pH were typically lower and specific conductivity was higher in lowland versus upland watercourses.
- Oliver Slough (at 112th St) had higher specific conductivity and TDS than other sampling sites.
- Elevated nitrate levels were observed in Briarwood Creek (upstream of Watershed Park slope culvert), near to but not exceeding the Canadian Council of Ministers of the Environment (CCME) guidelines for aquatic life (possibly naturally high in groundwater).
- Ammonia nitrogen and orthophosphate levels were highest in Oliver Slough near 112th St (possibly from agricultural runoff). No guidelines exist for these nutrients.

- Fecal coliform bacteria levels were 1600 MPN/100 ml at Oliver Slough near 112th St, well above the BC AWQG for primary contact recreation of 200 MPN/100 ml (guideline is for 5 samples in 30 days). All other sites were well below this guideline.
- Iron, aluminum, and cadmium levels were above the BC Approved Water Quality Guidelines (BC AWQGs) at one or more sites. Copper and chromium levels may also be above provincial guidelines[1].Shaw Creek (multiple sites) and Oliver Slough (at 112th St) showed the most evidence of metals concentrations at or slightly above BC AWQG's.
- It should be noted that levels of nutrients, fecal coliform, and metals in the water were assessed only from a single sample at each site. Further assessment to identify the extent of issues is needed.
- The upstream continuous temperature logger showed summer water temperatures in 2010 exceeded the BC AWQG for salmonids (maximum 17ºC for Coho and Cutthroat Trout) in Shaw Creek for 8.4 days in July 2010 and 10.3 days in August 2010. Based on the temperature differences measured in September 2010 during in-situ sampling, it is expected that Watershed Creek does not exceed this guideline on a regular basis. Data from the downstream logger (downstream of 112th St) was not available because of theft of the logger prior to the data being downloaded.

Full water quality sampling data can be found in Appendix B.

Link to Watershed Health

In the Shaw Creek ISMP study area, good water quality is important to protecting aquatic life and ecosystems, as well as a clean irrigation water source. In general, water quality sampling results were as expected for the level of urbanization in these watersheds and similar to other developed watersheds in Metro Vancouver. From the above analysis, priority water quality issues related to these uses are:

- Poor water quality in Shaw Creek, minor sloughs, and other lowland watercourses (including metals, nutrients, fecal coliforms, and dissolved oxygen levels), particularly Oliver Slough; and
- High summer water temperatures in Shaw Creek.

Sediment Quality

Sediment quality sampling was undertaken on September 15, 2010. Sediment samples are also useful for long-term monitoring of stream condition because they are much less variable than water quality measurements. Sediment samples were taken at five sites (same as grab water quality samples minus one lowland site which could not be sampled) and tested for total metals. Where possible, each sample was a composite of surface and shallow sub-surface fine sediment collected from 10–15 sites from within the active stream channel. Sampling sites are illustrated in Figure 2-7.

[1] The BC AWQG for copper is for mean of 5 samples in 30 days and BC AWQG for chromium is for trivalent chromium and hexavalent chromium separately, rather than for instantaneous total levels of this metal. In the case of total copper, instantaneous levels measured exceeded the mean guideline in Oliver Slough. For chromium, total chromium levels were above the value for hexavalent chromium and below the value for trivalent chromium in Oliver Slough. As a result, it is not possible to say with certainty whether these guidelines have been exceeded. Additional sampling and lab tests would be required.

- Arsenic levels were above the BC Working Water Quality Guidelines in Briarwood Creek (upstream of Watershed Park slope culvert) and Oliver Slough (at 112th St).
- Cadmium, chromium, and copper, and zinc levels were above the CCME's Probable Effect Levels (PELs)[2] for aquatic life in Oliver Slough (at 112th St).
- Nickel levels were above BC Working Water Quality Guidelines (BC WWQGs) in Shaw Creek (at Scott Road), Briarwood Creek (upstream of Watershed Park slope culvert), and Oliver Slough (at 112th St), zinc levels were above the BC WWQGs in Briarwood Creek, and chromium levels were above the BC WWQGs in Oliver Slough (at 112th St).
- It should be noted that levels of metals in sediments were assessed only from a single sample at each site, and in some cases this level of sampling is insufficient for comparison to appropriate guidelines (i.e., mean value based on 5 samples in 30 days required). Further assessment is needed.

Full sediment quality sampling data can be found in Appendix B.

Link to Watershed Health

Sediment quality is an indicator of the cumulative impacts of water pollution on watershed health. Similar to water quality, sediment quality sampling results were generally as expected given the land uses present in the watershed. From the above analysis, priority watershed health issues indicated by the sediment quality results are:

- High metal concentrations in Oliver Slough.

Benthic Invertebrates

Benthic invertebrates (streambed insects) are useful indicators of a stream's biological condition and can be monitored over time to track changes in stream or watershed health. Benthic invertebrate community sampling provides an integrated measure of cumulative effects of watershed changes, such as urbanization, not consistently captured by water quality measurements. Standardized methods used in Metro Vancouver (see EVS, 2003 provide replication and are robust against variability and outlier values (Page et al., 2008).

Benthic invertebrate sampling was undertaken on September 15, 2010 at four stations (two in Shaw Creek, one in Briarwood Creek, one in Watershed Creek). Each station consisted of a single composite sample of three Serber sampler placements (3 min substrate disturbance each) within the same or adjacent riffles. Sampling followed the field sampling protocol described in the GVRD Benthic Macroinvertebrate B-IBI Guide (EVS, 2003) (although 1-2 samples were taken within each stream, rather than four samples within one 500 m sampling reach in a single stream). Sample processing, subsampling, taxonomic identification, and B-IBI scoring (used as an index of watershed health) was completed by Rhithron Associates (Missoula, MT). Sampling sites are illustrated in Figure 2-7.

[2] Probably Effects Levels (PELs) are defined as "levels which, if exceeded, will cause severe effects on aquatic life" (Nagpal et al., 2006). PELs are typically 3–5 times higher than provincial or federal sediment quality guidelines, and indicate more severe levels of contamination.

- The sampling results indicate that the biological condition of Shaw Creek has been heavily impacted by human disturbance within the watershed. However, this result is similar to other Metro Vancouver watersheds with similar levels of development and is not unexpected given the high levels of urbanization and high total impervious area within the upper watershed, poor water quality in some areas, and low riparian forest integrity outside of Watershed Park (see Watershed and Riparian Forest Cover Assessment section).
- B-IBI scores across the four sampling sites ranged from 16 to 18 (Table 2-6)[3]. The overall mean B-IBI score for the watershed is 17.0 (SD 1.2).
- Across all four sites, mean taxa richness was 10.8 (SD 4.9, min 6, max 15). Variability in taxa richness accounts for the variability observed in B-IBI scores between sites.

Full taxonomic data and individual B-IBI scores are available in Appendix B.

Table 2-6: Benthic Invertebrate Sampling Results

Metric	Shaw C-1		Shaw C-2		Briarwood		Watershed		Mean	
Site	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
Taxa richness	15	3	7	1	6	1	15	3	10.75	1
E richness	1	1	1	1	1	1	2	1	1.25	1
P richness	0	1	0	1	0	1	2	1	0.5	1
T richness	2	1	0	1	0	1	2	1	1	1
Intolerant taxa richness	0	1	0	1	0	1	2	1	0.5	1
Clinger richness	3	1	1	1	0	1	5	1	2.25	1
Long-lived richness	1	1	0	1	1	1	2	1	1	1
% tolerant	7.51	5	2.49	5	1.06	5	1.91	5	3.24	5
% predator	3.76	1	27.07	5	19.58	3	1.20	1	12.90	3
% dominance (3)	84.74	1	80.39	1	94.18	1	75.84	3	83.79	1
Sample Score	**16**		**18**		**16**		**18**			
Site Score										**16**
Mean BIBI	**17.0 (SD = 1.2)**									

Link to Watershed Health

B-IBI is an overall indicator of watershed health, representing the cumulative impacts of upstream development on aquatic ecosystems (e.g., changes in flow regime, water quality, instream habitat). The B-IBI index operates on a scale of 10 to 50 with 10 representing a degraded watershed and 50 representing a pristine, old growth forest watershed. Typically undeveloped watersheds in the Lower Mainland score a maximum of 40 points. The B-IBI scores measured in the tributaries in the study area

[3] Under the 10-metric B-IBI scoring system, for each metric, each sample is given a score from 1 to 5. Therefore, the minimum possible B-IBI score is 10 and the maximum score is 50 (Page et al., 2008).

indicate a high level of human disturbance but are typical of watersheds with this level of development (see Section 3.3).

Fish Communities

Fish species present in creeks and ditches were assessed using information from a Delta-wide inventory from 2000–2003 (Rithaler and Rithaler, 2003), and the provincial Fisheries Information Summary System (FISS) database, and reports from fish salvages associated with recent instream work. No new fish sampling was undertaken as part of the ISMP.

- The known fish community in the study area consists of three salmonid species, five native non-salmonid species, and five exotic species (Table 2-7).
- Coho, chum, and cutthroat trout use the lower and transitional reaches of Watershed and Shaw creeks for spawning and rearing. Lowland ditches are used for rearing and migration to and from the Oliver Pump Station and access to Mud Bay. Chinook may also periodically move in from Boundary Bay to rear.
- Oliver Slough is also documented as fish-bearing with Coho and Cutthroat trout present in the Slough and its connected ditches (FISS, 2011). However, due to poor summer water quality, use is likely to be highly seasonal and restricted to winter months.
- Twenty-five thousand chum fry have been released annually into Watershed Creek since 2002 (Delta Parks, 2006). A small number of adults have returned to spawn. Chum salmon were likely historically present within the study area but disappeared when lowland areas were initially dyked.
- The only confirmed fish Species at Risk from the study area are Cutthroat Trout, *clarkii* subspecies (S3S4; blue-listed in BC).
- Other fish species may be periodically present in the study watersheds as a result of exchange with Mud Bay.

Fish presence (salmonids only) in the watercourses is illustrated in Figure 2-8.

Link to Watershed Health

Fish communities are an important component of aquatic ecosystems and salmonids, in particular, are part of important commercial and recreational fisheries within the lower Fraser River area. While native fish diversity in the study area is still relatively high, the abundance of native species, and salmonids in particular, is likely much lower than historical levels. Colonization by tolerant and predatory non-native fish species is both an indicator of and a concern to watershed health.

Table 2-7: Fish Species Presence

Species			Source(s)	Notes
CO	Coho Salmon	*Oncorhynchus kisutch*	Rithaler and Rithaler, 2003; FISS, 2011	Anadromous; overwinters as fry
CM	Chum Salmon	*Oncorhynchus keta*	Delta Parks Dept., pers. comm.	25,000 fry released annually (2002–10); few adults returning to spawn
CT	Cutthroat Trout	*Oncorhynchus clarki*	Rithaler and Rithaler, 2003; FISS, 2011	Species at Risk (blue-listed in BC); Resident likely; anadromous may also be present
CH	Chinook Salmon	*Oncorhynchus tshawytscha*	FISS, 2011	Sampled during fish sampling for golf course development; likely juveniles moving in/out from Boundary Bay
CAS	Prickly Sculpin	Cottus asper	Rithaler and Rithaler, 2003; FISS, 2011	Found in more natural watercourses in study area
TSB	Threespine Stickleback	Gasterosteus aculeatus	Rithaler and Rithaler, 2003; FISS, 2011	Very common and abundant throughout study area
BMC	Brassy Minnow	*Hybognathus hankinsoni*	Rithaler and Rithaler, 2003	Found in more natural watercourses in study area
PCC	Peamouth Chub	*Mylocheilus caurinus*	Rithaler and Rithaler, 2003; FISS, 2011	Found at single site in north end of Oliver Slough
BCB	Black Crappie*	*Pomoxis nigromaculatus*	Rithaler and Rithaler, 2003	Found at single site in north end of Oliver Slough
RSC	Redside Shiner	*Richardsonius balteatus*	Rithaler and Rithaler, 2003	Found at single site in Lorne Ditch at 112th St
BNH	Brown Catfish*	*Ameiurus nebulosus*	Rithaler and Rithaler, 2003; FISS, 2011	Found at single site in north end of Oliver Slough
GC	Goldfish*	*Carassius auratus*	Rithaler and Rithaler, 2003; P. Lilley, pers. obs.	Found in Shaw Creek in Watershed Park
CP	Carp*	*Cyprinus carpio*	Rithaler and Rithaler, 2003; FISS, 2011	Found in Shaw Creek above Highway 91
PMB	Pumpkinseed Sunfish*	*Lepomis gibbosus*	Rithaler and Rithaler, 2003	Found in 112th St Ditch south of Highway 10 and north end of Oliver Slough
* denotes a introduced (non-native) species				

Amphibians

Three amphibian species (one native, two introduced) have also been found to inhabit aquatic areas within the study area (Table 2-8).

- Northwestern Salamanders are one of the more common amphibian species in our region. Mesic forests are the main terrestrial habitat. Breeding habitats include ponds, wetlands, lakes, road ditches, and slow moving creeks.
- Green Frogs and Bullfrogs prefer warmer water temperatures and are known to have detrimental effects on native amphibian populations, mainly through predation.

Table 2-8: **Amphibian Species Presence**

Species		Source(s)	Notes
Northwestern Salamander	*Ambystoma gracile*	Rithaler and Rithaler, 2003	Found frequently in open wetlands, ditches, and sloughs
Green Frog*	*Rana clamitans*	Rithaler and Rithaler, 2003	Found in open wetlands, ditches, and sloughs
Bullfrog*	*Rana catesbeiana*	Rithaler and Rithaler, 2003	Found in ditches and sloughs south of Highway 10
* denotes a introduced (non-native) species			

Link to Watershed Health

The presence of only one native amphibian species and two non-native amphibian species indicate that wetlands in the study area have been degraded such that they are not able to sustain highly diverse native amphibian communities and that conditions favour invasive species.

Instream Fish Habitat

Fish habitat characteristics (channel conditions, substrates, complexity, etc.) were assessed during field visits in May and September 2010. To understand the distribution of different habitat types, conditions were assessed at representative reach points (data found in Appendix B) with reaches shown in Figure 2-9.

- In general, the lowland portion of the study area has been dyked and channelized due to agricultural development. This area likely supported a complex of wetlands and interconnected channels historically. Thus, much of the historical lowland rearing habitat capacity of the watershed has been lost.
- The middle reaches in the gradient transition between lowland and upland areas historically contained the best quality fish habitat. Watercourses in the western portion of Watershed Park and in the lower reaches in the Shaw Creek ravine contain more gravel and cobble substrates suitable for spawning and rearing.
- The upper or headwater reaches of all watercourses in the ISMP study area have been culverted and developed. As a result, the overall amount of spawning habitat in the ISMP study area is limited.
- Currently, the best spawning and rearing habitat for salmonids can be found: (1) in Watershed Creek (between the BNSF railway culvert and Kittson Parkway); (2) in Shaw Creek (between the BNSF railway culvert to the bottom of the clay ravine north of Highway 10; (3) in the 60th Ave Ditch. Unfortunately, due to fish passage barriers, this habitat is not all available to anadromous species (see section below).
- Instream fish habitat was improved within Watershed Creek in 2006. A large oxbow adding 80 m of rearing habitat and three large riffles for chum spawning was created on the portion of Watershed Creek immediately upstream of the BNSF Railway culvert crossing within the lowland portion of Watershed Park.

Link to Watershed Health

Historical instream fish habitat has been degraded in the upland reaches, where spawning habitats have been culverted and replaced by development, and in the lowlands, where rearing and overwintering habitats (for species moving in from Boundary Bay) have been dyked and channelized. Although likely not a highly productive watershed historically (due to the limited size of upland spawning areas), the productive capacity of the watershed has been diminished.

Fish Barriers

The following structures or crossings may present barriers to fish passage (see Figure 2-8):

- Oliver Pump Station: Although some fish likely do make it through the current floodbox, fish passage is likely impeded. Four new Archimedes screw pumps have been installed as part of a pump station upgrade in 2011 (R. Racine, pers. comm.) and will improve fish passage.
- Irrigation weir/dam on Lorne Ditch just west of 112th St (May–October) (Figure 2-8): An irrigation weir is used during the growing season to maintain water levels within the 112th St and associated ditches. As a result, during the dry season, all flow is diverted south down the 112th St Ditch. Access to Big Slough via Lorne Ditch is blocked and water levels vary by 60 cm on either side of the dam.
- 112th St Ditch, south of Lorne Ditch (October–May): When the irrigation weir is not in place, Rithaler and Rithaler (2003) reports that the 112th St Ditch channel is elevated and fish may not be able to pass through this section. Spawner access is still available to upstream areas via Big Slough and Lorne Ditch.
- Shaw Creek culvert under Highway 91 (CUL_236): This round culvert is 85 m long with a 0.9% slope. DFO's Land Development Guidelines for the Protection of Aquatic Habitat recommend that culvert slope not exceed 0.5% for culverts greater than 24 m in length (DFO, 2002). Further assessment of fish passage through this culvert is needed (see below).
- Watershed Creek culvert under the BNSF Railway (CUL_14): This round culvert is 25 m long with a 2.5% slope. Although this exceeds the recommended 0.5% slope threshold, the culvert does have a natural bottom and flows are typically maintained by influx from the artesian wells upstream. Further assessment of fish passage through this culvert is needed (see below).

- Historic weir within the Shaw Creek ravine south of Highway 10 (Figure 2-8): This old timber weir is located approximately 200 m upstream of Old Highway 10 and creates a cascading waterfall that obstructs fish passage to an additional 70-80 m of fish habitat below the upper Highway 10 culvert (which is a further barrier to fish passage).

Further work to assess culverts (listed in ascending level of effort) would be prescribed as:

1. Field visit to measure water widths and depths, high water mark (if visible), and outfall drops (if any).
2. Examination of water velocities through the culvert - would likely need to measure at different times of year but, most importantly, under range of conditions during the spawning and juvenile migration periods.
3. Fish sampling to identify fish presence on either side of the culvert.

Standard procedures for culvert inspections for fish passage can be found in Parker (2000): http://www.env.gov.bc.ca/wld/documents/wrp/wrtc_11.pdf

Link to Watershed Health

The presence of several fish barriers (1 full, 4 partial) has lowered the productivity of the study area because access to some of the spawning and rearing habitat in the watersheds have been restricted. Potential exists to improve access to some of these areas through removing or modifying barriers.

Watershed and Riparian Forest Cover Assessment

A desktop evaluation of watershed and riparian forest cover was undertaken to assess the amount and distribution of tree canopy cover within different regions of the study area and identify areas for potential riparian forest restoration. Forest cover was digitized on 2008 orthophotos. A standard 30 m buffer on either side of the stream centrelines (60 m total width) across all permanent streams was used to assess riparian forest integrity (RFI) across the study watersheds. Refer to Figure 2-9 for the locations of existing riparian corridors

- Approximately 23.1% (215.6 ha) of the Shaw Creek ISMP study area is forested. Two-thirds of this forest cover is located within Watershed Park and the Shaw Creek ravine south of Highway 10 (66.5%; 143.4 ha). The remainder is scattered throughout the study area in small forest patches in the lowland areas, smaller public parks, street medians, and private yards.
- Across the seven catchments which make up the study area, watershed forest cover ranged from 54.6% (Watershed Creek Tributary) to 6.9% (Southeast Catchment) (Table 2-9).
- Watershed forest cover was 27.0% in the Delta portion of the study area versus 10.8% in the Surrey portion. Watershed forest cover was 10.0% in the ALR portion of the study area versus 32.9% in the non-ALR portion.
- RFI in the major creeks that drain into the lowlands varies from 50.9% (Shaw Creek) to 96.6% (Briarwood Creek) (Table 2-9). Riparian forest integrity in the lowlands is much lower. The lowland ditches and sloughs have approximately 10% RFI.
- RFI is 11.8% in the ALR portion of the study area and 76.9% in the non-ALR portion of the study area.
- Overall, RFI across the study area was 31.0% which is low largely due to the lack of riparian along the lowland watercourses.

Link to Watershed Health

Watershed forest cover plays an important role in maintaining natural watershed hydrology through rainfall interception, capture, and evapotranspiration. The low watershed forest cover in the study area, while comparable to many Metro Vancouver watersheds with similar levels of development, means that these significant hydrologic functions have been lost during development and mitigation is required. Riparian forest cover protects streams by providing cooling shade, stabilizing banks, and supplying instream wood debris. Riparian forest integrity in this watershed is lower than most Metro Vancouver watersheds with similar levels of development, and is a particular problem in the lowlands.

Table 2-9: **Watershed Health Indicators – Watershed and Riparian Forest Cover**

Watershed/ Land Area	Total Area (ha)	Watershed Forest Cover (ha)	Watershed Forest Cover (%)	Riparian Forest Cover (ha)	Riparian Forest Integrity (RFI) (%)
Watershed Ck	137.0	53.6	39.2	6.7	84.2
Watershed Ck Tributary	66.5	54.3	81.7	6.4	88.1
Briarwood Ck	102.7	38.5	37.5	3.1	96.6
Shaw Ck	235.7	35.5	15.0	5.5	50.9
Southeast Catchment	22.7	6.9	30.2	0.0	0.0
Lowlands West	297.5	15.7	5.3	3.6	7.8
Lowlands East	69.3	11.0	15.9	1.4	13.0
Delta Portion	711.3	191.9	27.0	26.4	31.9
Surrey Portion	220.1	23.7	10.8	0.1	3.1
ALR Portion	396.3	39.7	10.0	7.2	11.8
Non-ALR Portion	535.1	175.9	32.9	19.4	76.9
Total Study Area	**931.4**	**215.6**	**23.1**	**26.5**	**31.0**

Terrestrial Species and Habitat

Terrestrial species and their habitats were assessed using existing information supplemented by minor amounts of field work:

- The only confirmed terrestrial Species at Risk from the study area is Great Blue Heron, *fannini* subspecies S2S3B, S4N; Special Concern under SARA; blue-listed in BC). Additional Species at Risk that may potentially inhabit the study area based on typical habitat associations and/or that have known occurrence records within close proximity to the study area (e.g., Burns Bog) are shown in Table 2-10.
- Two red-listed ecological communities at risk in BC have been provisionally identified in the study area: (1) red alder / skunk cabbage (S2; in wet lowland areas of Watershed Park); and (2) Douglas-fir / dull Oregon-grape (S2; upland forest areas in Watershed Park with richer soils) (Table 2-11). These communities are at risk in BC due to their increasing rarity within the lower Fraser Valley and sensitivity to disturbance from development. Both habitat types are largely protected within public parklands although small unprotected fragments may exist in lowland areas.
- In addition to watercourses and riparian areas, other ecologically-important features include all types of wetlands (swamps, shrub-swamps, and sloughs), mature forest patches, old fields, seasonally-flooded fields, and scattered large trees. These features are important either for their inferred ecological value or the presence of one or more ecological communities or species of conservation concern.

Link to Watershed Health

The presence of biodiversity is an indicator of terrestrial ecosystem health. The presence of at least one Species at Risk and two sensitive ecological communities in the study area indicates that remaining natural areas (wetlands and riparian areas, large forest patches) still maintain some function as important habitat reservoirs for biodiversity.

Table 2-10: Confirmed and Potential Species at Risk

Common Name	Scientific Name	Conservation Status				Status and habitat in Shaw Creek watershed	Reference(s)
		Global Rank	Prov Rank	COSEWIC	BC List		
Fish							
Cutthroat Trout, *clarkii* subspecies	*Oncorhynchus clarkii clarkii*	G4T4	S3S4	-	Blue	Confirmed present in Watershed Creek and 112th St Ditch, likely some are anadromous	Rithaler and Rithaler, 2003
Amphibians and Reptiles							
Red-Legged Frog	*Rana aurora*	G4	S3S4	SC (2004)	Blue	Possible; not found in 2000–03 sampling (Rithaler and Rithaler, 2003) but could be present in forested lowlands in parts of Watershed Park	
Birds							
Great Blue Heron, *fannini* subspecies	*Ardea herodias fannini*	G5T4	S2S3B, S4N	SC (2008)	Blue	Forages along most waterways in study area; no occupied breeding sites currently known	
Green Heron	*Butorides virescens*	G5	S3S4B	-	Blue	Possible breeder in forested or shrub wetlands	
American Bittern	*Botaurus lentiginosus*	G4	S3B	-	Blue	Possible breeder in forested or shrub wetlands	
Barn Owl	*Tyto alba*	G5	S3	SC (2001)	Blue	Possible breeder in barns and other structures	
Mammals							
Olympic Shrew	*Sorex rohweri*	G4G5	S1S2		Red	Unlikely; known from Burns Bog (only known population in BC)	
Pacific Water Shrew	*Sorex bendrii*	G4	S1S2	E (2006)	Red	Possible in Watershed Park lowlands	
Trowbridge's Shrew	*Sorex trowbridgii*	G5	S3S4	-	Blue	Probable in forested areas of Watershed Park	
Southern Red-backed Vole	*Scapanus townsendii*	G5	S1	E (2003)	Red	Unlikely; known from Burns Bog pine forest (only known population in BC)	
Invertebrates							
Dun Skipper	*Euphyes vestris*	G5	S3	T (2006)	Blue	Possible; known from Burns Bog at Highway 91 near 72nd Ave	
Autumn Meadowhawk	*Sympetrum vicinum*	G5	S3S4	-	Blue	Possible; known from nearby areas of Burns Bog	
Blue Dasher	*Pachydiplax longipennis*	G5	S3S4	-	Blue	Known from several wetland areas in south Surrey; becoming more common in lower mainland	
Vascular Plants							
Vancouver Island Beggarticks	*Bidens amplissima*	G3	S3	SC (2001)	Red	Found in Delta along Fraser River and in Elgin Heritage Park, Surrey	

Table 2-11: Provisionally Identified Ecosystems at Risk

Common Name	Scientific Name	Conservation Status			Locations
		Global Rank	Prov Rank	BC List	
red alder / skunk cabbage	*Alnus rubra / Lysichiton americanus*	GNR	S2	Red	Wet lowland areas of Watershed Park
Douglas-fir / dull Oregon-grape	*Pseudotsuga menziesii / Mahonia nervosa*	G2	S2	Red	Upland forest areas in Watershed Park with richer soils, particularly southern areas above Highway 10

2.5 Hydrogeology/Geotechnical

Hydrogeological and geotechnical hazard assessments were conducted and the following observations were made.

- Poor draining till and silt & clay soils in uplands.
- Poor draining peat and silt & clay soils in a majority of the lowlands.
- Small area of well draining gravel & sand in the Watershed Creek headwaters.
- Groundwater table in the lowlands is generally high.
- Artesian wells present at the toe of the uplands in Watershed Park.

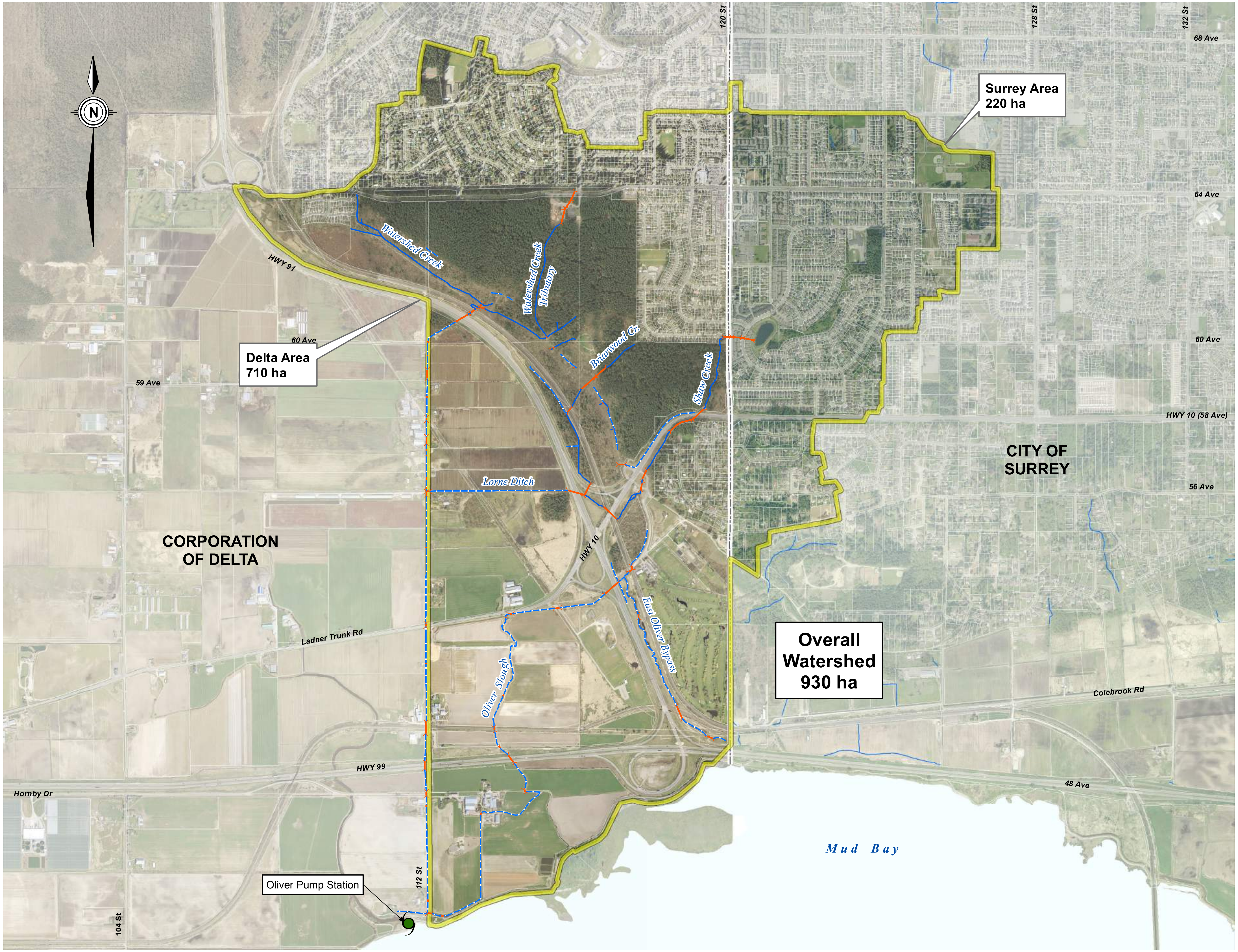
Infiltration rates were estimated for the poorly draining uplands soils (1.5 mm/hr), for the well draining gravel and sand soils (210 mm/hr) and for the lowlands soils (0 mm/hr due to high groundwater table and saturated soils). A soils map of the study area is included as Figure 2-10.

Erosion and Ravine Instability

Trow performed a geotechnical hazard assessment (see Appendix C) and noted the following:

- Numerous erosion sites mainly in Shaw Creek (4 severe locations – see Figure 2-3).
- Historic slope instability noted along Shaw Creek in Watershed Park and below the Panorama Ridge subdivision. Potential for future failures exists.
- Continued erosion of the Highway 10 embankment adjacent to Shaw Creek may pose a risk to the highway over time.
- Erosion at the toe of steep slopes may pose a risk to the Panorama Ridge lots at the top of the Shaw Creek ravine along the southeast side of Highway 10. Toe should be protected by riprap.
- Monitoring of slope movement below Panorama Ridge along Shaw Creek is recommended.

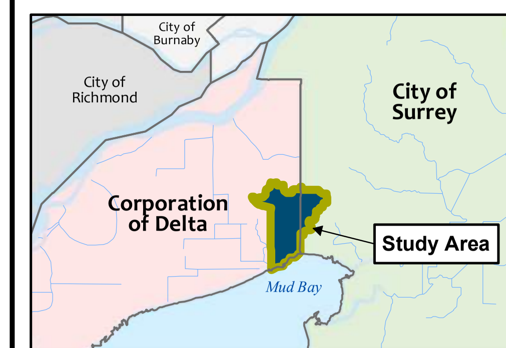
Further detailed geotechnical investigations are needed to provide specific recommendations.



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Culvert
- Ditch
- Creek



Location Map

Topographic, cadastral data and 2008 orthophoto provided by The Corporation of Delta and City of Surrey.

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323-059	January 2012

2008 Air Photo of Study Area

Figure 2-1

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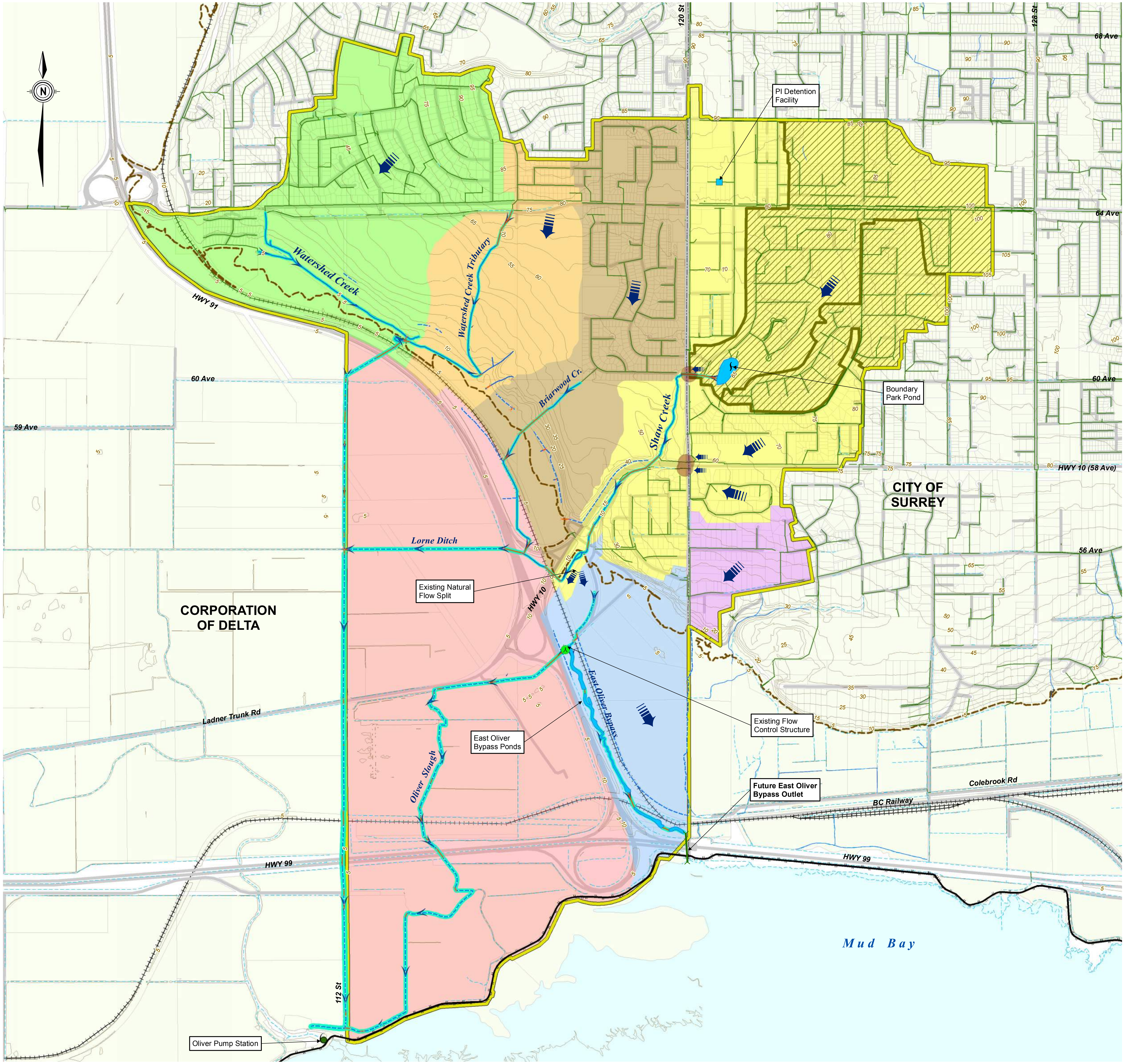

Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Contour (5m Interval)
- Lowland Boundary (5m)
- Railway
- Existing Dyke
- Storm Main
- Ponds/Wetland
- Culvert
- Ditch
- Creek
- Major Drainage Path
- Pond Subcatchment
- Cross Boundary Flow Location
- Overland Flow Direction

Subcatchment

- Watershed Creek
- Unnamed Tributary
- Briarwood Creek
- Shaw Creek
- Southeast Catchment
- Lowlands East
- Lowlands West

Topographic, cadastral data provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January, 2012

Drainage Overview

Figure 2-2

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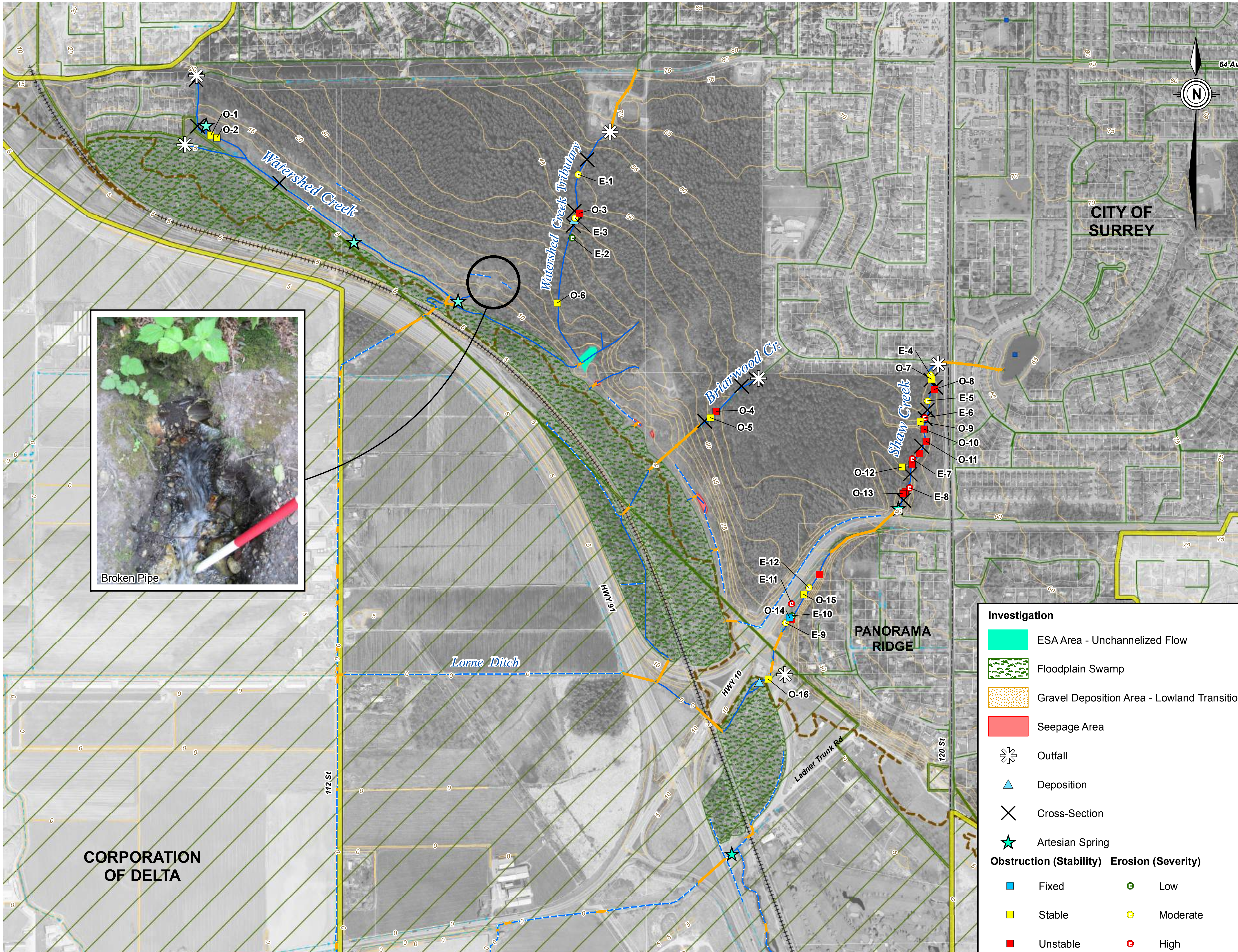
Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study



Legend

- Study Boundary
- Municipal Boundary
- Contour (5m Interval)
- Lowland Boundary (5m)
- Storm Main
- Culvert
- Ditch
- Creek
- ALR Boundary

Topographic, cadastral data nad 2008 orhtophoto provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Erosion and Obstruction Inventory (May 2010)

Figure 2-3

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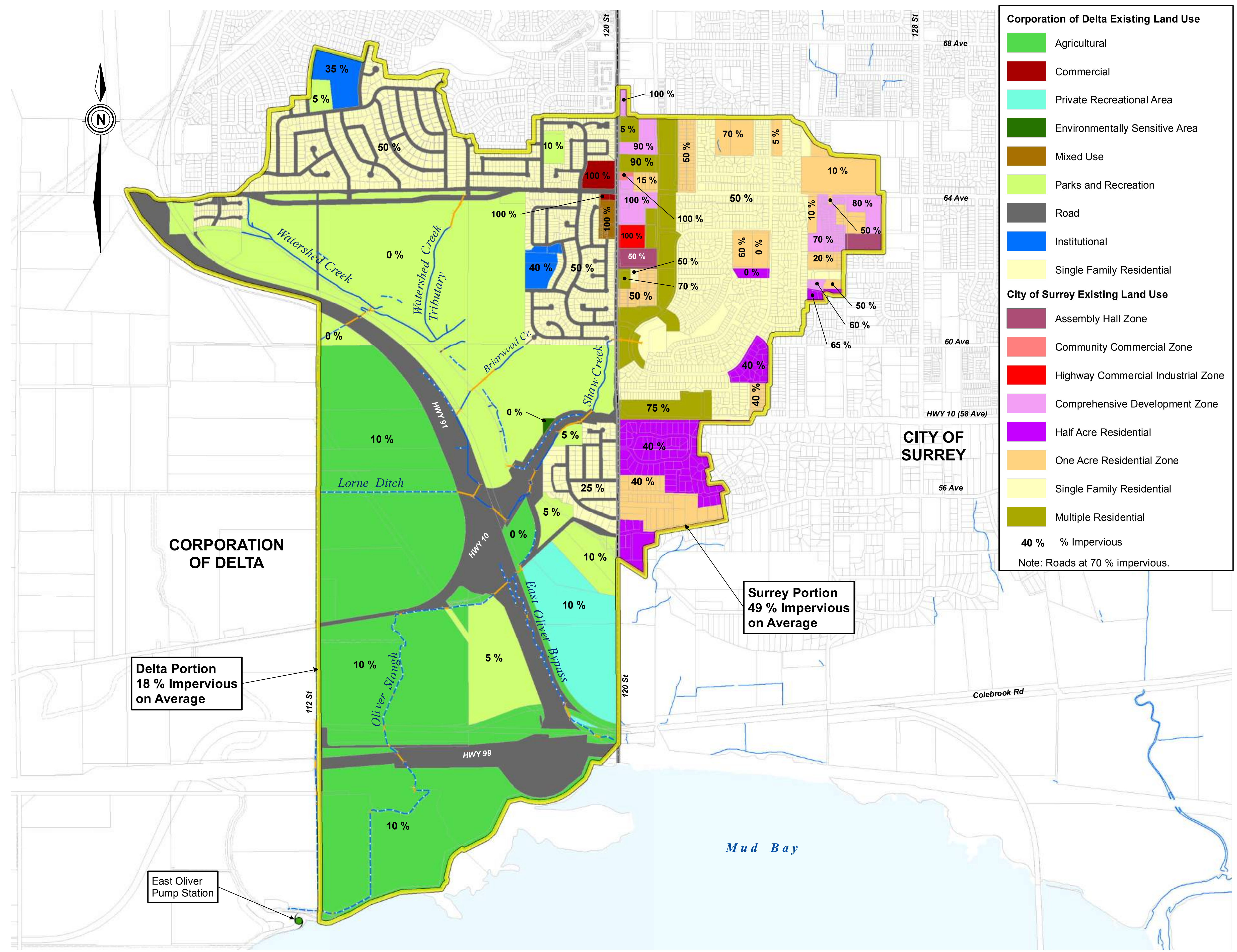
Author: ilau

Corporation of Delta/City of Surrey Boundary/Shaw Integrated Stormwater Management Study



Legend

- Study Boundary
- Municipal Boundary
- Culvert
- Ditch
- Creek

Topographic, cadastral and land use data provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Existing Land Use

Figure 2-4

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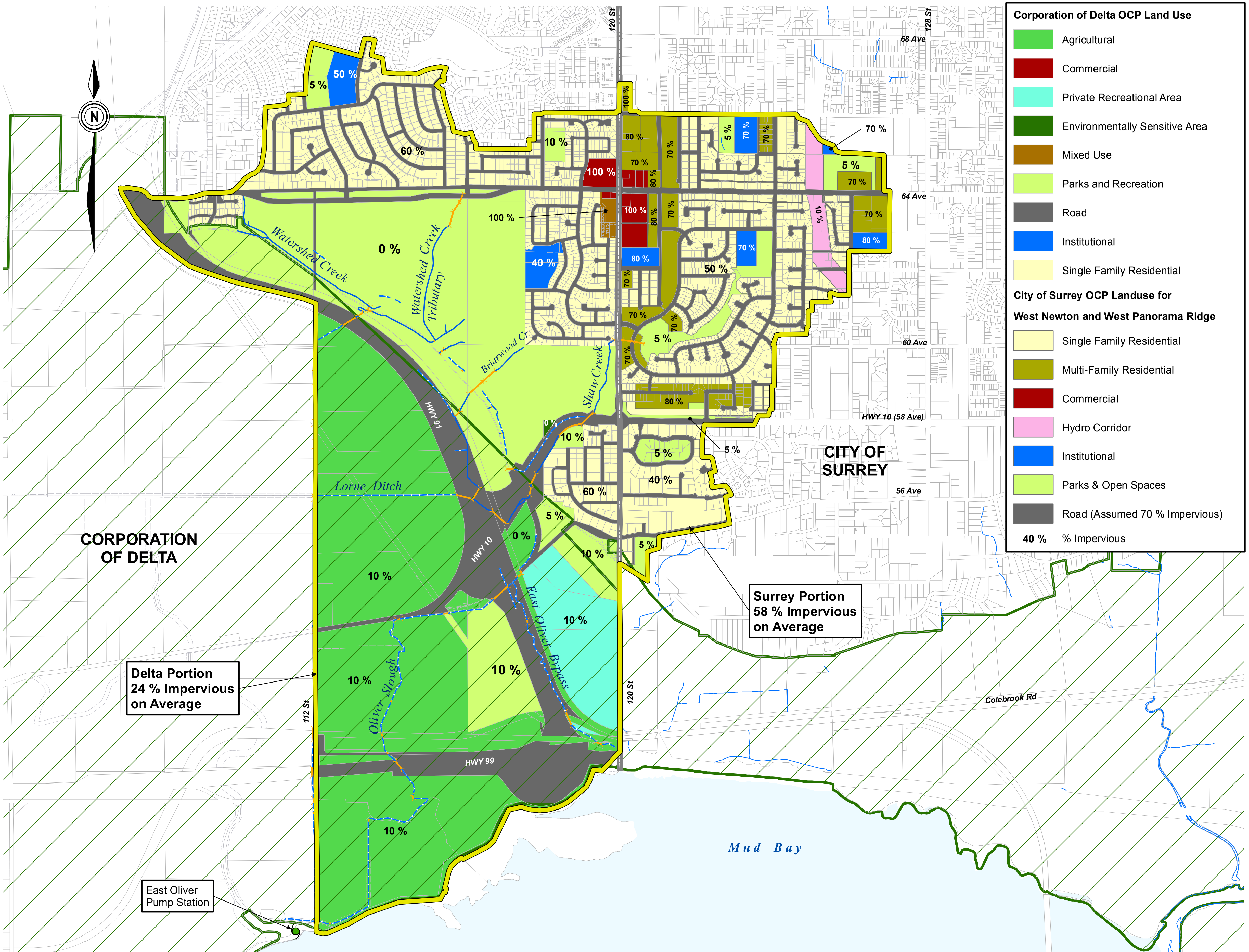
Author: jlau



Corporation of Delta/City of Surrey Boundary/Shaw Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Culvert
- Ditch
- Creek
- ALR Boundary

Topographic, cadastral and land use data provided by The Corporation of Delta and City of Surrey.

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Project No. 323-059
Date January 2012

Future Land Use (OCP)

Figure 2-5

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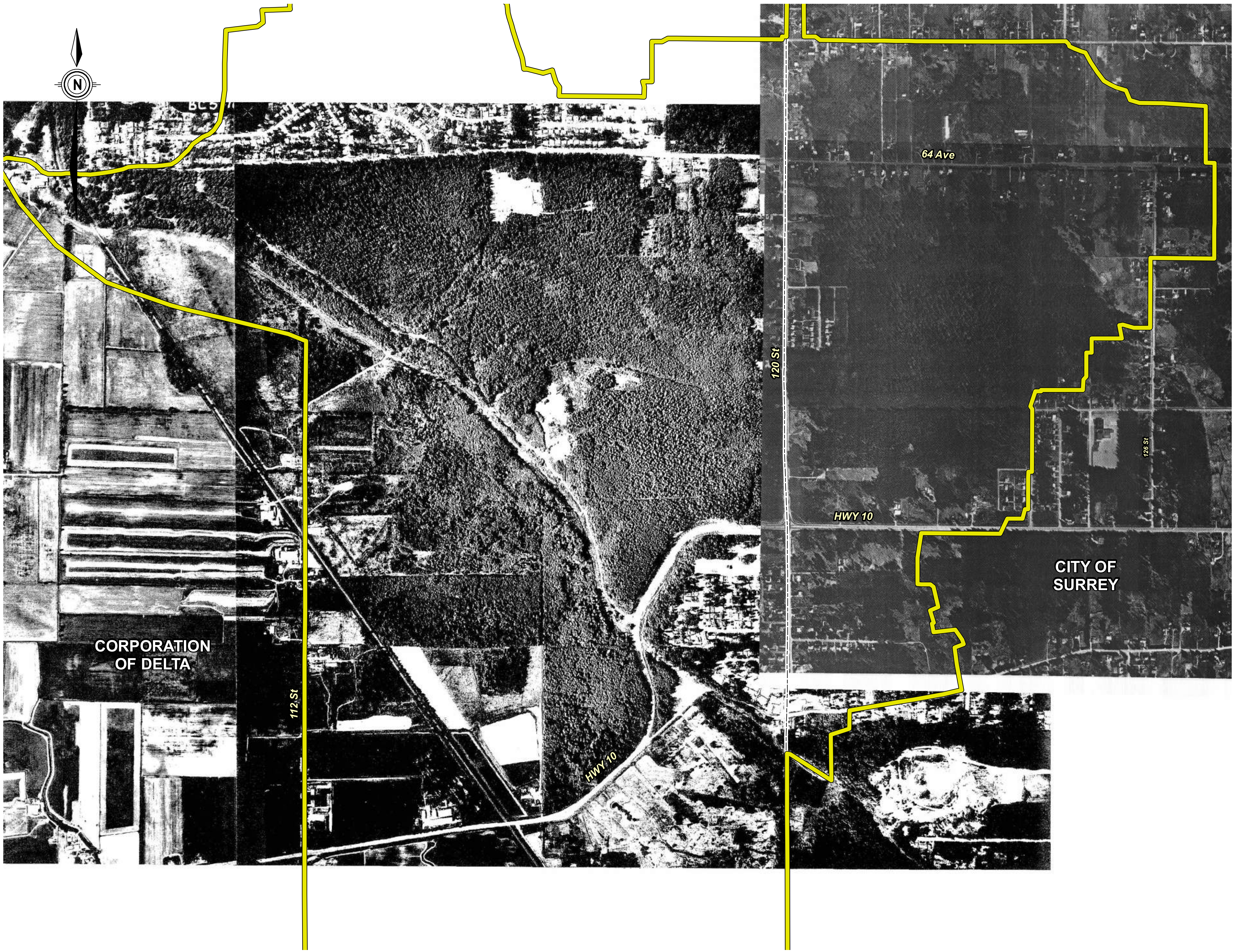
Author: jlau



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

Study Boundary

Municipal Boundary

Aerial photos provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Pre-development Land Use – Delta 1974/Surrey 1976

Figure 2-6

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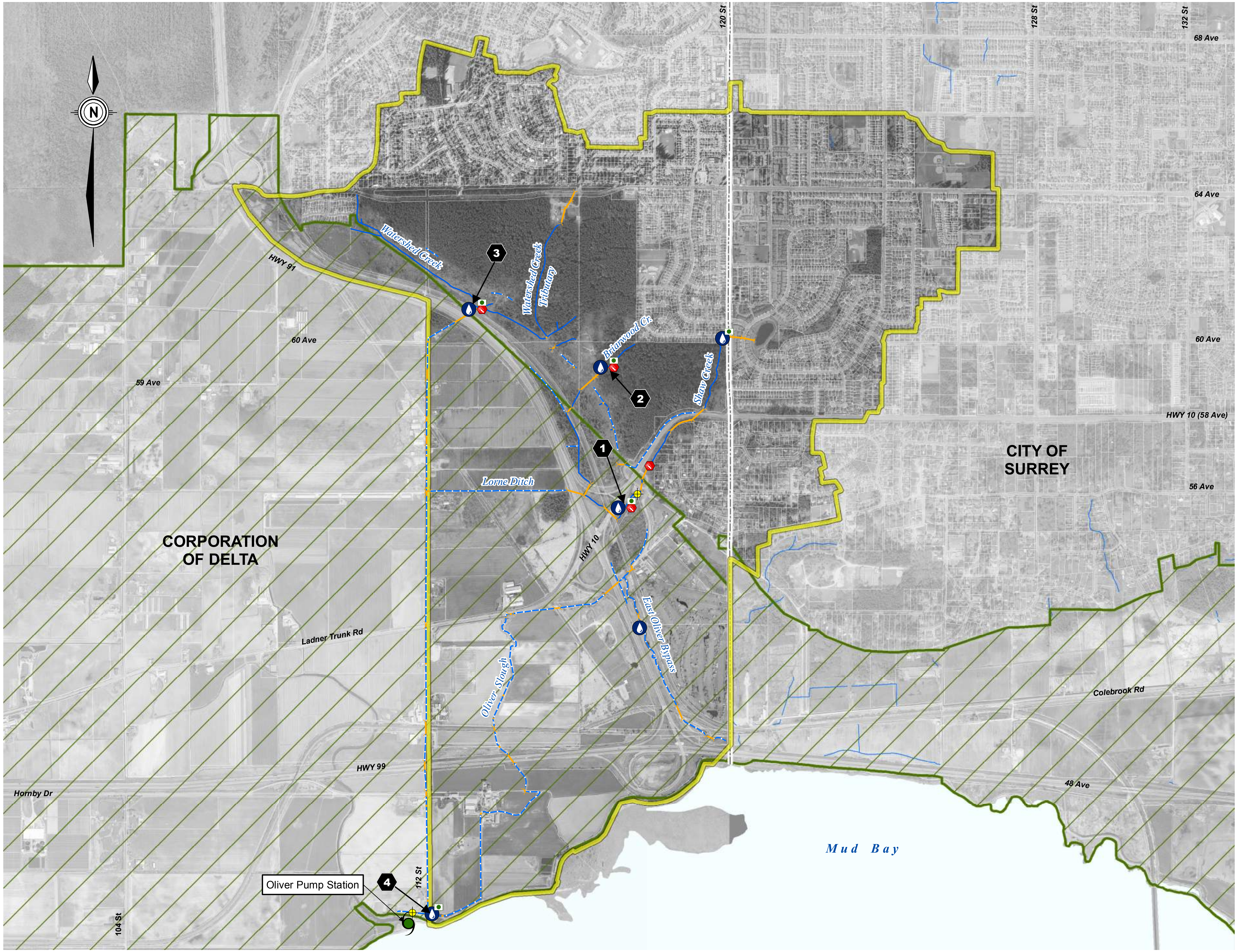
Author: jlau

Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study



Legend

- Study Boundary
- Municipal Boundary
- ALR Boundary

Watercourse (Type)

- Culvert
- Ditch
- Creek
- Benthic sites
- Water Quality Sites
- Temperature Probe
- Sediment Sampling Location
- Watershed Health Tracking System Locations

Topographic, cadastral data and 2008 orthophoto provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Sampling Site Locations

Figure 2-7

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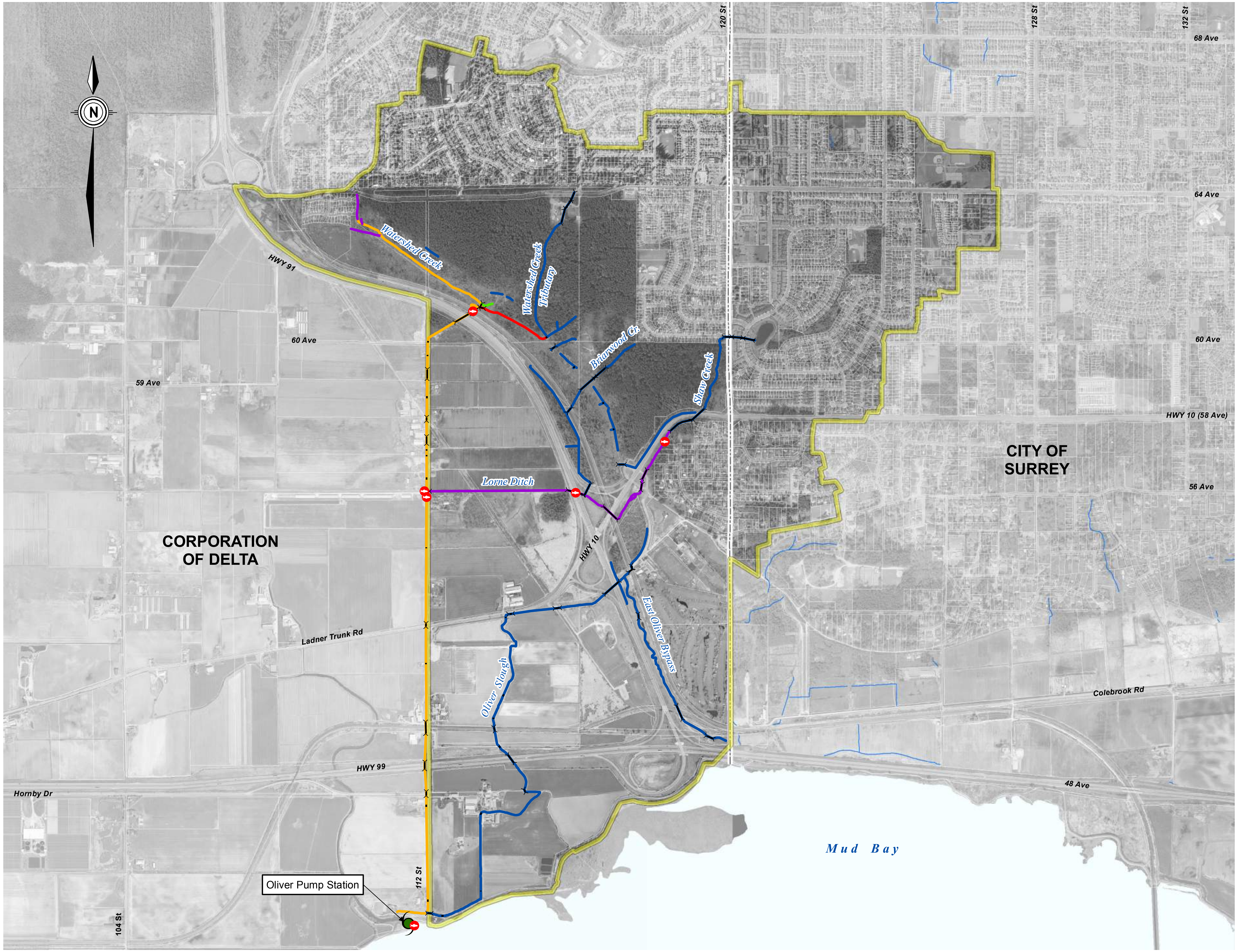
Author: ilau



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

Study Boundary
Municipal Boundary
Culvert
Fish Passage Barrier

Salminoid Presence

Absent
Present - (CO)
Present - (CO, CT)
Present - (CO, CM, CT)
Unknown

Fish Type:

CO - Coho
CM - Chum
CT - Cut Throat Trout

Topographic, cadastral data and 2008 orthophoto provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Fish Communities

Figure 2-8

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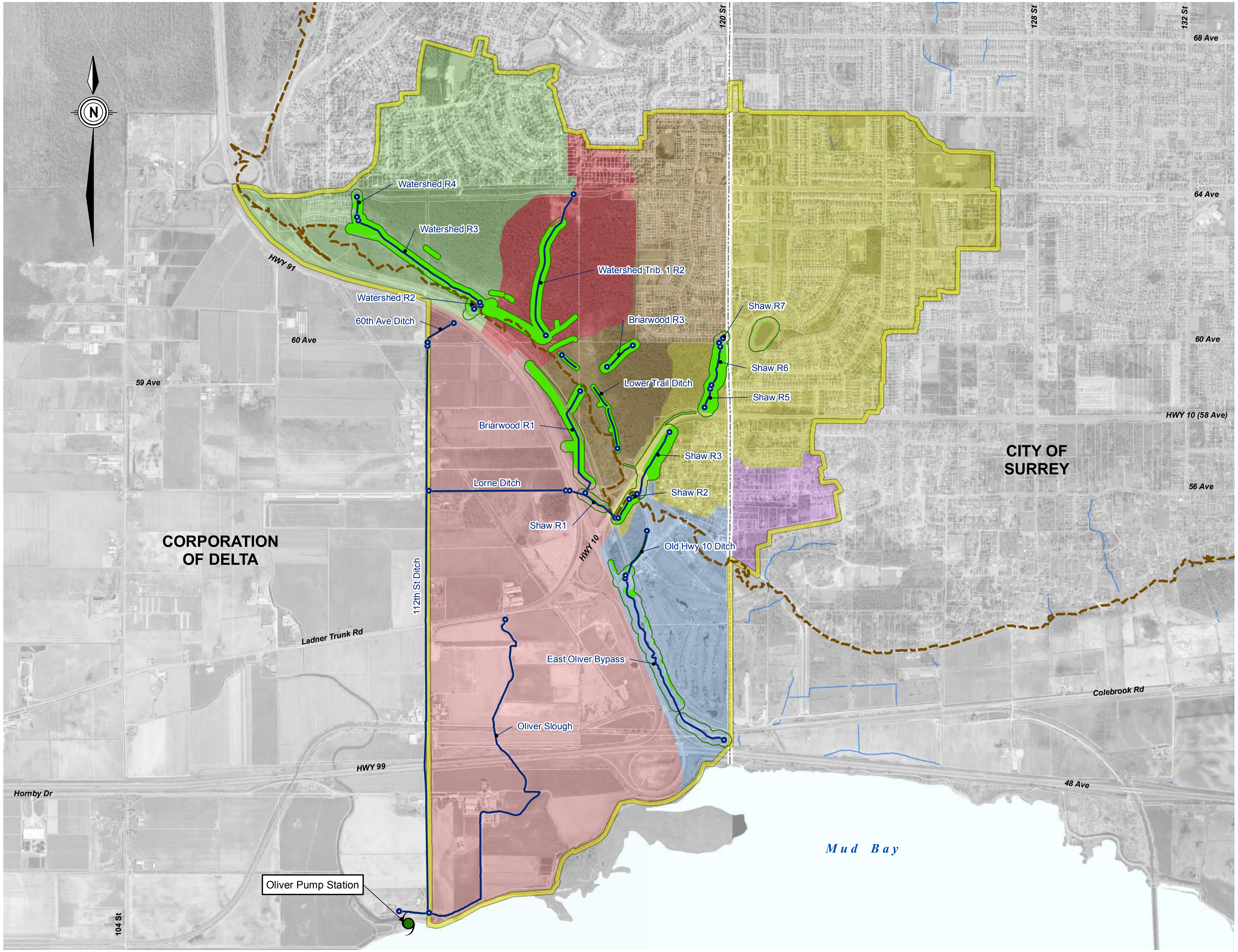
Author: jlau



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Lowland Boundary (5m)
- Culvert
- 30 m RFI Assessment Area
- Forest Cover
- Representative Reach

Subcatchment

- Watershed Creek
- Unnamed Tributary
- Briarwood Creek
- Shaw Creek
- Southeast Catchment
- Lowlands East
- Lowlands West

Topographic, cadastral data and 2008 orthophoto provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Existing Riparian Corridors and Representative Reaches

Figure 2-9

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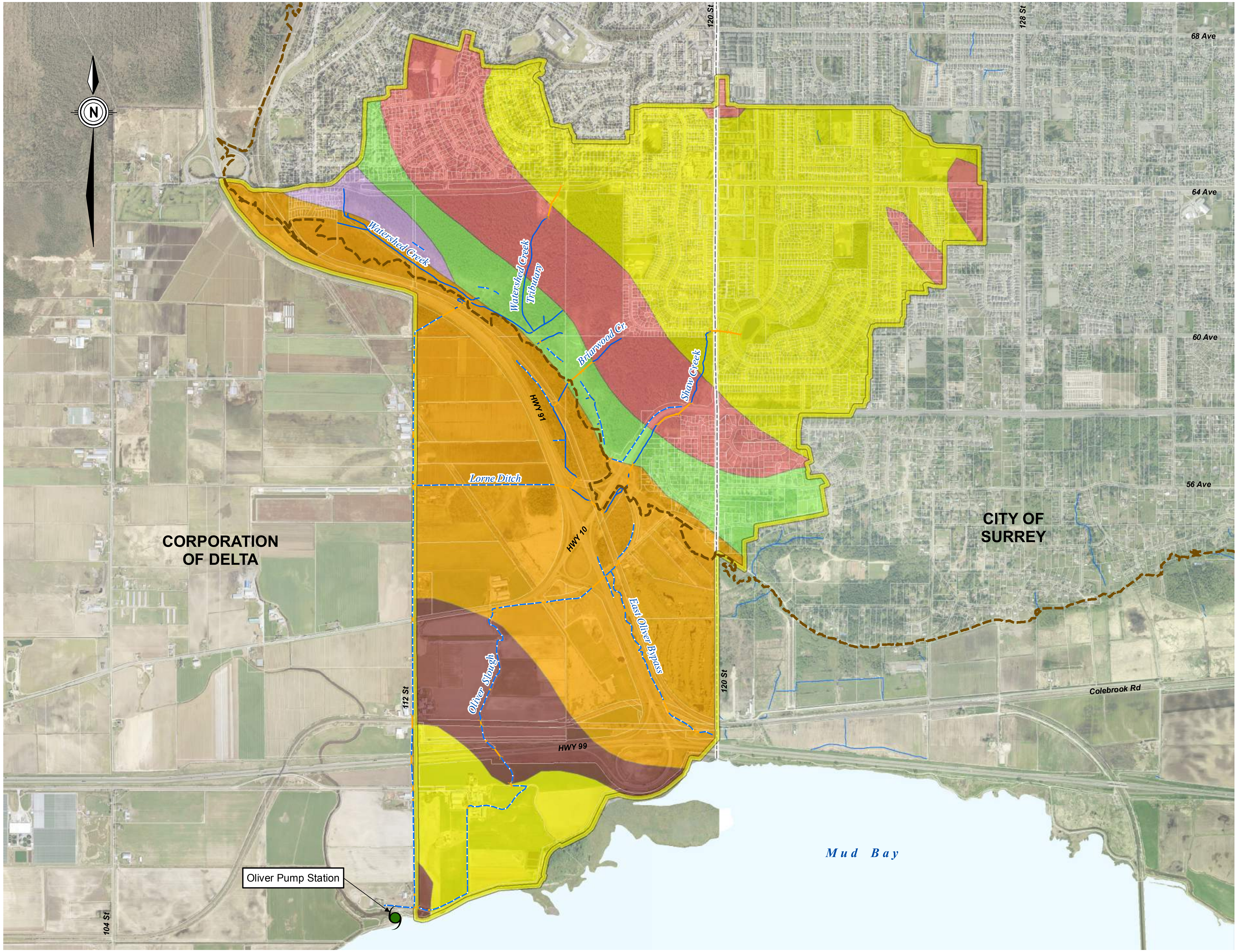
Author: ilau



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Culvert
- Ditch
- Creek
- Lowland Boundary (5 m Contour)

Soil Material (Infiltration mm/hr)

- Gravel and Sands (210 mm/hr)
- Peat (0 mm/hr*)
- Sand and Silt (0 mm/hr*)
- Silt and Clay (1.5 mm/hr*)
- Steepland Sediments (1.5 mm/hr)
- Till (1.5 mm/hr)

*** No Infiltration in Saturated Lowlands**

2008 orthophoto provided by The Corporation of Delta and The City of Surrey.
Surficial Geology Information: Natural Resource Canada and the Geological Survey of Canada

This information is not warranted as to its accuracy by Kerr Wood Leidal Associates and is provided for illustrative purposes only.

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Project No. 323-059

Date January 2012

Soils Map

Figure 2-10

Path: O:\0300-0399\323-059\430-GIS\MXD-Rp\323059Fig2-10_SoilsMap.mxd Date Saved: 1/27/2012 9:20:19 AM
Author: jlau

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Section 3

Watershed Analysis

3. Watershed Analysis

3.1 Hydrologic/Hydraulic Models

XP-SWMM and MIKE11 Model Development

The hydrologic and hydraulic models were developed for previous work done for Delta and were updated for this project. Two models were developed for the Boundary/Shaw watershed, XP-SWMM for hydrology (RUNOFF) and upland hydraulics (EXTRAN) and MIKE11 for lowland hydraulics. XP-SWMM RUNOFF uses inputs such as rainfall and catchment characteristics (area, slope, soil type, etc.) to estimate catchment flows. XP-SWMM EXTRAN and MIKE 11 use hydraulic system inputs (culvert/pipe/channel characteristics) to simulate flow routing, water levels, and flooding.

The models were not calibrated as no recorded flow data was available. The infiltration and groundwater parameters used in the models were based on KWL's database of calibrated model parameters for similar soil conditions in the Lower Mainland. Flow monitoring could be initiated prior to detailed design of any new drainage structures or upgrades in order to validate the model.

Details of the model development and validation are provided in Appendix D.

Design Storms

The drainage system analysis required the creation of three sets of design storms for the various scenarios that were modelled.

- The drainage system analysis was performed using design storms from the Surrey *Design Criteria Manual* (2004) for the Municipal Hall station:
  - the 2-year, 5-year, 10-year, and 100-year return period events for the 12-, 24-, and 48-hour durations;
  - the 6-month 24-hour event (72% of the 2-year 24-hour event); and
  - the ARDSA 10-year return period 2- and 5-day events.. These were used to determine whether the ARDSA criteria are met in the lowland areas.

  The rainfall amounts for each of the design storms are presented in Table D-1 in Appendix D.

Continuous Simulation

Continuous simulation modelling was performed for the pre-development, existing land use conditions with existing flow control, and future land use conditions with existing flow control for the period of 1991 to 2009.

- Rainfall from the GVRD DT34 rain gauge, located in North Delta at 8544 116th Street, was used to perform continuous simulation.
- The period of data available for this gauge is November 1, 1991 to December 31, 2009 and the data was obtained from Metro Vancouver.

The results were extracted and flow durations calculated to create the exceedance duration curves (Figures D-11 to D-13 in Appendix D). These curves were used in the detention facility analysis and to analyze the hydrologic impacts of future densification. The XP-SWMM models were also used to simulate the watershed response during recent large rainfall events in the last five years plus the October and November events of 2003 to quantify the impacts of development.

3.2 Results of Hydrologic/Hydraulic Modelling

Peak Flow Estimates at Strategic Locations

The XP-SWMM models were used to simulate the hydrology and upland hydraulics and to determine peak flows at strategic locations in the watershed. Flow hydrographs from the XP-SWMM models were used as inputs to the MIKE11 models (described below). The models simulated the East Oliver Bypass Ponds not connected to Mud Bay to represent the case as of 2010. Flows were estimated for the 6-month, 2-year, 5-year, 10-year and 100-year storms for the following three scenarios:

- Existing land use conditions without flow control;
- Existing land use conditions with existing flow control (existing detention and structures); and
- Future land use conditions with existing flow control.

Peak flow estimates are shown in Tables 3-1 to 3-3 below. As shown, the Watershed Creek, Watershed Creek Tributary, and Briarwood Creek flows are not influenced by the flow control as no detention or flow split structures are present in these areas. Furthermore, if left unmitigated, the future land use would increase 2-year to 100-year peak flows by approximately 5% to 10% and the 6-month flows by 20% to 40%.

Table 3-1: Flows at Strategic Locations for Existing Land Use with Existing Flow Control

Location	Peak Instantaneous Flow Estimate (m^3/s)				
	6-month[1]	2-year	5-year	10-year	100-year
Watershed Creek at BNSF Rail	0.59	1.77	2.47	2.95	4.48
Watershed Cr Tributary at mouth	0.29	0.88	1.26	1.50	2.26
Briarwood Creek at BNSF Rail	0.42	1.21	1.71	2.08	3.24
Shaw Creek at 120 Street Outfall	0.77	1.92	2.65	3.35	4.92
Shaw Flow Split to Lorne Ditch	0.82	1.78	2.29	2.50	3.18
Shaw Flow Split to Oliver Slough	0.07	0.15[2]	0.19[2]	0.24[2]	0.32[2]
Shaw Flow Split to East Oliver Bypass Ponds	0.13	0.50	0.68	0.76	0.97

[1] Only the 24-hour storm was simulated for the 6-month return period.
All flows are governed by the 12-hour design storm except:
[2] 48-hour duration governs

Table 3-2: Flows at Strategic Locations for Existing Land Use with No Flow Control

Location	Peak Instantaneous Flow Estimate (m^3/s)				
	6-month[1]	2-year	5-year	10-year	100-year
Watershed Creek at BNSF Rail	0.59	1.77	2.47	2.95	4.48
Watershed Cr Tributary at mouth	0.29	0.88	1.26	1.50	2.26
Briarwood Creek at BNSF Rail	0.42	1.21	1.71	2.08	3.24
Shaw Creek at 120 Street Outfall	1.16	3.02	4.13	4.80	6.79
Shaw Flow Split to Lorne Ditch	1.09	2.27	2.58	2.76	3.42
Shaw Flow Split to Oliver Slough	0.11	0.29[2]	0.40[2]	0.53[2]	0.81[2]
Shaw Flow Split to East Oliver Bypass Ponds	0.15	0.40	0.45	0.48	0.57

[1] Only the 24-hour storm was simulated for the 6-month return period.
All flows are governed by the 12-hour design storm except:
[2] 48-hour duration governs

Table 3-3: Flows at Strategic Locations for Future Land Use with Existing Flow Control

Location	Peak Instantaneous Flow Estimate (m^3/s)				
	6-month[1]	2-year	5-year	10-year	100-year
Watershed Creek at BNSF Rail	0.70	1.90	2.62	3.16	4.68
Watershed Cr Tributary at mouth	0.32	0.88	1.26	1.51	2.26
Briarwood Creek at BNSF Rail	0.51	1.35	1.94	2.32	3.46
Shaw Creek at 120 Street Outfall	0.99	2.09	2.84	3.43	5.12
Shaw Flow Split to Lorne Ditch	1.04	2.00	2.45	2.63	3.39
Shaw Flow Split to Oliver Slough	0.08	0.16[2]	0.20[2]	0.24[2]	0.32[2]
Shaw Flow Split to East Oliver Bypass Ponds	0.21	0.58	0.74	0.81	1.02

[1] Only the 24-hour storm was simulated for the 6-month return period.
All flows are governed by the 12-hour design storm except:
[2] 48-hour duration governs

Unit peak flows from the model were checked against unit flows estimated for similar creeks in the Lower Mainland. Table 3-4 shows the unit peak flow comparison.

Table 3-4: Unit Peak Flow Comparison

Location	Peak Flow (L/s/ha)			
	2-year	5-year	10-year	100-year
Residential Catchment				
Shaw Creek ISMP	16.7	22.4	26.0	36.6
Quibble Creek 619ha 44% TIA (Surrey) – calibrated model	14	24	-	48
Upper Serpentine 199ha 66% TIA (Surrey) – calibrated model	19	29	-	45
Surrey Design Criteria Manual - Table 5.3 (j) – SFR Runoff Design Value	17	-	-	-
Largely Undeveloped Catchment				
Shaw Creek ISMP	8.4	12.1	14.6	23.6
Mackay Creek 363ha 8% TIA (North Vancouver) - recorded	15.4	22.9	28.3	48.3
MacDonald Creek 394ha 9% TIA (West Vancouver) – calibrated model	20	-	44	66
Partington Creek 442ha 3% TIA (Coquitlam) – calibrated model	15	23	24	39
Clayburn Creek 1580ha 7% TIA (Abbotsford) - calibrated model	5.9	6.1	8.1	15.1
Morgan Creek 186ha 16% TIA (Surrey) – calibrated model	6	8	-	16
Archibald Creek 220ha 16% TIA (Surrey) – calibrated model	6	12	-	24
Surrey Design Criteria Manual - Table 5.3 (j) – Forested Runoff Design Value	5	-	-	-

In general, the unit flows from the model were inline with the estimates for similar creeks.

Refer to Figure D-1 in Appendix D for the catchments and modelling schematic.

Capacity Assessment

A culvert capacity assessment was performed to determine if any culverts were undersized and required upgrading. The assessment criteria were:

- For culverts under major roads (Highways 10, 91 and 99) or the railway, the culverts were evaluated using the 100-year peak flow (as per MOT and Delta criteria) limiting the surcharge time to 30 minutes.
- For culverts under minor crossings, the culverts were evaluated using the 10-year peak flow (as per Delta criteria) limiting the surcharge time to 30 minutes.
- For lowland culverts under minor crossings, the culverts were evaluated using the 10-year peak flow and a maximum head loss of 250 mm over the length of the culvert (as per Delta criteria).

The results indicated:

- Ten culverts, shown on Figure 3-1, did not meet the criteria for both the existing and future land use flows. Two creek crossings were surcharged during the 100-year event, and eight were surcharged in the 10-year event.

- Refer to Tables D-2 to D-5 in Appendix D for the results of the analysis for all culverts.

Detention Facility Assessment

A detention facility assessment was performed to determine the effectiveness of the existing flow control facilities and to determine modifications that would improve their effectiveness using both design events and continuous simulation. Figures D-3 to D-10 in Appendix D show the detention pond hydrographs and Figure D-11 shows the Shaw Creek exceedance duration curve which is influenced by the Boundary Park Pond. Figure 2-2 shows the facility locations.

- Boundary Park Pond is being fully utilized but it is not quite able to detain the 2-year and larger peak flows to pre-development values (see red and green hydrographs on Figures D-4 to D-6 in Appendix D). There is room for improvement by adjusting the outlet control structure (see blue hydrograph on Figures D-4 to D-6); however testing showed that this would result in an increase in exceedance duration of frequent small flows.
- Boundary Park Pond reduces the flow energy to half way between undetained existing land use and historic land use flows in Shaw Creek (see Figure D-11 in Appendix D). This is reasonable as only a portion of the Shaw Creek catchment is serviced by the pond.
- Improving the Boundary Park Pond outlet has limited effect on flow energy. A larger detention volume and capture source controls would be needed for additional benefit.
- Detention Tank P1 (6455 121 St) is not being fully utilized. An orifice is needed to improve its performance. The detention volume is insufficient to reduce peak flows to pre-development even with improvements to the control structure (see Figures D-7 to D-10 in Appendix D).
- East Oliver Bypass Ponds are currently acting as offline detention to effectively reduce peak flows into the lowlands as follows:
  - 10-year 12-hour: 0.77 m^3/s reduced to 0.06 m^3/s (92% reduction)
  - 10-year 24-hour: 0.75 m^3/s reduced to 0.11 m^3/s (85% reduction)
  - 10-year 48-hour: 0.72 m^3/s reduced to 0.15 m^3/s (79% reduction)
  - 100-year 12-hour: 0.89 m^3/s reduced to 0.11 m^3/s (88% reduction)
  - 100-year 24-hour: 0.85 m^3/s reduced to 0.15 m^3/s (82% reduction)
  - 100-year 48-hour: 0.79 m^3/s reduced to 0.25 m^3/s (68% reduction)

  Their effectiveness at reducing flows to the lowlands will be further improved when the East Oliver Bypass works are completed by interconnection to Eugene Creek/Mud Bay. The East Oliver bypass 100-year peak water level is approximately 1.76 m Geodetic.

Lowland Flooding Assessment

The MIKE11 software was used to model the lowland drainage system and determine maximum flood levels, flood durations and freeboard during baseflow for the lowland cells for the ARDSA 10-year 2-day growing season and 10-year 5-day winter events. A designated ground elevation which represents the 5th percentile of land elevations in the cell (i.e. 95% of the land in the cell is higher than this elevation) was estimated for each cell. The catchment flow hydrographs were generated using the XP-SWMM model and input into the MIKE11 model. The criteria used for evaluation is presented in Table 1-2.

ARDSA events were run for the existing land use conditions with existing flow control and the future land use conditions with existing flow control. Peak water levels, flood durations, freeboard and designated ground elevations are shown in Tables 3-5 and 3-6 below and in Figure 3-2.

Table 3-5: 10-Year 2-Day Peak Water Levels and Flooding Durations for the Lowland Cells

Cell ID	Designated Ground Elevation (m)	Existing Land Use		Future Land Use	
		Max. Flood Level (m)	Flood Duration (Days)	Max. Flood Level (m)	Flood Duration (Days)
31E	0.4	0.44	0.3	0.45	0.3
27E	0.3	0.49	0.5	0.49	0.5
28E	0.6	0.47	0	0.47	0
12E	0.4	0.48	0.3	0.48	0.3
Golf Course	1.2	1.30	0.8	1.32	0.9

Table 3-6: 10-Year 5-Day Peak Water Levels and Flooding Durations for the Lowland Cells

Cell ID	Freeboard (m)	Existing Land Use		Future Land Use	
		Max. Flood Level (m)	Flood Duration (Days)	Max. Flood Level (m)	Flood Duration (Days)
31E	0.95	0.48	0.4	0.48	0.4
27E	1.35	0.50	0.9	0.50	0.9
28E	1.65	0.48	0	0.48	0
12E	1.70	0.49	0.3	0.49	0.3
Golf Course	1.70	1.37	0.9	1.39	0.9
Shading indicates that the Cell fails the ARDSA freeboard during baseflow criterion.					

The existing and future land use conditions models indicate the following:

- The existing 6 m^3/s Oliver Pump Station and floodboxes are adequate to meet the ARDSA flooding duration criteria in all of the lowland cells in the study area.
- The ARDSA freeboard (>1.2m) during baseflow criterion is met in four of the five lowland cells. Cell 31E does not meet the freeboard criterion (0.95m). To meet the freeboard criterion in Cell 31E, the 112 Street ditch and all culverts including Highway 10, Highway 99, and the Railway would have to be lowered. This would require the cooperation of the Ministry of Transportation and the Railway Authority. Through discussions with Delta it was determined that servicing Cell 31E for additional freeboard would not be pursued.
- Delta Golf Course flooding meets the ARDSA flooding duration and freeboard criteria.
- Future land use conditions with no drainage improvements in general do not make the depth and duration of flooding measurably worse (in the Delta Golf Course the 10-year water level may increase by 2 cm)
- With the existing drainage configuration, less than 1/4 of 10-year Shaw Creek flow is going to the East Oliver Bypass ponds. Connecting the Bypass ponds at the south end to the Eugene Creek outlet into Mud Bay would increase the amount of flow passing through the ponds thereby reducing the peak flows to the farmland.

- Delta has recently upgraded the Oliver Pump Station capacity from 6 m^3/s to 9 m^3/s by adding four fish-friendly Archimedes screw pumps. This upgrade occurred after the analysis was performed and therefore the results do not account for the resulting improved level of service. The existing pump ON/OFF levels are -0.8 m/-1.1 m. If possible, it is recommended that the ON/OFF levels for this new pump are set to -1.2 m/-1.6 m Geodetic for the winter condition so that the land west of 112 Street that drains towards the pump station (DGE = -0.2 m Geodetic) will receive 1.2 m of freeboard during baseflow. Higher ON/OFF pump settings would be used in the growing season to increase water available for irrigation.

The lowlands flooding with irrigation controls in place was to be assessed. However, there are no irrigation structures within the study boundary and the Oliver Pump Station settings are identical in the winter and growing seasons. KWL was informed that there are baffles installed from June to November at the Oliver Pump Station, however, no height details were available. Furthermore, the irrigation structure near 112 Street and Lorne Ditch is just outside the study area boundary and was not assessed. The only other structure present is the East Oliver Bypass control structure whose settings do not change from season to season.

Hydrologic Impacts of Future Densification

The results of the XP-SWMM model continuous simulation and exceedance duration curves for the pre-development, existing, and future land use scenarios (Figures D-11 to D-13 in Appendix D) indicated that unmitigated future land use densification would increase the flow in Shaw, Watershed, and Briarwood Creeks, mainly for infrequent large storms and rare large floods. A 20% to 40% increase above pre-development values was also noted in the 6-month to 5-year flows for a given flow duration. This shows the need for stormwater measures to mitigate these impacts to not exacerbate erosion and avoid degradation of aquatic habitat.

The existing erosion in the portion of Shaw Creek between Highway 10 and the Panorama Ridge development should be monitored and critical locations stabilized to prevent future impacts to the Highway 10 embankment and the Panorama Ridge development.

Watershed Performance during Recent Large Storms

The XP-SWMM models were also run to simulate the watershed response during recent large rainfall events. The results of these simulations are presented in Appendix D. The large events were run for the pre-development, existing, and future land use conditions with existing flow control.

- Six events were extracted from the continuous simulation models and presented for the Watershed Creek at BNSF Railway and Shaw Creek at 120 Street Outfall locations (see Figures D-14 to D-25 in Appendix D).
- The hydrographs show that the existing and future land use condition scenarios are similar in their response to the storms. The existing and future peak flows are higher than the pre-development peak flow especially during large dry initial condition events.

3.3 Watershed Health Tracking System

The watershed health was estimated using the Watershed Health Tracking System (WHTS) which uses the indicators of impervious percentage and riparian forest integrity to estimate the benthic index of biotic integrity (B-IBI) score. Figures 3-3 and 3-4 show the WHTS graphs for a number of locations in the study area as shown on Figure 2-8. Site 5 does not represent a single physical location but rather the sum of the entire non-ALR area. This point was included on the WHTS because neither the Delta Streamside Protection and Enhancement Areas Bylaw or the Riparian Areas Regulation apply to ALR land or agricultural operations and therefore Site 5 represents the portion of the study area where riparian protection is mandatory.

The B-IBI samples collected, as discussed in Section 2.5, resulted in the scores shown in Table 3-6. There was general agreement between the measured score and that predicted by the WHTS from impervious area and riparian forest integrity.

Table 3-7: Measured and Predicted B-IBI Scores

Sampling Location	2010 B-IBI Score	
	Measured	WHTS Predicted
1. Shaw Creek at Old Highway 10	16	14
2. Briarwood Creek upstream of Culvert CUL_372	16	15
3. Watershed Creek near BNSF Railway	18	20
See Figure 2-8 for sampling locations.		

The land use analysis shows that imperviousness is predicted to increase by approximately 10%. Upland riparian corridors are expected to remain in the current condition as they are protected by the riparian bylaws and regulations currently in place. Measures will be proposed to mitigate the watershed heath impacts and perhaps to improve stream health in certain areas.

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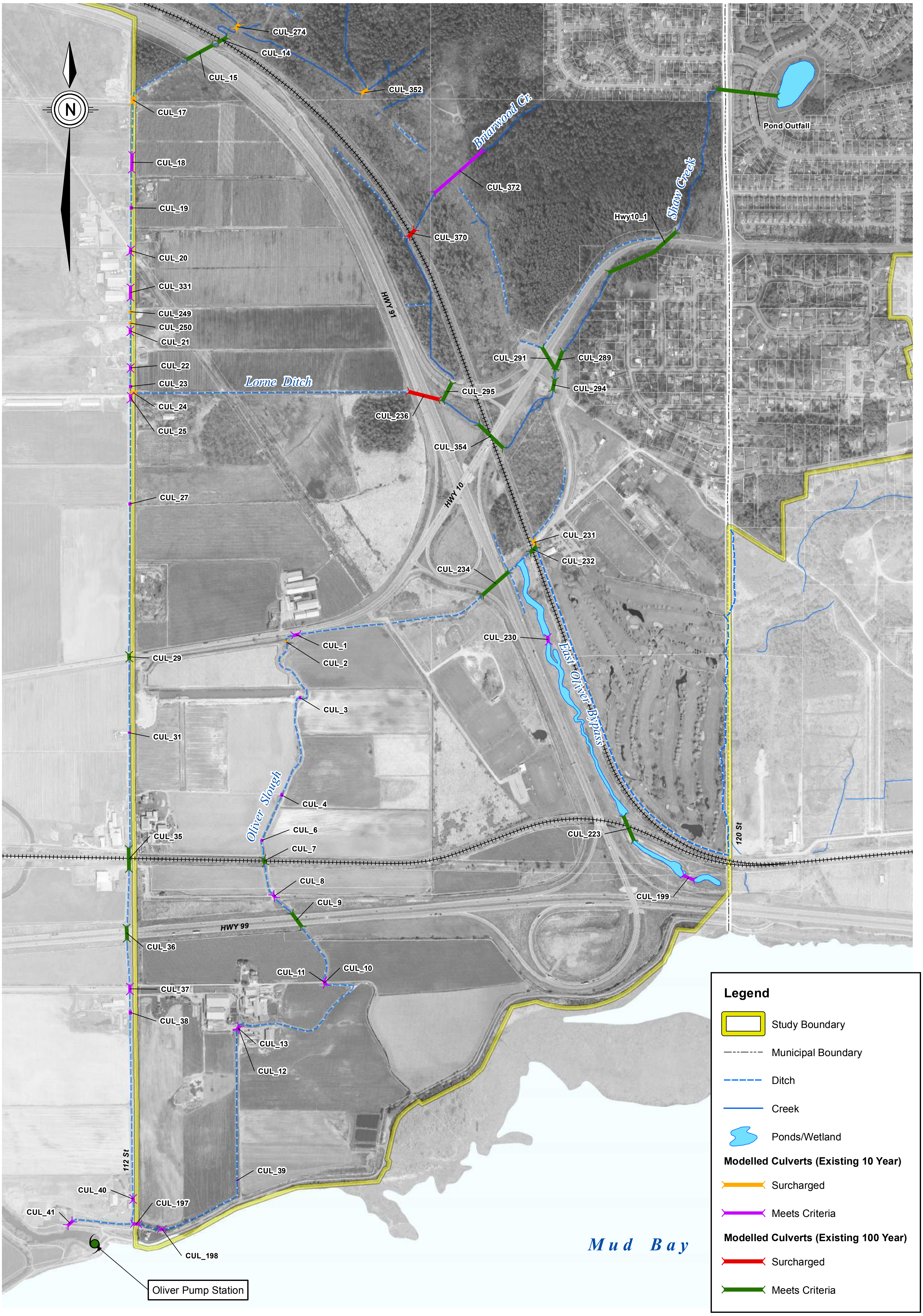
Author: jlau



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Boundary/Shaw Integrated Stormwater Management Study

Project No. 323-059

Date January, 2012

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Hydrotechnical Modelling Results - Existing and Future 10-Year and 100-Year Conveyance

Figure 3-1

Path: O:\0300-0399\323-059\430-GIS\MXD-Rp\323059Fig3-2_LowlandFloodingExtents.mxd Date Saved: 1/27/2012 9:06:15 AM
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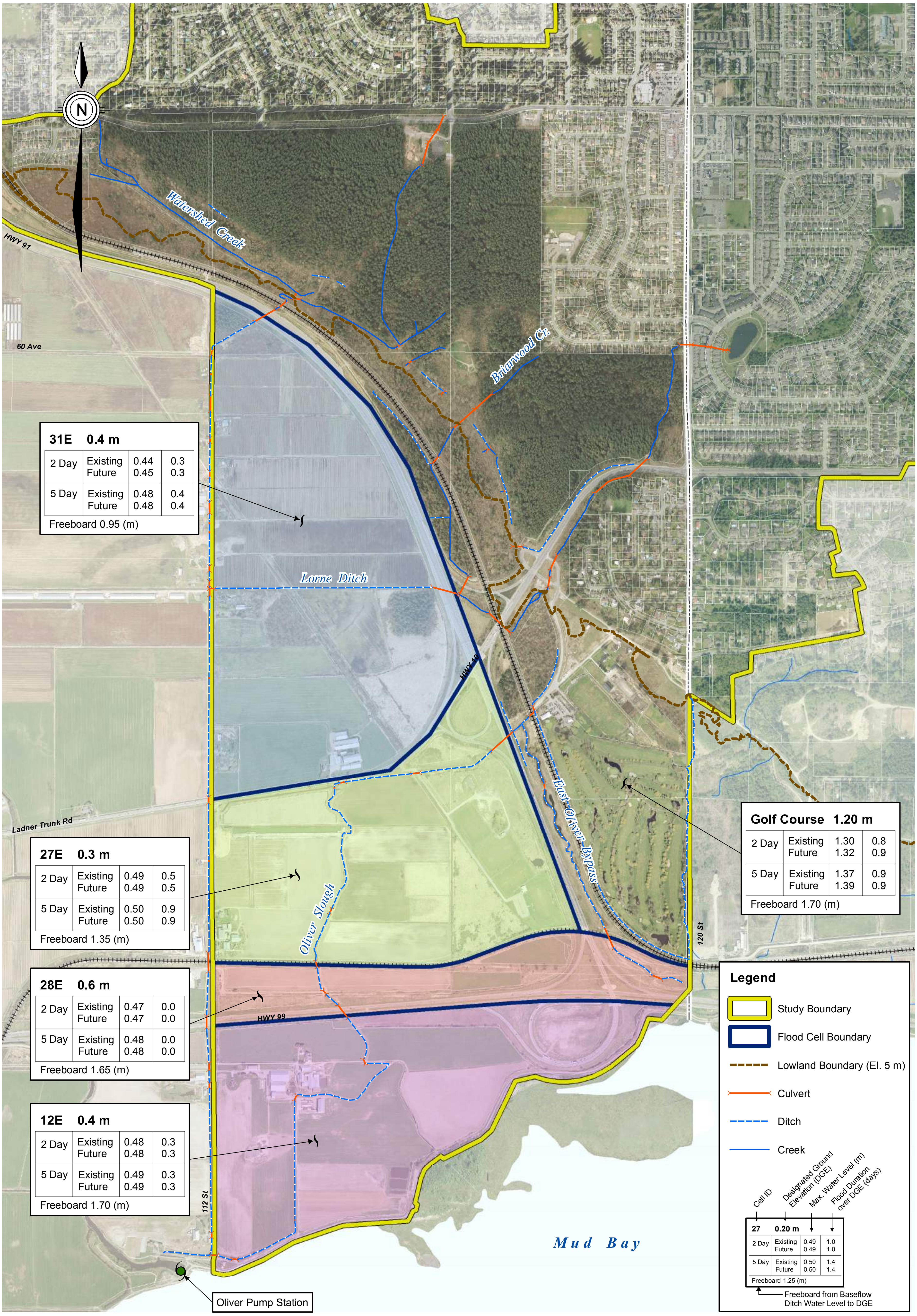

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Corporation of Delta
Boundary/Shaw Integrated Stormwater Management Study

Project No. 323-059

Date January, 2012

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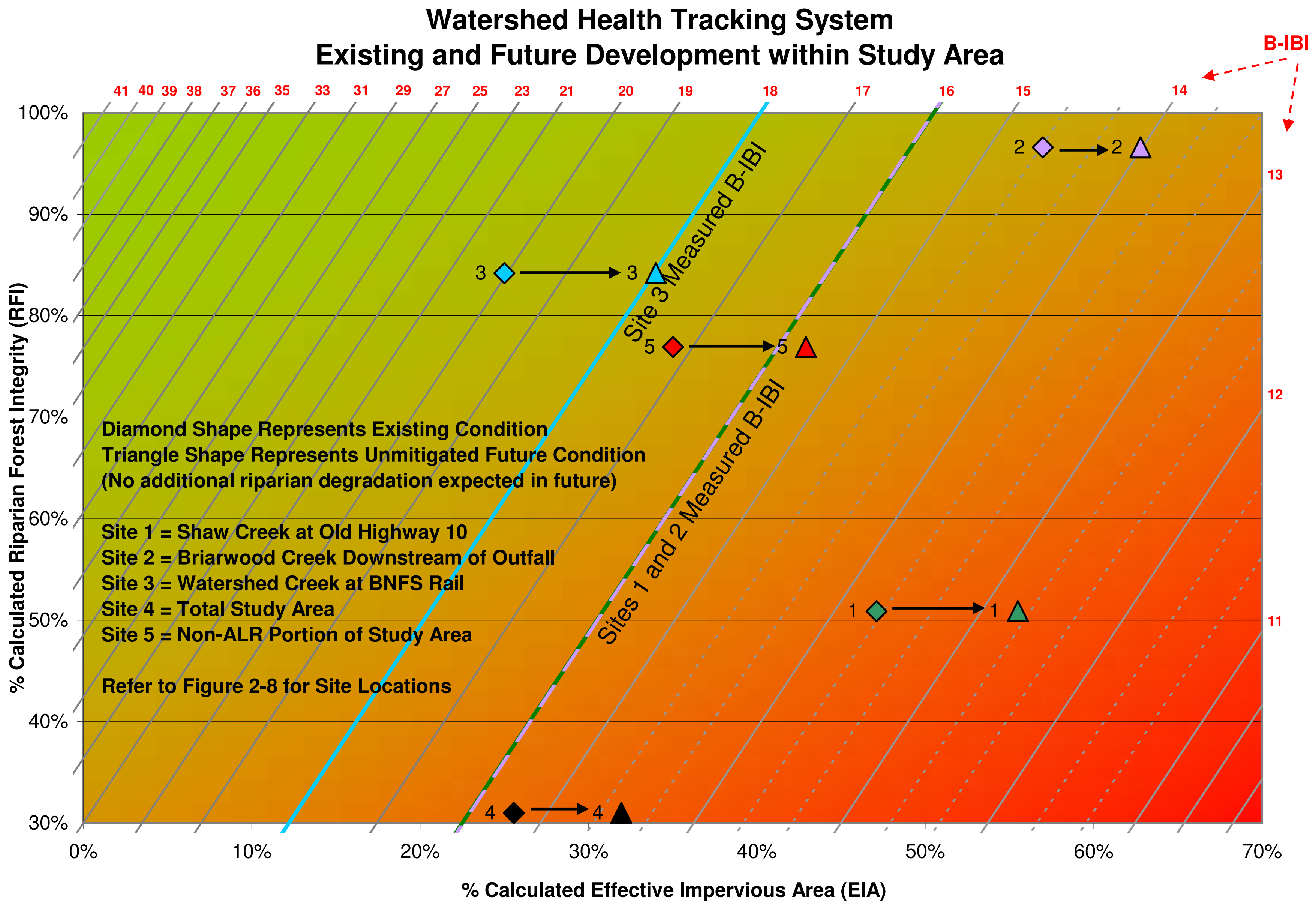
ARDSA Lowland Flooding Extents and Durations

Figure 3-2



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O:\0300-0399\323-059\400-work\WHTS\WHTS_ShawCr_v2.xls[Fig_3-4]

Figure 3-3

Watershed Health Tracking System
Existing and Future Development in City of Surrey

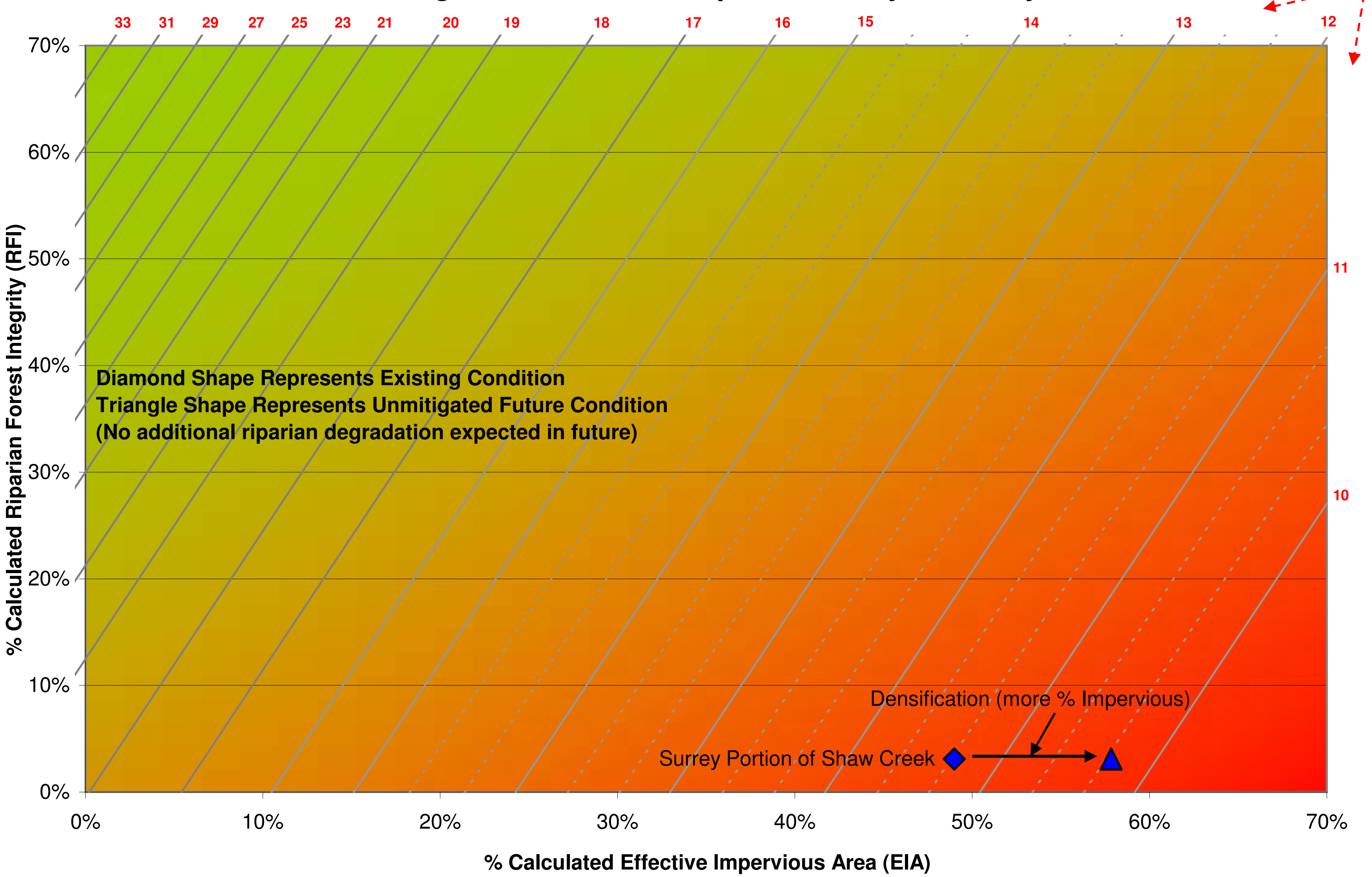

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Figure 3-4

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Section 4

Mitigation Alternatives

4. Mitigation Alternatives

4.1 Introduction

Alternatives were developed to address the key issues and mitigate the potential impacts of future development and also to improve the watershed health by partially mitigating the impacts of past development. Comments from stakeholders were also used to identify projects. The hydrotechnical upgrades identified in Section 4.2 are necessary to protect property and infrastructure. The projects identified in Section 4.3 are required as a minimum to offset the impacts of future development to meet the no-net-loss of watershed health goal. The alternatives identified in Section 4.4 could be implemented to improve the watershed health above current conditions or to make up for any shortcomings in implementation of the required projects in Section 4,3. The projects listed in Section 4.4 should be viewed as potential or possible projects that vary in benefit and will not all be recommended in the proposed plan. Table 4-1 and Figures 4-1 and 4-2 summarize the alternatives considered.

4.2 Required Hydrotechnical Upgrades

A number of undersized culverts and priority works were identified. The proposed hydrotechnical upgrades (see Table 4-1 for details) are shown on Figure 4-1 and include:

- MOT should construct bank protection on the right bank (looking downstream) of Shaw Creek at Highway 10 south side major erosion spot (E-11).
- Delta to inspect riprap at the top end of Shaw Creek near 6007 Scott Road following all greater than 2-year rainfall events and maintain as required to fill any spots left unprotected by riprap movement and protect concrete wall toe and concrete outfall edge. Alternatively, replace riprap with a larger size that will not move during the peak design flow or construct an energy dissipater in order to reduce the flow velocities.
- MOT should construct an improved inlet and new trash rack at the Hwy 10 Shaw Creek culvert with wider bar spacing and debris interceptor upstream. This will reduce the likelihood of inlet blockage and Highway 10 overtopping.
- Delta to confirm whether accumulation is a problem at the u/s end of Briarwood Creek culvert CUL_372 and if so, remove accumulated debris more frequently to reduce the likelihood of inlet blockage and flows traveling overland down the steep bank causing erosion. Inspect monthly and after storm events. Alternatively, replace existing inlet with a standard headwall and trash rack to reduce the amount of debris accumulating on the existing grill.
- Delta to complete the construction of the East Oliver Bypass backwater berms near the Delta Golf Course as per the 2001 detailed design drawings..
- Delta to upgrade culvert CUL_274 in Watershed Park to 1,350 mm diameter pipe to prevent path from overtopping.
- Delta to upgrade culvert CUL_352 in Watershed Park to 1,050 mm diameter pipe to prevent path from overtopping.

The above list includes upgrading only 2 of the 10 culverts identified as being undersized for both the existing and future land use flows (see Tables D-2 to D-5 in Appendix D). The capacity issues for the other culverts (CUL_2, CUL_17, CUL_24, CUL_231, CUL_236, CUL_249, CUL_250, and CUL_370) may be addressed with detention and diversion works described in the alternative section below or the culverts should be replaced at the end of their design life.

4.3 Mitigate Impacts of Future Development

In order to meet the no-net-loss requirement of an ISMP, future development impacts need to be mitigated. This mitigation can be performed at the source or with compensation works elsewhere in the watershed. The developable portions of the watershed are already largely developed and any future densification would be from re-development. Compensation works for redeveloping parcels are an option once the potential impacts can be quantified and projects from Section 4.4 could be used to offset redevelopment impacts. However, it is difficult to estimate how much of the area will redevelop and therefore difficult to estimate the required amount of compensation works. Therefore, for the purpose of this ISMP, developers in both Surrey and Delta should apply the following source controls to allow development while not making conditions worse in the downstream creeks or in the farmlands before considering compensation works (see Figure 4-2):

- Apply volume reduction source controls on all new development and redevelopment including roadways for all areas changing from pervious to impervious in upland areas. The types of source controls for volume reduction are discussed in Appendix E. Capture 6-month 24-hour storm (40 mm) to meet the DFO Guideline and not make creek erosion worse. It can be shown that a forested catchment in the study area, even one underlain by poorly drained soils, is able to capture 40 mm of rainfall or approximately 90% or rainfall annually, resulting in only 10% runoff annually. Figure 4-3 shows the WHTS for the improvement alternatives. The line labeled "Redev. Source Controls" represents this item.
- Treat runoff from new paved surfaces, including municipal roadways, resulting from a 6-month 24-hour storm (or 90% of annual flows) to remove pollutants. The types of source controls for water quality treatment are discussed in Appendix E. This level of treatment will meet the DFO Guideline.
- Because the entire study area drains to fish bearing streams, restrict post-development flows to pre-development levels for all storms up to and including the 5-year storm on all new development and roadways and redevelopment as per the Surrey Design Criteria Manual and the DFO Guidelines. The Delta Stormwater Management Design Manual requires a further detention of the 10-year return period flows for Development in Delta. .
- Protect existing riparian areas as per the Delta Streamside Protection and Enhancement Areas (SPEA) Bylaw or the Riparian Areas Regulation (RAR). Future land use changes are not expected to result in additional riparian loss as the creeks are not in developable areas. However, losses not associated with development land use change may occur. Quantify any riparian loss within 30 m of permanent streams due to narrower-than-30 m setbacks, new creek crossings, new streamside trails, and riparian clearing on land uses where the SPEA Bylaw or RAR does not apply (for example Agriculture). Look for reforestation opportunities to compensate for any such losses.
- Replant riparian areas that are currently not forested to compensate for the any shortcomings in source controls applied to future densification. Assume 1 ha of replanting by Delta at upstream end of East Oliver Bypass as shown in Figure 4-2 to compensate for this.

4.4 Improve Watershed Health

The works listed in Sections 4.2 and 4.3 address existing hydrotechnical issues and mitigate the impacts of future development to achieve a no-net-loss in the watershed. There are a number of other issues in the watershed that were identified that are a result of existing conditions in the watershed (past development, agricultural use, riparian encroachment, etc.) that could be addressed to go beyond no-net-loss and in fact improve the watershed health. The alternatives for addressing these issues are divided into six categories as shown in Table 4-1 and presented below. The potential projects are shown on Figure 4-2. Figure 4-3 shows the WHTS for the improvement alternatives. The projects listed in this section should be viewed as potential or possible projects that vary in benefit and will not all be recommended in the proposed plan.

Lowlands Drainage Improvement

Lowland owners have noted that the amount of flow entering the lowlands from the uplands has increased resulting in lower levels of service for drainage and that irrigation water is needed in the growing season. This is not unusual given that development (impervious surfaces) increases runoff and reduces the amount of evaporation and infiltration. Reduced infiltration decreases baseflows in the creeks which would be used for irrigation in the lowlands.

Even though the agricultural drainage assessment showed that the existing level of service met the ARDSA criteria for flooding in all cells and for freeboard in most cells, the following improvements (shown in orange on Figure 4-2) could be or have recently been implemented to further improve the lowlands drainage and irrigation:

- Delta will connect the East Oliver Bypass to Mud Bay and adjust the flow split between Oliver Slough and the bypass if necessary (see Figure 4-1). Maintain baseflows to Oliver Slough and divert peak flows to the bypass. This project is underway.
- Delta has increased the Oliver Pump Station capacity from 6 m^3/s to 9 m^3/s (see Figure 4-1). This project was completed in 2011.

A. Consider constructing a 900 mm dia. culvert under the railway and a channel from the downstream end of the culvert to the East Oliver Bypass to take more of the Shaw Creek high flows into the East Oliver Bypass and out to Mud Bay. A flow split structure on the upstream end of the culvert would send baseflows and low flows to Lorne Ditch and high flows to the bypass. This would likely bring culverts CUL_2, CUL_24, CUL_231, and CUL_236 closer to meeting (or in compliance with) the capacity criteria.

Riparian Reforestation

Riparian forest integrity (RFI) is one of the major indicators of watershed health as shown on the WHTS discussed in Section 3.3. While a majority of the upland creek riparian areas are within Watershed Park and forested, there are a number of riparian reforestation opportunities in the study area (shown in green on Figure 4-2) including the following:

B. Add to the riparian planting along the East Oliver Bypass.

C. Add to riparian trees around Boundary Park Pond on the south, west, and east sides to provide shade to the pond and increase the riparian forest by 2,880 m^2.

D. Consider relocating Briarwood Creek away from roadways/railway in the section between Highway 91 and the BNSF railway to gain intact riparian on both sides of streams increasing the riparian by 2,800 m^2.

The line labeled “Riparian Reforestation” on Figure 4-3 represents the above four items.

E. Delta could encourage planting trees along the lowland ditches by working with the Environmental Farm Plan Program to increase the RFI by up to 5% in the watershed. The line labeled "Environmental Farm Practices" on Figure 4-3 represents this item.

The Environmental Farm Plan (EFP) is a voluntary program that farmers and ranchers can use to identify both environmental strengths and potential risks on their land. EFPs will help protect water quality, water quantity and biodiversity in the watershed. Because the Riparian Areas Regulation does not apply to agricultural lands, the EFP outlines practices for managing livestock access to watercourses and improving riparian vegetation to prevent bank erosion and improve fish habitat. The EFP program is initiated by Agriculture and Agra-Food Canada and is implemented at the provincial level through the BC Ministry of Agriculture and Lands (MAL), and the BC Agriculture Council. Please refer to the following website: http://www.bcac.bc.ca/efp_documents.htm

Water Quality Improvement

The environmental inventory and sampling has identified a number of water quality issues in the watercourses. Further monitoring would be required to more conclusively identify and quantify pollutants. A number of projects could be initiated to identify pollutants and treat the water quality of outflows into the creeks (shown in blue on Figure 4-2) including:

F. Evaluate benefits of a water quality treatment wetland at top end of Watershed Creek and pipe residential runoff into it to treat runoff from a 76 ha residential catchment in Delta (80% removal of TSS).

G. Delta could monitor water quality at the outfall into the top end of the Watershed Creek tributary (at former Works Yard) to determine if there is a need for treatment. Monitor runoff from an 8.3 ha residential catchment in Delta.

H. Delta could monitor water quality at the outfall into the top end of Briarwood Creek to determine if there is a need for treatment. Monitor runoff from a 60 ha developed area in Delta.

I. Delta could monitor water quality at the outfall into the top end of Shaw Creek to determine if there is a need for treatment. Monitor runoff from the Surrey portion of the Shaw Creek catchment.

J. Consider constructing a small linear wetland along the south side of Highway 10 immediately west of Scott Road and daylight 600 mm and 300 mm storm sewers into it to partially treat runoff from an 8 ha residential catchment in Surrey (est. 40% removal of TSS).

K. Further education of residents in the catchment on the use of BMP's (ie. environmentally friendly soaps for car washing.) Also confirm that commercial facilities are discharging to sanitary and not storm sewer in order to reduce the soapy water in creeks.

E. Encourage the Environmental Farm Plan Program in order to reduce fertilizers and pesticides entering lowland channels.

L. Consider a policy to retrofit existing streets with roadside source controls (rain gardens or grassed swales) at time of redevelopment in upland areas to treat runoff from up to 40 km (Surrey) and 29 km (Delta) of roadway (80% removal of TSS). Homeowners would maintain these as part of the required boulevard maintenance.

M. Develop a policy to encourage retrofit of large parking areas by directing pavement runoff to rain gardens (e.g. Safeway parking lot and Sunrise Baptist Church and GM Dealership pavement area retrofits would reduce the EIA of 3 ha of pavement from 100% to 10%).

Detention and Diversion to Reduce Existing Erosion

Erosion, due in part to existing development, occurs in the steep sections of creeks, especially Shaw Creek. In order to reduce this erosion, the peak flows and volumes of flows could be reduced by detaining runoff or diverting flows away from Shaw Creek with the following potential alternatives (shown in pink on Figure 4-2):

N. Evaluate benefits of constructing a high flow piped diversion from the top of Shaw Creek south on Scott Road and outlet to Mud Bay to greatly reduce the existing erosion in Shaw Creek. This would likely negate the need for riprap maintenance at the top end of Shaw Creek and the need to upgrade culverts CUL_2, CUL_24, CUL_231, and CUL_236. It may also reduce the upland flows to the Delta Golf Course reducing flooding at its south end. The pipe would need to convey approximately 1 m^3/s in a 10-year event which equates to a 750 mm diameter pipe at 2% grade. The line labeled "Shaw Creek Diversion" on Figure 4-3 represents this item.

Volumetric Reduction to Mitigate Existing Development Flows

Traditional development alters the flows in the creeks by increasing the peak flows, the runoff volumes, and the frequency of flows. The existing development outflows into the creek could be improved by reducing the effective impervious area (EIA) with the following alternatives (shown in yellow on Figure 4-2):

M. Develop a policy to encourage retrofit of large parking areas by directing pavement runoff to rain gardens (e.g. Safeway parking lot and Sunrise Baptist Church and GM Dealership pavement area retrofits would reduce the EIA of 3 ha of pavement from 100% to 10%).

O. Consider a rain garden in the parkette leading to the Boundary Park Pond and daylight the Boundary Drive East storm sewer into it. This would reduce the EIA of a 9 ha residential area from 60% to 10%. The line labeled "Regional Rain Gardens" on Figure 4-3 represents the above two items.

P. Develop a policy to construct full volume reduction source controls during redevelopment/ densification to not only maintain EIA at existing values but reduce the EIA to less than existing on-site values to reduce the overall study area EIA to less than existing (2010) values. The line labeled "Retrofit Lots" on Figure 4-3 represents this item.

Q. Evaluate volunteer program to help homeowners install rain barrels on existing single family development in Surrey to reduce potable water usage and increase rainfall capture.

R. Allow disconnected roof leaders directing roof runoff to landscaped areas on existing single family development in Delta and initiate a volunteer program to help homeowners do so. This would reduce the EIA of approximately 120 ha of residential area by approximately 30%.

S. Surrey and Delta could initiate a volunteer program to help home owners plant trees on their properties to increase evapotranspiration and reduce runoff volumes to creeks.

L. Surrey and Delta could develop and implement policy to retrofit existing streets with roadside source controls in upland areas to reduce the EIA from 100% to 10% of approximately 70 ha of roadway in the study area. This is the same policy referred to in the water quality section as source controls would provide both capture and treatment. The line labeled "Retrofit Roads" on Figure 4-3 represents this item.

Fish Habitat Improvements

A number of instream works could be undertaken to improve the conditions for fish including (shown in purple on Figure 4-2):

- Delta connecting the East Oliver Bypass to Mud Bay will provide rearing habitat for juvenile salmon moving in from the Bay (see Figure 4-1).

T. MOT could remove a fish passage obstruction (old weir) in Shaw Creek along south side of Highway 10 to improve fish access to 70 to 80m of channel.

U. BNSF and MOT, could improve fish passage through the Watershed Creek culvert under railway (CUL_14) and the Shaw Creek culvert under Highway 91 (CUL_236) by adding fish baffles or rock weir. This would improve fish access to approximately 2 km of channel.

V. MOT could create fish habitat along Shaw Creek between Old Highway 10 and the BNSF Railway to enhance 150 m of channel.

4.5 Evaluation of Potential Projects

The hydrotechnical upgrades listed in Section 4.2 and the mitigation measures listed in Section 4.3 mitigate the impacts of future development and address existing conveyance capacity issues. These are required to meet the no-net-loss in the watershed. The various projects listed in Section 4.4 go beyond a no-net-loss to improve the conditions in the watershed offsetting impacts of existing and historic development.

It is difficult to compare the costs/benefits of the various optional projects because they achieve different types of improvement benefits that cannot be readily converted to a common value system. Some improve water quality while others reduce runoff or provide riparian benefits. Through discussions with Surrey and Delta, however, the projects were assigned a timeline and importance which results in a prioritization. A capital cost was also estimated for the construction projects as shown in Table 4-1.

The Green Growth Index (GGI) was adapted to evaluate the potential projects using the leaf/branch/tree rating system where a leaf represents some benefit, a branch represent more benefit, and a tree represents the most benefit. These symbols were incorporated in Table 4-1.

The various options and projects were discussed with Surrey and Delta and the majority of them were selected to be incorporated into the ISMP as presented in the next section.

Table 4-1: Issues and Improvement Alternatives

Key Issue	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	GGI	Comment	Recommen-ded (Y/N)	Identified By
Erosion and Sedimentation *- See Figure 4-1 for Locations*										
Major Creek Bank Erosion	Construct bank protection on right bank of Shaw Creek at Highway 10 south side major erosion spot (E-11).	Protect Hwy 10 embankment at major scour.	$ 40,000	Short Term	High	MOT	[tree]		Y	KWL/Trow
Riprap Movement and Scour at Lock Block Wall	Inspect riprap at the top end of Shaw Creek directly d/s of Boundary Pond outfall at Scott Rd following all greater than 2-year rainfall events and maintain as required.	Fill any spots left unprotected by riprap movement and protect concrete wall toe and concrete outfall edge.	$ -	Short Term	Medium	Delta	[leaf]	Recommended option (potential cost share with Surrey)	Y	Stakeholders
	Or Replace riprap with larger size.	Protect toe of lock block wall and end of outfall headwall and prevent riprap movement.	$ 70,000	Medium Term			[tree]	Difficult due to access	N	
	Or Construct an energy dissipator.	Reduce flow velocity to below existing riprap erosion threshold.	$ 340,000	Short Term			[branch]	Costly solution	N	
Debris Accumulation and Inlet Capacity	Improve inlet and new trash rack at Hwy 10 Shaw Creek with wider bar spacing and debris interceptor upstream.	Reduce the likelihood of inlet blockage and Highway 10 overtopping.	$ 100,000	Medium Term	Medium	MOT	[tree]		Y	Delta
Debris Accumulation	Confirm if accumulation is a problem and if so, remove debris more frequently at u/s end of Briarwood Creek culvert CUL_372. Inspect monthly and after storm events.	Reduce the likelihood of inlet blockage and flows traveling overland down the steep bank (erosion).	$ -	Short Term		Delta	[leaf]		Y	KWL
	Or Replace existing inlet with a standard headwall and trash rack to reduce the amount of debris accumulating on the existing rack.	Reduce the likelihood of inlet blockage and flows traveling overland down the steep bank (erosion).	$ 60,000	Medium Term	To be determined		[tree]	Monitor accumulation first	N	
Hydrotechnical Improvements (Requirement) *- See Figure 4-1 for Locations*										
Golf Course Flooding	Complete the construction of the East Oliver Bypass backwater berms near the Delta Golf Course as per the 2001 detailed design drawings.	Prevent existing major event overflows and future minor event overflows if more water is directed towards the Bypass.	$ 60,000	Medium Term	Medium	Delta	[tree]	This might not be needed if new culvert is installed under railway (see below).	Y	KWL
Culvert Capacity	Upgrade two high head loss culverts in Watershed Park. Upgrade culverts CUL_274 to 1,350 mm & CUL_352 to 1,050 mm dia. pipes (Figure 3-1).	Prevent path overtopping in Watershed Park & meet Delta criteria.	$ 80,000	Medium Term	Low	Delta	[tree]	Path estimated to overtop annually with existing pipe sizes.	Y	KWL
	Allow culverts CUL_17, CUL_249 and CUL_250 to surcharge in the near term and replace at end of life with larger sizes (Figure 3-1).	Meet the Delta capacity criteria.	$ -	Long Term	Low	Delta	[leaf]		Y	KWL
	Allow culverts CUL_2, CUL_24 and CUL_231 to surcharge in the near term and replace at end of life with larger sizes (Figure 3-1).	Meet the Delta capacity criteria.	$ -		Low	Delta	[leaf]	Culverts would have sufficient capacity if diversion constructed (see below)	Y	KWL
	Allow culvert CUL_236 to surcharge in the near term and replace at end of life with larger size (Figure 3-1).	Meet the MOT capacity criteria.	$ -		Low	MOT	[leaf]	CUL_236 would have sufficient capacity if diversion constructed (see below)	Y	KWL
	Allow culvert CUL_370 to surcharge in the near term and replace at end of life with larger size (Figure 3-1).	Meet the Delta capacity criteria.	$ -		Low	BNSF	[leaf]		Y	KWL

Note: GGI is the adapted rating system of Delta's Green Growth Index that shows the relative amount of environmental benefit of the works. A leaf sysmbol represents some benefit, a branch represents more benefit, and a tree represents the most benefit.

Table 4-1: Issues and Improvement Alternatives

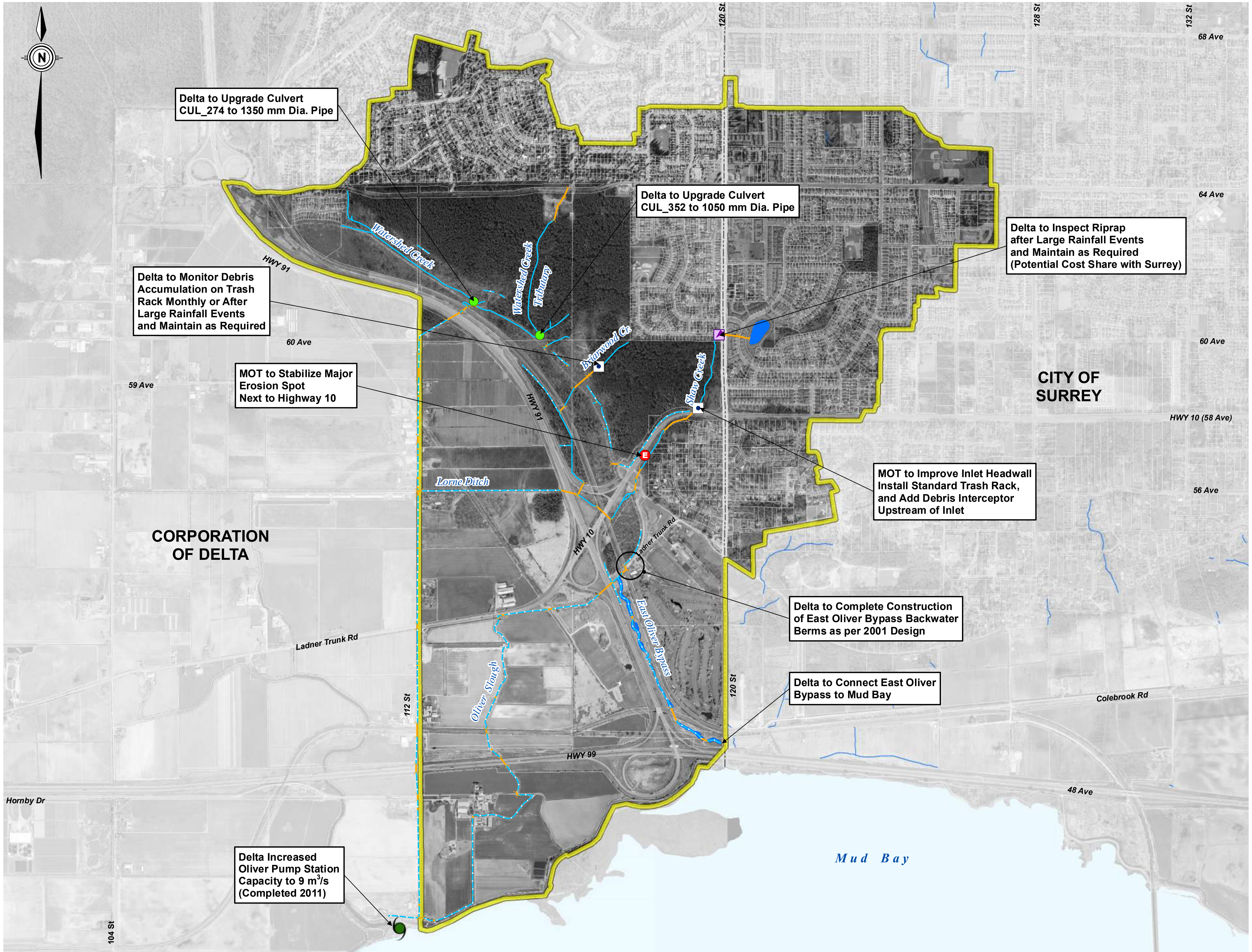
Key Issue	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	GGI	Comment	Recommen-ded (Y/N)	Identified By
Hydrologic Mitigation of Future Development/Densification (Requirement) *- See Figure 4-2*										
Reduce Erosive Flows from Development	Implement policy to apply volume reduction source controls on all new development / redevelopment including roadways. Capture 6-month 24-hour storm (40 mm) to meet the DFO Guideline & mitigate creek erosion.	Restore pre-development hydrology on densifying parcels and roads to minimize EIA increase of additional impervious surfaces.	Developer	At Time of Dev.	High	Surrey Delta		An option would be to stabilize the steep sections of Shaw and Briarwood Creeks but this would have negative impacts on creeks.	Y	KWL
Treat Water Quality from Development	Treat runoff from new paved surfaces, including municipal roadways to remove pollutants using biofiltration or manufactured systems (swales, rain gardens, oil/grit separators, etc.).	Remove pollutants from proposed additional travelled surfaces to meet DFO WQ Guideline.	Developer	At Time of Dev.	High	Surrey Delta		An option would be to construct regional WQ facilities but this would require land.	Y	KWL
Reduce Peak Flows from Development	Detain post-development flows to pre-development levels for all storms up to and including the 10-year storm for all new development, new roadways, and redevelopment using onsite detention facilities.	Maintain the peak flows at existing levels to meet the DFO, Delta, and Surrey requirements.	Developer	At Time of Dev.	High	Surrey Delta		An option would be to construct regional detention facilities or stabilize the steep sections of Shaw and Briarwood Creeks.	Y	KWL
Development within Riparian Areas	Protect existing riparian areas as per RAR. Quantify any riparian loss within 30m of permanent streams due to narrower-than-30m RAR setbacks, new creek crossings, new streamside trails, and riparian clearing on land uses where RAR does not apply (Agriculture).	Maintain existing level of watershed health by ensuring no-net-loss of riparian area. Future land use changes are not expected to result in additional riparian loss.	$ -	Ongoing	Medium	Surrey Delta		Delta SPEA Bylaw and RAR do not apply to ALR.	Y	KWL
Riparian Planting Compensation for Densification	Replant riparian areas that are currently not forested to compensate for riparian losses using a 1-for-1 compensation ratio if performed before the loss incurred or 2-for-1 compensation ratio if performed after loss incurred.	Densification with source controls may still increase EIA and 1 ha of riparian replanting at the upstream end of the East Oliver Bypass would offset shortfalls (WHTS Figure 4-5).	$30,000 by Delta, remainder by developer	Ongoing	Medium/ High	Delta		Plant in short term so vegetation matures before densification health loss occurs.	N	KWL

Table 4-1: Issues and Improvement Alternatives

Key Issue	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	GGI	Comment	Recommen-ded (Y/N)	Identified By
Watershed Health Improvement (Optional) *- See Figure 4-2 for Locations*										
Lowlands Drainage Improvement	Connect the East Oliver Bypass to Mud Bay and adjust the flow split between Oliver Slough and bypass if necessary (Figure 4-1).	Reduce peak flows into the farmlands and flooding duration to better-than-ARDSA level of service.	Unknown	Underway		Delta			Y	Delta
	Increase Oliver Pump Station capacity from 6 m^3/s to 9 m^3/s (Figure 4-1).	Reduce flooding duration in farmlands to better-than-ARDSA level of service and improve fish passage.	Unknown	Completed		Delta		Completed in 2011.	Y	Delta
	Consider constructing 900 mm dia. pipe under railway to convey more high flows from Shaw Creek into the East Oliver Bypass and away from Lorne Ditch.	Further reduce peak flows and flooding duration in farmlands to better-than-ARDSA level of service (est. 25% more flows to Bypass). This would likely help culverts CUL_2, CUL_24, CUL_231, and CUL_236 meet the criteria.	$ 180,000	Medium Term	Medium	Delta		Utilize Bypass capacity. Work with BNSF.	Y	KWL
Riparian Reforestation	Add to the East Oliver Bypass riparian planting, ensure maintenance access is preserved.	Potential to increase RFI by up to 15%.	$40/m2	Medium Term	Medium	Delta		This could perhaps be done as compensation for impacts of other projects over time.	Y	KWL
	Work with Environmental Farm Plan Program to selectively plant a 2m to 5m setback from lowland watercourses.	Selected planting along ditches could increase RFI by up to 5%.	$ -	Ongoing	Low	Delta		There may be resistance to this.	Y	KWL
	Add riparian trees around Boundary Park Pond to provide shade on west, east, and south sides.	Approx. 2,880 m^2 of area planted increasing RFI by 1%.	$ 120,000	Long Term	Low	Surrey		There may be resistance unless residents informed of benefits.	N	KWL
	Consider relocating stream in MOT ROW away from roadways/railway to gain intact riparian on both sides of stream (Figure 4-2).	Approx. 2,800 m^2 of riparian area gained increasing RFI by 1%.	$ 50,000	Medium Term	Low	MOT		Work with Streamkeepers.	Y	KWL
Fish Habitat Improvements	Remove fish passage obstruction (old weir) in Shaw Creek along south side of Highway 10 in MOT ROW.	Improve fish access to 70-80 m of channel.	$ 20,000	Medium Term	Low	MOT		Work with Streamkeepers.	Y	Raincoast
	Add fish baffles or rock weir to improve fish passage through Watershed Creek culvert under railway (CUL_14) & Shaw Creek culvert under Highway 91 (CUL_236).	Improve fish access to approximately 2 km of channel.	$ 70,000	Long Term	Medium	MOT and BNSF		Work with Streamkeepers.	Y	Raincoast
	Create fish habitat along Shaw Creek between Old Highway 10 and BNSF Railway in MOT ROW.	Enhance 150 m of channel.	$ 40,000	Long Term	Low	MOT		Work with Streamkeepers.	Y	Delta
Improve Water Quality	Evaluate benefits of WQ treatment wetland at top end of Watershed Creek and pipe residential runoff into it.	Treat runoff from a 76 ha residential catchment in Delta (80% removal of TSS).	$ 450,000	Long Term	Low	Delta			Y	KWL
	Monitor WQ at top end of Watershed Creek tributary at outfall at former Works Yard to determine need for treatment.	Monitor runoff from an 8.3 ha residential catchment in Delta.		Long Term	Low	Delta			Y	KWL
	Monitor WQ at top end of Briarwood Creek to determine need for treatment.	Monitor runoff from 60 ha developed area in Delta.		Long Term	Low	Delta		High turbidity measured in Briarwood Creek.	Y	KWL
	Monitor WQ at top end of Shaw Creek to determine need for treatment.	Monitor runoff from Surrey portion of catchment.		Long Term	Low	Delta		Potential cost share with Surrey.	Y	KWL
	Consider constructing small linear wetland along south side of Highway 10 west of Scott Road in MOT ROW and daylight 600 mm & 300 mm storm sewers into it.	Partially treat runoff from an 8 ha residential catchment in Surrey (est. 40% removal of TSS).	$ 100,000	Medium Term	Low	MOT		Work with Streamkeepers.	Y	KWL
	Further education of residents on the use of BMPs (e.g. environmentally friendly soaps for car washing.) Confirm commercial facilities are discharging wash water to sanitary and not storm sewer.	Reduce the soapy water in creeks.	$ -	Short Term	High	Delta Surrey			Y	Stakeholders
	Encourage Environmental Farm Plan Program.	Reduce fertilizers and pesticides .	$ -	Ongoing	High	Delta			Y	KWL
	Consider a policy to retrofit existing streets with roadside source controls (rain gardens or grassed swales) at time of redevelopment in upland areas. Homeowners to maintain as part of boulevard maintenance.	Treat runoff from up to 40 km (Surrey) and 29 km (Delta) of roadways (80% removal of TSS)	Developer	At Time of Dev.	High	Surrey Delta		Very long term strategy as roads are redeveloped.	Y	KWL

Table 4-1: Issues and Improvement Alternatives

Key Issue	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	GGI	Comment	Recommen-ded (Y/N)	Identified By
***Watershed Health Improvement (Optional) Continued** - See Figure 4-2 for Locations*										
Mitigate Existing Development Hydrology through Detention/Diversion of Peak Flows	Add orifice outlet to Detention Tank P1 at 6455 121 Street.	Make use of available detention volume.	$ 10,000	Short Term	Low	Surrey		Limited benefit.	N	KWL
	Evaluate benefits of constructing a diversion pipe south on 120 Street and outlet to Mud Bay.	Greatly reduce the existing erosion in Shaw Creek. Likely negate need for riprap maintenance at top end of Shaw Creek, need to upgrade culverts CUL_ 2, CUL_24, CUL_231, and CUL_236, and reduce Golf Course flooding at south end.	$ 2,200,000	Long Term	Low	Surrey			N	Stakeholders/ KWL
Mitigate Existing Development Hydrology through Volumetric Reduction	Consider a rain garden in parkette leading to Boundary Park Pond and daylight Boundary Drive East storm sewer into it.	Reduce the EIA of a 9 ha residential area from 60% to 10%. Total study area EIA reduced by 0.5%.	$ 340,000	Long Term	Low	Surrey			Y	Surrey
	Develop policy to construct source controls during redevelopment to reduce EIA to less than existing values (e.g. during densification of 50% imp SFR area to 60% imp, reduce EIA to less than 50%).	Reduce overall EIA to less than 2010 values.	Developer	Ongoing	High	Surrey Delta		Very long term strategy as lots are redeveloped. Consider incentives to maximize EIA reduction.	N	KWL
	Develop policy to encourage retrofit of large parking areas by directing pavement runoff to rain gardens (Safeway parking lot and Sunrise Baptist Church/GM Dealership pavement)	Reduce the EIA of a 3 ha of pavement from 100% to 10%. Total study area EIA reduced by 0.5%.	$160,000/ha	Medium Term	Low	Surrey Delta			N	Stakeholders
	Evaluate a volunteer program to help homeowners install rain barrels on existing single family development in Surrey.	Reduce potable water usage and increase rainfall capture.	$ -	Short Term	Medium	Surrey		Delta has a rain barrel program.	N	KWL
	Allow disconnected roof runoff directed to landscaped areas on existing single family development in Delta and initiate volunteer program to help homeowners do so.	Reduce EIA of approx. 120 ha of residential area by 30%. Total study area EIA reduced by 4%.	$ -	Short Term	Medium	Delta		Surrey already has disconnected roof leaders policy.	Y	KWL
	Initiate volunteer program to help homeowners plant trees on their properties.	Increase evapotranspiration reducing volumes to creeks & erosion.	$ -	Short Term	Medium	Surrey Delta			N	KWL
	Consider options to retrofit existing streets with roadside source controls in upland areas.	Reduce EIA of 70 ha of roadway from 100% to 10%. Total study area EIA reduced by 7%.	Developer	At Time of Dev.	High	Surrey Delta		Very long term strategy as roads are redeveloped.	Y	KWL



Corporation of Delta/City of Surrey
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Ponds/Wetlands
- Culvert
- Ditch
- Creek

Topographic, cadastral data and 2008 orthophoto provided by The Corporation of Delta and City of Surrey.

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consulting engineers

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Project No.	Date
323-059	January 2012

Proposed Hydrotechnical Upgrades

Figure 4-1

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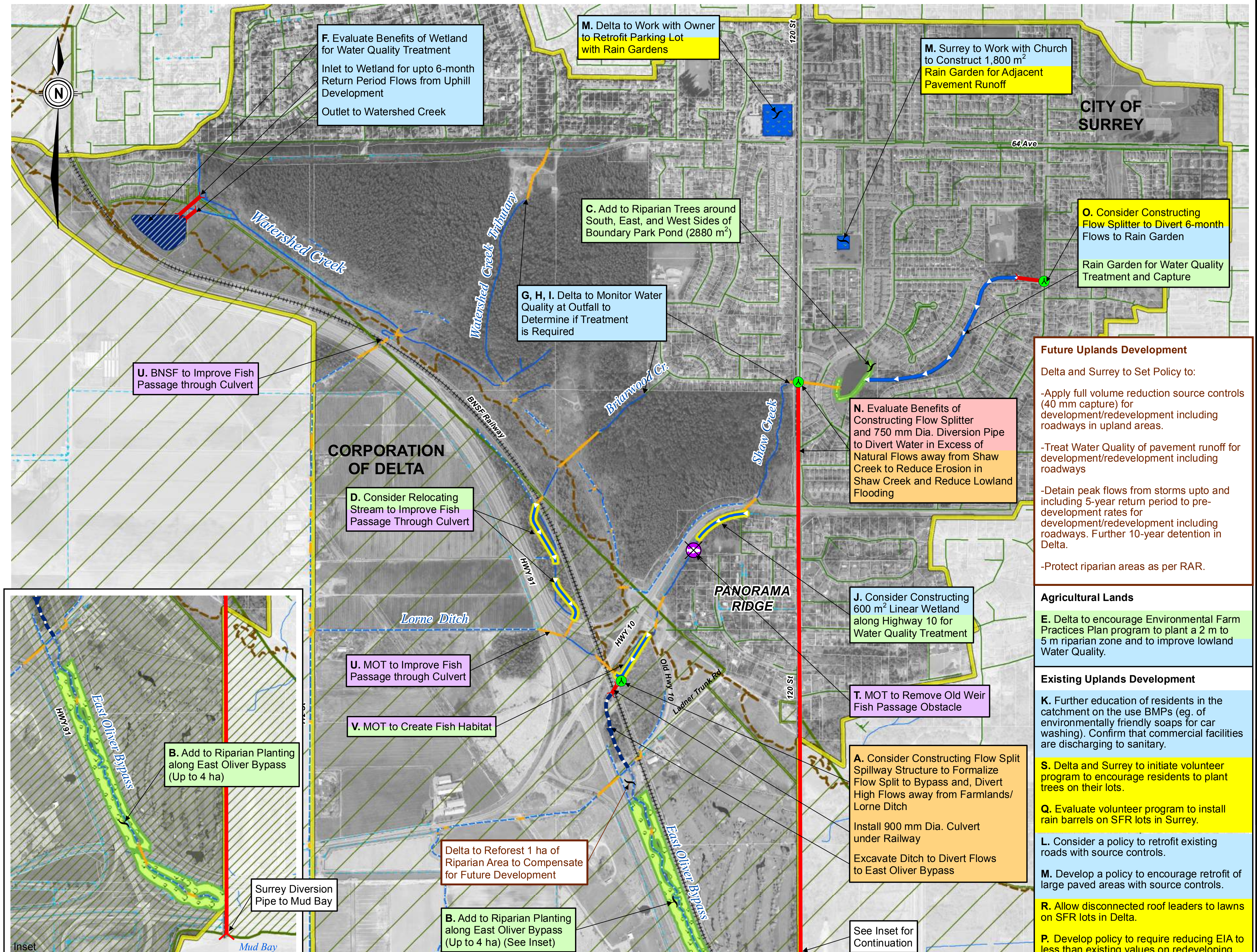

Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Lowland Boundary (5m)
- Storm Main
- Existing Culvert
- Existing Ditch
- Existing Creek
- ALR Boundary
- Required Works

Enhancement Alternatives

- Lowlands Drainage Improvements
- Riparian Reforestation
- Water Quality Improvement
- Detention and Diversion to Reduce Erosion
- Volumetric Reduction to Mitigate Existing Development
- Fish Habitat Improvements

Topographic, cadastral data nad 2008 orhtophoto provided by The Corporation of Delta and City of Surrey.

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consulting engineers

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Project No.	Date
323-059	January 2012

Watershed Health Improvement Alternatives

Figure 4-2

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Author: ilau

Watershed Health Tracking System for Improvement Alternatives
Total ISMP Study Area

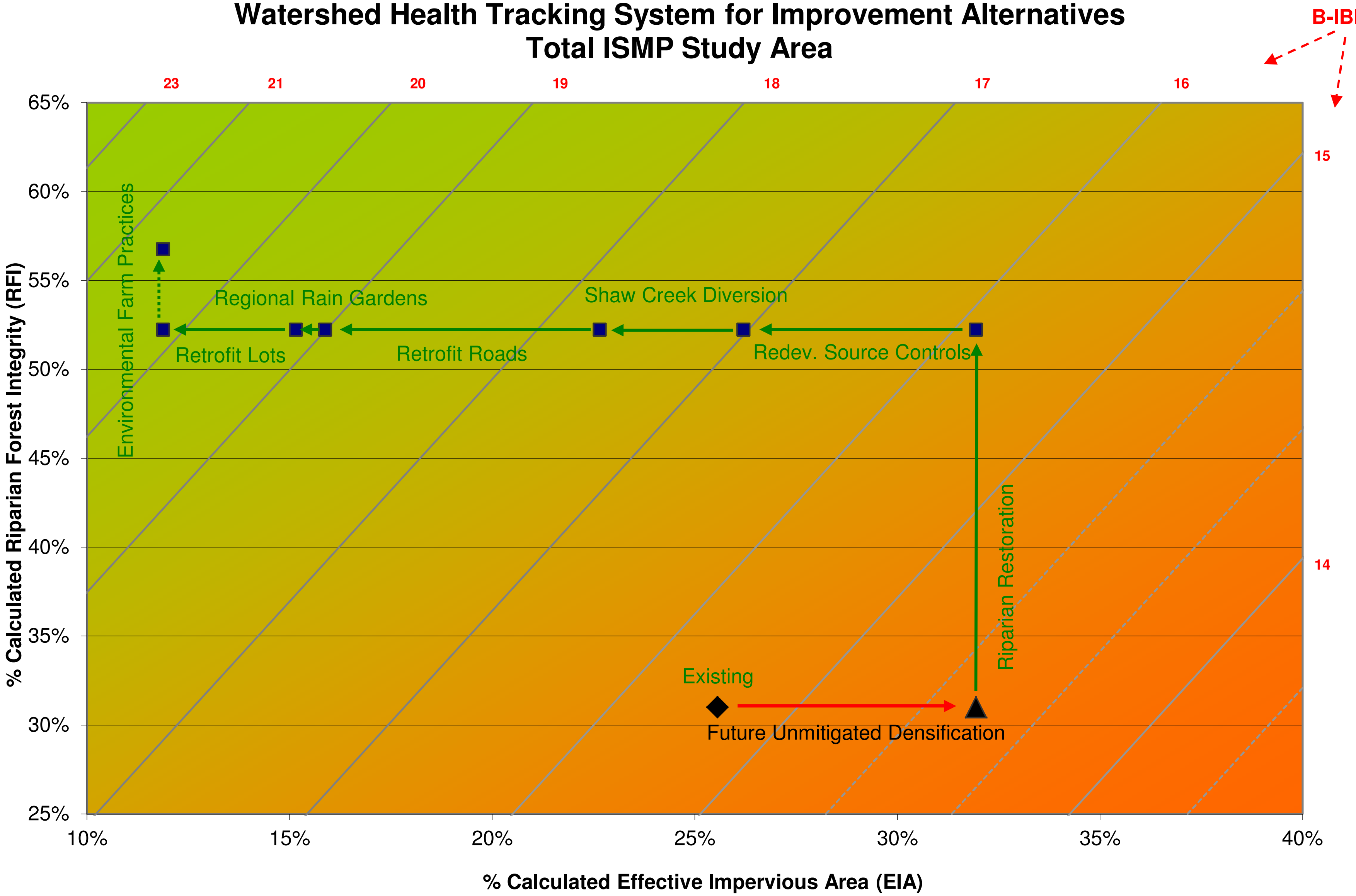

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Figure 4-3

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consulting engineers

Section 5

Proposed Shaw Creek ISMP

5. Proposed Shaw Creek ISMP

5.1 Introduction

The overall strategy for the Shaw Creek ISMP study area consists of many components for flood management and environmental protection and enhancement as summarized in the following sections. The strategy was developed by incorporating preferred elements from the alternatives.

The ISMP Strategy is depicted in plan view on three figures and described in this section:

- **Figure 5-1: Short Term Projects** that address safe flood conveyance for both existing and future conditions and also shows works currently underway and recently completed outside of this ISMP.
- **Figure 5-2: Medium Term Projects** that address lower priority nuisance impacts, some of the impacts from existing and past development, and riparian improvements.
- **Figure 5-3: Long Term Projects** that address some of the impacts from existing and past development and long term improvements to fish habitat.

The sizing of facilities in the ISMP is conceptual in nature and should be thoroughly assessed during pre-design. The capital cost estimates are summarized into four timeline categories, 1) Short Term, 2) Medium Term, 3) Long term, and 4) Ongoing. They are also summarized into the four groups 1) Delta, 2) Surrey, 3) MOT, and 4) BNSF. Developer costs are not estimated (see Table 5-1).

5.2 Required Hydrotechnical Improvements

A number of undersized culverts and priority works were identified. The proposed hydrotechnical upgrades were listed in Section 4.2 and are prioritized below.

Short Term Projects

The following short term projects are shown on Figure 5-1:

1. MOT to construct bank protection on right bank of Shaw Creek at Highway 10 south side major erosion spot (E-11).
2. Delta to inspect riprap at the top end of Shaw Creek following all greater than 2-year rainfall events and maintain as required to fill any spots left unprotected by riprap movement and protect concrete wall toe and concrete outfall edge. This project could potentially be cost shared with Surrey.
3. Delta to confirm whether debris accumulation is a problem at the upstream end of Briarwood Creek culvert CUL_372 and if so, remove accumulated debris more frequently to reduce the likelihood of inlet blockage and flows traveling overland down the steep bank causing erosion. Inspect monthly and after storm events.

Medium Term Projects

The following medium term projects are shown on Figure 5-2:

4. Possible upgrade of culvert CUL_352 under path in Watershed Park to 1,050 mm diameter pipe.

Table 5-1: ISMP Class D Capital Cost Estimate

ISMP Component	Timeline	Class D Cost Estimates	
Hydrotechnical Improvements			
1. Construct bank protection on right bank of Shaw Creek at Highway 10 south side major erosion spot (E-11).	Short Term	$40,000	
2. Inspect riprap at the top end of Shaw Creek following all greater than 2-year rainfall events and maintain as required to fill any spots left unprotected by riprap movement and protect concrete wall toe and concrete outfall edge.		$0	
3. Confirm whether accumulation is a problem at the u/s end of Briarwood Creek culvert CUL_372 and if so, remove accumulated debris more frequently to reduce the likelihood of inlet blockage. Inspect monthly and after storm events.		$0	
4. Possible upgrade of culvert CUL_352 in Watershed Park to 1050mm diameter pipe.	Medium Term	$40,000	
5. Review improved inlet and trash rack options at Hwy 10 Shaw Creek with wider bar spacing and debris interceptor upstream. This will reduce the likelihood of inlet blockage and Highway 10 overtopping.		$100,000	
6. Complete the construction of the East Oliver Bypass backwater berms near the Delta Golf Course as per the 2001 detailed design drawings.		$60,000	
7. Possible upgrade of culvert CUL_274 in Watershed Park to 1350mm diameter pipe.		$40,000	
8. Delta, MOT, and BNSF to replace the following culverts with the larger sizes noted at the end of the design life of the existing culverts: CUL_2, CUL_17, CUL_24, CUL_231, CUL_236, CUL_249, CUL_250, and CUL_370. Cost for end of life upgrades not included.	Long Term	$0	**Hydrotech. Subtotal $280,000**
Lowlands Drainage Improvements			
9. Consider constructing a 900 mm dia. culvert under the railway and a channel to the East Oliver Bypass to divert more of the Shaw Creek high flows away from the lowlands and out to Mud Bay.	Medium Term	$220,000	**$220,000**
Water Quality Treatment			
10. Further education of residents on the use of BMPs (e.g. environmentally friendly soaps for car washing). Confirm that commercial facilities are discharging to sanitary and not storm sewer in order to reduce the soapy water in creeks.	Short Term	$0	
11. Consder options for treatment of runoff from new paved surfaces, including municipal roadways, resulting from a 6-month 24-hour storm (or 90% of annual flows) to remove pollutants.	At Time of Development and Ongoing		
12. Incorporate stormwater BMPs when retrofitting existing streets with roadside source controls (rain gardens or grassed swales) at time of redevelopment in upland areas to treat runoff from up to 40 km (Surrey) and 29 km (Delta) of roadways.			
13. Encourage the Environmental Farm Plan Program in order to reduce fertilizers and pesticides in lowland channels.		$0	
14. A small linear wetland is suggested along the south side of Highway 10 immediately west of Scott Road. Daylight 600 mm and 300 mm storm sewers into it to partially treat runoff from an 8 ha residential catchment in Surrey (est. 40% removal of TSS).	Medium Term	$100,000	
15. A water quality treatment wetland should be considered at top end of Watershed Creek. Pipe residential runoff into it to treat runoff from a 76 ha residential catchment (80% removal of TSS).	Long Term	$450,000	
16. Monitor water quality at the top end of the Watershed Creek Tributary (at former Works Yard outfall) to determine if there is a need for treatment. Monitor runoff from an 8.3 ha residential catchment in Delta. This is the first year cost and subsequent years would cost approximately $6000/yr.		$14,000	
17. Monitor water quality at the outfall into the top end of Briarwood Creek to determine if there is a need for treatment. Monitor runoff from a 60 ha developed area in Delta. This is the first year cost and subsequent years would cost approximately $6000/yr.		$14,000	
18. Monitor water quality at the outfall into the top end of Shaw Creek to determine if there is a need for treatment. Monitor runoff from the Surrey portion of the Shaw Creek catchment. This is the first year cost and subsequent years would cost approximately $6000/yr.		$14,000	**WQ Treat. Subtotal $592,000**
Volumetric Reduction to Mitigate Frequently Occurring Flows and Sustain Baseflows			
19. Require volume reduction source controls on all new development and redevelopment including roadways for all areas changing from pervious to impervious. Capture 6-month 24-hour storm (40 mm) with source controls.	At Time of Development and Ongoing		
20. Review options for retrofitting existing streets with roadside source controls in upland areas to reduce the EIA of approximately 70 ha of roadway in the study area. This is the same policy referred to in the water quality section.			
21. Create a rain garden in the parkette leading to the Boundary Park Pond and daylight the Boundary Drive East storm sewer into it. This would reduce the EIA of a 9 ha residential area from 60% to 10%.	Long Term	$340,000	
22. Review options for disconnected roof leaders directing roof runoff to landscaped areas on existing single family development and initiate a volunteer program to help homeowners do so.		$0	**Vol. Red. Subtotal $340,000**
Flow Rate Control to meet DFO Guidelines, and Surrey and Delta Bylaws			
23. Restrict post-development flows to pre-development levels for all storms up to and including the 5-year storm (plus 10-year in Delta) on all new development and roadways and redevelopment.	At Time of Development		
Riparian Protection and Enhancement			
24. Continue with implementation of Delta SPEA Bylaw and Riparian Areas Regulation. Look for offsetting riparian replanting opportunities within the watershed to compensate for areas where the Riparian Areas Regulation (RAR) does not apply (see Item 27 below).	At Time of Development and Ongoing		
25. Encourage Environmental Farm Plan Program to incorporate riparian plantings (e.g. 2m riparian width) along lowland watercourses to increase the study area RFI.		$0	
26. Improve the riparian along the East Oliver Bypass.	Medium Term	$40/m2	
27. Consider options to relocate Briarwood Creek away from railway and highway between Highway 91 and the BNSF railway to gain intact riparian on both sides of streams increasing the riparian by 2800 m2.		$50,000	**Riparian Subtotal $50,000**
Restoration and Enhancement for Fish			
28. Remove a fish passage obstruction (old weir) in Shaw Creek along south side of Highway 10 to improve fish access to 200m of channel.	Medium Term	$20,000	
29. Improve fish passage through the Watershed Creek culvert under railway (CUL_14) by adding fish baffles or rock weir.	Long Term	$35,000	
30. Improve fish passage through the Shaw Creek culvert under Highway 91 (CUL_236) by adding fish baffles or rock weir.		$35,000	
31. Create fish habitat along Shaw Creek between Old Highway 10 and the BNSF Railway to enhance 150 m of channel.		$40,000	**Fish Habitat Subtotal $130,000**
TOTAL CAPITAL COST Excluding Developer Costs (Excluding HST)		**$1,612,000**	
		Breakdown by Group	
	Total Delta Cost	**$852,000**	
	Total Surrey Cost	**$340,000**	
	Total MOT Cost	**$385,000**	
	Total BNSF Cost	**$35,000**	
	Total Developer Cost	**not estimated**	
		Breakdown by Timeline	
	Total Short Term Cost	**$40,000**	
	Total Medium Term Cost	**$630,000**	
	Total Long Term Cost	**$942,000**	

Refer to Figures 5-1 to 5-3

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5. MOT to review improved inlet and trash rack options on Shaw Creek at Highway 10 with wider bar spacing and debris interceptor upstream, to reduce the likelihood of inlet blockage and Highway 10 overtopping.
6. Delta to complete the construction of the East Oliver Bypass backwater berms near the Delta Golf Course as per the 2001 detailed design drawings.
7. Possible upgrade of culvert CUL_274 under path in Watershed Park to 1,350 mm diameter pipe.

Long Term Projects

The following long term projects are shown on Figure 5-3:

8. Delta, MOT, and BNSF to replace the following culverts with the larger sizes noted at the end of the design life of the existing culverts:
   - CUL_2 – Existing: 600 mm ∅ conc, Proposed: to be determined once East Oliver Bypass flow split finalized (Delta)
   - CUL_17 – Existing 1200 mm ∅ CMP, Proposed: 1,500 mm ∅ CMP (Delta)
   - CUL_24 – Existing: 1.8 m x 1.2 m conc box, Proposed: to be determined once East Oliver Bypass flow split finalized (Delta)
   - CUL_231 – Existing: 900 mm CMP, Proposed: to be determined once East Oliver Bypass flow split finalized (Delta)
   - CUL_236 – Existing: 2,000 mm ∅ CMP, Proposed: to be determined once East Oliver Bypass flow split finalized (MOT)
   - CUL_249 – Existing 600 mm ∅ conc, Proposed: 750 mm ∅ CMP (Delta)
   - CUL_250 – Existing 600 mm ∅ conc, Proposed: 750 mm ∅ CMP (Delta)
   - CUL_370 – Existing: 1,200 mm ∅, Proposed: 2,000 mm ∅ CMP (BNSF)

5.3 Lowlands Drainage Improvement

The following improvements would further improve lowlands drainage and irrigation:

Recently Completed and Upcoming Work by Others in the Study Area

Oliver Pump Station Capacity

Delta increased the Oliver Pump Station capacity from 6 m^3/s to 9 m^3/s. Completed in 2011. If possible, the ON/OFF switch elevations for the new pump should be set so that their average value is El. -1.4m Geodetic in order to provide 1.2m of freeboard to the adjacent lowlands.

East Oliver Bypass Completion

Delta to complete the East Oliver Bypass by connecting it to Mud Bay and adjusting the flow split between the agricultural land to the west and the bypass if necessary (see Figure 5-1).

Medium Term Projects

The following medium term projects are shown on Figure 5-2:

9. Consider constructing a 900 mm diameter culvert under the railway and a channel from the downstream end of the culvert to the East Oliver Bypass to divert more of the Shaw Creek high flows away from the lowlands and out to Mud Bay. A flow split structure on the upstream end of the culvert would send baseflows and low flows to Lorne Ditch and high flows to the bypass.

5.4 Water Quality Treatment

The environmental inventory and sampling has identified a number of water quality issues in the watercourses. Further monitoring would be required to more conclusively identify and quantify pollutants. The following projects will be initiated to identify pollutants and treat the water quality of outflows into the creeks:

Short Term Projects

The following short term projects are shown on Figure 5-1:

10. Further education of residents on the use of BMP's (e.g. environmentally friendly soaps for car washing). Confirm that commercial facilities are discharging to sanitary and not storm sewer in order to reduce the soapy water in creeks.

Developer, DCC, and Ongoing Projects

The following are developer, DCC, and ongoing projects:

11. Consider options for treatment of runoff from new paved surfaces, including municipal roadways, resulting from a 6-month 24-hour storm (or 90% of annual flows) to remove pollutants (see Appendix E for typical BMPs).
12. Incorporate stormwater BMP's when retrofitting existing streets with roadside source controls (rain gardens or grassed swales) at time of redevelopment in upland areas to treat runoff from up to 40 km (Surrey) and 29 km (Delta) of roadway (80% removal of TSS) (see Appendix E for typical BMPs). Homeowners would maintain these as part of the required boulevard maintenance.
13. Delta to encourage the Environmental Farm Plan Program in order to reduce fertilizers and pesticides in lowland channels.

Medium Term Projects

The following medium term projects are shown on Figure 5-2:

14. A small linear wetland is suggested along the south side of Highway 10 immediately west of Scott Road. Daylight 600 mm and 300 mm storm sewers into it to partially treat runoff from an 8 ha residential catchment in Surrey (est. 40% removal of TSS).

Long Term Projects

The following long term projects are shown on Figure 5-3:

15. A water quality treatment wetland should be considered at top end of Watershed Creek. Pipe residential runoff into it to treat runoff from a 76 ha residential catchment (80% removal of TSS).
16. Selectively monitor water quality at the outfall into the top end of the Watershed Creek Tributary (at former Works Yard) to determine if there is a need for treatment. Monitor runoff from an 8.3 ha residential catchment in Delta.
17. Selectively monitor water quality at the outfall into the top end of Briarwood Creek to determine if there is a need for treatment. Monitor runoff from a 60 ha developed area in Delta.
18. Selectively monitor water quality at the outfall into the top end of Shaw Creek to determine if there is a need for treatment. Monitor runoff from the Surrey portion of the Shaw Creek catchment.

5.5 Volumetric Reduction for Environmental Protection

In order to meet the no-net-loss requirement of an ISMP, future development impacts need to be mitigated. Volumetric reduction is one step in addressing development impacts. Existing development impacts can also be mitigated in part with volumetric reduction. The following volumetric reduction projects are proposed:

Developer, DCC, and Ongoing Projects

The following are developer, DCC, and ongoing projects:

19. Require volume reduction source controls capable of capturing the 6-month 24-hour storm (40 mm) on all new development and redevelopment including roadways for all areas changing from pervious to impervious (see Appendix E for typical BMPs).
20. Review options for retrofitting existing streets with roadside source controls in upland areas to reduce the EIA of approximately 70 ha of roadway in the study area (see Appendix E for typical BMPs). This is the same policy referred to in the water quality section as source controls would provide both capture and treatment.

Long Term Projects

The following long term projects are shown on Figure 5-3:

21. Create a rain garden in the parkette leading to the Boundary Park Pond and daylight the Boundary Drive East storm sewer into it. This would reduce the EIA of a 9 ha residential area from 60% to 10%.
22. Delta to review options for disconnected roof leaders directing roof runoff to landscaped areas on existing single family development in Delta where impacts to neighbouring properties and adjacent steep slope areas can be avoided. Initiate a volunteer program to help homeowners do so. This would reduce the EIA of approximately 120 ha of residential area by approximately 30%.

5.6 Flow Rate Control

In order to meet the no-net-loss requirement of an ISMP, future development impacts need to be mitigated. Flow rate control is the second step in addressing development impacts. The following volumetric reduction projects are proposed:

Developer and DCC Projects

The following are developer and DCC projects:

23. Restrict post-development flows to pre-development levels for all storms up to and including the 5-year storm on all new development and roadways and redevelopment as per the Surrey Design Criteria Manual and DFO Guidelines. The Delta Stormwater Management Design Manual requires a further detention of the 10-year return period flows for development in Delta.

5.7 Protect Riparian Setbacks

Riparian forest integrity is one of the major indicators of watershed health as shown on the WHTS discussed in Section 3.3. There are a number of riparian reforestation opportunities in the study area including the following:

Developer, DCC, and Ongoing Projects

The following are developer, DCC, and ongoing projects:

24. Continue with implementation of Delta SPEA Bylaw and Riparian Areas Regulation.. Look for offsetting riparian replanting opportunities within the watershed to compensate for areas where the RAR does not apply (see Item 27 below).
25. Encourage Environmental Farm Plan Program to incorporate riparian plantings (e.g. 2 m riparian width) to increase the study area RFI.

Medium Term Projects

The following medium term projects are shown on Figure 5-2:

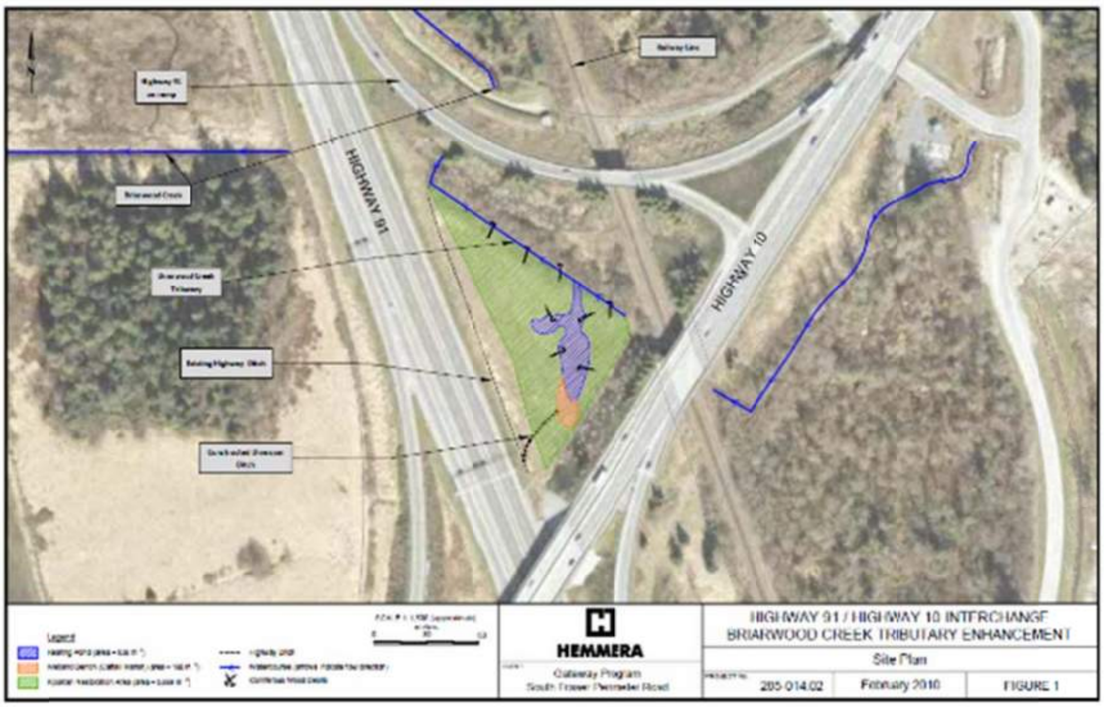
26. Improve the riparian along the East Oliver Bypass.
27. Consider options to relocate Briarwood Creek away from roadways/railway between Highway 91 and the BNSF railway to gain intact riparian on both sides of streams increasing the riparian by 2800 m^2.

5.8 Restoration and Enhancement for Fish

Recently Completed and Upcoming Work by Others

Shaw Creek (Briarwood Creek Tributary) Enhancement

This project is located Shaw Creek between Highway 91 and the BNSF Railway, adjacent to the Highway 10 to Highway 91 on-ramp. The work will involve rearing habitat creation (Aquatic habitat created = 838 m^2) and riparian enhancement (riparian habitat created = 5,849 m^2) within a grass-covered highway interchange that is routinely maintained. The primary objective will be to improve existing habitat within the watercourse and create overwintering habitat for juvenile salmonids (coho salmon and cutthroat trout). Proposed works primarily entail the construction of one off-channel rearing pond (3-5 m deep), which will be excavated in-the-dry, and creating/enhancing riparian habitat by removing Himalayan blackberry and planting grass covered areas with native shrubs and trees. The rearing pond and enhanced adjacent riparian area are also expected to provide improved habitat values for other wildlife species (e.g., amphibians and waterfowl). The pond, outlet channel and existing channel will be complexed with anchored coarse woody debris (CWD) and root wads (mainstem and secondary stems attached), and large boulders (see Figure 5-1). This work is part of fish habitat compensation associated with construction of the South Fraser Perimeter Road through Delta.

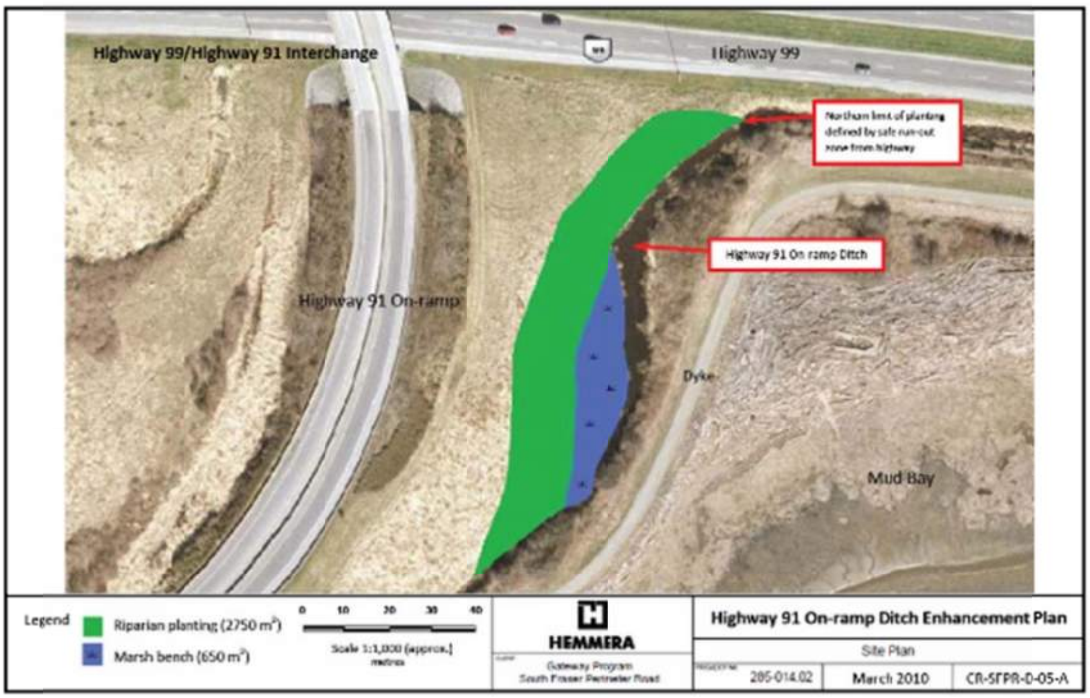


The Corporation of Delta and the Pacific Salmon Foundation Rearing Channel

An 80 m rearing channel in the shape of a horseshoe was created in a low lying area adjacent to Watershed Creek. The rearing channel has three 15 m gravel riffles, each with a 10 cm drop to provide spawning habitat. Large woody debris and boulders were placed for cover and bank stabilization. Seven 3 m Douglas Fir trees were planted along the channel edge to help provide shade and cover and moderate the water temperatures during the warmer calendar days. Two gravel trails furnished with trail benches lead to the stream to provide access for future public fish releases. Four interpretive signs installed along the stream edge provide information about the chum salmon life cycle and the benefits of the stream restoration improvements (see Figure 5-1).

Highway 91 On-ramp Ditch Enhancement

The proposed restoration/enhancement works will occur within vacant areas between the ditch and the side slope of the fill associated with the southern approach to the Hwy 99 Overpass. This is an area that is not only vacant but also experiences ongoing maintenance by MOT (i.e., mowing to within 0.5 to 1.0 m of the high water mark on the western side of the ditch channel). A marsh bench (cattails) would be constructed alongside the ditch, to provide enhanced channel complexity. An excavation depth of approximately 1.0 to 1.5 m is anticipated to be required, to achieve the appropriate invert for marsh plant persistence and consistent inundation. Riparian vegetation, consisting of native shrubs and trees, would be planted within the vicinity of the enhanced channel and adjacent reaches of the ditch. The works will more likely benefit resident rather than migratory fish (e.g., threespine stickleback, prickly sculpin, etc.). Aquatic habitat created = 650 m^2 (marsh bench). Riparian habitat created = 2,750 m^2 (see Figure 5-1). This project is part of fish habitat compensation associated with construction of the South Fraser Perimeter Road through Delta.



Medium Term Projects

The following medium term projects are shown on Figure 5-2:

28. MOT to remove a fish passage obstruction (old weir) in Shaw Creek along south side of Highway 10 to improve fish access to 200 m of channel.

Long Term Projects

The following long term projects are shown on Figure 5-3:

29. BNSF to improve fish passage through the Watershed Creek culvert under railway (CUL_14) by adding fish baffles or rock weir.
30. MOT to improve fish passage through the Shaw Creek culvert under Highway 91 (CUL_236) by adding fish baffles or rock weir. Projects 29 and 30 will improve fish access to approximately 2 km of channel, including some of the above mentioned projects underway.
31. MOT to create fish habitat along Shaw Creek between Old Highway 10 and the BNSF Railway to enhance 150 m of channel.

5.9 Further Studies and Monitoring Program

Detailed Geotechnical Investigations

The geotechnical hazard assessment performed by Trow identified the need for further study of the following:

- Monitoring of slope movement below Panorama Ridge along Shaw Creek
- Identifying areas along the Shaw Creek left (south) bank where riprap is needed to prevent future slope instability below the Panorama Ridge residential areas.

Ongoing Benthic, Water Quality, and Sediment Sampling

To monitor the success of mitigation measures and measures to improve watershed health as outlined in the ISMP, ongoing benthic sampling of the same sites that were used in the ISMP is recommended. To establish trends over time, sites should be monitored approximately once every two years. At the time of the benthic sampling, water and sediment samples should be taken and analyzed to quantify long term trends of pollutants in the water and sediment. The cost of benthic, water, and sediment sampling would be approximately $7,000 per year for the four locations used in this study.

Detailed Fish Presence and Fish Passage Investigations

Fish presence and distributions within the ISMP study area, especially in the lowlands, is not well-known. Therefore, further fish sampling and a fish utilization study, particularly of the minor lowland watercourses (minor sloughs, ditches, etc.), is recommended.

In addition, some culverts have been identified as potential barriers to fish passage based on general characteristics (length, slope, etc.) but further investigation is needed to assess whether they actually present a barrier to fish.

ISMP Performance Monitoring and Accountability of Plan

In order to measure and track the levels and changes in the health of a watershed, and to provide accountability to the ISMP, a suite of performance parameters has been developed that match the key issues identified above. Table 5-2 lists the parameters or “indicators” that should be measured and tracked over time.

The proposed schedule for review of the watershed health indicators should be once every five years. It is suggested that indicators be measured every two years.

Table 5-2: Boundary/Shaw Creek Watershed Adaptive Management Indicators

	Performance Indicator	Method of Analysis	2010	2015
1.	Total Impervious Area (% of Watershed Area)	GIS Analysis of Aerial Photos and Assessment Data	26%	Small increase expected due to development
2.	Effective Impervious Area (% of Watershed Area)	Estimated from surface cover type and source controls implemented	Flow monitoring required to quantify	decrease when source controls implemented
3.	Riparian Forrest Integrity (% of Riparian Area)	GIS Analysis of Aerial Photos	31%	Same or Increase
4.	Watershed Forest Cover (% of Watershed Area)	GIS Analysis of Aerial Photos	23%	Same or Increase
5.	Benthic Invertebrates	B-IBI scores based on methods used in this study	mean = 17.0	18
6.	Fish Populations	Density, species composition	No data	Collect Data
7.	Fish Passage Barriers	City/Streamkeepers Records	Full Barriers 1 Partial Barriers 4	Progressive Removal of Non-natural Barriers
8.	Average Summer Water Temperature (°C)	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 10.6 - 18.3 Mean: 15.0	Same or Decrease
9.	Dissolved Oxygen (DO, mg/L)	Field Measurement (during spring/summer baseflow)	Range: 1.5 – 10.8 Mean: 7.1	Same or Increase
10.	Water pH	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 5.7 – 7.5 Mean: 6.8	Same or Trend Toward Neutral
11.	Water Conductivity (µS)	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 83 – 7,590 Mean: 505	Same or Decrease
12.	Turbidity (NTU)	Monitoring (continuous station at Shaw Creek at Old Highway 10)	Range: 0 – 160 Mean: 15	Same or Decrease
13.	Water Quality Fecal Coliforms (MPN/100mL)	Field Sample at Oliver Slough near 112 Street & Lab Testing	1,600	< 200
14.	Sediment Quality	Metals in sediment	See Section 2.4	Same or Decrease
15.	No. of Erosion Sites	Field Assessment and Designation as Low, Medium, or High Severity and Consequence	See Table 2-2	Same or Decrease
16.	Lineal km of Roadside Ditches/Swales/Rain Gardens (km)	As-Constructed Drawings / GIS	16 km	18 km

5.10 Capital Cost Estimates and Funding

Capital Cost Estimate

The sizing of facilities in the ISMP is conceptual in nature and should be thoroughly assessed during pre-design. The capital cost estimates of the overall proposed works in the ISMP are summarized in Table 5-2. The detailed cost estimates are included in Appendix F.

Class 'D' Cost Estimate and Assumptions

The cost estimates provided in this study are of Class 'D' accuracy. This means that the general requirements for upgrading including size and approximate depth of excavation, as well as some general site conditions are known. The projects identified have not considered the following factors affecting construction:

- relocation of adjacent services (gas, hydro, telephone, etc.);
- special permitting requirements (fisheries windows, contaminated site, etc.);
- geotechnical issues requiring special construction such as pile-supported piping, buoyancy problems or rock blasting; and
- critical market shortages of materials.

As the above factors have not been allowed for in estimating construction unit rates or project design, the following factors are applied to all projects:

- Contractor Markup/Overhead – 6% (included in unit price);
- Mobilization/Demobilization – 6%;
- Bonding/Insurance – 2%;
- Engineering – 20%; and
- Contingency – 40%.

HST has not been included in the estimated project costs. The unit prices reflect KWL's recent experience with similar work, and therefore represent the best prediction of actual (2011) costs as of the date prepared. Actual tendered costs would depend on such things as market conditions generally, remoteness factor, the time of year, contractors' work loads, any perceived risk exposure associated with the work, and unknown conditions.

Funding Strategies

The cost estimates in Table 5-2 are summarized into four timeline categories, 1) Short Term, 2) Medium Term, 3) Long term, and 4) Ongoing. They are also summarized into four groups, 1) Delta, 2) Surrey, 3) MOT, and 4) Streamkeepers. Developer costs are not estimated.

- Funding opportunities from senior governments should be pursued for some of the items for example:
- Fish barrier removals and habitat improvements – Wildlife Habitat Canada Conservation Grant;
- Riparian enhancement and conservation areas – Environment Canada Habitat Stewardship Program; and
- Conveyance upgrades – Infrastructure grant programs.

5.11 Operation and Maintenance

Regular drainage system and stormwater facility maintenance is required to effectively convey design flows, minimize flooding and erosion, and mitigate the impacts of development. The following inspection and maintenance procedures are recommended.

Inspection: The Boundary/Shaw Creek drainage systems should be inspected annually during low flow conditions, ideally in the spring so that identified problems can be undertaken during the dry summer months. The primary purpose of the inspection is to assess the condition of the conveyance facilities including creek channels for erosion locations and hydraulic structures, and identify the need for maintenance. The annual inspection should include all open channels, culverts, ponds, diversions, flow splitters, and floodboxes. An overall drainage system inspection should also be completed after major storm events.

Vegetation Maintenance: Access to ditches and the conveyance ditches themselves should be maintained to prevent the growth of weeds, small trees and bushes. The hydraulic conveyance capacities of the ditches must be maintained. Ditch maintenance should occur annually.

Sediment Removal: Silt accumulation in the lowland drainage system can be expected due to the flat topography. The sediment should be removed when it affects the conveyance capacities of the drainage system and has an impact on water levels. Removal of sediment should be undertaken on a required basis (4 years).

Debris Control: Debris blockages at hydraulic structures can cause flooding problems. Regular debris removal (at least annually) from the ditches, culverts and floodboxes is necessary.

Pump Station: Undertake pump maintenance, as recommended by manufacturers, maintain and clean bar screens and trash racks.

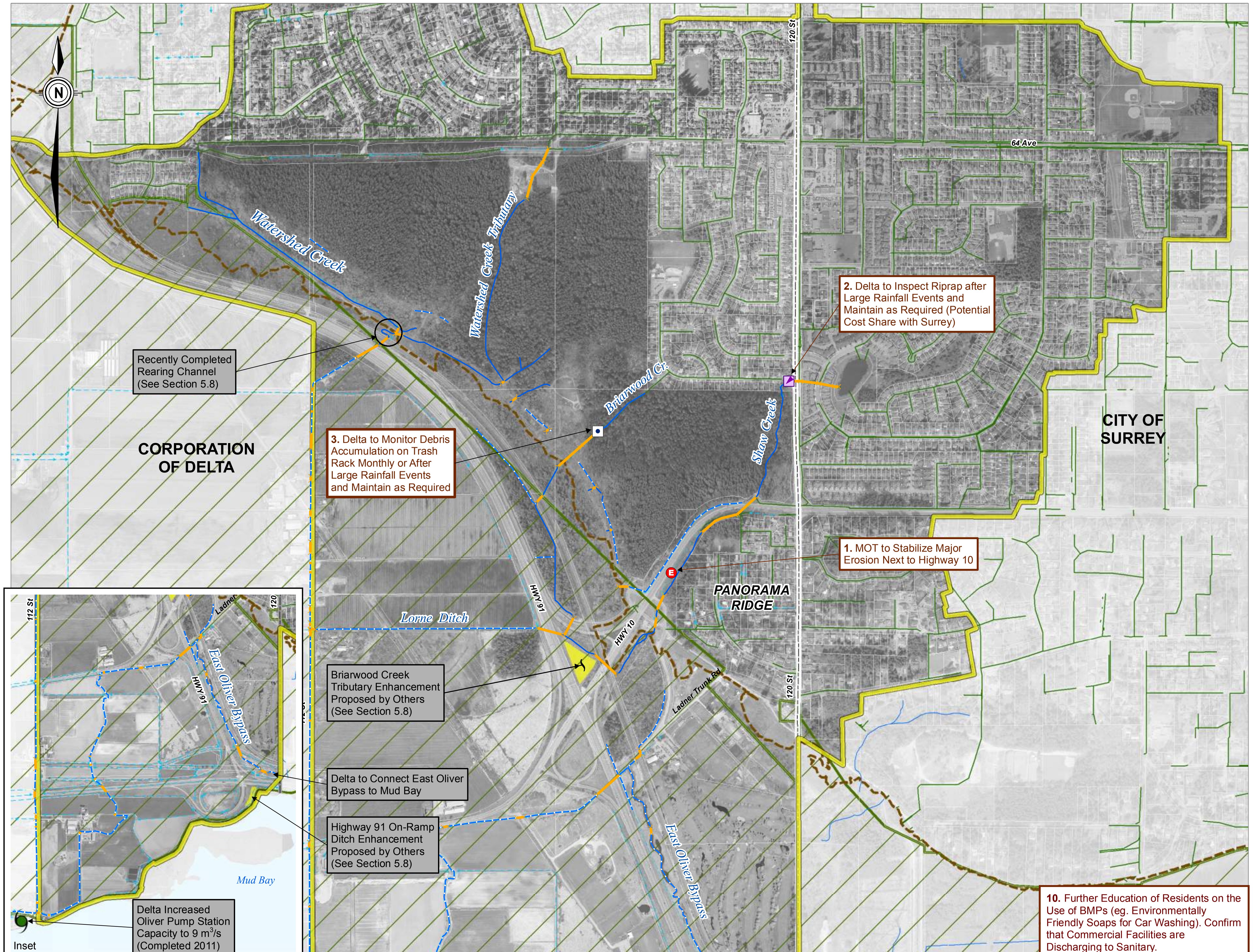
Wet Pond: Inspect periodically during wet weather to observe function, clean sediment forebay every 5 to 7 years or when 50% capacity has been lost, remove accumulated sediment form pond bottom when 10 to 15% of pool volume is lost, inspect hydraulic and structural facilities annually and mow side-slopes, embankments and spillways as required to prevent over growth.

Detention Tanks: Inspect annually and remove floating debris and oil.

Wetlands: Inspect annually and after each major storm event. At beginning of wet season remove trash and floatables and unclog outlet structures.

Grassed Swales: Inspect routinely especially after large storm events. Correct erosion problems as necessary, mow to keep grass in the active growth phase, remove clippings to prevent clogging of outlets, and remove trash and debris.

Bioretention with Underdrain: Remove leaves each fall, inspect overflow, hydraulic and structural facilities annually.



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Lowland Boundary (5m)
- Storm Main
- Existing Culvert
- Existing Ditch
- Existing Creek
- ALR Boundary
- Required Works
- Work Completed by Others

Topographic, cadastral data nad 2008 orhtophoto provided by The Corporation of Delta and City of Surrey.

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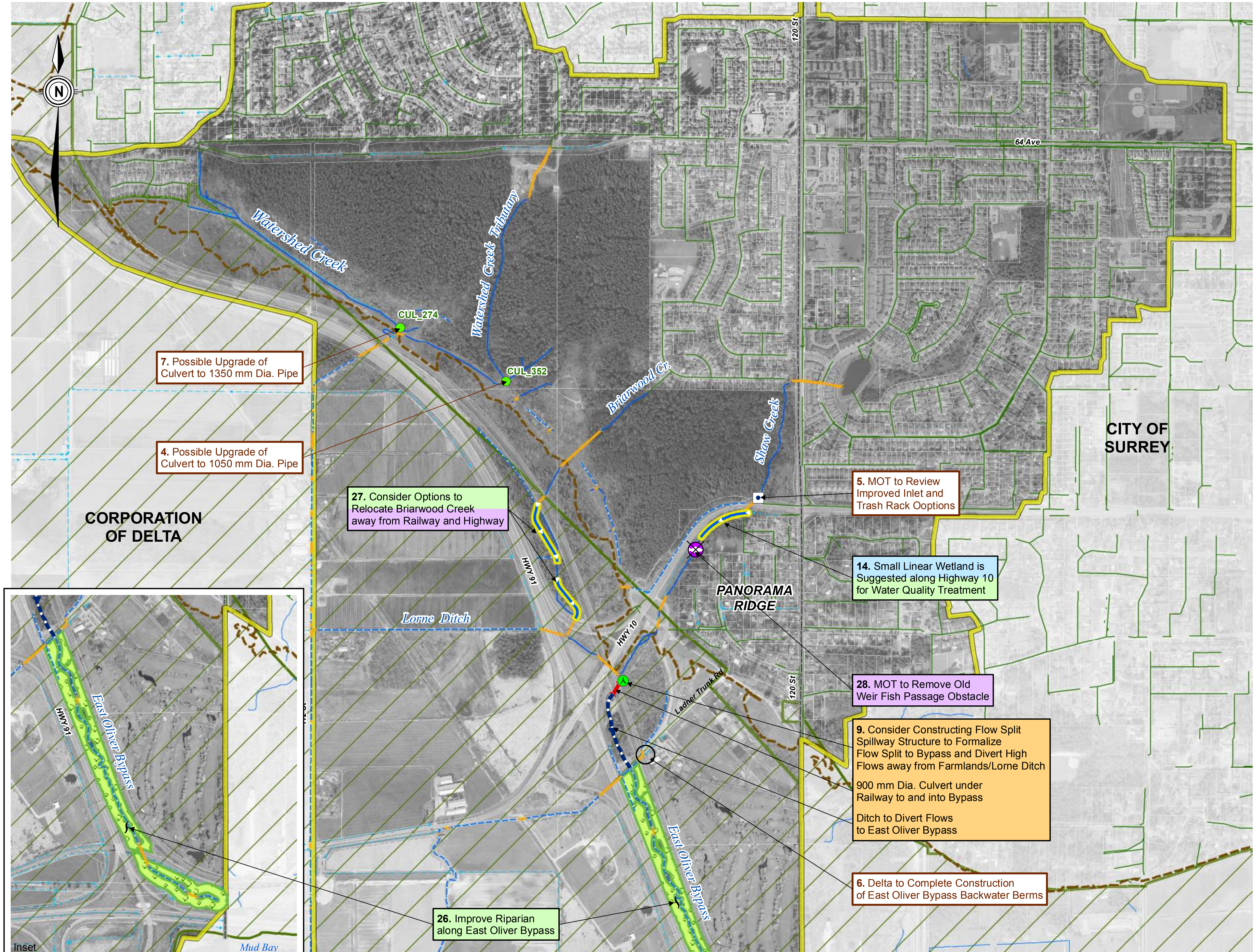
Project No.	Date
323-059	January 2012

Proposed Short Term Projects

Figure 5-1



Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study

Legend

- Study Boundary
- Municipal Boundary
- Lowland Boundary (5m)
- Storm Main
- Existing Culvert
- Existing Ditch
- Existing Creek
- ALR Boundary
- Required Works

Enhancement Alternatives

- Lowlands Drainage Improvements
- Riparian Reforestation
- Water Quality Improvement
- Fish Habitat Improvements

Topographic, cadastral data nad 2008 orhtophoto provided by The Corporation of Delta and City of Surrey.

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Project No.	Date
323-059	January 2012

Proposed Medium Term Projects

Figure 5-2

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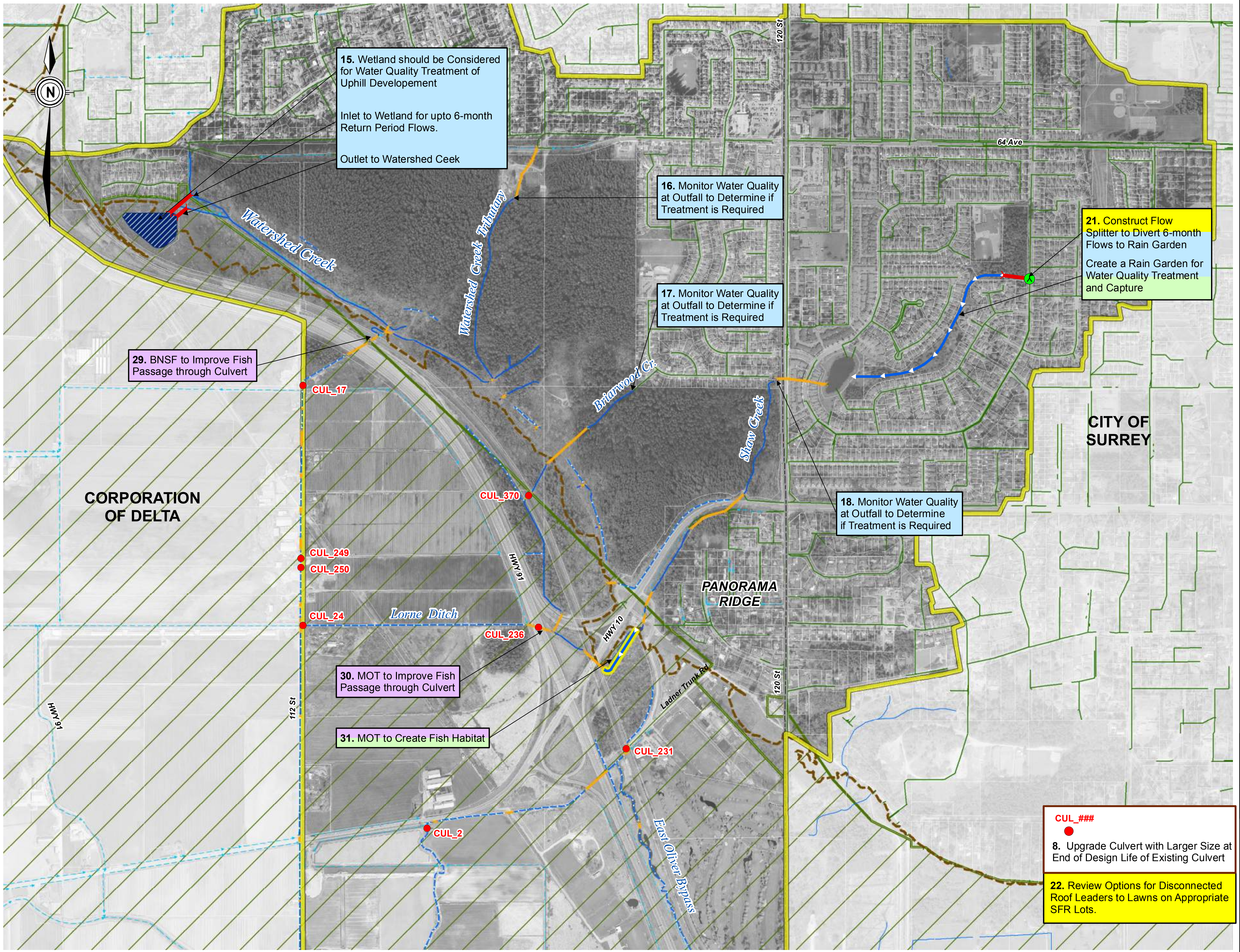
Author: ilau

Corporation of Delta Boundary/Shaw Integrated Stormwater Management Study



Legend

- Study Boundary
- Municipal Boundary
- Lowland Boundary (5m)
- Storm Main
- Existing Culvert
- Existing Ditch
- Existing Creek
- ALR Boundary
- Required Works

Enhancement Alternatives

- Riparian Reforestation
- Water Quality Improvement
- Volumetric Reduction to Mitigate Existing Development
- Fish Habitat Improvements

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Project No.	Date
323-059	January 2012

Proposed Long Term Projects

Figure 5-3

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Author: jlau

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Section 6

Summary and Recommendations

6. Summary and Recommendations

6.1 Summary

Introduction

- The Boundary/Shaw Creek ISMP employed a multi-disciplinary approach including stormwater engineering, and environmental protection.
- The study included consultation of Municipal Advisory Committees, City Council and the public.
- Two main watershed goals directed the IWMP: Protect aquatic ecosystems and water resources and minimize the risk to life and property associated with flooding.
- Key ISMP issues included existing flooding, irrigation, erosion, and environmental issues such as fish passage barriers and poor water quality.
- Applicable stormwater criteria included Delta and Surrey 10-year minor and 100-year major conveyance standards and detention criteria, BC Ministry of Transportation design guide, DFO Guidelines for 6-month volume reduction, 6-month to 5-year detention, and water quality treatment of 90% of annual runoff, and the Riparian Area Regulation for riparian protection.

Boundary/Shaw Creek Watershed

Land Use

- The historic, existing and future land uses were summarized. The existing land use is largely developed in the Surrey area (220 ha at 49% impervious) and mostly undeveloped or agricultural land in the Delta area (710 ha at 18% impervious). The future land use has very few zoning changes and mainly has redevelopment at higher impervious percentages (Surrey 58% impervious and Delta 24% impervious).

Drainage Inventory

- The Boundary/Shaw Creek watershed is 930 ha and drains to Mud Bay via the Oliver Pump Station. There are three significant watercourses in the watershed: Shaw Creek, Watershed Creek and Briarwood Creek. Watershed Creek has one significant tributary.
- There is an existing erosion problem in Shaw Creek between 120 Street and Highway 10 and existing flooding problems in the south portion of Delta Golf course, the lower part of Watershed Park, and the farmlands west of Highway 91.
- Irrigation water supply of the farmland is necessary in the growing season.
- A drainage inventory included investigations on creek crossings, channel cross-sections, erosion, deposition, obstructions and a condition assessment of hydraulic structures. Severe erosion was noted along Shaw Creek between 120 Street and Old Highway 10.

Environmental Inventory and Assessment

- Water quality sampling shows elevated nitrate levels in Briarwood Creek near to Canadian Council of Ministers of the Environment guidelines and levels of iron, aluminum, and cadmium above BC

Approved Water Quality Guidelines at one or more sites. Because of the limited amount of water quality sampling undertaken, comparison to guidelines is for the purpose of flagging issues of potential concern only. Further sampling to identify the extent of issues is recommended.

- Continuous temperature logging showed summer water temperatures in 2010 exceeded the BC Approved Water Quality Guidelines for salmonids in Shaw Creek for 8.4 days in July and 10.3 days in August.
- Sediment quality sampling showed elevated arsenic, cadmium, chromium, copper, zinc and nickel levels in several sample sites.
- The biological condition of Boundary/Shaw Creek has been heavily impacted by human disturbances in the watershed as reflected in the 2010 B-IBI score of 17.0 and a mean taxa richness of 10.8. This result was not unexpected given the high levels of urbanization and total impervious area within the upper watershed and low riparian forest integrity.
- The study area supports a known fish community with three salmonid species, five native non-salmonid species, and five exotic species. Coho, Chum and Cutthroat trout use the lower and transitional reaches of Watershed and Shaw Creeks for spawning and rearing. Lowland ditches are used for rearing and migration to and from the Oliver Pump Station and access to Mud Bay. Chinook may also periodically move in from Boundary Bay to rear.
- Instream fish habitat includes the lowland portion that has been dyked and channelized, the middle reaches that contain more gravel and cobble substrates suitable for spawning and rearing, and the upper reaches that have been culverted and developed. The best spawning and rearing habitat for salmonids is found in Watershed and Shaw Creeks. This habitat may not be available due to fish passage barriers.
- Six structures or crossings were identified as possible barriers to fish passage.
- Approximately 23% of the watershed is forest, with 27% riparian forest cover.
- Wildlife use in the watershed is diverse including species of conservation significance.
- Confirmed Species at Risk are Cutthroat Trout, *clarkii* subspecies and Great Blue Heron, *fannini* subspecies. Two red-listed ecological communities at risk in BC have been provisionally identified in the study area: red alder / skunk cabbage and Douglas-fir / dull Oregon-grape.

Geotechnical/Hydrogeological Assessment

- The hydrogeological assessment revealed mostly poor draining soils in the majority of the study area with a small area of well draining gravel and sand in the Watershed Creek headwaters. Groundwater tables in the lowlands are generally high and artesian wells are present at the toe of the uplands in Watershed Park.
- The geotechnical hazard assessment revealed numerous erosion sites mainly in Shaw Creek and historic slope instability along Shaw Creek in Watershed Park and below the Panorama Ridge subdivision. Monitoring of slope movement below Panorama Ridge along Shaw Creek is recommended.

Watershed Analysis

Hydrologic and Hydraulic Modelling

- Previously-developed XP-SWMM and MIKE 11 models were updated with more detailed information and validated.
- Three sets of design storms were created: the 2-, 5-, 10-, and 100-year return period 12-, 24-, and 48-hour duration events, the 6-month 24-hour event, and the ARDSA 10-year 2- and 5-day events taken from the Surrey *Design Criteria Manual* (2004) for the Municipal Hall Station.
- Continuous simulation modelling was performed using rainfall from 1991 to 2009 from the GVRD DT34 rain gauge. Results were used to create exceedance duration curves. The models were run for three scenarios: existing land use conditions without flow control, existing land use conditions with existing flow control, and future land use conditions with existing flow control. Results showed that there was little difference between the existing and future land uses. Both had higher peak flows for longer durations that the pre-development case. The Boundary Park Pond appears to be mitigating approximately half of the land use impacts in Shaw Creek.
- Peak flows for design events were estimated at strategic locations within the watershed for all three scenarios.
- The future land use, if left unmitigated, would increase 2-year to 100-year peak flows by approximately 5% to 10% and the 6-month flows by 20% to 40%. Watershed Creek, Watershed Creek Tributary, and Briarwood creek flows are not influenced by flow control as no detention or flow split structures are present in those areas.
- Exceedance duration curves developed from continuous simulation indicated that the future land use densification increase the flows and flow durations in Shaw, Watershed and Briarwood Creeks.
- A culvert capacity assessment was performed. Culverts under major roads or the railway were checked using the 100-year peak flow limiting the surcharge time to 30 minutes. Upland culverts under minor crossings were checked using the 10-year peak flow limiting surcharge time to 30 minutes. Lowland culverts under minor crossings were checked using the 10-year peak flow and a maximum head loss of 250 mm over the length of the culvert. Results indicate that ten culverts do not meet the criteria for both the existing and future land use flows. There are two surcharged creek crossings during the 100-year event and eight surcharged creek crossings in the 10-year event.
- A detention facility assessment was performed to determine the effectiveness of the existing flow control facilities and determine changes that would improve their effectiveness. Outlet adjustments to the Boundary Park Pond would provide some improvement and Detention Tank P1 is too small to benefit from outlet adjustment. The East Oliver Bypass Ponds reduce peak flows by 70 to 90% and will further reduce peak flows to the lowlands when completed and connected to Mud Bay.
- The ARDSA criteria were largely met in the lowland agricultural areas with the exception of freeboard in Cell 31 (the land bounded by Highway 10, Highway 91, and 112 Street).

Watershed Health Tracking System

- The Watershed Health Tracking System shows general agreement between the measured scores (16 to 18) and the scores predicted form impervious area and riparian forest integrity (14 to 20). The watershed health is as would be expected for a watershed with this level of development and would benefit from improvements.

Mitigation Alternatives

- Alternatives were developed and explored with Delta and Surrey to address the existing issues and mitigate the potential impacts of future development.
- Hydrotechnical upgrades to protect property and infrastructure were identified.
- To meet the no-net-loss requirement of an ISMP, future development impacts need to be mitigated. Developers in both Surrey and Delta should apply source controls to allow development while not making conditions worse in the downstream creeks or farmlands.
- To go beyond the no-net-loss requirement of an ISMP and in fact improve the watershed, a number of existing issues could be addressed. Six categories of alternatives are identified.
    - **Lowland drainage improvements** to improve the lowland drainage and irrigation.
    - **Riparian reforestation** to improve watershed health.
    - **Water quality improvements** to improve identify pollutants and treat the water quality of outflows into the creek.
    - **Detention and diversion alternatives** to reduce existing erosion.
    - **Volumetric reduction alternatives** to reduce existing development flows.
    - **Fish habitat improvements** to improve the conditions for fish in the creeks.
- The potential projects were discussed with Delta and Surrey and evaluated based on cost and qualitative benefit. The projects were assigned a timeline and importance which results in a prioritization. The majority of the options were selected to be incorporated into the ISMP.

Proposed Shaw/Boundary Creek ISMP Strategy

The ISMP strategy is summarized in four timeline categories: Short term, medium term, long term and ongoing with capital cost estimates provided for each (see Table 5-1 and Figures 5-1 to 5-3).

- **Required hydrotechnical improvements** include three short term projects ($40,000), four medium term projects ($240,000), and one long term projects ($0).
- **Lowland drainage improvements** to further improve the lowlands drainage and irrigation include one medium term project ($220,000).
- **Water quality treatment** to improve instream conditions for fish includes one short term project ($0), three ongoing projects ($0), one medium term project ($100,000), and four long term projects ($492,000).
- **Volumetric reduction** for environmental protection includes two ongoing projects ($0) and two long term projects ($340,000).
- **Flow rate control** to meet bylaws and guidelines includes one ongoing project ($0).
- **Riparian protection and enhancement** for improving watershed health includes two ongoing projects ($0) and two medium term projects ($50,000).
- **Restoration and enhancement for fish** includes one medium term project ($20,000) and three long term projects ($110,000).

- Further studies and monitoring are recommended for the Boundary/Shaw Creek study area to investigate the geotechnical hazards along Shaw Creek, to continue benthic sampling, to document fish presence and fish passage through culverts, and to measure the performance of the ISMP.
- The total capital cost of the ISMP projects is up to $1.6 million of which $0.4M to $0.85M is attributable to Delta projects, $0.34M to Surrey projects, $0.38M to MOT projects, and $35k to BNSF projects. Short term cost projects are valued at $40,000, medium term projects at $630,000, and long term projects at $940,000. Funding opportunities from senior governments may be pursued for some of these projects.
- Additional regular drainage system maintenance was recommended.

6.2 Recommendations

Based on the above summary, it is recommended that Delta and Surrey:

1. Adopt the goal of net gain of ecological health for Boundary/Shaw Creek watershed as a whole.
2. Initiate a monitoring program to collect benthic samples, water quality samples, and sediment samples. Undertake further fish presence and fish passage investigations. Track the performance of the ISMP by comparing trends in indicators as shown in Table 5-1.
3. Implement the proposed short term projects and improvements first, followed in turn by the medium and long term projects and improvements.
4. Develop and implement policy requiring volume reduction source controls and detention on all new development and redevelopment.
5. Continue with roadside source controls BMP's in upland areas and review policy options.
6. Review implications of a roof leader disconnection program that directs roof runoff to landscaped areas and consider a volunteer program to assist home owners to do so.
7. Expand and enhance education program for residents in the catchment on the use of local BMPs (e.g. environmentally friendly soaps for car washing, fertilizer/pesticide usage, benefits of trees, and protection of riparian areas).
8. Initiate a detailed geotechnical study to monitor the slope movement and identify the need for bank protection to minimize risk of slope instability below Panorama Ridge along the left (south) bank of Shaw Creek.
9. Continue with and possibly expand maintenance programs required to protect infrastructure and facilities to promote their proper and effective function. Maintain source controls to meet watershed health targets.

6.3 Report Submission

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Technical Review

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Appendix A

Drainage Inventory

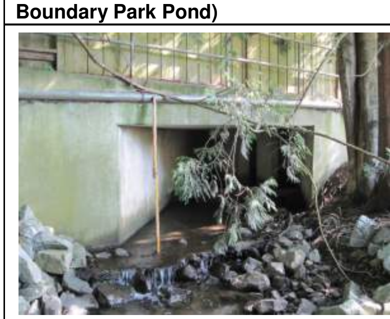
Appendix A

Figure A-1: Photo Overview of Boundary / Shaw Creek – Upland Culverts and Bridges (Page 1)

Bridge in Watershed Park	**Bridge in Watershed Park**	**Inlet of Culvert CUL_372 on Briarwood Creek**
		
Inlet to culvert under HWY 10	**Inlet to culvert under HWY 10 east ramp to Ladner Trunk Road**	**Outlet to culvert under HWY 10 East ramp to Ladner Trunk Road**
		
Inlet to culvert under Railway at HWY 10 overpass	**Outlet to culvert under Railway at HWY 10 overpass**	**2 storm outfalls east of 63A Street (outfall to watercourse in Watershed Park)**
		

Appendix A

Figure A-1: Photo Overview of Boundary / Shaw Creek – Upland Culverts and Bridges (Page 2)

Broken pipe in artesian well area	**Outlet of culvert under path (culvert drains flow from artesian wells)**	**Pond area created by artesian wells**
		
Inlet to culvert under railway (culvert drains flow from artesian wells)	**Outfall south-east of 63 Street (Well)**	**Outfall from Briarwood Cres.**
		
Storm sewer outfall (120 street sewer, Boundary Park Pond)	**Storm sewer outfall (120 street sewer, Boundary Park Pond)**	
		

Appendix A

Figure A-2: Photo Overview of Boundary / Shaw Creek - Major Erosion Sites

Erosion downstream of work yard on 64 street	**Erosion downstream of Boundary Park outfall**	**Erosion further downstream of Boundary Park outfall**
		
Erosion further downstream of Boundary Park outfall (half way between outfall and HWY 10)		**Erosion site downstream of HWY 10 culvert and upstream of ramp to Ladner Trunk Road**
		
Erosion, Debris Barrier, and Gravel Deposit downstream of HWY 10 culvert and upstream of ramp to Ladner Trunk Road	**Erosion site downstream of HWY 10 culvert and upstream of ramp to Ladner Trunk Road**	
		

Appendix A

Figure A-3: Photo Overview of Boundary / Shaw Creek - Watercourse Obstructions

Obstruction downstream of Briarwood Cres. outfall	Obstruction downstream of Boundary Park outfall	
		
Obstruction further downstream of Boundary Park outfall (half way between outfall and HWY 10)		Obstruction further downstream of Boundary Park outfall (Closer to HWY 10)
		
Obstruction further downstream of Boundary Park outfall (Closer to HWY 10)	Obstruction site downstream of HWY 10 culvert and upstream of ramp to Ladner Trunk Road	
		

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Appendix B

Environmental Inventory and Assessment

Contents

Appendix B-1.

In-situ water quality parameter sampling data for Shaw Creek ISMP study area streams (September 2010).

ID	Catchment	Location Description	Date	Time	UTM-E (NAD27)	UTM-N (NAD27)	Temp (ºC)	Cond (µS/cm)	SpCond (µS/cm)	DO (%)	DO (mg/l)	pH pH	TDS (mg/l)	Turbidity (NTU)	ORP ORP	Comments
1	Shaw	Shaw Ck south of Highway 10, approx. 130 m d/s of lower culvert at Old Hwy 10 interchange, 75 m u/s of BNSF railway culvert	15-Sep-10	10:15	507641	5440988	15.37	118	145	85.8	8.57	6.92	0.094	4.05	22.2	SHAW C-1 benthic site
2	Shaw	Shaw Ck u/s of railway culvert	15-Sep-10	11:01	507601	5440928	15.34	119	146	86.5	8.65	6.81	0.095	4.72	62.8	
3	Shaw	Shaw Ck u/s of Highway 91 culvert	15-Sep-10	11:14	507421	5441058	15.00	133	165	80.3	8.03	6.71	0.108	2.58	36.5	at confluence with Briarwood Ck; no fish observed in pools here
4	Shaw	Shaw Ck d/s of railway culvert	15-Sep-10	11:24	507525	5440993	15.35	128	157	85.4	8.50	6.60	0.102	4.72	7.3	
5	Briarwood	Briarwood Ck along regional greenway trail	15-Sep-10	11:38	507394	5441174	12.90	241	314	15.1	1.53	6.54	0.204	160.0	-20.7	
6	Shaw	Shaw Ck within Highway 10/Old Highway 10 interchange	15-Sep-10	11:53	507734	5441138	15.87	119	145	93.7	9.26	7.08	0.094	2.34	0.2	Salamander sp. seen briefly in pool at sampling site
7	Shaw	Shaw Ck 20 m d/s of Highway 10/Old Highway 10 interchange	15-Sep-10	12:04	507715	5441063	16.12	120	145	93.9	9.22	7.11	0.094	4.05	26.9	
8	Shaw	Shaw Ck 25 m u/s of Ladner Trunk Rd	15-Sep-10	12:16	507774	5441214	15.96	119	144	76.9	7.60	7.02	0.093	3.33	45.2	SHAW C-2 benthic site
9	Shaw	Shaw Ck immed. d/s of Scott Road/120 St culvert	15-Sep-10	12:51	508166	5441899	17.04	104	122	95.2	9.19	7.00	0.080	9.86	98.4	SHAW SCOTT water quality/sediment site
10	Briarwood	Briarwood Ck immed. u/s of of Watershed Park slope culvert	15-Sep-10	13:16	507546	5441744	17.56	175	204	98.2	9.33	7.16	0.132	4.82	88.6	BRIARWOOD C-1 benthic site
11	Briarwood	Briarwood Ck immed. d/s of Briarwood Cres storm outfall	15-Sep-10	13:51	507690	5441864	17.58	175	203	94.2	8.99	7.12	0.135	2.58	66.9	
12	Watershed	Watershed Ck 5 m u/s of railway culvert	15-Sep-10	14:15	506838	5442056	10.96	133	181	77.0	8.48	6.84	0.118	2.03	98.0	WATERSHED C-1 benthic site
13	Lowlands West	Oliver Slough immed. u/s of 112 St culvet	15-Sep-10	15:08	506605	5438806	16.06	673	811	52.5	5.13	6.60	0.525	9.02	44.7	LOW-W water quality/sediment site
14	Lowlands East	East Oliver Bypass east of Highway 91, north of Highway 99	15-Sep-10	16:04	507720	5440343	18.32	285	327	90.6	8.51	7.28	0.212	1.81	67.8	LOW-E water quality site
15	Watershed	Watershed Ck immed. d/s of Kittison Pkwy	16-Sep-10	9:22	506201	5442665	16.77	116	137	96.3	9.43	7.49	0.089	3.27	79.5	
16	Watershed Trib.	Unnamed trib. 10 d/s of Watershed Park maintenance yard	16-Sep-10	9:34	507226	5442428	14.59	78	98	78.6	7.99	7.16	0.063	-0.19	124.6	
17	Shaw	Boundary Park Stormwater Pond	16-Sep-10	9:48	508344	5441902	17.42	104	122	103.8	9.97	7.37	0.079	9.95	111.8	
18	Shaw	Shaw Ck 20 m u/s of Highway 10 culvert	16-Sep-10	9:58	508076	5441546	16.66	74	83	90.1	8.76	7.02	0.057	10.33	134.9	
19	Watershed	Watershed Park groundwater-fed trib. immed. d/s of Lower Trail culvert	16-Sep-10	10:20	507519	5441548	10.63	157	216	96.7	10.76	7.23	0.141	0.64	123.1	
20	Lowlands East	Ditch across from Delta Golf Course entrance	16-Sep-10	10:37	507715	5440730	14.12	162	208	15.7	1.61	6.65	0.124	8.33	86.0	water stagnant; ditch was RCG-infested
21	Lowlands West	Lorne Ditch immed. u/s of 112 St	16-Sep-10	10:51	506590	5441077	14.63	158	197	23.4	2.37	6.39	0.128	3.16	405.7	irrigation dam 10 m west of 112 St is 2 foot drop
22	Lowlands West	60 Ave Ditch d/s of 6015 112 St driveway crossing	16-Sep-10	11:10	506582	5441872	10.91	137	188	82.6	9.12	6.87	0.122	2.13	280.6	water flowing at this location; good potential spawning habitat (gravels, etc.)
23	Lowlands West	Private E-W ditch north of 5860 112 St	16-Sep-10	11:34	506591	5441665	14.77	166	206	18.6	1.89	5.72	0.134	0.56	120.7	
24	Lowlands West	112 St Ditch at concrete footbridge in front of 5655 112 St	16-Sep-10	11:42	506575	5441181	12.78	160	209	62.7	6.71	6.22	0.136	2.73	237.5	ditch has muddy bottom
25	Lowlands West	112 St Ditch 25 m u/s of Ladner Trunk Rd	16-Sep-10	11:54	506571	5440401	13.96	168	213	73.9	7.62	6.60	0.138	5.36	-20.9	
26	Lowlands West	Ditch E of 112 St S of Ladner Trunk Rd at u/s end of box culvert to W side ditch	16-Sep-10	12:06	506589	5440298	16.11	336	405	30.7	3.01	6.21	0.263	10.5	40.3	flow is W along S side of Ladner Trunk Rd then turns S then through box culvert
27	Lowlands West	Oliver Slough S of Highway 99	16-Sep-10	12:26	507107	5439528	16.32	6333	7590	52.2	4.94	6.44	4.933	106.6	-18.7	
28	Lowlands West	112 St Ditch immed u/s of 4455 112 St driveway culvert	16-Sep-10	12:39	506582	5438882	15.26	247	304	61.6	6.16	7.36	0.192	n/a	34.3	ditch too steep to sample; salinity = 0.14
						mean	15.16	394	478	71.9	7.19	6.84	0.310	14.0	85.2	
						min	10.63	74	83	15.1	1.53	5.72	0.057	-0.19	-20.9	
						max	18.32	6333	7590	103.8	10.76	7.49	4.933	160.0	405.7	
						count	28	28	28	28	28	28	28	27	28	

Coordinates in UTM NAD27.

Appendix B-2.

Bacteriological, anion, nutrient, and metal concentrations in water samples from Shaw Creek ISMP study areas streams (September 2010).

RESULTS OF ANALYSIS

Sample ID Date Sampled Time Sampled	Units	Detection Limits	SHAW C-1 15-SEP-10 10:27	SHAW SCOTT 15-SEP-10 12:50	BRIARWOOD C-1 15-SEP-10 13:15	WATERSHED C-1 15-SEP-10 14:10	LOW-W 15-SEP-10 14:59	LOW-E 15-SEP-10 16:00	BC Approved (A) and Working (W) Water Quality Guidelines (2006) **BCWQ 2006**	CCME Water Quality Guidelines for the Protection of Aquatic Life (December 2007) **CCME 2007**
Bacteriological Tests										
Coliform Bacteria - Fecal	MPN/100mL	2	49	49	49	23	1600	33-46	200	200
Coliform Bacteria - Total	MPN/100mL	2	920	>1600	350	920	>1600	240-350		
Anions and Nutrients										
Alkalinity, Total (as CaCO3)	mg/L	2.0	43.2	35.2	46.1	74.2	64.3	115		
Ammonia as N	mg/L	0.0050	0.0596	0.0052	<0.0050	0.0152	0.280	<0.0050		
Nitrate (as N)	mg/L	0.0050	0.772	0.883	2.56	0.582	0.632	<0.0050		2.9
Ortho Phosphate as P	mg/L	0.0010	<0.0010	0.0191	0.0076	0.0553	0.121	<0.0010		
Total Metals										
Aluminum (Al)-Total	mg/L	0.0050	0.295	0.206	<0.040	<0.040	0.373	<0.020		0.005 @ pH<6.5; 0.1@ pH>6.5
Antimony (Sb)-Total	mg/L	0.00050	<0.00050	0.00057	<0.00050	<0.00050	<0.00050	<0.00050	0.02 (W)	
Arsenic (As)-Total	mg/L	0.00050	0.00146	0.00163	0.00382	0.00350	<0.0040	<0.00050	0.005 (W)	0.005
Barium (Ba)-Total	mg/L	0.020	<0.020	<0.020	0.024	<0.020	<0.020	<0.020	5 (W)	
Beryllium (Be)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0053 (W)	
Boron (B)-Total	mg/L	0.10	<0.10	<0.10	<0.10	<0.10	0.12	<0.10		
Cadmium (Cd)-Total	mg/L	0.000017	0.000021	0.000019	<0.000017	<0.000017	0.000068	<0.000017	0.00001 (b) (W)	0.000017
Calcium (Ca)-Total	mg/L	0.10	15.9	14.1	16.8	19.7	30.2	32.2		
Chromium (Cr)-Total	mg/L	0.0010	0.0011	0.0013	<0.0010	0.0010	0.0019	<0.0010	0.001 Cr(VI); 0.0089 Cr(III) (W)	0.001 Cr(VI); 0.0089 Cr(III)
Cobalt (Co)-Total	mg/L	0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00223	<0.00030	0.110 (A)	
Copper (Cu)-Total	mg/L	0.0010	0.0037	0.0054	0.0031	<0.0010	0.0038	<0.0010	0.003 to 0.007 mg/L [(0.094(hardness)+2) (A)]	0.002 @ CaCO3 = 0-120 mg/L
Iron (Fe)-Total	mg/L	0.030	0.835	0.408	0.161	0.071	3.64	0.106	0.3 (W)	0.3
Lead (Pb)-Total	mg/L	0.00050	0.00079	0.00080	<0.00050	<0.00050	<0.00050	<0.00050	0.018 mg/L at 30 mg/L $e^{[1.273 \ln(hardness)-1.460]}$ (A)	0.001 @ CaCO3 = 0-60 mg/L
Lithium (Li)-Total	mg/L	0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0056	0.0057	5 (W)	
Magnesium (Mg)-Total	mg/L	0.10	2.72	2.08	3.50	6.83	19.6	14.2		
Manganese (Mn)-Total	mg/L	0.00030	0.0758	0.0339	0.00287	0.0124	0.248	0.180	0.8 - 1.1 @ CaCO3 = 25-50 mg/L (A)	
Mercury (Hg)-Total	mg/L	0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.0001 (A)	
Molybdenum (Mo)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	2 (A)	0.073
Nickel (Ni)-Total	mg/L	0.0010	<0.0010	0.0010	<0.0010	<0.0010	0.0087	0.0045	0.025 @ CaCO3 = 0-60 mg/L (W)	0.025 @ CaCO3 = 0-60 mg/L
Potassium (K)-Total	mg/L	2.0	<2.0	<2.0	2.5	<2.0	8.5	3.4		
Selenium (Se)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0040	<0.0010	0.001 (A - drinking water)	0.001
Silver (Ag)-Total	mg/L	0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.0001 @ CaCO3 < 100 mg/L (A)	0.0001
Sodium (Na)-Total	mg/L	2.0	8.0	6.1	14.3	7.4	90.7	16.3		
Thallium (Tl)-Total	mg/L	0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.0003 (W)	0.0008
Tin (Sn)-Total	mg/L	0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Titanium (Ti)-Total	mg/L	0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010		
Uranium (U)-Total	mg/L	0.00020	<0.00020	<0.00020	<0.00020	0.00057	0.00036	<0.00020		
Vanadium (V)-Total	mg/L	0.0010	0.0014	0.0010	<0.0010	0.0047	<0.0040	<0.0010		
Zinc (Zn)-Total	mg/L	0.0050	0.0114	0.0207	0.0066	<0.0050	0.0141	<0.0050	0.033 @ CaCO3 = 0-90 mg/L (A)	
Physical Tests										
Hardness (as CaCO3)	mg/L	0.50	50.9	43.7	56.3	77.4	156	139		
Total Suspended Solids	mg/L	3.0	27.1	11.8	<3.0	<3.0	17.8	7.8		

noticeably higher levels at site(s) compared with other sites in the study area

Sampling Sites	UTM-E	UTM-N	Location Description
SHAW C-1	507641	5440988	Shaw Ck south of Highway 10, approximately 130 m d/s of lower culvert at Old Highway 10 interchange, 75 m upstream of BNSF railway culvert
SHAW SCOTT	508166	5441899	Shaw Ck, immediately d/s of Scott Road/120 St culvert
BRIARWOOD C-1	507546	5441744	Briarwood Ck, immediately u/s of inlet to steep gradient culvert in Watershed Park
WATERSHED C-1	506838	5442056	Watershed Ck, 5 m u/s of BNSF railway culvert
LOW-W	506605	5438806	Oliver Slough, immediately u/s of 112 St culvert; representative of lowlands west of Highway 91
LOW-E	507720	5440343	East Oliver Bypass, east of Highway 91; representative of lowlands east of Highway 91

Coordinates in NAD27 Ground.

Appendix B-3.

Metal concentrations in sediment samples from Shaw Creek ISMP study area streams (September 2010).

RESULTS OF ANALYSIS

Sample ID			SHAW C-1	SHAW SCOTT	BRIARWOOD C-1	WATERSHED C-1	LOW-W	BC Working Sediment Quality Guidelines - Freshwater (August 2006)		CCME Sediment Quality Guidelines - Freshwater (Update 2002)		Other Comparative Values		
Date Sampled			15-SEP-10	15-SEP-10	15-SEP-10	15-SEP-10	15-SEP-10							
Metals	Units	Detection Limits						**ISGQ BC 2006**	**PEL BC 2006**	**ISGQ CCME 2002 (Aquatic Life)**	**PEL CCME 2002 (Aquatic Life)**	**Still Creek Subbasin 1995 (median)**	**Brunette River Subbasin 1995 (median)**	**Oh (2003) thesis Table 2-3**
Antimony (Sb)	mg/kg	10	<10	<10	<10	<10	<10							
Arsenic (As)	mg/kg	5.0	<5.0	<5.0	12.1	<5.0	10.7	5.9	17	5.9	17.0			
Barium (Ba)	mg/kg	1.0	43.8	35.4	44.0	21.2	72.6							
Beryllium (Be)	mg/kg	0.50	<0.50	<0.50	<0.50	<0.50	2.69							
Cadmium (Cd)	mg/kg	0.50	<0.50	<0.50	<0.50	<0.50	5.66	0.6	3.5	0.6	3.5	141	103	
Chromium (Cr)	mg/kg	2.0	19.1	23.9	30.8	9.6	53.8	37.3	90	37.3	90.0			
Cobalt (Co)	mg/kg	2.0	4.6	5.8	7.2	4.9	14.6							18
Copper (Cu)	mg/kg	1.0	12.1	25.1	33.8	15.1	257	35.7	197	35.7	197.0	130	51	33-210
Lead (Pb)	mg/kg	30	<30	<30	<30	<30	<30	35	91	35.0	91.3	130	55	10-223
Mercury (Hg)	mg/kg	0.050	<0.050	<0.050	0.123	<0.050	0.086	0.170	0.486					
Molybdenum (Mo)	mg/kg	4.0	<4.0	<4.0	<4.0	<4.0	7.4							
Nickel (Ni)	mg/kg	5.0	13.5	16.7	16.9	7.7	67.9	16	75			17	12	32-340
Selenium (Se)	mg/kg	2.0	<2.0	<2.0	<2.0	<2.0	<2.2	5						
Silver (Ag)	mg/kg	2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.5*						
Tin (Sn)	mg/kg	5.0	<5.0	<5.0	<5.0	<5.0	<5.0							
Vanadium (V)	mg/kg	2.0	40.5	36.7	41.7	40.4	54.6							
Zinc (Zn)	mg/kg	1.0	62.6	74.0	124	43.5	361	123	315	123.0	315.0	251	128	159-983
Physical Tests														
pH			7.20	7.86	7.54	7.44	7.02							

*Ontario sediment quality guideline

noticeably higher levels at site(s) compared with other sites in the study area

Sampling Sites	**UTM-E**	**UTM-N**	**Location Description**
SHAW C-1	507641	5440988	Shaw Ck south of Highway 10, approximately 130 m d/s of lower culvert at Old Highway 10 interchange, 75 m upstream of BNSF railway culvert
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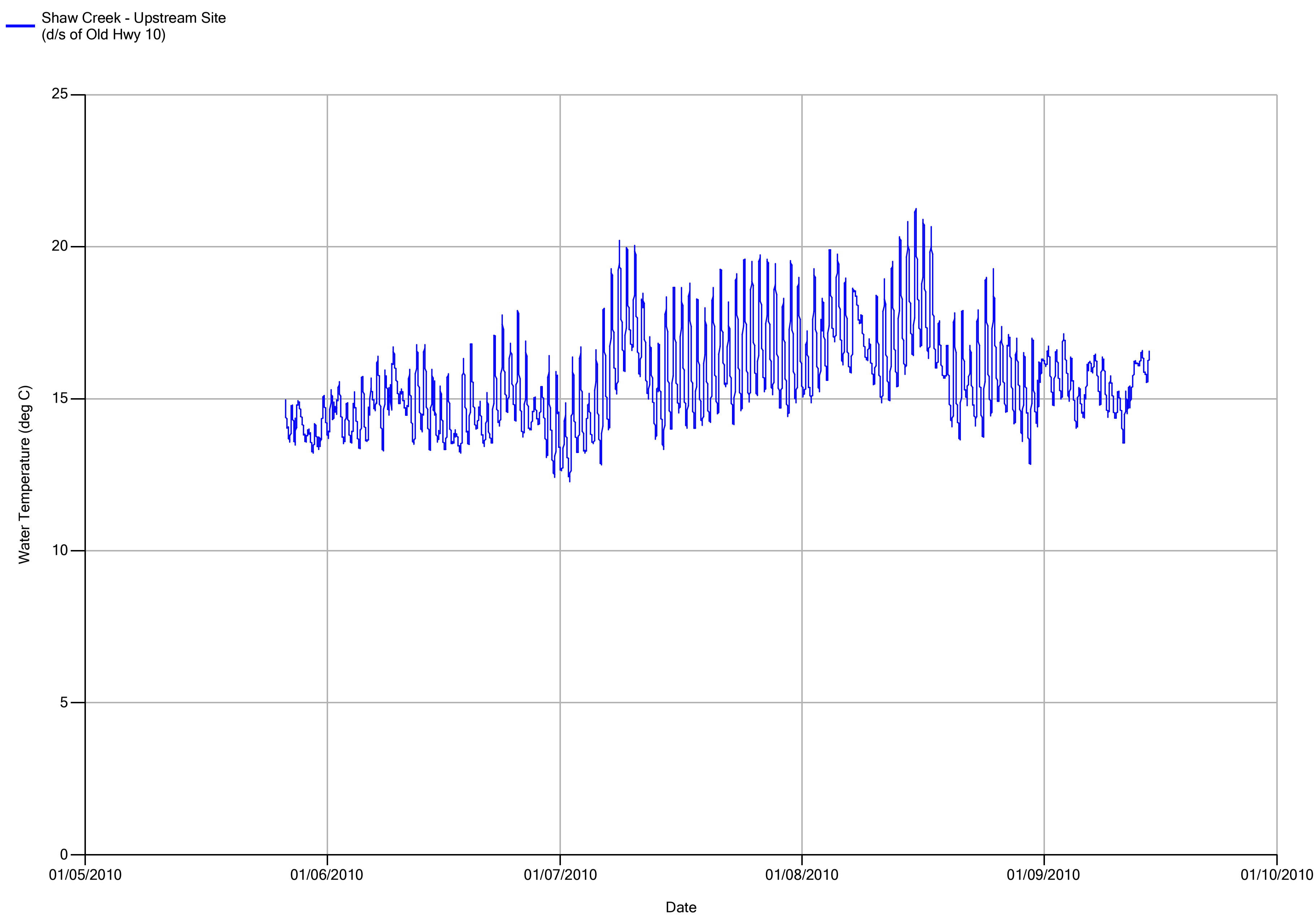
LOW-E	507720	5440343	East Oliver Bypass, east of Highway 91; representative of lowlands east of Highway 91

Coordinates in NAD27 Ground.

Shaw Creek: Raw Water Temperature 2010



Analysis of biological samples:
Technical summary of methods and quality assurance procedures
Prepared for Raincoast Applied Ecology
Nick Page, Project Manager
March 8, 2011

by
W. Bollman, Chief Biologist
Rhithron Associates, Inc.
Missoula, Montana

METHODS

Sample processing

Four macroinvertebrate samples from the Shaw Creek ISMP Project were delivered to Rhithron's laboratory facility in Missoula, Montana on December 10, 2010. All samples arrived in good condition. An inventory document containing sample identification information was provided by the Raincoast Applied Ecology (RAE) Project Manager. Upon arrival, samples were unpacked and examined, and checked against the RAE inventory. An inventory spreadsheet was created and sent to the RAE Project Manager. This spreadsheet included project code and internal laboratory identification numbers and was verified by the RAE Project Manager prior to upload into the Rhithron database.

Samples were preserved in formalin. Upon arrival all samples were rinsed to remove formalin preservative. Samples were re-preserved in 95% ethanol. Standard sorting protocols were applied to achieve representative subsamples of a minimum of 400 organisms. Caton sub-sampling devices (Caton 1991), divided into 30 grids, each approximately 5 cm by 6 cm were used. Each individual sample was thoroughly mixed in its jar(s), poured out and evenly spread into the Caton tray, and individual grids were randomly selected. The contents of each grid were examined under stereoscopic microscopes using 10x-30x magnification. All aquatic invertebrates from each selected grid were sorted from the substrate, and placed in 95% ethanol for subsequent identification. Grid selection, examination, and sorting continued until at least 400 organisms were sorted. All unsorted sample fractions were retained and stored at the Rhithron laboratory.

Organisms were individually examined by certified taxonomists, using 10x – 80x stereoscopic dissecting scopes (Leica S8E and S6E) and identified to target taxonomic levels consistent with Washington LPTL (Plotnikoff and White 1996) protocols and data generated for previous RAE projects, using appropriate published taxonomic references and keys.

Identification, counts, life stages, and information about the condition of specimens were recorded on bench sheets. Organisms that could not be identified to the taxonomic targets because of immaturity, poor condition, or lack of complete current regionally-applicable published keys were left at appropriate taxonomic levels that were coarser than those specified. To obtain accuracy in richness measures, these organisms were designated as "not unique" if other specimens from the same group could be taken to target levels. Organisms designated as "unique" were those that could be definitively distinguished from other organisms in the sample. Identified organisms were preserved in 95% ethanol in labeled vials, and archived at the Rhithron laboratory.

Representatives of each unique identified taxon were placed in labeled vials. Each reference specimen was internally verified by three Rhithron taxonomists. Specimens added to the collection and their verifications were continuously tracked on a reference collection form.

Quality control procedures

Quality control procedures for initial sample processing and subsampling involved checking sorting efficiency. These checks were conducted on 100% of the samples by independent observers who microscopically re-examined at least 20% of sorted substrate from each sample. Quality control procedures for each sample proceeded as follows:

The quality control technician poured the sorted substrate from a processed sample out into a Caton tray, redistributing the substrate so that 20% of it could be accurately lifted out by removing entire grids in a random fashion. Grids were selected, and re-examined until 20% of the substrate was re-sorted. All organisms that were missed were counted and this number was added to the total number obtained in the original sort. Sorting efficiency was evaluated by applying the following calculation:

$$SE = \frac{n_1}{n_1 + n_2} \times 100$$

where: SE is the sorting efficiency, expressed as a percentage, n_1 is the total number of specimens in the first sort, and n_2 is the total number of specimens expected in the second sort, based on the results of the re-sorted 20%.

Quality control procedures for taxonomic determinations of invertebrates were performed on a random selection of samples from the City of North Vancouver, City of Surrey, Metro Vancouver and Maple Creek ISMP Fall 2010 projects. The 10% minimum requirement was fulfilled within those projects.

Six taxonomists independently reviewed the reference collection to verify consistency of identifications.

Data analysis

Taxa lists and counts for each sample were constructed. Metric calculations and scoring for the B-IBI for Puget Sound Lowlands streams (Karr and Chu 1999) were performed using Rhithron's customized database software. A sites-by-taxa and sites-by-metrics data matrix was compiled in Microsoft Excel XP.

RESULTS

Quality Control Procedures

Results of quality control procedures for subsampling are given in Table 1. Sorting efficiency averaged 95.05% and data entry efficiency averaged 100% for the project. These similarity statistics fall within acceptable industry criteria (Stribling et al. 2003).

Data analysis

Taxa lists and counts and metric summary pages for each sample are given in the Appendix. Electronic spreadsheets containing macroinvertebrate identifications and metric values and scores were provided to the RAE Project Manager via email. The complete verified reference collection was held at the Rhithron laboratory and will be delivered to the RAE Project Manager upon completion of all City of Surrey projects.

Table 1. *Results of internal quality control procedures for subsampling and taxonomy.* Shaw Creek ISMP, Fall 2010.

RAI Sample ID	Station name	Client ID	Sorting efficiency
RAE10CS2082	Shaw Creek C1	C1-1	96.66%
RAE10CS2083	Shaw Creek C2	C2-1	97.26%
RAE10CS2084	Briarwood Creek		91.84%
RAE10CS2085	Watershed Creek		94.42%

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APPENDIX

Taxa lists and metric summaries

Shaw Creek ISMP

Fall 2010

Taxa Listing

Project ID: RAE10CS2
RAI No.: RAE10CS2082

RAI No.: RAE10CS2082 | Sta. Name: Shaw Creek C1
Client ID: C1-1
Date Coll.: 9/15/2010 | No. Jars: 1 | STORET ID: Shaw Creek ISMP

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Nematoda	8	1.88%	Yes	Unknown		5	UN
Oligochaeta	125	29.34%	Yes	Unknown		10	CG
Turbellaria	4	0.94%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	32	7.51%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	26	6.10%	Yes	Unknown		6	CG
Sphaeriidae							
Sphaeriidae	1	0.23%	Yes	Unknown		8	CF
Ephemeroptera							
Baetidae							
Baetis sp.	1	0.23%	No	Larva	Early Instar	5	CG
Baetis tricaudatus	11	2.58%	Yes	Larva		4	CG
Trichoptera							
Hydropsychidae							
Parapsyche sp.	1	0.23%	Yes	Larva	Early Instar	0	PR
Rhyacophilidae							
Rhyacophila narvae	1	0.23%	Yes	Larva		0	PR
Diptera							
Ceratopogonidae							
Ceratopogoninae	2	0.47%	Yes	Larva		6	PR
Empididae							
Neoplasta sp.	6	1.41%	Yes	Larva		5	PR
Simuliidae							
Simulium sp.	2	0.47%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	1	0.23%	Yes	Larva		3	PR
Limnophila sp.	1	0.23%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Chironomidae	184	43.19%	Yes	Larva		10	CG
Chironomidae	20	4.69%	No	Pupa		10	CG
Sample Count	426						

Taxa Listing

Project ID: RAE10CS2
RAI No.: RAE10CS2083

RAI No.: RAE10CS2083
Sta. Name: Shaw Creek C2
Client ID: C2-1
Date Coll.: 9/15/2010
No. Jars: 1
STORET ID: Shaw Creek ISMP

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Oligochaeta	97	26.80%	Yes	Unknown		10	CG
Turbellaria	98	27.07%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	9	2.49%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	96	26.52%	Yes	Unknown		6	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	50	13.81%	Yes	Larva		4	CG
Diptera							
Simuliidae							
Simulium sp.	2	0.55%	Yes	Larva		6	CF
Simulium sp.	1	0.28%	No	Pupa		6	CF
Chironomidae							
Chironomidae							
Chironomidae	8	2.21%	Yes	Larva		10	CG
Chironomidae	1	0.28%	No	Pupa		10	CG
Sample Count	362						

Taxa Listing

Project ID: RAE10CS2
RAI No.: RAE10CS2084

RAI No.: RAE10CS2084 Sta. Name: Briarwood Creek
Client ID:
Date Coll.: 9/15/2010 No. Jars: 1 STORET ID: Shaw Creek ISMP

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Amphipoda	6	3.17%	Yes	Unknown	Damaged	4	CG
Oligochaeta	131	69.31%	Yes	Unknown		10	CG
Turbellaria	37	19.58%	Yes	Unknown		4	PR
Planorbidae							
Promenetus sp.	2	1.06%	Yes	Unknown		6	SC
Ephemeroptera							
Baetidae							
Baetidae	2	1.06%	No	Larva	Damaged	4	CG
Baetis tricaudatus	1	0.53%	Yes	Larva		4	CG
Chironomidae							
Chironomidae							
Chironomidae	10	5.29%	Yes	Larva		10	CG
Sample Count	189						

Taxa Listing

Project ID: RAE10CS2
RAI No.: RAE10CS2085

RAI No.: RAE10CS2085 Sta. Name: Watershed Creek
Client ID:
Date Coll.: 9/15/2010 No. Jars: 1 STORET ID: Shaw Creek ISMP

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Amphipoda	6	1.44%	No	Unknown	Damaged	4	CG
Oligochaeta	54	12.92%	Yes	Unknown		10	CG
Asellidae							
Caecidotea sp.	1	0.24%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	109	26.08%	Yes	Unknown		6	CG
Planariidae							
Polycelis coronata	9	2.15%	Yes	Unknown		1	OM
Planorbidae							
Promenetus sp.	7	1.67%	Yes	Unknown		6	SC
Sphaeriidae							
Sphaeriidae	3	0.72%	Yes	Unknown		8	CF
Ephemeroptera							
Baetidae							
Baetis sp.	18	4.31%	No	Larva	Early Instar	5	CG
Baetis bicaudatus	6	1.44%	Yes	Larva		2	CG
Baetis tricaudatus	154	36.84%	Yes	Larva		4	CG
Plecoptera							
Nemouridae							
Malenka sp.	1	0.24%	Yes	Larva		1	SH
Zapada cinctipes	17	4.07%	Yes	Larva		3	SH
Trichoptera							
Hydropsychidae							
Parapsyche almota	1	0.24%	Yes	Larva		3	PR
Limnephilidae							
Ecclisomyia sp.	1	0.24%	Yes	Larva		4	CG
Diptera							
Simuliidae							
Simulium sp.	14	3.35%	Yes	Larva		6	CF
Simulium sp.	3	0.72%	No	Pupa		6	CF
Tipulidae							
Dicranota sp.	4	0.96%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Chironomidae	1	0.24%	No	Pupa		10	CG
Chironomidae	9	2.15%	Yes	Larva		10	CG
Sample Count	418						

Metrics Report

Project ID: RAE10CS2
RAI No.: RAE10CS2082
Sta. Name: Shaw Creek C1
Client ID: C1-1
STORET ID: Shaw Creek ISMP
Coll. Date: 9/15/2010

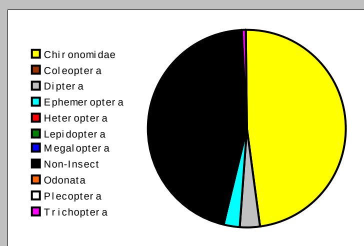
Abundance Measures

Sample Count: 426
Sample Abundance: 555.65 76.67% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	6	196	46.01%
Odonata			
Ephemeroptera	1	12	2.82%
Plecoptera			
Heteroptera			
Megaloptera			
Trichoptera	2	2	0.47%
Lepidoptera			
Coleoptera			
Diptera	5	12	2.82%
Chironomidae	1	204	47.89%

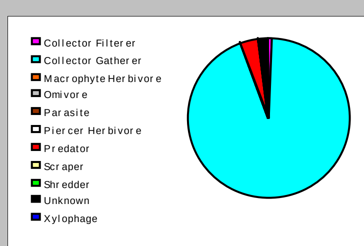


Dominant Taxa

Category	A	PRA
Chironomidae	204	47.89%
Oligochaeta	125	29.34%
Caecidotea	32	7.51%
Crangonyx	26	6.10%
Baetis tricaudatus	11	2.58%
Nematoda	8	1.88%
Neoplasta	6	1.41%
Turbellaria	4	0.94%
Simulium	2	0.47%
Ceratopogoninae	2	0.47%
Sphaeriidae	1	0.23%
Rhyacophila narvae	1	0.23%
Limnophila	1	0.23%
Dicranota	1	0.23%
Baetis	1	0.23%

Functional Composition

Category	R	A	PRA
Predator	7	16	3.76%
Parasite			
Collector Gatherer	5	399	93.66%
Collector Filterer	2	3	0.70%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper			
Shredder			
Omivore			
Unknown	1	8	1.88%

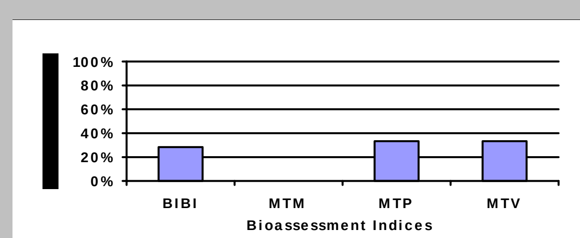


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	15	1	1		0
Non-Insect Percent	46.01%				
E Richness	1	1		0	
P Richness	0	1		0	
T Richness	2	1		1	
EPT Richness	3		1		0
EPT Percent	3.29%		0		0
Oligochaeta+Hirudinea Percent	29.34%				
Baetidae/Ephemeroptera	1.000				
Hydropsychidae/Trichoptera	0.500				
Dominance					
Dominant Taxon Percent	47.89%		1		0
Dominant Taxa (2) Percent	77.23%				
Dominant Taxa (3) Percent	84.74%	1			
Dominant Taxa (10) Percent	98.59%				
Diversity					
Shannon H (loge)	1.508				
Shannon H (log2)	2.176		1		
Margalef D	2.332				
Simpson D	0.312				
Evenness	0.114				
Function					
Predator Richness	7		3		
Predator Percent	3.76%	1			
Filterer Richness	2				
Filterer Percent	0.70%			3	
Collector Percent	94.37%		1		0
Scraper+Shredder Percent	0.00%		0		0
Scraper/Filterer	0.000				
Scraper/Scraper+Filterer	0.000				
Habit					
Burrower Richness	3				
Burrower Percent	49.53%				
Swimmer Richness	1				
Swimmer Percent	2.82%				
Clinger Richness	3	1			
Clinger Percent	0.94%				
Characteristics					
Cold Stenotherm Richness	0				
Cold Stenotherm Percent	0.00%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	2				
Air Breather Percent	0.47%				
Voltinism					
Univoltine Richness	10				
Semivoltine Richness	1	1			
Multivoltine Percent	53.52%		2		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	29.81%				
Sediment Sensitive Richness	0				
Sediment Sensitive Percent	0.00%				
Metals Tolerance Index	4.681				
Pollution Sensitive Richness	0	1		0	
Pollution Tolerant Percent	7.51%	5		2	
Hilsenhoff Biotic Index	9.096		0		0
Intolerant Percent	0.47%				
Supertolerant Percent	84.98%				
CTQa	85.308				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	14	28.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	10	33.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	6	33.33%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	0	0.00%	Severe



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Metrics Report

Project ID: RAE10CS2
RAI No.: RAE10CS2083
Sta. Name: Shaw Creek C2
Client ID: C2-1
STORET ID: Shaw Creek ISMP
Coll. Date: 9/15/2010

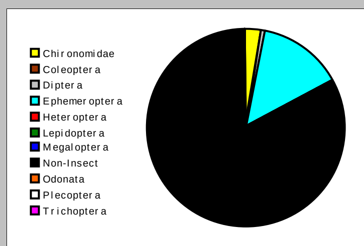
Abundance Measures

Sample Count: 362
Sample Abundance: 362.00 100.00% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	4	300	82.87%
Odonata			
Ephemeroptera	1	50	13.81%
Plecoptera			
Heteroptera			
Megaloptera			
Trichoptera			
Lepidoptera			
Coleoptera			
Diptera	1	3	0.83%
Chironomidae	1	9	2.49%

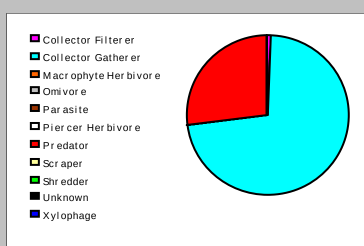


Dominant Taxa

Category	A	PRA
Turbellaria	98	27.07%
Oligochaeta	97	26.80%
Crangonyx	96	26.52%
Baetis tricaudatus	50	13.81%
Chironomidae	9	2.49%
Caecidotea	9	2.49%
Simulium	3	0.83%

Functional Composition

Category	R	A	PRA
Predator	1	98	27.07%
Parasite			
Collector Gatherer	5	261	72.10%
Collector Filterer	1	3	0.83%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper			
Shredder			
Omivore			
Unknown			

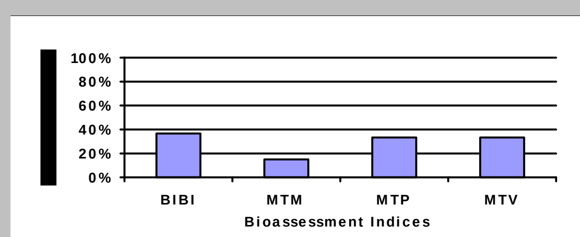


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	7	1	0		0
Non-Insect Percent	82.87%				
E Richness	1	1		0	
P Richness	0	1		0	
T Richness	0	1		0	
EPT Richness	1		0		0
EPT Percent	13.81%		1		0
Oligochaeta+Hirudinea Percent	26.80%				
Baetidae/Ephemeroptera	1.000				
Hydropsychidae/Trichoptera	0.000				
Dominance					
Dominant Taxon Percent	27.07%		3		2
Dominant Taxa (2) Percent	53.87%				
Dominant Taxa (3) Percent	80.39%	1			
Dominant Taxa (10) Percent	100.00%				
Diversity					
Shannon H (loge)	1.540				
Shannon H (log2)	2.222		1		
Margalef D	1.019				
Simpson D	0.236				
Evenness	0.169				
Function					
Predator Richness	1		0		
Predator Percent	27.07%	5			
Filterer Richness	1				
Filterer Percent	0.83%			3	
Collector Percent	72.93%		2		1
Scraper+Shredder Percent	0.00%		0		0
Scraper/Filterer	0.000				
Scraper/Scraper+Filterer	0.000				
Habit					
Burrower Richness	1				
Burrower Percent	2.49%				
Swimmer Richness	1				
Swimmer Percent	13.81%				
Clinger Richness	1	1			
Clinger Percent	0.83%				
Characteristics					
Cold Stenotherm Richness	0				
Cold Stenotherm Percent	0.00%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	0				
Air Breather Percent	0.00%				
Voltinism					
Univoltine Richness	4				
Semivoltine Richness	0	1			
Multivoltine Percent	43.37%		2		
Tolerance					
Sediment Tolerant Richness	1				
Sediment Tolerant Percent	26.80%				
Sediment Sensitive Richness	0				
Sediment Sensitive Percent	0.00%				
Metals Tolerance Index	4.388				
Pollution Sensitive Richness	0	1		0	
Pollution Tolerant Percent	2.49%	5		3	
Hilsenhoff Biotic Index	6.403		1		0
Intolerant Percent	0.00%				
Supertolerant Percent	31.77%				
CTQa	102.000				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	18	36.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	10	33.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	6	33.33%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	3	14.29%	Severe



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Metrics Report

Project ID: RAE10CS2
RAI No.: RAE10CS2084
Sta. Name: Briarwood Creek
Client ID:
STORET ID: Shaw Creek ISMP
Coll. Date: 9/15/2010

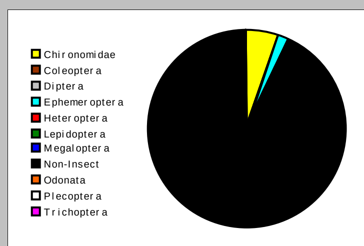
Abundance Measures

Sample Count: 189
Sample Abundance: 189.00 100.00% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	4	176	93.12%
Odonata			
Ephemeroptera	1	3	1.59%
Plecoptera			
Heteroptera			
Megaloptera			
Trichoptera			
Lepidoptera			
Coleoptera			
Diptera			
Chironomidae	1	10	5.29%

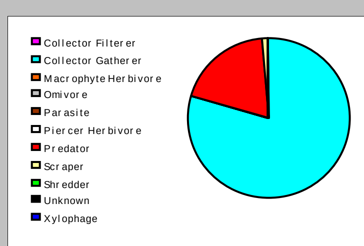


Dominant Taxa

Category	A	PRA
Oligochaeta	131	69.31%
Turbellaria	37	19.58%
Chironomidae	10	5.29%
Amphipoda	6	3.17%
Promenetus	2	1.06%
Baetidae	2	1.06%
Baetis tricaudatus	1	0.53%

Functional Composition

Category	R	A	PRA
Predator	1	37	19.58%
Parasite			
Collector Gatherer	4	150	79.37%
Collector Filterer			
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	1	2	1.06%
Shredder			
Omivore			
Unknown			

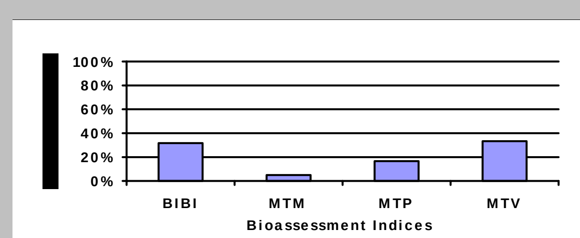


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	6	1	0		0
Non-Insect Percent	93.12%				
E Richness	1	1		0	
P Richness	0	1		0	
T Richness	0	1		0	
EPT Richness	1		0		0
EPT Percent	1.59%		0		0
Oligochaeta+Hirudinea Percent	69.31%				
Baetidae/Ephemeroptera	1.000				
Hydropsychidae/Trichoptera	0.000				
Dominance					
Dominant Taxon Percent	69.31%		0		0
Dominant Taxa (2) Percent	88.89%				
Dominant Taxa (3) Percent	94.18%	1			
Dominant Taxa (10) Percent	100.00%				
Diversity					
Shannon H (loge)	0.913				
Shannon H (log2)	1.318		0		
Margalef D	0.956				
Simpson D	0.531				
Evenness	0.140				
Function					
Predator Richness	1		0		
Predator Percent	19.58%	3			
Filterer Richness	0				
Filterer Percent	0.00%			3	
Collector Percent	79.37%		2		1
Scraper+Shredder Percent	1.06%		0		0
Scraper/Filterer	0.000				
Scraper/Scraper+Filterer	0.000				
Habit					
Burrower Richness	1				
Burrower Percent	5.29%				
Swimmer Richness	1				
Swimmer Percent	0.53%				
Clinger Richness	0	1			
Clinger Percent	0.00%				
Characteristics					
Cold Stenotherm Richness	0				
Cold Stenotherm Percent	0.00%				
Hemoglobin Bearer Richness	1				
Hemoglobin Bearer Percent	1.06%				
Air Breather Richness	0				
Air Breather Percent	0.00%				
Voltinism					
Univoltine Richness	2				
Semivoltine Richness	1	1			
Multivoltine Percent	26.46%		3		
Tolerance					
Sediment Tolerant Richness	2				
Sediment Tolerant Percent	70.37%				
Sediment Sensitive Richness	0				
Sediment Sensitive Percent	0.00%				
Metals Tolerance Index	4.026				
Pollution Sensitive Richness	0	1		0	
Pollution Tolerant Percent	1.06%	5		3	
Hilsenhoff Biotic Index	8.497		0		0
Intolerant Percent	0.00%				
Supertolerant Percent	74.60%				
CTQa	99.000				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	16	32.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	5	16.67%	Severe
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	6	33.33%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	1	4.76%	Severe



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Metrics Report

Project ID: RAE10CS2
RAI No.: RAE10CS2085
Sta. Name: Watershed Creek
Client ID:
STORET ID: Shaw Creek ISMP
Coll. Date: 9/15/2010

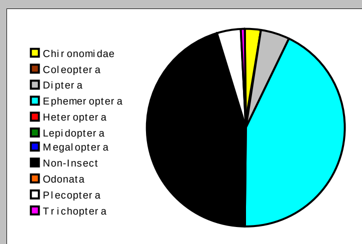
Abundance Measures

Sample Count: 418
Sample Abundance: 1,140.00 36.67% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	6	189	45.22%
Odonata			
Ephemeroptera	2	178	42.58%
Plecoptera	2	18	4.31%
Heteroptera			
Megaloptera			
Trichoptera	2	2	0.48%
Lepidoptera			
Coleoptera			
Diptera	2	21	5.02%
Chironomidae	1	10	2.39%

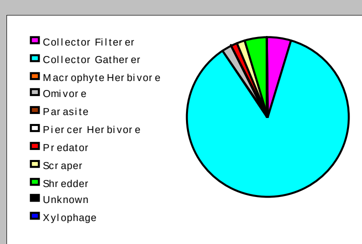


Dominant Taxa

Category	A	PRA
Baetis tricaudatus	154	36.84%
Crangonyx	109	26.08%
Oligochaeta	54	12.92%
Baetis	18	4.31%
Zapada cinctipes	17	4.07%
Simulium	17	4.07%
Chironomidae	10	2.39%
Polycelis coronata	9	2.15%
Promenetus	7	1.67%
Baetis bicaudatus	6	1.44%
Amphipoda	6	1.44%
Dicranota	4	0.96%
Sphaeriidae	3	0.72%
Parapsyche almota	1	0.24%
Malenka	1	0.24%

Functional Composition

Category	R	A	PRA
Predator	2	5	1.20%
Parasite			
Collector Gatherer	7	359	85.89%
Collector Filterer	2	20	4.78%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	1	7	1.67%
Shredder	2	18	4.31%
Omivore	1	9	2.15%
Unknown			

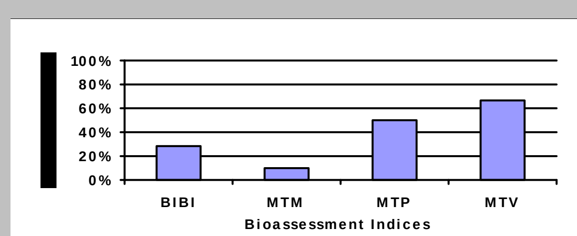


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	15	1	1		0
Non-Insect Percent	45.22%				
E Richness	2	1		1	
P Richness	2	1		2	
T Richness	2	1		1	
EPT Richness	6		2		0
EPT Percent	47.37%		2		1
Oligochaeta+Hirudinea Percent	12.92%				
Baetidae/Ephemeroptera	1.000				
Hydropsychidae/Trichoptera	0.500				
Dominance					
Dominant Taxon Percent	36.84%		2		1
Dominant Taxa (2) Percent	62.92%				
Dominant Taxa (3) Percent	75.84%	1			
Dominant Taxa (10) Percent	95.93%				
Diversity					
Shannon H (loge)	1.709				
Shannon H (log2)	2.465		2		
Margalef D	2.347				
Simpson D	0.256				
Evenness	0.111				
Function					
Predator Richness	2		0		
Predator Percent	1.20%	1			
Filterer Richness	2				
Filterer Percent	4.78%			3	
Collector Percent	90.67%		1		0
Scraper+Shredder Percent	5.98%		1		0
Scraper/Filterer	0.350				
Scraper/Scraper+Filterer	0.259				
Habit					
Burrower Richness	1				
Burrower Percent	2.39%				
Swimmer Richness	2				
Swimmer Percent	42.58%				
Clinger Richness	5	1			
Clinger Percent	8.85%				
Characteristics					
Cold Stenotherm Richness	2				
Cold Stenotherm Percent	1.67%				
Hemoglobin Bearer Richness	1				
Hemoglobin Bearer Percent	1.67%				
Air Breather Richness	1				
Air Breather Percent	0.96%				
Voltinism					
Univoltine Richness	9				
Semivoltine Richness	2	1			
Multivoltine Percent	47.13%		2		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	15.55%				
Sediment Sensitive Richness	0				
Sediment Sensitive Percent	0.00%				
Metals Tolerance Index	4.626				
Pollution Sensitive Richness	2	1		2	
Pollution Tolerant Percent	1.91%	5		3	
Hilsenhoff Biotic Index	5.483		2		0
Intolerant Percent	3.83%				
Supertolerant Percent	16.27%				
CTQa	72.833				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	14	28.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	15	50.00%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	12	66.67%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	2	9.52%	Severe



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Appendix B-6. Reach Summary Data.

Table B6-1: Summary of Channel and Substrate Characteristics in the Shaw Creek ISMP study area

Reach	Length (m)	Bankfull Width (m)	Wetted Width (m)	Riffle Depth (cm)	Gradient (%)	Embeddedness (%)	%Boulder	%Cobble	%Large Gravel	%Small Gravel	%Fines
112 St Ditch	3219	1.2	1.2	n/a	< 0.5	n/a	0	0	0	0	100
Lorne Ditch	759	2.3	2.3	n/a	< 0.5	n/a	n/a	n/a	n/a	n/a	n/a
60 Ave Ditch	203	1.6	1.6	12	< 0.5	30	0	15	30	30	25
Oliver Slough	2342	4	4	>30	< 0.5	n/a	0	0	0	0	100
Gourley Ditch	702				< 0.5						
East Oliver Bypass	1157	10	10	>30	< 0.5	n/a	n/a	n/a	n/a	n/a	n/a
Old Hwy 10 Ditch	294	2.5	2	n/a	< 0.5	n/a	0	0	0	0	100
Shaw R1	311	2.3	1.5	10	2-3	10	0	0	0	0	100
Shaw R2	233	2.2	1.9	4	5	30	2.5	35	35	20	7.5
Shaw R3	406	7.5	2.5	6	5-10	15	2.5	15	45	35	2.5
Shaw R4	215				20-30						
Shaw R5	130	4.6	1.9	6	5-10	30	15	35	20	20	10
Shaw R6	241	6	0.9	6	5-7	20	10	20	30	30	10
Shaw R7	60	2.5	2	8	5	20	50	35	10	2.5	2.5
Shaw R8	166				2-3						

Table B6-2: Summary of Channel and Substrate Characteristics in the Shaw Creek ISMP study area

Reach	Length (m)	Bankfull Width (m)	Wetted Width (m)	Riffle Depth (cm)	Gradient (%)	Embeddedness (%)	%Boulder	%Cobble	%Large Gravel	%Small Gravel	%Fines
Briarwood R1	640	1.6	0.9	11	< 0.5	n/a	0	0	0	0	100
Briarwood R2	175				35-40						
Briarwood R3	204	2.6	1.5	5	5-7	30	20	20	30	25	5
Lower Trail Ditch	532	0.7	0.3	1	0	15	0	0	0	70	30
Watershed R1	121				< 0.5						
Watershed R2	116	1.5	1.1	5	5	10	5	15	40	35	5
Watershed R3	818				0.5-2						
Watershed R4	132				7-10						
Watershed Trib. 1 R1	411				< 0.5						
Watershed Trib. 1 R2	850	0.8	0	0	7	10	0	5	40	50	5
Watershed Trib. 2	169				< 0.5						

Table B6-3: Summary of Channel Characteristics, Complexity, Erosion, and Fish Presence in the Shaw Creek ISMP study area

Reach	**% culverted**	**% channelized**	**LWD per 100m**	**Erosion***	**Fish Presence**	**Salmonid Presence**	**Fish Species** (see codes in text)
112 St Ditch	10% (339 m)	90 % (2880 m)	< 1	Moderate	Present	Present	CO, CM, CT, TSB, BMC
Lorne Ditch	19% (135 m)	81% (624 m)	< 1	Minor	Present	Present	CO, CT?
60 Ave Ditch	5% (10 m)	95% (193 m)	< 1	Minor	Present	Present	CO, CM, CT, CAS, TSB, PMB, RSC
Oliver Slough	6% (157 m)	94% (2185 m)	< 1	Moderate	Present	Absent	TSB
Gourley Ditch	19% (135 m)	81% (567 m)	< 1	-	Present	Absent	TSB, PCC, BCB, BNH, PMB
East Oliver Bypass	11% (124 m)	89% (1033 m)	< 1	Minor	Present	Absent	TSB, BMC
Old Hwy 10 Ditch	10% (29 m)	90% (265 m)	1 to 3	Minor	Unknown	Absent	Unknown
Shaw R1	57% (177 m)	43% (134 m)	< 1	Moderate	Present	Present	CO, CT?, TSB, BMC
Shaw R2	0%	51% (118 m)	1 to 3	Minor	Present	Present	CO, CT?, CAS, TSB, BMC, CP
Shaw R3	20% (81 m)	7% (30 m)	1 to 3	Major	Present	Present	CO, CT?, CAS, CP
Shaw R4	100% (215 m)	n/a	n/a	n/a	Absent	Absent	None
Shaw R5	0%	0%	1 to 3	Moderate	Present	Absent	GC, CP
Shaw R6	0%	0%	2 to 5	Major	Present	Absent	GC, CP
Shaw R7	0%	0% (modified)	< 1	Historic/none	Present	Absent	GC, CP
Shaw R8	100% (166 m)	n/a	n/a	n/a	Absent	Absent	None

* note that the erosion rating is related to fish habitat concerns and is not as detailed as Section 2.2.

Table B6-4: Summary of Channel Characteristics, Complexity, Erosion, and Fish Presence in the Shaw Creek ISMP study area

Reach	% culverted	% channelized	LWD per 100m	Erosion*	Fish Presence	Salmonid Presence	Fish Species (see codes in text)
Briarwood R1	14% (92 m)	86 % (549 m)	2 to 5	Minor	Present	Absent	TSB
Briarwood R2	100% (175 m)	n/a	n/a	n/a	Absent	Absent	None
Briarwood R3	0%	0% (modified)	2 to 4	Minor	Unknown	Absent	Unknown
Lower Trail Ditch	5% (28 m)	82% (435 m)	3 to 6	Minor	Absent	Absent	None
Watershed R1	88% (107 m)	12% (14 m)	< 1	n/a	Present	Present	CO, CM, CT, TSB
Watershed R2	19% (22 m)	0%	1 to 3	Minor	Present	Present	CO, CM, CT, TSB
Watershed R3	0%	100% (818 m)	2 to 5	Moderate	Present	Present	CO, CM, CT, TSB
Watershed R4	0%	0%	1 to 3	Minor	Present	Present	CO, CT
Watershed Trib. 1 R1	8% (32 m)	69% (285 m)	1 to 3	Minor	Unknown	Unknown	Unknown
Watershed Trib. 1 R2	21% (179 m)	0%	2 to 5	Moderate	Absent	Absent	None
Watershed Trib. 2	0%	100% (169 m)	1 to 3	Minor	Present	Present	CO, CT, TSB

* note that the erosion rating is related to fish habitat concerns and is not as detailed as Section 2.2.

Figure B7-1: Photos of Representative Channel Conditions in Shaw Creek ISMP Study Area

112 St Ditch

Lorne Ditch

60 Ave Ditch

Oliver Slough

East Oliver Bypass

Old Hwy 10 Ditch

Shaw R1

Shaw R2

Shaw R3

Shaw R4
(culvert inlet)

Shaw R5

Shaw R6

Figure B7-2: Photos of Representative Channel Conditions in Shaw Creek ISMP Study Area

Shaw R7

Shaw R8

Boundary Park Pond

Briarwood R1

Briarwood R2
(culvert inlet)

Briarwood R3

Lower Trail Ditch

Watershed R1
(culvert inlet)

Watershed R2

Watershed R4

Watershed Trib. 1 R2

Appendix B-8. RFI Method Summary.

The 30 m buffer width was selected to provide a generalized and consistent assessment method of the area where riparian-stream channel interactions are potentially strongest. A 30 m buffer is used for RFI assessments because it has been found to be most strongly correlated with other measures of stream health (May et al., 1999). It is not meant to prescribe an appropriate setback to development and supersede or conflict with the Riparian Area Regulation (RAR), municipal stream protection bylaws, or other riparian protection measures. The use of permanent streams only increases data consistency for areas where the stream network mapping is variable (Page et al., 1999). Where possible, culverted stream sections were also included to represent the entire historical stream network within the watershed. This was not possible in headwater sections of the study area where it is difficult to infer whether permanent watercourses would have been historically present.

KERR WOOD LEIDAL
consulting engineers

Appendix C

Geotechnical Report

Trow

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Buildings

Environment

Geotechnical

Infrastructure

Materials & Quality

September 14, 2010 Reference: VAN-00010608

Kerr Wood Leidel Associates Inc.
200-4185A Still Creek Drive
Burnaby, BC, V5C 6G9 Via E-Mail: dzabil@kwl.ca

Attention: Mr. David Zabil, M.A.Sc., P.Eng.

Geotechnical Review
Shaw Creek, Delta, BC

Dear Mr. Zabil:

1.0 INTRODUCTION

As requested, Trow Associates Inc. (Trow) has completed a geotechnical review of the Shaw Creek channel and adjacent slopes within Watershed Park, Delta, BC (see attached Map 1). The purpose of our review was to characterize the subject site with regards to slope stability, stream erosion and soils and to present options for mitigative measures where appropriate.

There is an inherent level of uncertainty associated with the prediction of long term stability of natural slopes, particularly in seismically active terrain as is present in this case. This uncertainty combined with the lack of long term historical records and information on subsurface soil conditions significantly limits our ability to complete a quantitative assessment of slope stability within the subject site. Therefore we are presenting a qualitative assessment of geologic hazards, which may influence nearby development, based on our characterization of the site.

Our characterization was based on the following information sources:

- Published surficial geology information from GSC Map 1448A (1:50,000);
- Aerial photographs of the general area dated from 1949 to 2004;
- Regional topographic contour map provided by Kerr Wood Leidel;
- Information from previous Trow projects in the general vicinity of Watershed Park;
- Site reconnaissance of Shaw Creek conducted by Trow personnel.

2.0 SITE DESCRIPTION

The study area contains Shaw Creek which flows from north to south in a channel incised into the subgrade soils up to about 5 m deep. The channel ranges in width from about 5 m to 10 m and maintains a generally consistent gentle grade with numerous bends. The study area has been divided into a northern portion and a southern portion on either side of Highway 10 (see attached Map 2).

The creek is sub-parallel to 120th Street in the northern portion (see attached Map 3) and sub-parallel to Highway 10 in the southern portion (see Map 4). The northern portion of the creek ranges from about 40 m to 100 m horizontal distance from 120th

Street and the southern portion ranges from about 15 m to 40 m horizontal distance from Highway 10. The creek flows under Highway 10 for a distance of about 170 m from the north portion to the south portion, through a culvert.

A trash gate was located at the intake of the culvert located at the southern end of the north portion of the creek channel and two separate stockpiles; one containing organics and wood debris and the other boulders, cobbles and gravel (likely removed from the trash gate), were noted in the area.

Indications of a previous dirt road with creek crossings were noted along the west side of the southern portion of the creek. This roadway has been abandoned with creek crossings removed long ago, as there were no indications of creek crossings observed in aerial photographs dating back to 1949. Erosion generally did not appear to be prevalent in areas of presumed former creek crossings where minimal rip rap had been placed; however, some minor slope failures due to erosion of the underlying soils were noted in these areas. In some areas, the old roadway had been undermined by the creek resulting in parts of the roadway sloughing into the creek channel.

There were no structures noted, either between the creek and 120th Street or in close proximity to the west side of the creek within the northern portion of the study area with the exception of single family residential dwellings on either side of the creek channel immediately south of an outlet for a box culvert at the northern end of the study area. In the area of these residential dwellings, as the creek outlets from the box culvert, there is a sharp bend in the creek channel to the west followed closely by another sharp bend back to the south. Protection measures to protect the properties from erosion by the creek on the outside banks of these bends were in place. A lock block wall, 2.25 m in height was located on the west side of the creek and rip rap consisting of boulders with a size of approximately 600 mm diameter had been placed on the east side.

Near the middle and southern parts of the southern portion of the creek channel, residential development was located behind the crest of a slope originating at the creek channel and cresting near the backyards of some of the residences east of the channel. The horizontal distance from the creek channel to the backyards of these residences ranges from about 30 m to 50 m with an elevation difference of about 15 m. The slope is generally moderately inclined with some localized steeply inclined areas, particularly near the crest of the slope. In the southern portion of the study area, the slope between Highway 10 and the creek is a gently inclined slope increasing in steepness as it approaches the creek channel, with near vertical creek banks. The overall elevation difference from the creek channel to the highway appears to be about 5 m.

The study area lies within an area of Vashon Drift deposits. The banks of the creek generally consist of very dense gravelly sand with some silt (till-like) soils overlain with loose to compact gravelly sand with some cobbles, boulders and trace to some silt. Based on the exposed soils within the creek channel banks, the overlying gravelly sand varies in thickness from less than 1 m up to about 5 m. Within the creek channel, the till-like soils generally have a near vertical inclination, with the overlying soils being inclined from about 1H: 1V to near vertical adjacent to the creek. In general, the till-like soils were more prevalent in the northern portion of the study area, with exposed heights of up to about 4 m. Overhangs of the overlying gravelly sand layer were noted near the creek in areas where tree root masses have provided sufficient binding of the soils. In addition, fallen trees with root masses and other debris were noted within the creek channel in several locations, particularly within the northern portion of the creek channel.

Along the east bank of the southern portion of the study area, undulating topography was observed near the creek and within gullies and bowls above the creek banks. The bowls were up to about 20 m wide and the crests were noted to be located near the western property boundaries of the residential lots located above the slope. Depositional fans were noted at the base of some of the gullies and bowls.

Vegetation along the creek consists of widely spaced deciduous and coniferous trees with trunk diameters up to about 200 mm. In numerous areas trees were noted to have curved trunks or were leaning towards the creek. Ferns and thick underbrush were noted within the gullies and bowls along the eastern side of the creek.

3.0 DISCUSSION

The study area has been divided into a northern portion and a southern portion on either side of Highway 10 (see Map 2). The northern portion of the creek is generally removed from roadways or developments except near the southern end where the creek crosses Highway 10 through a culvert and the northern end where two residential dwellings were located. Development near the southern portion of the creek includes Highway 10 to the west and residential development to the east.

3.1 Northern Portion – The creek banks are generally comprised of very dense till-like soils overlain with gravelly sand in the northern portion of the study area. These very dense soils are somewhat resistant to erosion, causing the erosion process to occur much more gradually that with most other soil types. In several locations along the creek, the continuing erosion process of the creek banks has resulted in the undermining of the loose to compact granular soils overlying the till-like soils and trees at the crests of the channel banks. The undermining of the trees has resulted in several areas where trees have fallen into the creek channel along with the root mass. The presence of fallen trees within the creek channel, with the accompanying accumulated debris upstream of the fallen trees, may create blockages of the creek in the future. A sudden release of such a blockage, at a time of high water flow, may overwhelm the culvert capacity downstream, particularly when combined with the associated additional debris which may create a blockage at the culvert.

We understand that in the recent past debris has clogged the intake for the culvert, where the creek flows under Highway 10 from the north, and backed up the creek such that overflowing water affected the highway. The presence of the stockpiles of debris, likely removed from the trash gate, indicates that blockage of the culvert may have occurred in the recent past.

Surficial movement of the slopes above the creek banks were noted, as indicated by undulating topography and curved or leaning trees. It is considered likely that the sliding material would be confined to the soils overlying the till-like soils limiting the extent and depth of such slope failures. However, such movement may result in soil and vegetation sliding into the creek channel, creating similar issues to those described above.

3.2 Southern Portion – The banks of the creek appear to consist of varying types of soil, including very dense till-like soils, compact gravelly sand and laminated sand with some silt. As expected, areas of till-like soils appear to have experienced less erosion than the other soil types; however erosion has resulted in some undermined soils and trees in several areas. The extent to which the undermining has occurred does not appear to be as extensive as that observed in the northern portion, likely due to the lower height of the till-like soils with the overlying gravel and sand exposed to erosion by the creek. These less dense soils are less capable of maintaining the very steep inclinations of the till-like soils; hence, overhangs are prevented from developing. The overall slope inclination from the creek to the highway over a distance of approximately 25 m is about 6H: 1V. The rate of erosion of the west creek bank appears to be about 1 m since the dirt road was constructed, which based on interpretation of aerial photographs is about 50 years ago.

The leaning and curved trees, undulating topography, gullies and bowls on the east side of the creek channel are all indicative of historic slope instabilities. The steeply inclined areas near the crests of the slopes within the bowls are likely head scarps of such slope failures as charaterized by their curved shape. Of particular interest is large failure scarps located near the back of the properties located along Fairlight Crescent where a depositional fan created by the slope failure(s) has been reshaped into a BMX bike area. Thick vegetation and garden refuse prevented a thorough visual review of the slopes during our site reconnaissance to assess the size of the possible slope failures or to assess the surficial soils in the area. A review of aerial photographs dating back to 1949 indicate that the slope failure(s) occurred prior to that date; however, vegetation within the bowl area prior to the residential development differs from that found in the surrounding area, indicating that the failure may have been relatively recent relative to the time of the aerial photograph. The presence of ferns and other wet soil type vegetation within the bowls and gullies indicate that these areas are likely zones with higher water tables or more saturated soils, likely contibuting to the instabilities of these slopes. Continued movement or remobilization of these slopes may influence the private properties located at the crest of the slope.

4.0 RECOMMENDATIONS

Recommendations for the mitigation of affects of erosion of the creek banks and slope instabilities where such activity is occurring or is likely to occur, is provided below.

4.1 Northern Portion – Creek banks within the northern portion of the study area (north of Highway 10) are generally comprised of very dense till-like soils which are somewhat resistant to erosion by the creek; however, the erosion that has occurred over time has is created overhangs resulting in trees falling into the creek channel. This debris may cause blockages within the creek channel with sudden releases of water and debris being possible. The result of such action may cause blockages of the culvert near Highway 10 and flooding of the adjacent highway as has occurred in the past when the trash gate was blocked. We recommend that the creek channel, including the trash gate for the culvert, be reviewed on a regular basis (approximately every 6 months) to identify such blockages. No blockages were identified within the channel during our field reconnaissance.

As there are no developments or roadways with the exception of the two residences at the north end of this portion of the study area, the continuing erosion of the creek beds does not present a risk to buildings or roadways. The two existing residences appear to have sufficient protection from erosion with the existing rip rap slope covering and lock block walls.

The slope instabilities in the northern portion appear to generally be comprised of surficial movement related to undermining of the slope by the creek. These slope instabilities are not in close proximity to buildings or infrastructure and as such are not considered likely to affect developments.

4.2 Southern Portion – Highway 10 is located near the crest of the slopes on the west side of the creek channel. Though no significant slope stability issues were noted on the west side of the creek channel erosion of the banks along this side of the creek channel has resulted in small failures in various locations and in some instances has resulted in the loss of portions of the abandoned dirt road. The relatively gentle overall inclination of the slope between the highway and the creek creates a situation where a significant slope failure is unlikely; however, continued erosion of the west creek bank may influence the highway over time. We recommend continued monitoring of the west creek bank to identify areas of ongoing erosion which may eventually influence the highway.

Portions of the slope on the east side of the creek channel appear to have experienced historic slope failures, particularly in the southern areas near the residential development. The significance of these slope failures appear to vary between surficial sloughs to large scale (20 m across) failures. Presently the toes of the more significant failure areas are protected from erosion by depositional fans which currently prevent further toe erosion of the slopes; however should these fans be eroded away in the future, continued erosion at the toe of the slopes could further destabilize these slopes. We recommend that rip rap be placed along the creek banks in areas where potentially unstable slopes may influence residential developments above the slopes, in order to mitigate erosion of the toes of these slopes. Monitoring of slope movement below the residences should be implemented to determine whether the slope is currently active.

In order to provided a quantitative analysis of the slope stability in this area with a factor of safety for static and seismic conditions, subsurface exploration would be required to characterize the soil stratigraphy and water table. To acquire such information bore holes would likely be required, and was beyond the scope of this report.

5.0 CLOSURE

As there was no subsurface investigation conducted, we have provided a qualitative assessment of the existing slope stability based on our characterization of the subject site including recent and historical slope failures. Our characterization of the subject site is based on site reconnaissance, topographic plan maps, surficial geology plans and Trows' experience with similar sites throughout British Columbia.

The above noted and attached information is provided for the exclusive use of our client and their designated consultants and agents and may not be used by other parties without the written consent of Trow Associates Inc. The attached "Interpretation and Use of Study and Report" forms an integral part of this report and must be included with any copies of this report.

Yours truly,

Trow Associates Inc.

PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, E. G. SYKES — Sept 15, 2010

Evan Sykes, P.Eng.
Senior Engineer

Reviewed by:

Ben Weiss, P.Eng.
Senior Engineer

Enclosures: Interpretation and Use of Study and Report
Photos
Location Plan (Map 1)
Overall Site Plan (Map 2)
Northern Portion Site Plan (Map 3)
Southern Portion Site Plan (Map 4)

ES/es

Trow

INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering consulting practices in this area. No other warranty, expressed or implied, is made. Engineering studies and reports do not include environmental consulting unless specifically stated in the engineering report.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT

The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report, or any portion thereof, available to any party without our written permission. Any use which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. We accept no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT

a. Nature and Exactness of Descriptions: Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations, or building envelope descriptions, utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b. Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.

c. To avoid misunderstandings, Trow Associates Inc. (Trow) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by Trow. Further, Trow should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor's work is being carried out in general conformity with Trow's recommendations. Any reduction from the level of services normally recommended will result in Trow providing qualified opinions regarding adequacy of the work.

6.0 ALTERNATE REPORT FORMAT

When Trow submits both electronic file and hard copies of reports, drawings and other documents and deliverables (Trow's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by Trow shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by Trow shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of Trow's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Trow. The Client warrants that Trow's instruments of professional service will be used only and exactly as submitted by Trow.

The Client recognizes and agrees that electronic files submitted by Trow have been prepared and submitted using specific software and hardware systems. Trow makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

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Fax: 604-874-2358

CLIENT	KERR WOOD LEIDAL
PROJECT	SHAW CREEK ISMP DELTA, B.C.
TITLE:	LOCATION PLAN

PROJECT NO.	DFTR.	DSGN.	CHK.	DATE	SCALE:	DWG NO.
VAN 00010608	MG	EGS	BW	2010-09-10	NTS	MAP 1

TROW ASSOCIATES INC.
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CLIENT	KERR WOOD LEIDAL
PROJECT	SHAW CREEK ISMP DELTA, B.C.
TITLE:	OVERALL SITE PLAN

PROJECT NO.	DFTR.	DSGN.	CHK.	DATE	SCALE:	DWG NO.
VAN 00010608	MG	EGS	BW	2010-09-10	1:5000 APPROX.	MAP 2

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Telephone: 604-874-1245
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CLIENT: KERR WOOD LEIDAL				TITLE: NORTHERN PORTION SITE PLAN		
PROJECT: SHAW CREEK ISMP DELTA, B.C.						
PROJECT NO. VAN 00010608	DFTR. MG	DSGN. EGS	CHK. BW	DATE 2010-09-10	SCALE: 1:3000 APPROX.	DWG NO. MAP 3

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Telephone: 604-874-1245
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CLIENT: KERR WOOD LEIDAL				TITLE: SOUTHERN PORTION SITE PLAN	
PROJECT: SHAW CREEK ISMP DELTA, B.C.					
PROJECT NO.: VAN 00010608	DFTR.: MG	DSGN.: EGS	CHK.: BW	DATE: 2010-09-10	SCALE: 1:3000
DWG NO.: MAP 4					

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Trow

NORTHERN PORTION

File: Van-00010608
Date: Sept. 10, 2010

Photo 1 – Erosion Resulting in Overhang

Photo 2 – Tree Fallen Into Creek Channel

Photo 3 – North Culvert

Photo 4 – Lock Block Wall Mitigating Erosion

NORTHERN PORTION

PHOTO 5 – Rip Rap Mitigating Erosion

PHOTO 6 – Fallen Tree and Wood Debris

PHOTO 7 – Soughing Slope with Associated Leaning/ Curved Trees

PHOTO 8 – Fallen Undermined Trees

NORTHERN PORTION

File: Van-00010608
Date: Sept. 10, 2010

PHOTO 9 – Undulating Topography
Indicating Slope Movement

PHOTO 10 – South Culvert

PHOTO 11– Cobbles and Boulder Material
Removed from Trash Gate (Culvert Entrance)

PHOTO 12 – Vegetation and Wood Debris
Removed from Trash Gate (Culvert Entrance)

SOUTHERN PORTION

PHOTO 13 – Curved Trees Indicating Slope Movement

PHOTO 14 – Gully East Side of Creek Channel

PHOTO 15 – Abandoned Dirt Road – Note Slough Resulting From Undermining

PHOTO 16 – BMX Track on Depositional Fan Below Residential Development

Trow

SOUTHERN PORTION

File: Van-00010608
Date: Sept. 10, 2010

PHOTO 17 – Depositional Fan

PHOTO 18 – Slide Scarp Below Residential Lot – Note Heavy Brush/Waste Covering Slope

PHOTO 19 – Depositional Fan Providing Erosion Mitigation

PHOTO 20 – Rip Rap Placed for Creek Crossing

SOUTHERN PORTION

PHOTO 21 – Eroded Rip Rap Bank From Abandoned Road Crossing

PHOTO 22 – Rip Rap Bank From Abandoned Road Crossing

PHOTO 23 – Leaning Trees and Undulating Topography Indicative of Slope Movement

PHOTO 24 – Slide Scarp Near Residential Development

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Appendix D

Hydrologic/Hydraulic Modelling

Appendix D – Hydrologic/Hydraulic Modelling

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Appendix D – Hydrologic/Hydraulic Modelling

1. Hydrologic and Hydraulic Modelling

1.1 Introduction

This appendix outlines the development of the detailed hydrologic and hydraulic model of the Boundary/Shaw Creek Drainage Basin.

1.2 XP-SWMM and MIKE 11 Model Development

The drainage system is shown in Figure D-1 and includes portions of both Delta and Surrey. For this study, the Boundary/Shaw Creek basin is separated into two major sections for assessment, uplands area and lowlands area.

Hydrologic and hydraulic models developed for previous work done for Delta were updated for this project. Two models were developed for the Boundary/Shaw watershed, XP-SWMM for hydrology (RUNOFF) and upland hydraulics (EXTRAN) and MIKE11 for lowland hydraulics. XP-SWMM RUNOFF uses inputs such as rainfall and catchment characteristics (area, slope, soil type, etc.) to estimate catchment flows. XP-SWMM EXTRAN and MIKE 11 use hydraulic system inputs (culvert/pipe/channel characteristics) to simulate flow routing, water levels, and flooding.

1.3 XP-SWMM Overview

The East Delta flood analysis model that was developed for the 2007 Delta Flood Management Study was used as a base for the XP-SWMM modelling. This model used the XP-SWMM RUNOFF module to generate the flow hydrographs for the MIKE 11 model.

The East Oliver Bypass models were developed for the design of the East Oliver Bypass Ponds. This model was developed by KWL in 2001 and included both RUNOFF and EXTRAN modules.

Both of these models were combined to form the base of the Boundary/Shaw Creek watershed model. The East Delta model was used for the lowland and lumped catchment runoff, while the Bypass model was used to add details of existing detention and flow control structures into the XP-SWMM hydraulics layer.

The hydrologic and hydraulic model was developed with the aid of the Corporation of Delta and City of Surrey GIS databases and with information gathered during the drainage inventory.

XP-SWMM Model Catchments

The East Delta watershed was discretized into sub-catchments using contours, field watercourse information, and existing drainage information. The major model sub-catchments for the Boundary/Shaw Creek study area are shown on Figure D-1.

In total, 52 catchments were created and imported into the XP-SWMM model. Catchments were assigned the following attributes:

- areas;
- slopes, using contour information;

Appendix D – Hydrologic/Hydraulic Modelling

- impervious percentage values; and
- infiltration and groundwater parameters.

Impervious Percentage

Existing land use impervious percentages were estimated based on the land use type visible in the aerial photography and typical impervious percentage values.

The future land use impervious percentages were derived using the OCP zoning information and Panorama Ridge and West Newton local area plans combined with typical impervious percentage values.

Soil Parameters

The groundwater portion of XP-SWMM – RUNOFF was used to estimate the groundwater and interflow portions of the runoff hydrograph. Figure 2-4 shows the surficial geology that was used to determine soil parameters. The majority of the watershed is silt-clay soils and peat, with some till, steepland sediments, sand and silt, and gravel and sand soils.

The infiltration and groundwater parameters used in the models were based on KWL's database of calibrated model parameters for similar soil conditions.

Model Update

The RUNOFF portion of the XP-SWMM model was updated with the following information:

- Catchment areas were refined and updated;
- Eugene Creek catchments were added;

The EXTRAN portion of the XP-SWMM model was modified to include a portion of the lowland area also modelled in MIKE11 at the request of the Corporation of Delta. The hydraulics model was updated with the following information:

- Added two detention ponds located in Surrey;
- Added Shaw Creek channel details up to Scott Rd.
- Added Briarwood Creek, Watershed Creek, and Watershed Creek Tributary;
- Added golf course ditch and storage areas;
- Added Eugene Creek floodboxes and culverts at lower end of golf course;
- Upland culverts on Shaw Creek, Briarwood Creek, Watershed Creek, and Watershed Creek Tributary; and
- Added the East Oliver Bypass ponds and flow control structure.

Model Validation

The available recorded information for model validation consisted of measured Boundary Park Pond water levels. No flow information on the creeks was available. The XP-SWMM model was validated against the pond water levels recorded in 2010. The rainfall during the monitored period (March to July 2010) included a number of small storm events, all less than 2-year return period. Figure D-2 shows the validation results.

Appendix D – Hydrologic/Hydraulic Modelling

The model appears to overestimate the peak water levels by up to 0.34m (2 May 2010) but appears to be able to replicate the drawdown curve well. The control structure at the pond outlet is a weir with sloping sides (the width increases with depth) for which a rating curve was developed in a previous study. The model produces conservative pond water levels and no adjustment was made prior to performing design storm or continuous simulation.

1.4 Mike 11 Overview

The MIKE 11 East Delta flood analysis model that was developed for the 2007 Delta Flood Management Study was used as a base for the lowland modelling. The model incorporates East Delta's network of lowland drainage ditches, culverts, pump stations, and other drainage structures, as well as flood storage and overland conveyance mechanisms. This conceptual model uses unsteady hydraulic analysis to simulate the response (flow and water level) of the East Delta drainage system to storms between several hours and several days long.

The East Delta MIKE 11 model area encompasses the south-eastern quadrant of Delta, extending from 72nd Street (near Boundary Bay Airport) in the west to the toe of the upland area in the east, and from Burns Bog in the north to Mud Bay in the south. The boundaries of the model are generally set to include all areas that are tributary to Oliver pump station, the Beharrel pump station and the Airport pump station.

Data Collection

The hydraulic model requires various scales of topographic and infrastructure data to build the computational framework. East Delta is an expansive area (11 km by 6 km, including Shaw Creek Catchment) with generally older agricultural development and large drainage structures. Given the age and land use in the area, the existing database of as-constructed information is generally poor; most of the available data has been collected in the past 5 to 10 years by the Delta survey and operations staff. Additionally, typical high water levels and the large scale of the drainage ditches and culverts make collection of topographic information difficult.

To develop the model, the area was initially delineated using two primary sources of information:

- the Delta DEM; and
- infrastructure mapping from the Delta GIS system.

Achieving an accurate representation of the drainage ditches and culverts required more detailed survey information. The Delta survey department supplied GPS survey information for road centrelines and some isolated areas of survey of culverts and ditches. Road centreline information was used to identify cell boundaries and potential overflow areas. Other information supplied by Delta was generally limited to Centre Slough and parts of 104th Street. A survey was done to obtain all other necessary information.

The model network was built to include only major drainage ditches and culverts. Each culvert was assigned a unique identifier. Ditch cross-sections were obtained by survey and were surveyed at intervals required for modelling (i.e. with greater resolution in rapidly changing geometry, and less resolution in uniform reaches).

Appendix D – Hydrologic/Hydraulic Modelling

All other required data was obtained from Delta record drawings, pump curves, floodbox and pump station inventory manuals, and drainage operation manuals.

Additional drainage inventory work was undertaken in the Shaw Creek study area. The drainage inventory survey was completed between May 20 and June 8, 2010 for Watershed Park as well as the area south of Highway 10 and north of Ladner Trunk Road. To accomplish this, the creek bed was traversed on foot and locations of interest were identified and recorded with a Trimble GeoXT handheld global positioning system (GPS) receiver. Measurements, photographs and additional observations were recorded as attributes associated with these positions to create a comprehensive geographical information system (GIS) database. The goals of the inventory field work program were to identify:

- Locations of significant erosion and to rate these sites based on relative severity and potential risk;
- natural and anthropogenic channel obstructions and to rate these obstructions based on relative stability;
- locations of significant deposition;
- drainage control structures; and
- drainage pathways within Watershed Park.

See Appendix A for photo overviews of the field inventory.

Channel Sections

Typical creek channel sections were measured during the field visits. Section properties such as bank height, bed width and material, and bank material were recorded. This information was incorporated into the hydrologic/hydraulic model.

Model Construction

The model was constructed in North American Datum 1927 (NAD 27) UTM horizontal coordinate system, the spatial coordinate system used by the Delta GIS and engineering system. To simplify the spatial analyses, all model structures (ditches, culverts, etc.) were input into the model with approximately accurate spatial locations.

Model Update

The East Delta flood analysis model was updated with more detailed information in the area east of Highway 91. Updates included the including:

- Added typical channel cross-sections and storage areas for Briarwood Creek, Watershed Creek, and Watershed Creek Tributary,
- Updated and added additional culverts; and
- Added golf course ditch and storage areas.

Appendix D – Hydrologic/Hydraulic Modelling

1.5 Boundary Conditions

Rainfall Input

The design storms used in analysis were those contained in the Surrey *Design Criteria Manual* (2004). The 48-hour rainfall totals were estimated based on the IDF curve on Figure 5.4 of the manual and the 24-hour storm distribution was used for the 48-hour storm as well as the 24-hour storm. The 12-, 24-, and 48-hour design storms were used for the culvert capacity and detention facility assessments.

The RFP initially asked that Chicago storms be used for the analysis in the Delta portion of the study area, however it was found that the intensity in these storms were too high and resulted in unrealistically-high peak flows. Delta staff agreed to use the Surrey design storms throughout the study area.

The lowland areas were analysed under the Agri-food Regional Development Subsidiary Agreement (ARDSA) using the ARDSA design storms from the Surrey *Design Criteria Manual* (2004). The model was also run for the 10-year 2-day and 10-year 5-day storms to determine whether the ARDSA criteria are met in the lowland areas and to evaluate the lowland culverts. The 5-day winter and 2-day growing season storms reflect actual recorded storm events modified to reflect the specified return period rainfall intensities for all durations from 1 hour to 5 days.

Table D-1 shows precipitation totals for all events and the ARDSA storms.

Table D-1: Total Precipitation Amounts for Climate Stations

Duration	Total Rainfall (mm)				
	6-month	2-year	5-year	10-year	100-year
Surrey Municipal Hall					
12-hour	-	39.2	47.3	52.6	69.4
24-hour	40.5	56.2	67.7	75.3	99.1
48-hour	-	81.6	96.0	115.2	172.8
ARDSA Storms					
2-day	-	-	-	84.02	-
5-day	-	-	-	143.36	-

Design storms were developed for the 6-month, 2-year, 5-year, 10-year, and 100-year return periods.
ARDSA Storms are from the City of Surrey Design Criteria Manual, 2004, 2-Day Surrey Municipal Hall and 5-day Pitt Meadows STP

Rainfall from the GVRD DT34 rain gauge for 1991 to 2009 was used to perform continuous simulation. The 5 minute rainfall data was obtained from the Metro Vancouver for this time period. The GVRD DT34 gauge is located in North Delta at 8544-116th Street. The period of data available for this gauge is November 1, 1991 to December 31, 2009.

Appendix D – Hydrologic/Hydraulic Modelling

Water Level Boundaries

The outlets to Mud Bay include floodboxes and pump stations and were simulated using water level boundary conditions. The tidal signal used on the boundary of these outlets was consistent with the design water level time series that KWL and UMA used previously for the modelling of the Nicomekl River and Serpentine River. This tidal series represents a normal high tide series for a winter condition in Boundary Bay, and does not include other components such as storm surge.

1.6 Results Analysis

The modelling results are presented in Section 3 of the main body.

Capacity Assessment

A culvert capacity assessment was preformed for the culverts in the study area to determine if any culverts were undersized and required upgrading. Tables D-2 to D-5 show the results of the analysis for all the culverts in the study area. Modelling results indicate that the same ten culverts do not meet the criteria for both the existing and future land use flows. There are two surcharged creek crossings during the 100-year event, and eight surcharged creek crossings in the 10-year event.

Detention Facility Assessment

A detention facility assessment was preformed to determine the effectiveness of the existing flow control facilities and to determine improvements that would improve the effectiveness. Three scenarios were simulated to perform this assessment:

- Pre-development land use conditions,
- Future land use conditions with existing flow control, and
- Future land use conditions with improved flow control.

Changes to the outlet control structures were made in the "Improved Flow Control" models to reduce the peak flows downstream of the facilities. Figures D-3 to D-6 show the Boundary Park detention pond hydrographs for the 6-month, 2-year, 5-year, and 10-year 24-hour events. As shown, the Boundary Park Pond outlet could be modified so that the pond outflows better match the pre-development flows in the 2-year to 10-year events while limiting the peak 10-year pond level to 65.1m Geodetic, approximately 5cm higher than the water level reached with the existing outlet. This modification involves replacing the existing weir structure with two orifices and an overflow.

Figures D-7 to D-10 show the Detention Tank P1 detention pond hydrographs. As shown, adding an orifice to the Detention Tank P1 outlet could slightly reduce the peak 6-month event flow, however, there is insufficient storage volume to reduce the larger events.

Hydrologic Impacts of Future Densification

XP-SWMM was used to perform a continuous model simulation using rainfall from the GVRD DT34 rain gauge for 1991 to 2009 and exceedance duration curves were created.

Exceedance duration curves for the pre-development, existing land use with existing flow control, and future land use with existing flow control scenarios are shown in Figures D-11 to D-13 for Shaw,

Appendix D – Hydrologic/Hydraulic Modelling

Briarwood, and Watershed Creeks. Figure D-11 also shows the existing land use with no flow control and future land use with improved flow control scenarios for Shaw Creek. The Boundary Park Pond and Detention Tank P1 storage volumes were removed in the "No Flow Control" scenario and the outlets were adjusted in the "Improved Flow Control" scenario as described in the Detention Facility Assessment section.

Exceedance duration curves show the duration of any given flow rate over the simulation period. In catchments that have been developed, the curves often show higher flows for a given duration under the developed condition, while pre-developed conditions often have lower flows for the same duration.

The curves indicated that the land use densification increases the flow in Shaw, Watershed, and Briarwood Creeks, mainly in infrequent large flows and rare large flows. For Shaw Creek, the difference between the exiting land use with and without flow control results shows the significant benefit of the Boundary Park Pond on peak flow reduction. The small difference between the future land use with existing and improve flow control results shows that the potential improvements to be realized by the outlet structure improvements are limited. Greater storage volumes would be required to realize a larger benefit.

Watershed Performance during Recent Large Storms

The XP-SWMM models were used to simulate the watershed response during recent large rainfall events in the last five years plus the October and November events of 2003. The large events were run for the following three scenarios:

- Pre-development land use conditions,
- Existing land use conditions with existing flow control, and
- Future land use conditions with existing flow control.

Figures D-14 to D-19 show the flow hydrographs for Shaw Creek at 120 Street and Figures D-20 to D-25 show Watershed Creek at the BNSF railway. The hydrographs show that the existing with flow control and future with flow control scenarios are similar in their reaction to the storms. The existing and future peak flows are higher then the pre-development peak flow especially during the large dry initial conditions storms (September 2006 and October 2006).

Table D-2: Culvert Assessment for Existing Land Use 100-Year Flow

Culvert ID	Diameter	Material	Pipe Capacity	Capacity Inlet Controlled to d/D=1.0	100-Year Peak Flow	Surcharge Time	Meets Criteria	Notes
	(m)		(m^3/s)	(m^3/s)	(m^3/s)	(min)	(Y/N)	
Boundary Park Pond Outfall	1.50	CONC	4.36	3.90	4.92	0	Y	SWMM FLOW
Hwy10_1	1.50	PVC	13.69	3.90	5.21	0	Y	SWMM FLOW
CUL_289	1.60	CMP	36.49	4.50	5.75	0	Y	SWMM FLOW
CUL_291	0.60	CMP	1.97	0.40	0.70	0	Y	SWMM FLOW
CUL_294	1.60	CMP	4.50	4.50	6.28	0	Y	SWMM FLOW
CUL_232	0.90	CMP	2.17	1.10	0.88	0	Y	MIKE11 FLOW
CUL_14	1.80	CMP	15.09	6.00	5.20	0	Y	MIKE11 FLOW
CUL_15	2.40	CMP	14.54	10.20	5.17	0	Y	MIKE11 FLOW
CUL_370	1.20		10.37	2.20	4.31	315	N	MIKE11 FLOW
CUL_295	1.80	CMP	7.24	6.00	4.45	0	Y	MIKE11 FLOW
CUL_354	1.50	CMP	2.08	3.90	3.70	0	Y	MIKE11 FLOW
CUL_236	2.00	CMP	13.2	7.00	7.69	135	N	MIKE11 FLOW
CUL_234	0.90	CMP	0.91	1.10	0.25	0	Y	MIKE11 FLOW
CUL_9	1.40	CMP	15.05	3.50	0.57	0	Y	MIKE11 FLOW
CUL_7	1.20	CMP	2.29	2.20	0.52	0	Y	MIKE11 FLOW
CUL_223	1.20	CONC	0.04	2.20	0.58	0	Y	MIKE11 FLOW
CUL_35	1.60	CMP	1.13	4.50	1.25	0	Y	MIKE11 FLOW
CUL_29	1.20	CONC	6.40	2.20	1.32	0	Y	MIKE11 FLOW
CUL_36	1.60	CMP	6.18	4.50	1.63	0	Y	MIKE11 FLOW

Shaded entries do not meet the criteria

See Figure 3-2 for locations.

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Table D-3: Culvert Assessment for Future Land Use 100-Year Flow

Culvert ID	Diameter	Material	Pipe Capacity	Capacity Inlet Controlled to d/D=1.0	100-Year Peak Flow	Surcharge Time	Meets Criteria	Notes
	(m)		(m^3/s)	(m^3/s)	(m^3/s)	(min)	(Y/N)	
Boundary Park Pond Outfall	1.50	CONC	4.36	3.90	5.12		Y	SWMM FLOW
Hwy10_1	1.50	PVC	13.69	3.90	5.42		Y	SWMM FLOW
CUL_289	1.60	CMP	36.49	4.50	6.02		Y	SWMM FLOW
CUL_291	0.60	CMP	1.97	0.40	0.70		Y	SWMM FLOW
CUL_294	1.60	CMP	4.50	4.50	6.58		Y	SWMM FLOW
CUL_232	0.90	CMP	2.17	1.10	0.89		Y	MIKE11 FLOW
CUL_14	1.80	CMP	15.09	6.00	5.43		Y	MIKE11 FLOW
CUL_15	2.40	CMP	14.54	10.20	5.39		Y	MIKE11 FLOW
CUL_370	1.20		10.37	2.20	4.48	315	N	MIKE11 FLOW
CUL_295	1.80	CMP	7.24	6.00	4.61		Y	MIKE11 FLOW
CUL_354	1.50	CMP	2.08	3.90	3.78		Y	MIKE11 FLOW
CUL_236	2.00	CMP	13.2	7.00	7.88	165	N	MIKE11 FLOW
CUL_234	0.90	CMP	0.91	1.10	0.26		Y	MIKE11 FLOW
CUL_9	1.40	CMP	15.05	3.50	0.56		Y	MIKE11 FLOW
CUL_7	1.20	CMP	2.29	2.20	0.49		Y	MIKE11 FLOW
CUL_223	1.20	CONC	0.04	2.20	0.59		Y	MIKE11 FLOW
CUL_35	1.60	CMP	1.13	4.50	1.25		Y	MIKE11 FLOW
CUL_29	1.20	CONC	6.40	2.20	1.32		Y	MIKE11 FLOW
CUL_36	1.60	CMP	6.18	4.50	1.63		Y	MIKE11 FLOW

Shaded entries do not meet the criteria

See Figure 3-2 for locations.

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Table D-4: Culvert Assessment for Existing Land Use 10-Year Flow

						For Inlet Control		For Outlet Control		
Culvert ID	Diameter	Material	Pipe Capacity	Capacity Inlet Controlled to d/D=1.0	Outlet Controlled	10-Year Peak Flow	Surcharge Time	10-Year Peak Flow	Head Loss	Meets Criteria
	(m)		(m^3/s)	(m^3/s)	(Y/N)	(m^3/s)	(min)	(m^3/s)	(m)	(Y/N)
CUL_41	1.80	CMP	13.90	6.0	Y	3.04		3.04	0.02	Y
CUL_40	1.20	CMP	5.41	2.2	Y	1.41		1.41	0.01	Y
CUL_38	1.50	CMP	8.62	3.9	Y	1.27		1.27	0.01	Y
CUL_37	1.50	CMP	1.97	3.9	Y	1.26		1.26	0.01	Y
CUL_31	1.30	WOODSTV	4.55	3.0	Y	1.03		1.03	0.01	Y
CUL_27	0.90	CONC	2.96	1.1	Y	0.78		0.78	0.11	Y
CUL_25	0.90	CONC	1.70	1.1	Y	0.80		0.80	0.12	Y
CUL_24	1.80	CON	9.79	6.0	Y	5.77		5.77	0.40	N
CUL_23	0.75	CMP	0.28	0.7	Y	0.67		0.67	0.16	Y
CUL_22	1.05	STL	2.75	1.6	Y	0.66		0.66	0.03	Y
CUL_21	0.75	CONC	0.94	0.7	Y	0.66		0.66	0.15	Y
CUL_249	0.60	CONC	0.98	0.4	Y	0.67	3045	0.67	0.41	N
CUL_331	1.20	CONC	0.04	2.2	Y	0.69		0.69	0.03	Y
CUL_20	1.05	CMP	4.77	1.6	Y	0.74		0.74	0.04	Y
CUL_19	1.05	CMP	2.53	1.6	Y	0.74		0.74	0.02	Y
CUL_18	1.05	CMP	1.50	1.6	Y	0.74		0.74	0.06	Y
CUL_17	1.20	CMP	4.38	2.2	Y	3.39	870	3.39	0.20	N
CUL_250	0.60	CONC	0.17	0.4	Y	0.67	3420	0.67	0.38	N
CUL_1	1.20	CONC	2.75	2.2	Y	0.19		0.19	0.00	Y
CUL_2	0.60	CONC	0.59	0.4	Y	0.45	2610	0.45	0.06	N
CUL_3	1.40	CMP	1.81	3.5	Y	0.45		0.45	0.00	Y
CUL_4	1.05	CONC	2.51	1.6	Y	0.47		0.47	0.01	Y
CUL_6	1.50	CMP	5.00	3.9	Y	0.49		0.49	0.00	Y
CUL_8	1.20	CMP	2.35	2.2	Y	0.52		0.52	0.01	Y
CUL_10	1.00	CMP	0.20	1.4	Y	0.88		0.88	0.03	Y
CUL_11	1.00	CMP	0.53	1.4	Y	0.88		0.88	0.03	Y
CUL_12	1.05	CMP	1.15	1.6	Y	0.81		0.81	0.02	Y
CUL_13	1.05	CMP	1.82	1.6	Y	0.81		0.81	0.02	Y
CUL_39	1.05	CONC	4.09	1.6	Y	1.48		1.48	0.09	Y
CUL_197	1.20	CMP	3.91	2.2	Y	1.55		1.55	0.05	Y
CUL_198	1.20	CMP	3.91	2.2	Y	1.53		1.53	0.05	Y
CUL_230	1.20	CONC	1.23	2.2	Y	0.55		0.55	0.00	Y
CUL_231	0.90	CMP	2.33	1.1	Y	1.32	130	1.32		N
CUL_199	1.20	CONC	3.06	2.2	Y	0.18		0.18	0.00	Y
CUL_274	0.45	CMP	0.00	0.2	Y	2.85	1395	2.85		N
CUL_352	0.25		0.18	0.1	N	1.53	1890	1.53		N
CUL_372	1.50		31.00	3.9	N	2.02		2.02		Y

Shaded entries do not meet the criteria. See Figure 3-1 for locations.
Bold entries were also checked for 100-year flow conveyance (see Tables B-1 and B-2).

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Table D-5: Culvert Assessment for Future Land Use 10-Year Flow

						For Inlet Control		For Outlet Control		
Culvert ID	Diameter	Material	Pipe Capacity	Capacity Inlet Controlled to d/D=1.0	Outlet Controlled	10-Year Peak Flow	Surcharge Time	10-Year Peak Flow	Head Loss	Meets Criteria
	(m)		(m^3/s)	(m^3/s)	(Y/N)	(m^3/s)	(min)	(m^3/s)	(m)	(Y/N)
CUL_41	1.80	CMP	13.90	6.0	Y	3.05		3.05	0.02	Y
CUL_40	1.20	CMP	5.41	2.2	Y	1.42		1.42	0.01	Y
CUL_38	1.50	CMP	8.62	3.9	Y	1.28		1.28	0.01	Y
CUL_37	1.50	CMP	1.97	3.9	Y	1.27		1.27	0.01	Y
CUL_31	1.30	WOODSTV	4.55	3.0	Y	1.03		1.03	0.01	Y
CUL_27	0.90	CONC	2.96	1.1	Y	0.79		0.79	0.11	Y
CUL_25	0.90	CONC	1.70	1.1	Y	0.80		0.80	0.12	Y
CUL_24	1.80	CON	9.79	6.0	Y	6.05	315	6.05	0.44	N
CUL_23	0.75	CMP	0.28	0.7	Y	0.67		0.67	0.16	Y
CUL_22	1.05	STL	2.75	1.6	Y	0.66		0.66	0.03	Y
CUL_21	0.75	CONC	0.94	0.7	Y	0.66		0.66	0.15	Y
CUL_249	0.60	CONC	0.98	0.4	Y	0.67	1875	0.67	0.41	N
CUL_331	1.20	CONC	0.04	2.2	Y	0.69		0.69	0.03	Y
CUL_20	1.05	CMP	4.77	1.6	Y	0.74		0.74	0.04	Y
CUL_19	1.05	CMP	2.53	1.6	Y	0.75		0.75	0.02	Y
CUL_18	1.05	CMP	1.50	1.6	Y	0.75		0.75	0.06	Y
CUL_17	1.20	CMP	4.38	2.2	Y	3.49	840	3.49	0.20	N
CUL_250	0.60	CONC	0.17	0.4	Y	0.67	3390	0.67	0.38	N
CUL_1	1.20	CONC	2.75	2.2	Y	0.19		0.19	0.00	Y
CUL_2	0.60	CONC	0.59	0.4	Y	0.45	2610	0.45	0.06	N
CUL_3	1.40	CMP	1.81	3.5	Y	0.45		0.45	0.01	Y
CUL_4	1.05	CONC	2.51	1.6	Y	0.47		0.47	0.01	Y
CUL_6	1.50	CMP	5.00	3.9	Y	0.50		0.50	0.00	Y
CUL_8	1.20	CMP	2.35	2.2	Y	0.52		0.52	0.01	Y
CUL_10	1.00	CMP	0.20	1.4	Y	0.88		0.88	0.03	Y
CUL_11	1.00	CMP	0.53	1.4	Y	0.88		0.88	0.03	Y
CUL_12	1.05	CMP	1.15	1.6	Y	0.81		0.81	0.02	Y
CUL_13	1.05	CMP	1.82	1.6	Y	0.81		0.81	0.02	Y
CUL_39	1.05	CONC	4.09	1.6	Y	1.48		1.48	0.09	Y
CUL_197	1.20	CMP	3.91	2.2	Y	1.55		1.55	0.05	Y
CUL_198	1.20	CMP	3.91	2.2	Y	1.53		1.53	0.05	Y
CUL_230	1.20	CONC	1.23	2.2	Y	0.55		0.55	0.00	Y
CUL_231	0.90	CMP	2.33	1.1	Y	1.48	150	1.48		N
CUL_199	1.20	CONC	3.06	2.2	Y	0.20		0.20	0.00	Y
CUL_274	0.45	CMP	0.00	0.2	Y	3.03	1305	3.03		N
CUL_352	0.25		0.18	0.1	N	1.53	1890	1.53		N
CUL_372	1.50		31.00	3.9	N	2.26		2.26		Y

Shaded entries do not meet the criteria. See Figure 3-1 for locations.
Bold entries were also checked for 100-year flow conveyance (see Tables B-1 and B-2).

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Appendix D – Hydrologic/Hydraulic Modelling

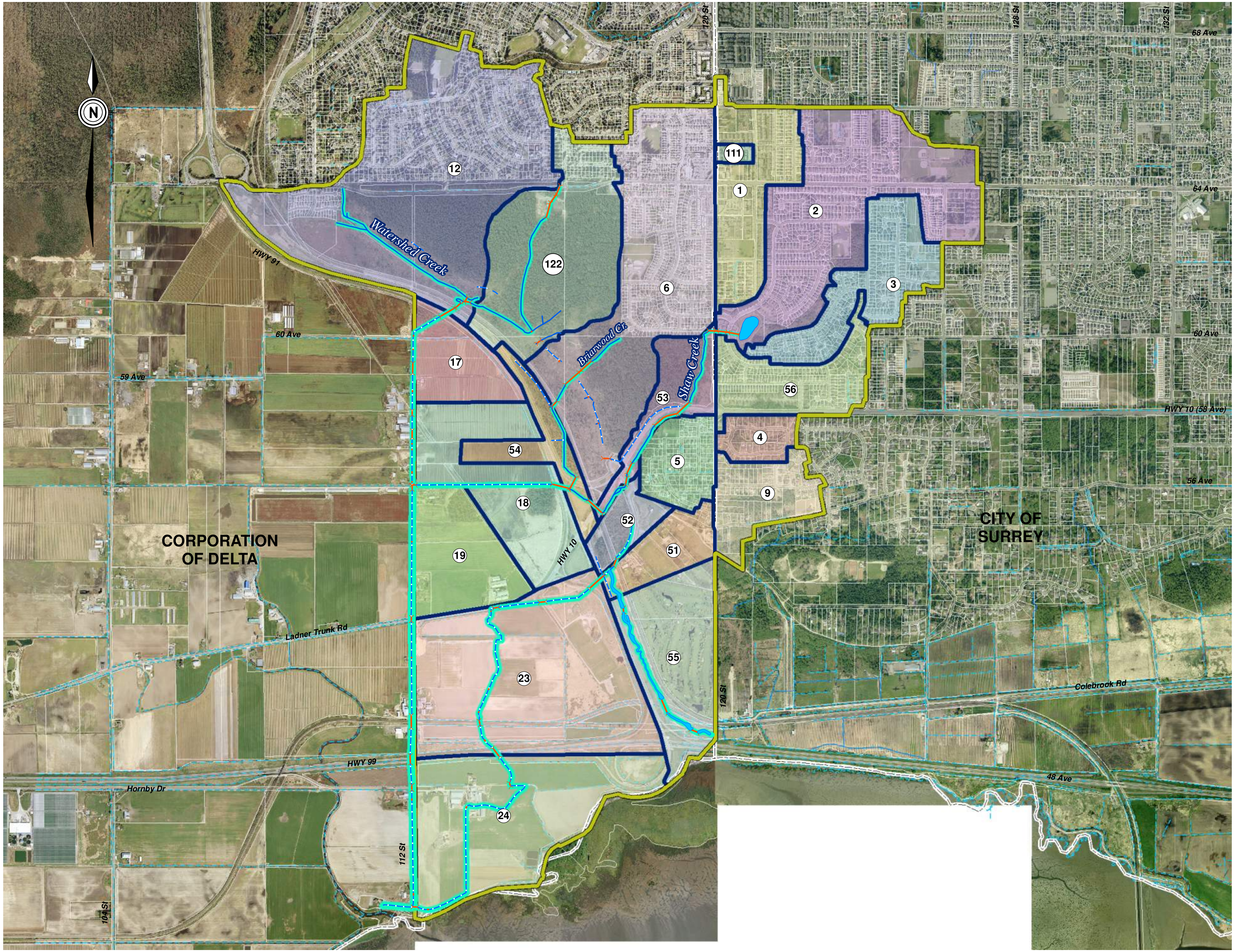
The rainfall data shows the following recent large events and their approximate return period and duration (see Table D-6).

Table D-6: Large Precipitation Events 2003-2009

Date	Return Period	Duration	Rain Depth
October 16, 2003	2- to 5-year 10- to 25-year >100-year >100-year	2-hour 6-hour 12-hour 24-hour	22 mm 51.6 mm 91 mm 132 mm
November 28, 2003	10-year 25-year 50-year	6-hour 12-hour 24-hour	47.2 mm 75.6 mm 93.2 mm
January 17, 2005	10-year 10- to 25-year 25-year	12-hour 24-hour 48-hour	66 mm 80.6 mm 129.2 mm
September 14, 2006	2-year 2-year 5-year 2- to 5-year	15-minute 30-minute 1-hour 2-hour	7.2 mm 11 mm 19.2 mm 23 mm
October 17, 2006	25-year	5-minute	7 mm
March 11 2007	10- to 25-year 10-year 5- to 10-year	24-hour 48-hour 72-hour	81.6 mm 114.6 mm 120.4 mm
Events may span multiple return periods and durations during the course of a storm			

Hydrographs for these events were created for Shaw and Watershed Creeks (See Figures D-14 to D-25). The hydrographs show that the existing with flow control and future with flow control scenarios are similar in their reaction to the storms. The existing and future peak flows are higher than the pre-development peak flow and the future scenario has slightly higher peak flows than the existing scenario.

Corporation of Delta
Boundary/Shaw
Integrated Stormwater Management Study



Legend

- Study Boundary
- Municipal Boundary
- ID Subcatchments
- Culvert
- Ditch
- Creek
- Modelled Conveyance System

2008 Orthophoto and cadastral data provided by The Corporation of Delta and City of Surrey.
ALR source from Agricultural Land Commission

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500 0 500
Scale in Metres 1:20,000

Project No.	Date
323-059	August 2011

Catchments and Modelling Schematic

Figure D-1

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Boundary Park Pond Water Levels
XP-SWMM Model Validation

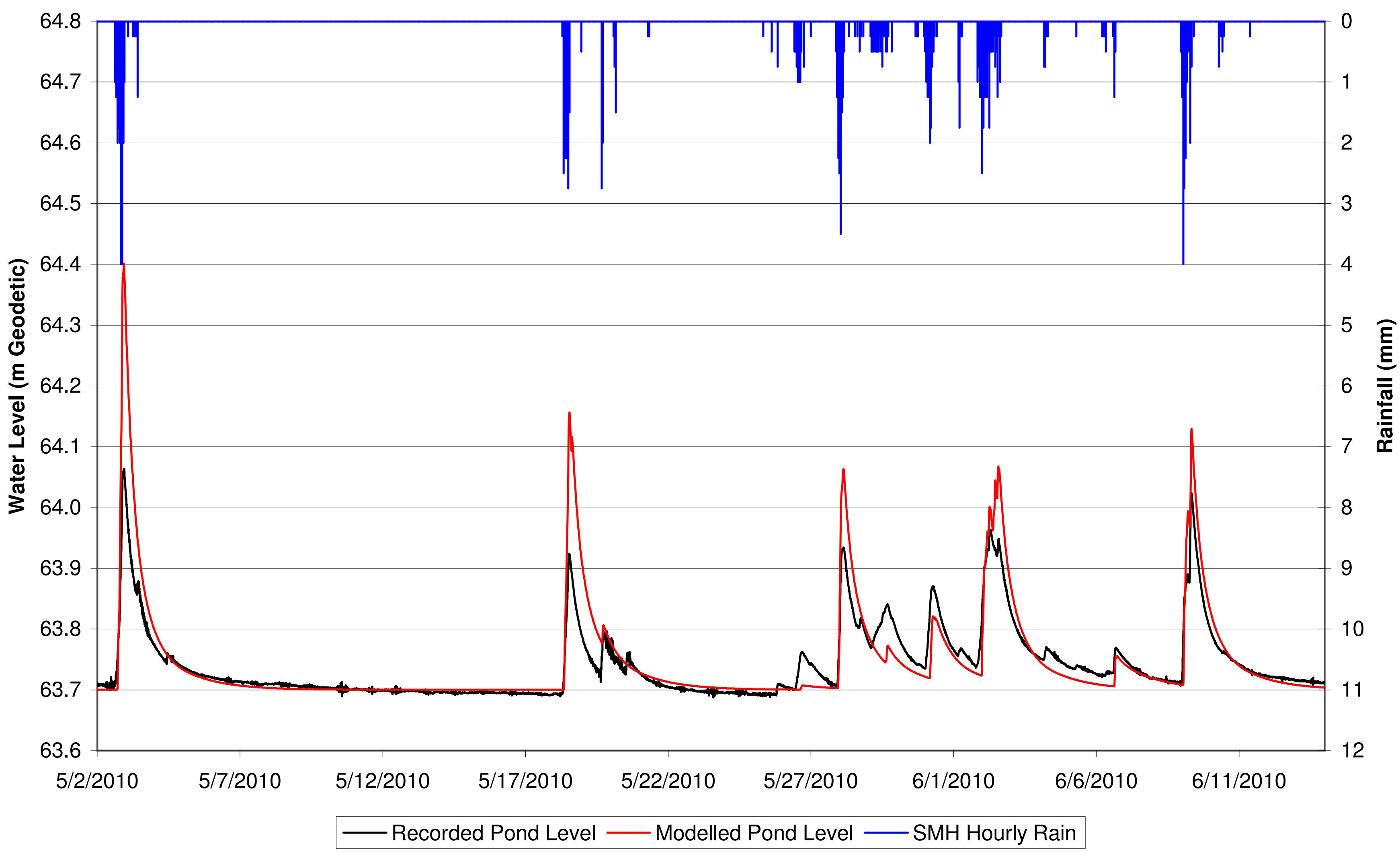

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Figure D-2

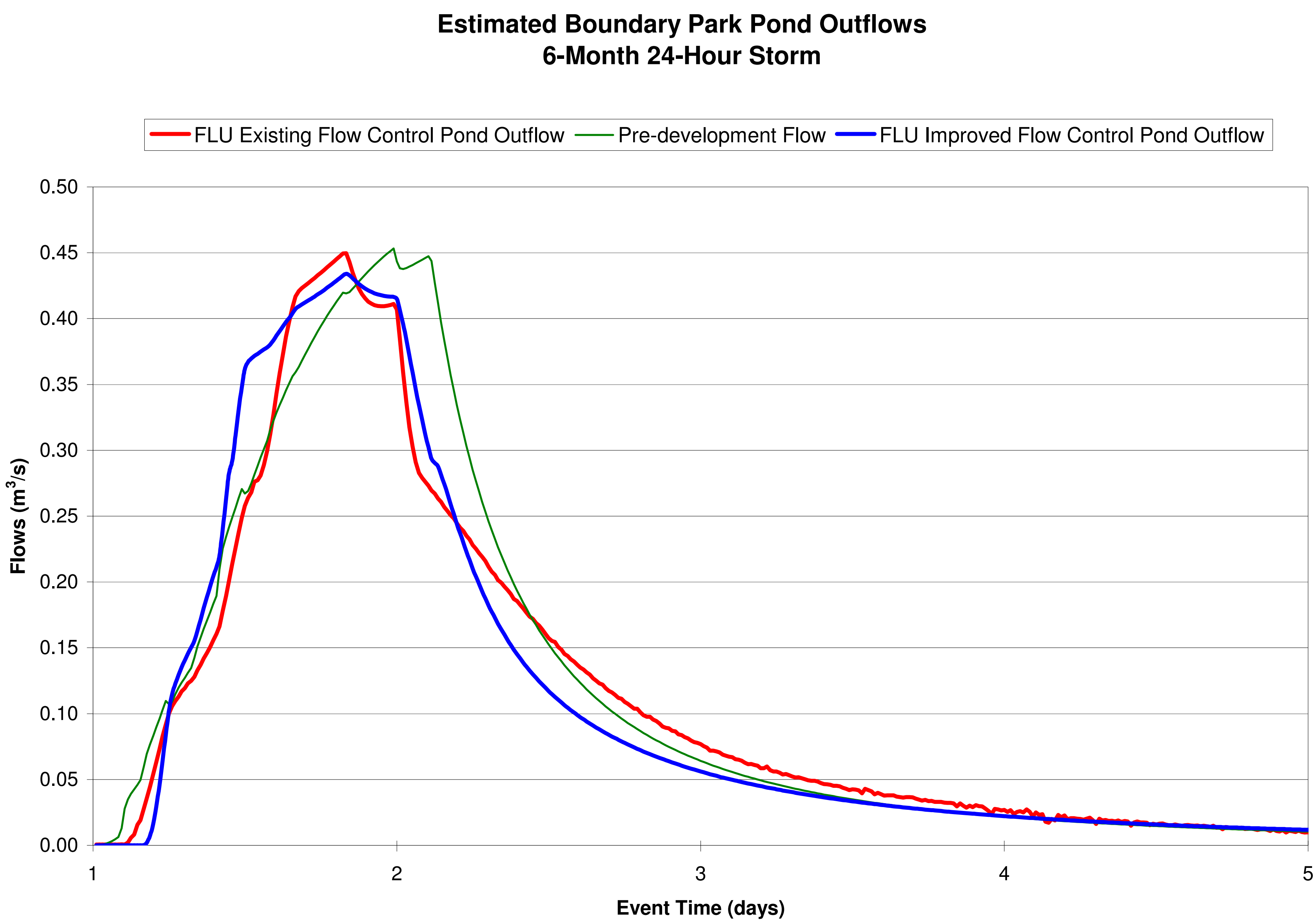

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Figure D-3

Estimated Boundary Park Pond Outflows
2-Year 24-Hour Storm

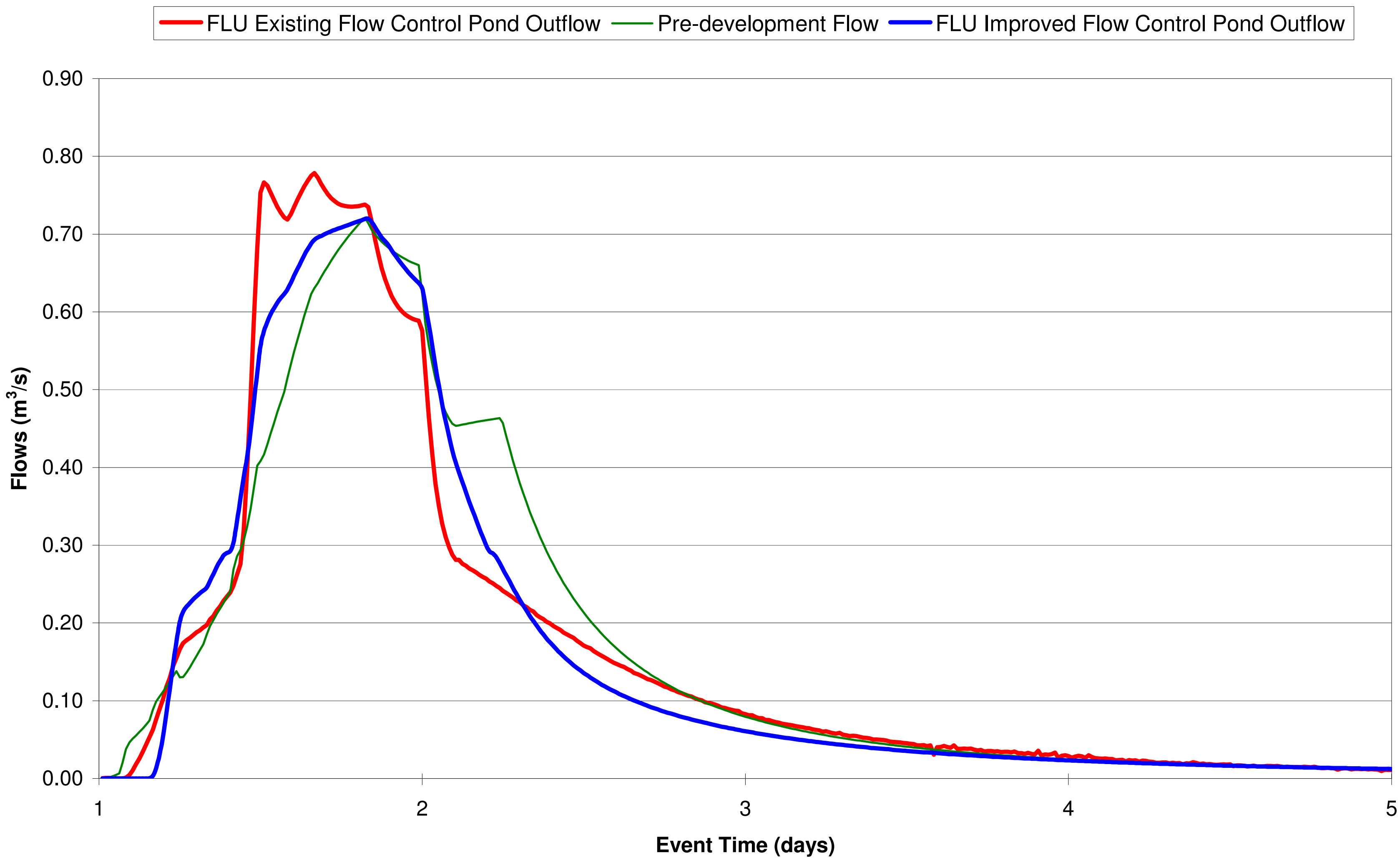

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Figure D-4

Estimated Boundary Park Pond Outflows
5-Year 24-Hour Storm

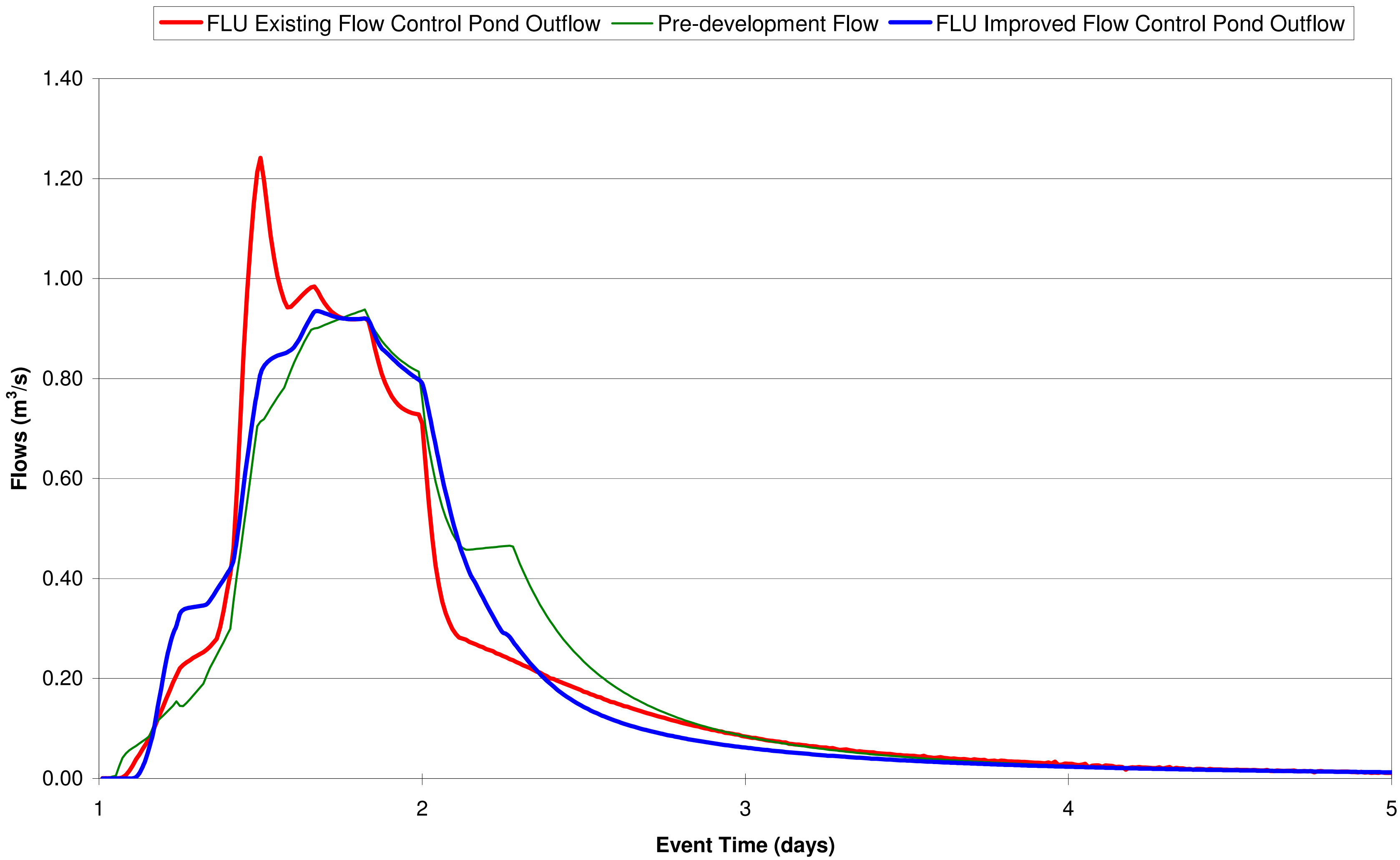

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Figure D-5

Estimated Boundary Park Pond Outflows
10-Year 24-Hour Storm

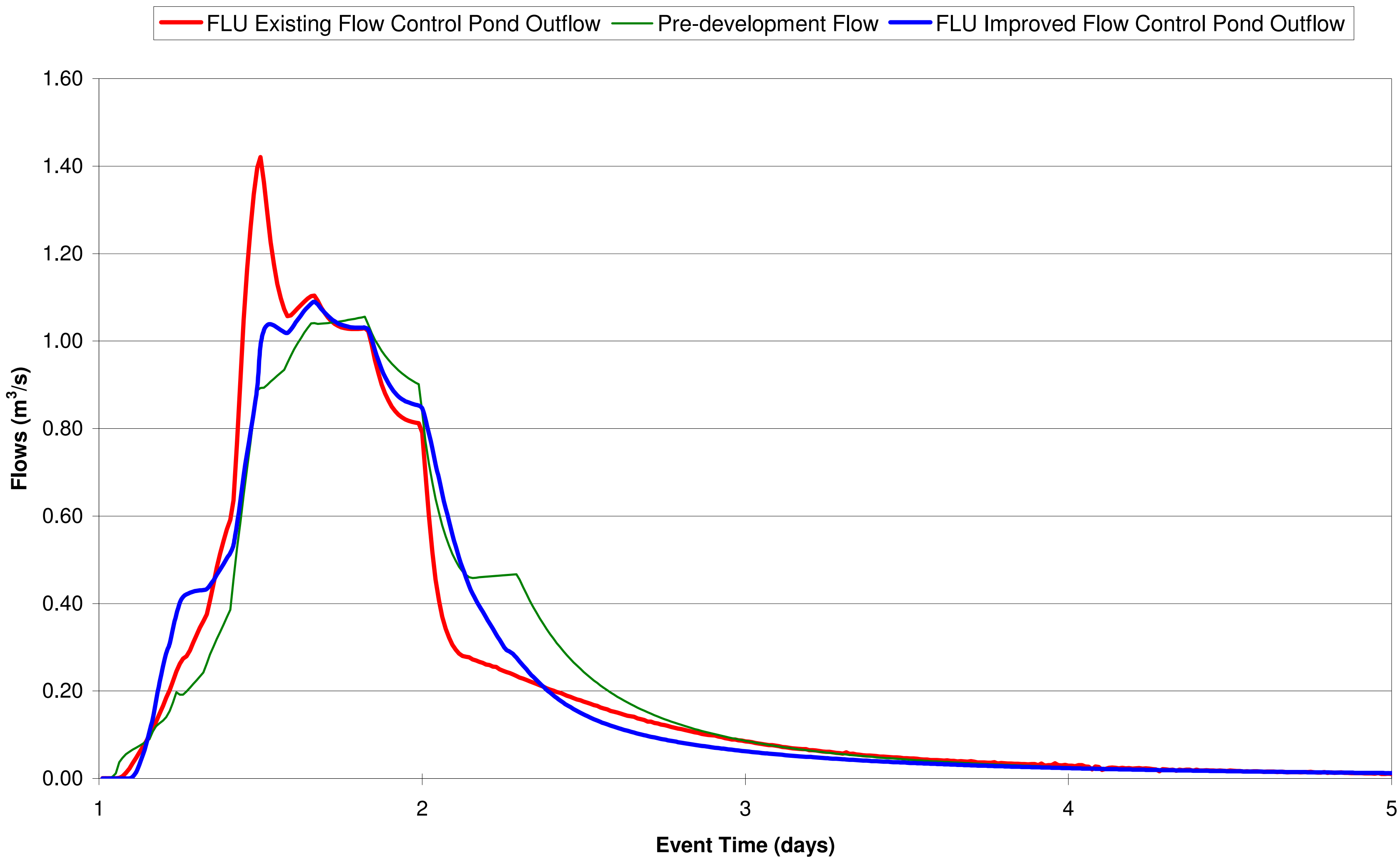

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Figure D-6

Estimated P1 Detention Outflows
6-Month 24-Hour Storm

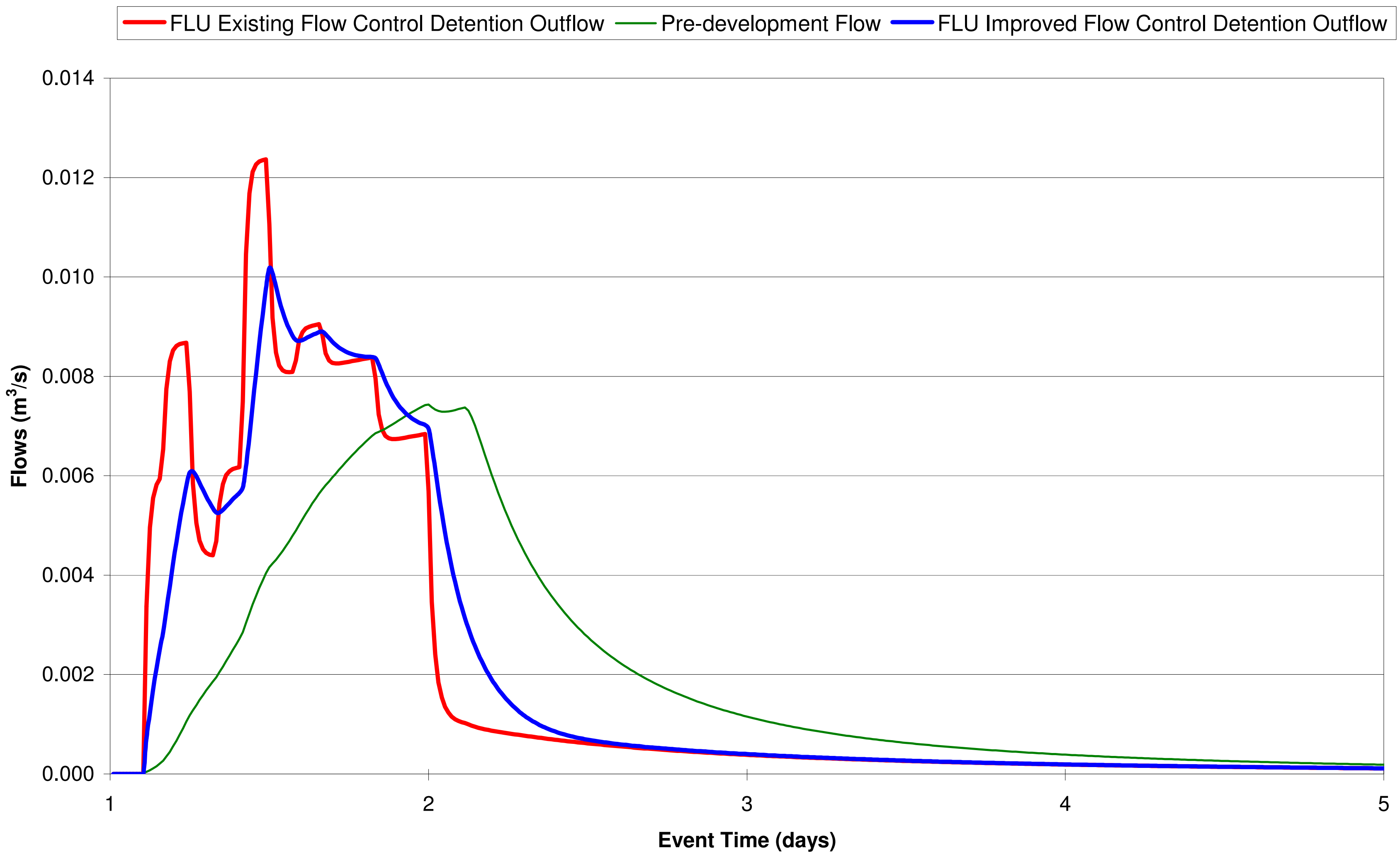

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Figure D-7

Estimated P1 Detention Outflows
2-Year 24-Hour Storm

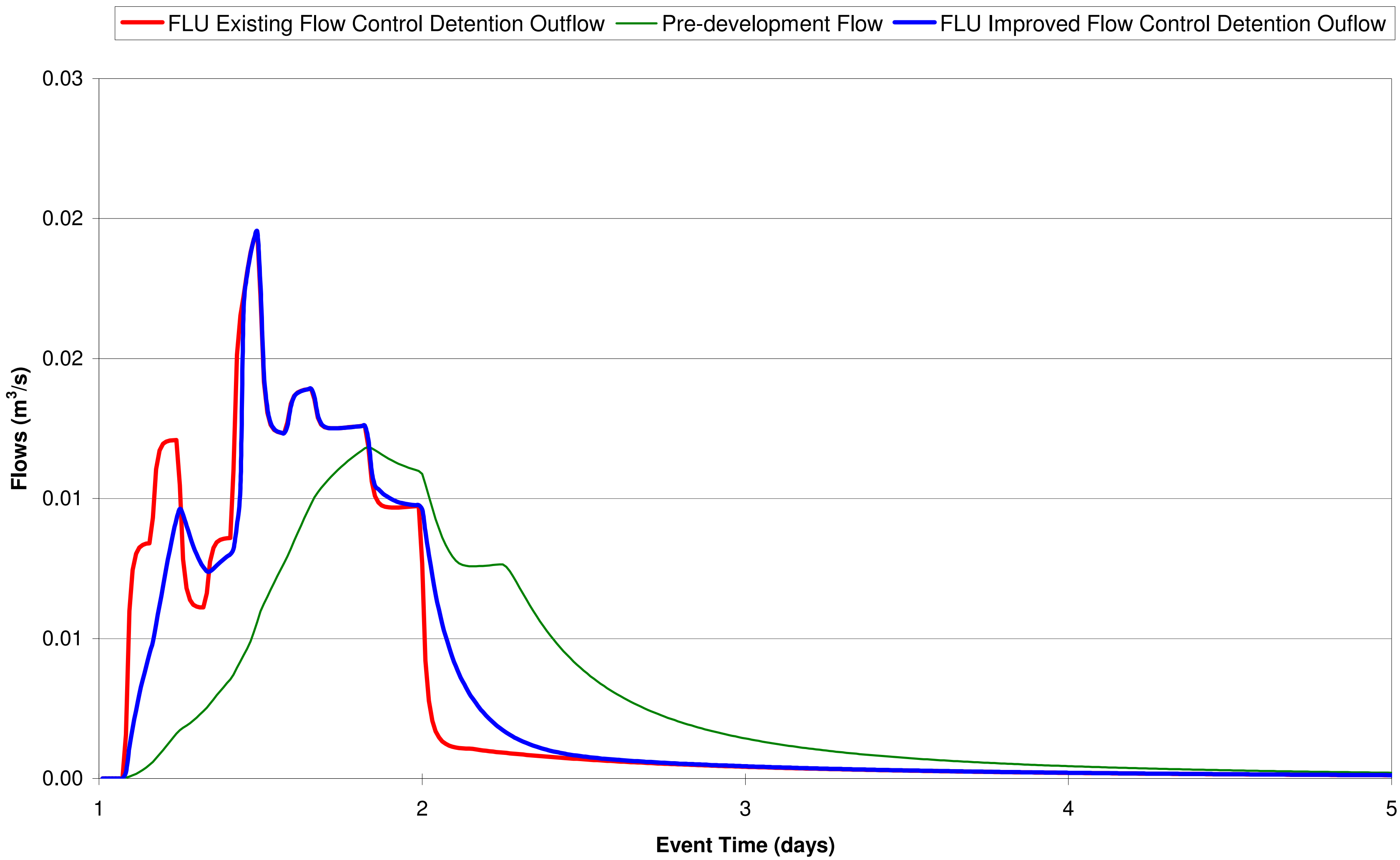

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Figure D-8

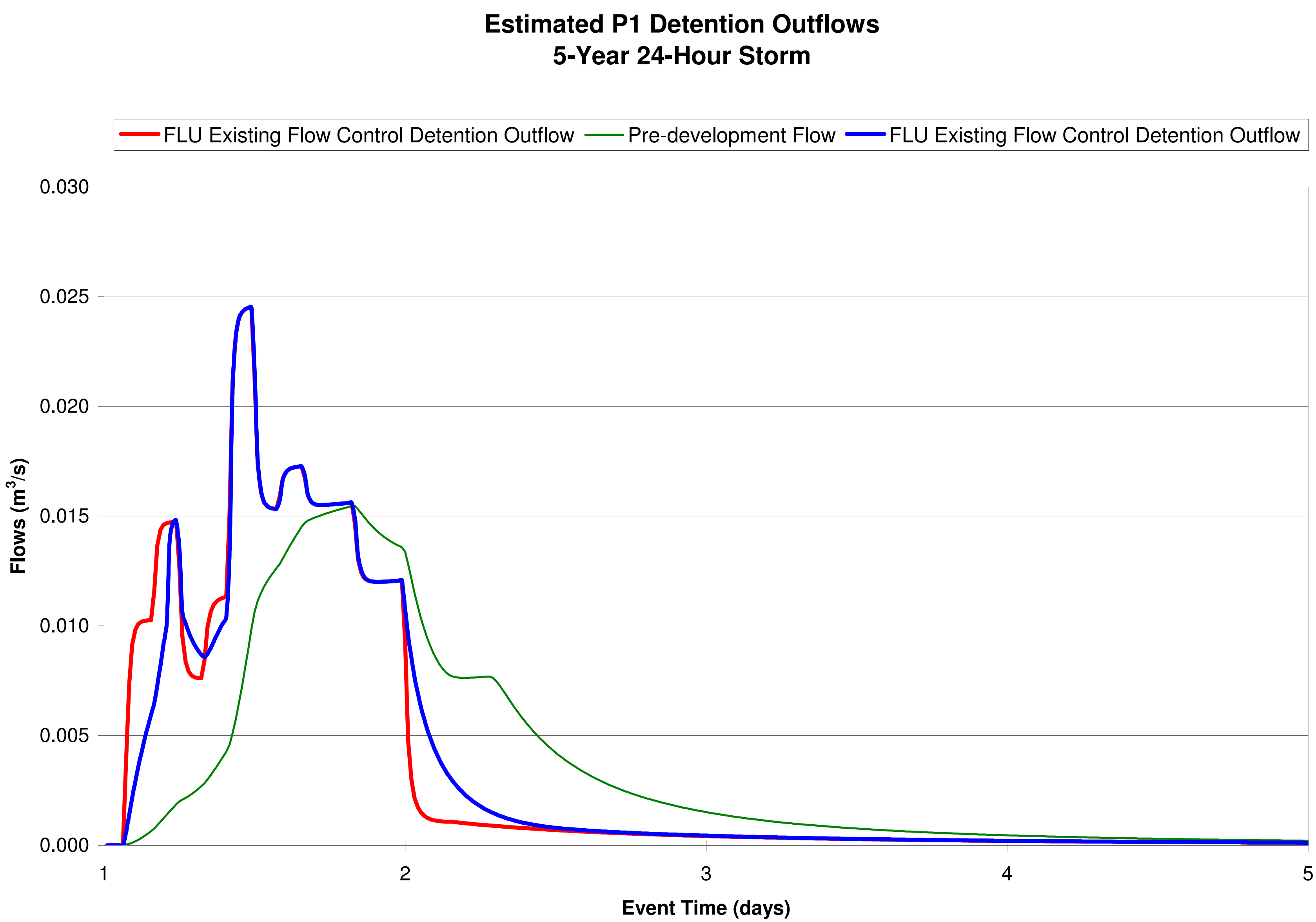

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Figure D-9

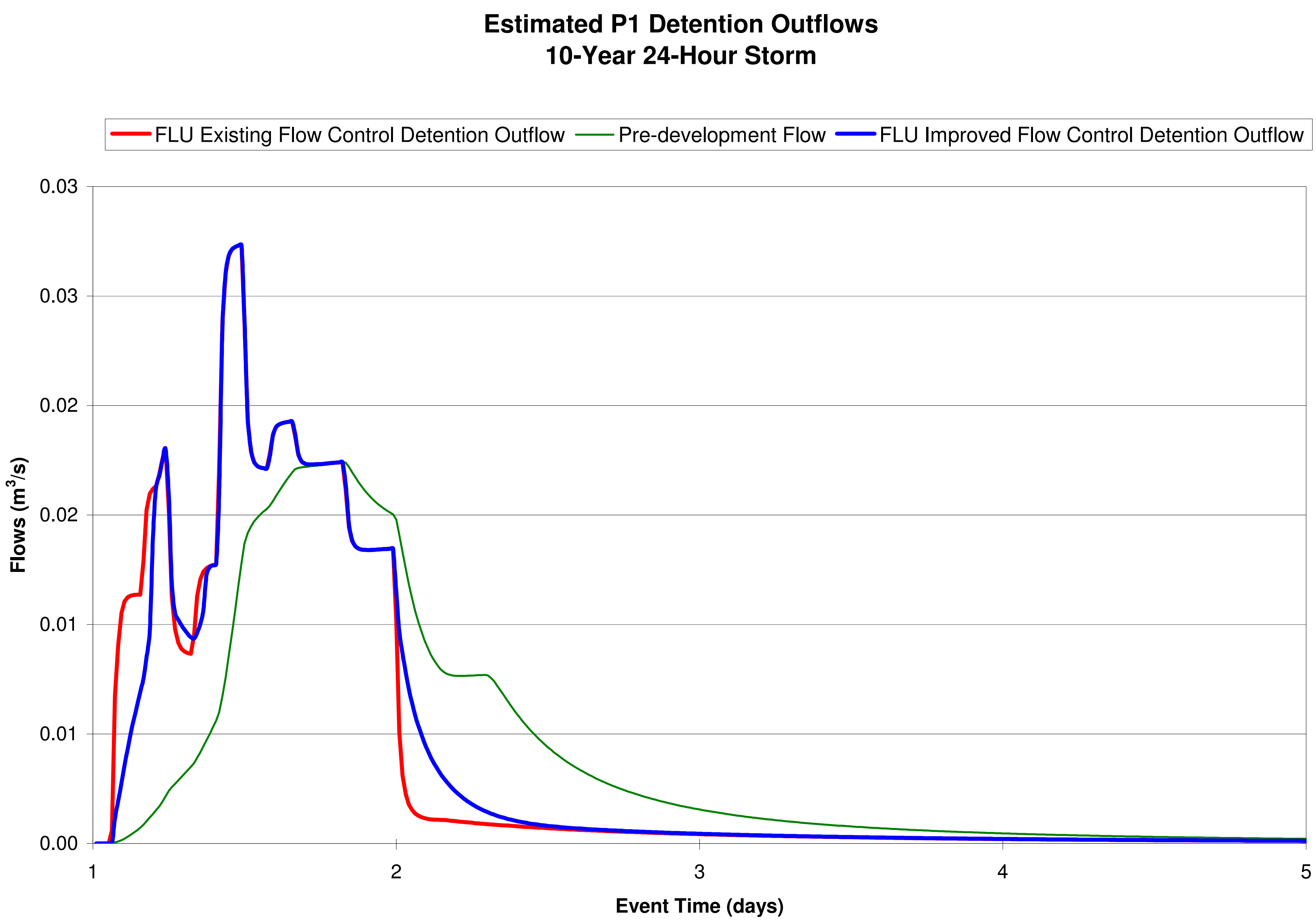

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Figure D-10

Exceedance Duration Curve for Shaw Creek
At 120 Street Outfall

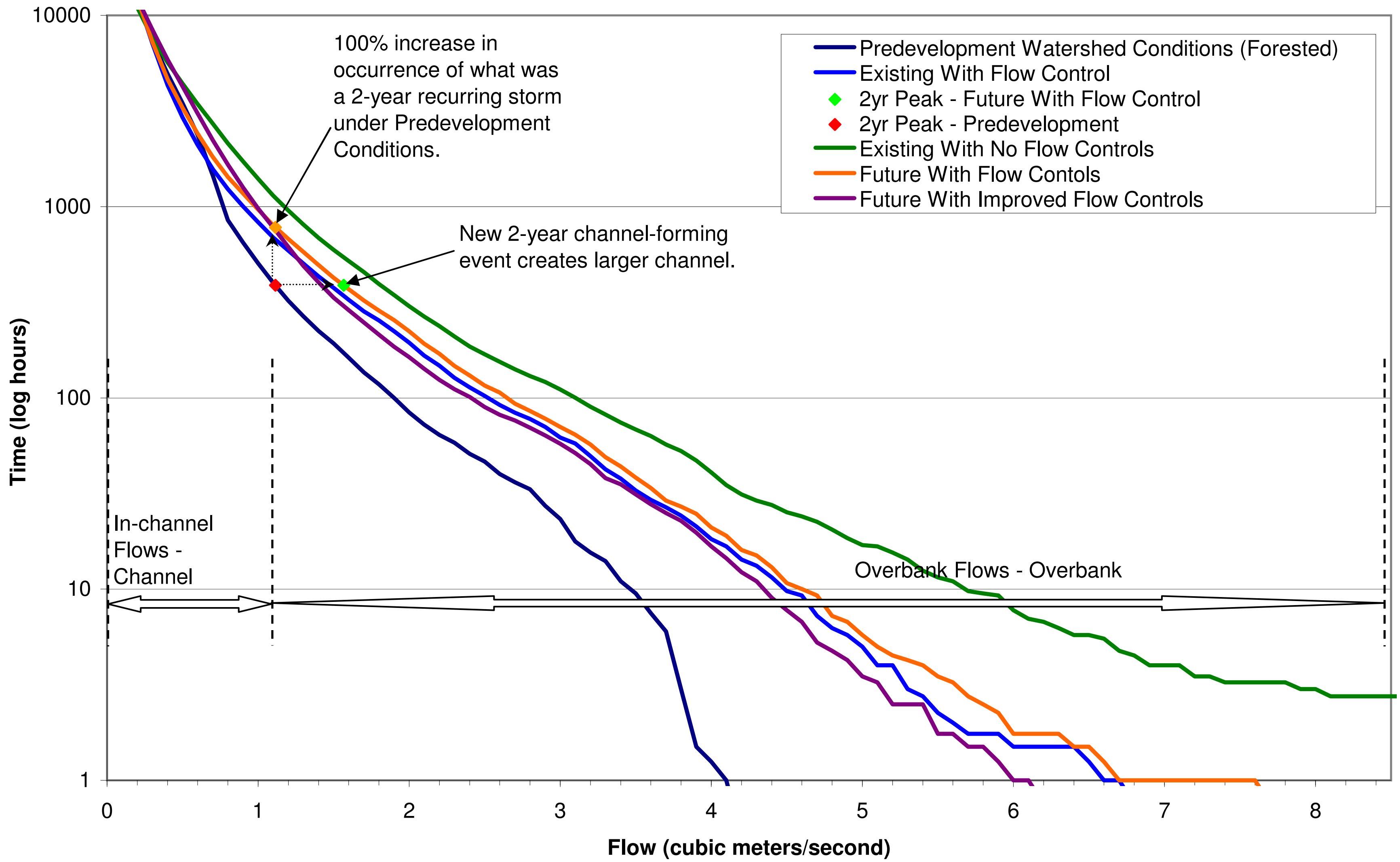

Figure D-11

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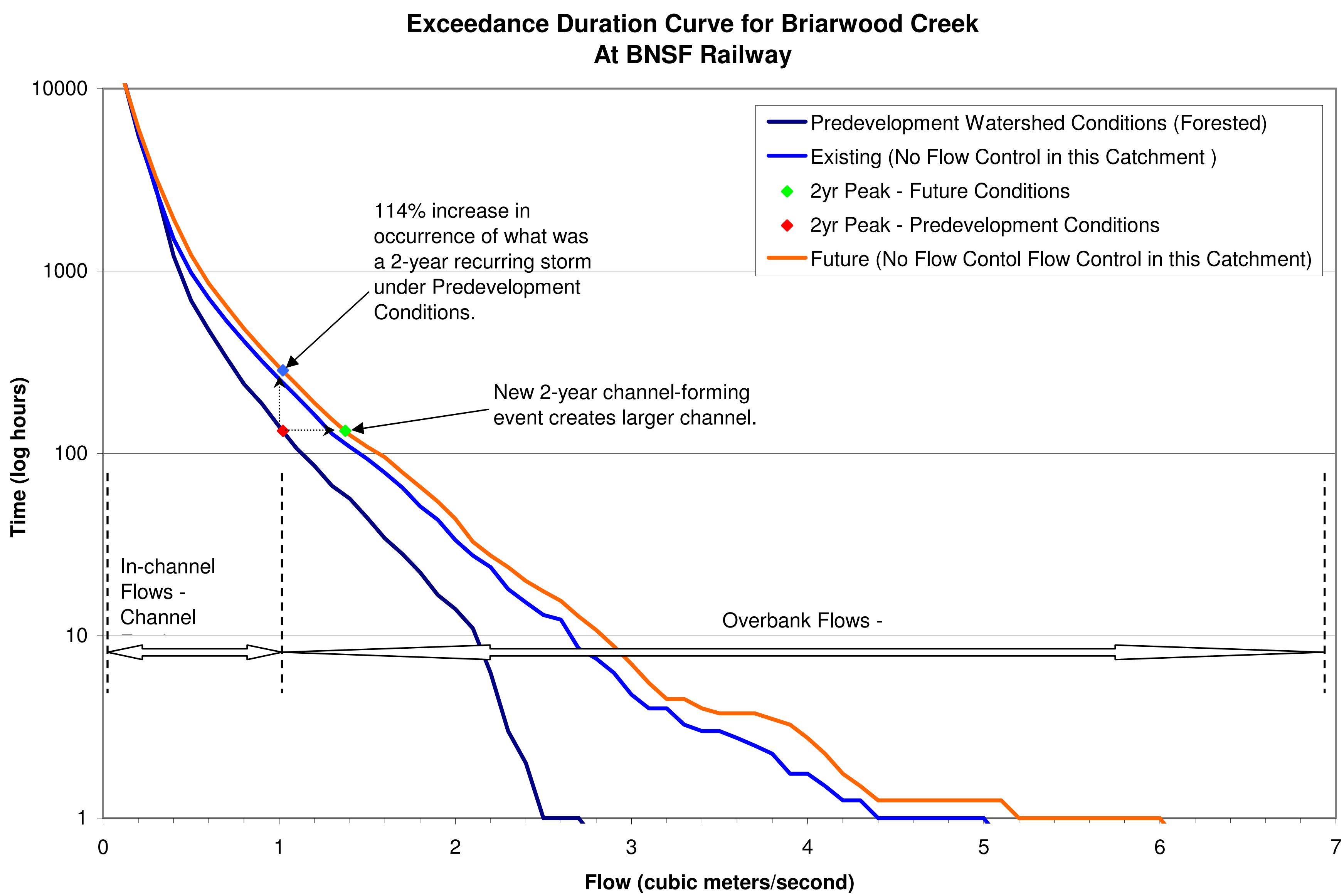

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Figure D-12

Exceedance Duration Curve for Watershed Creek
At BNSF Railway

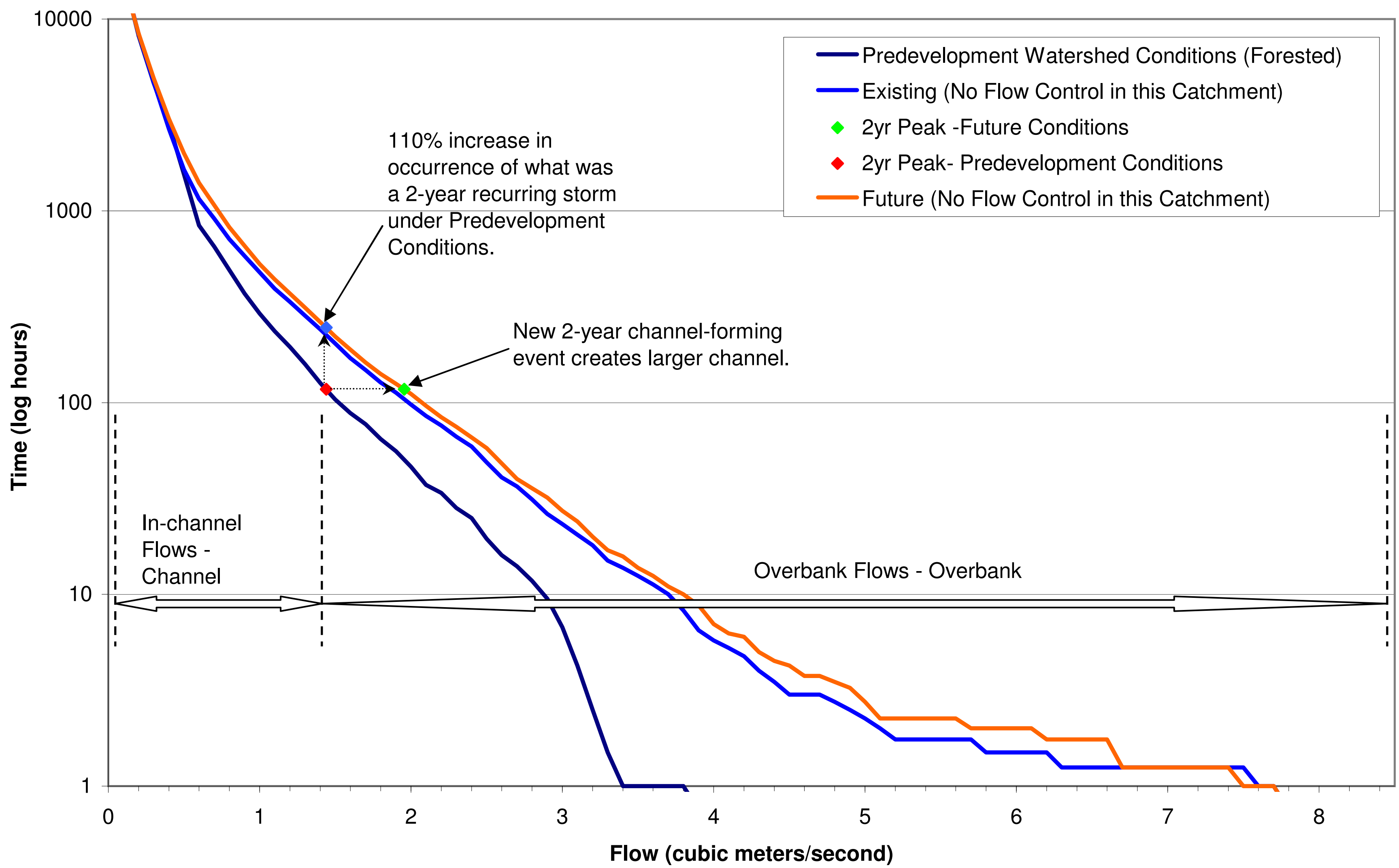

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Figure D-13

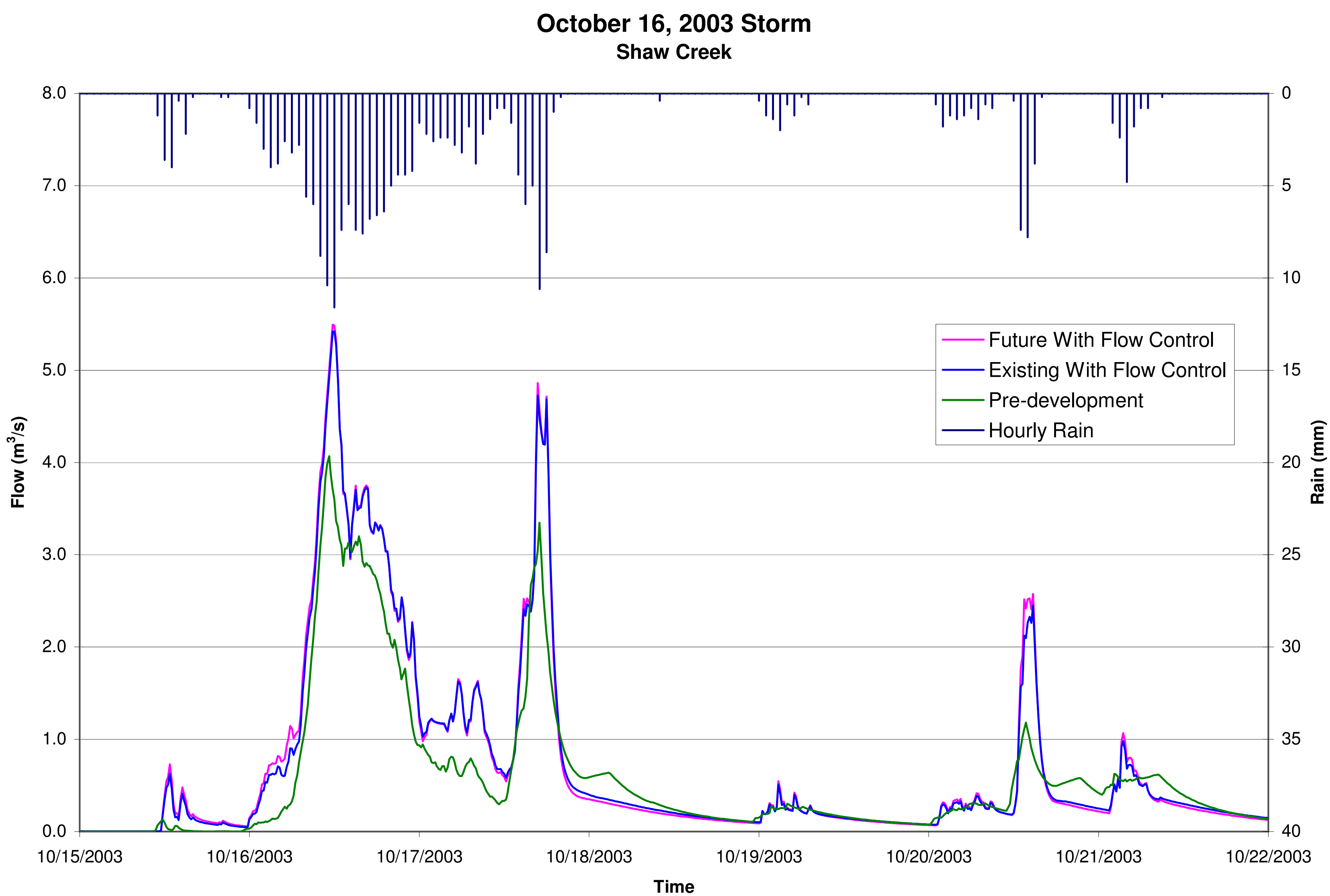

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Figure D-14

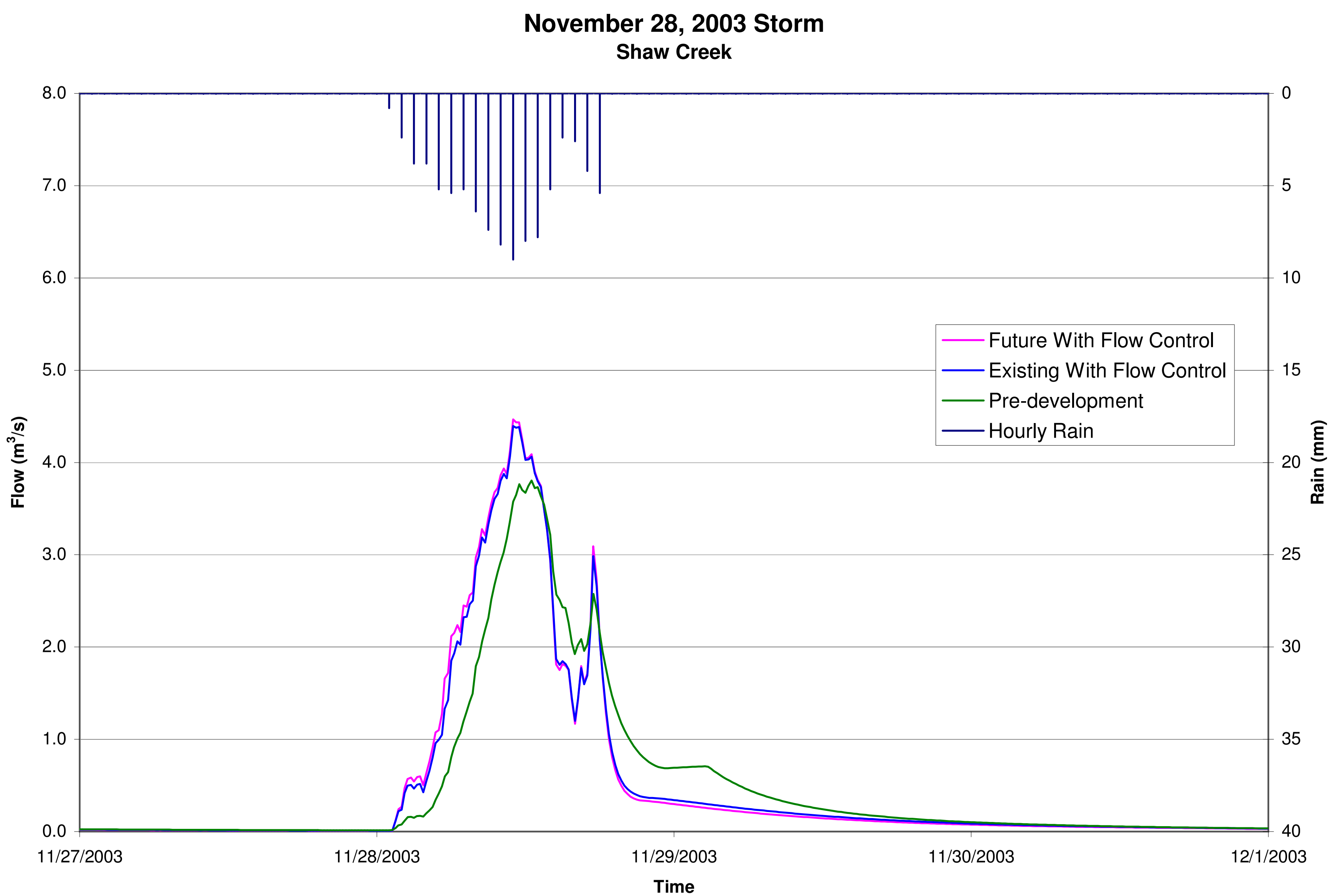

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Figure D-15

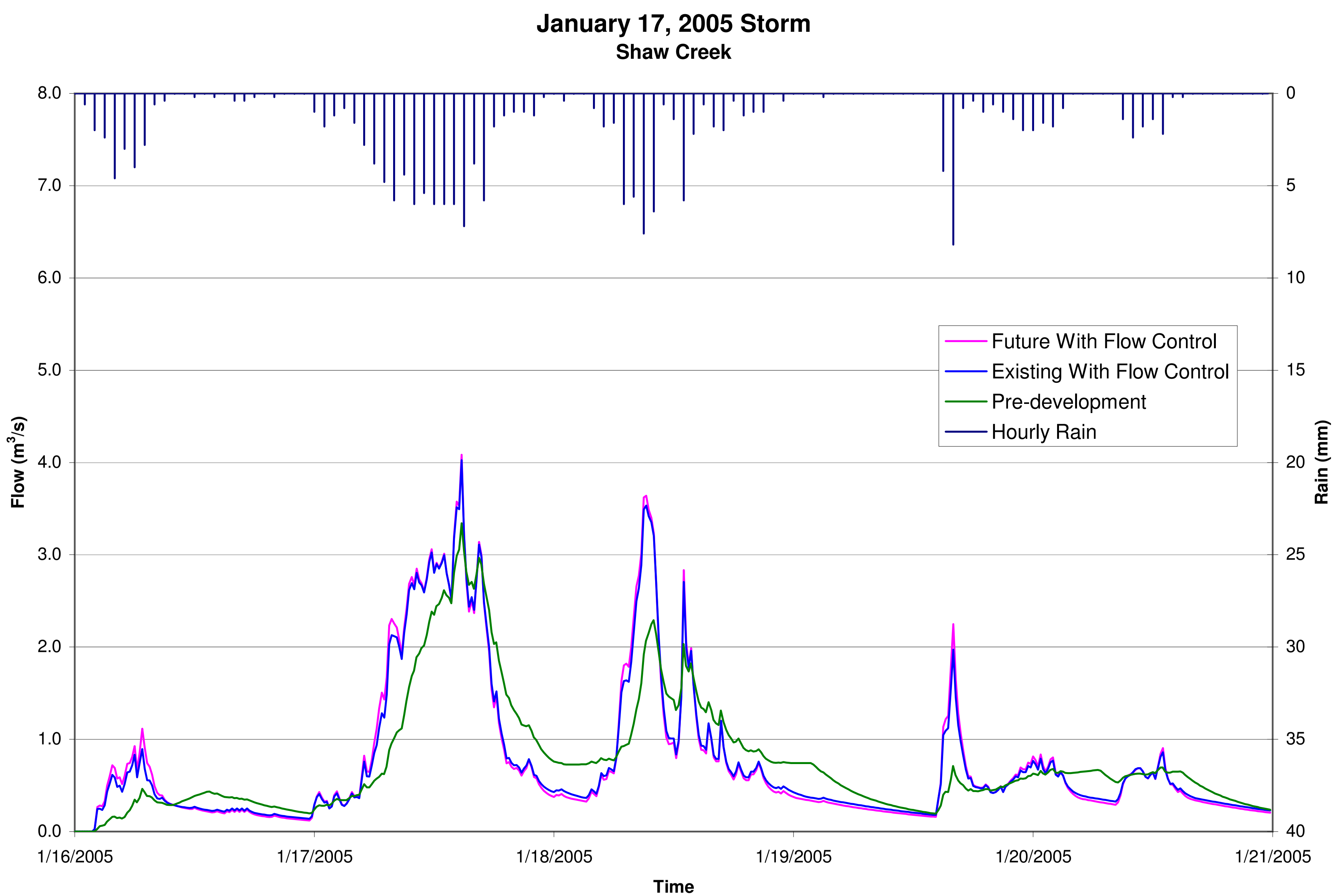

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Figure D-16

September 14, 2006 Storm
Shaw Creek

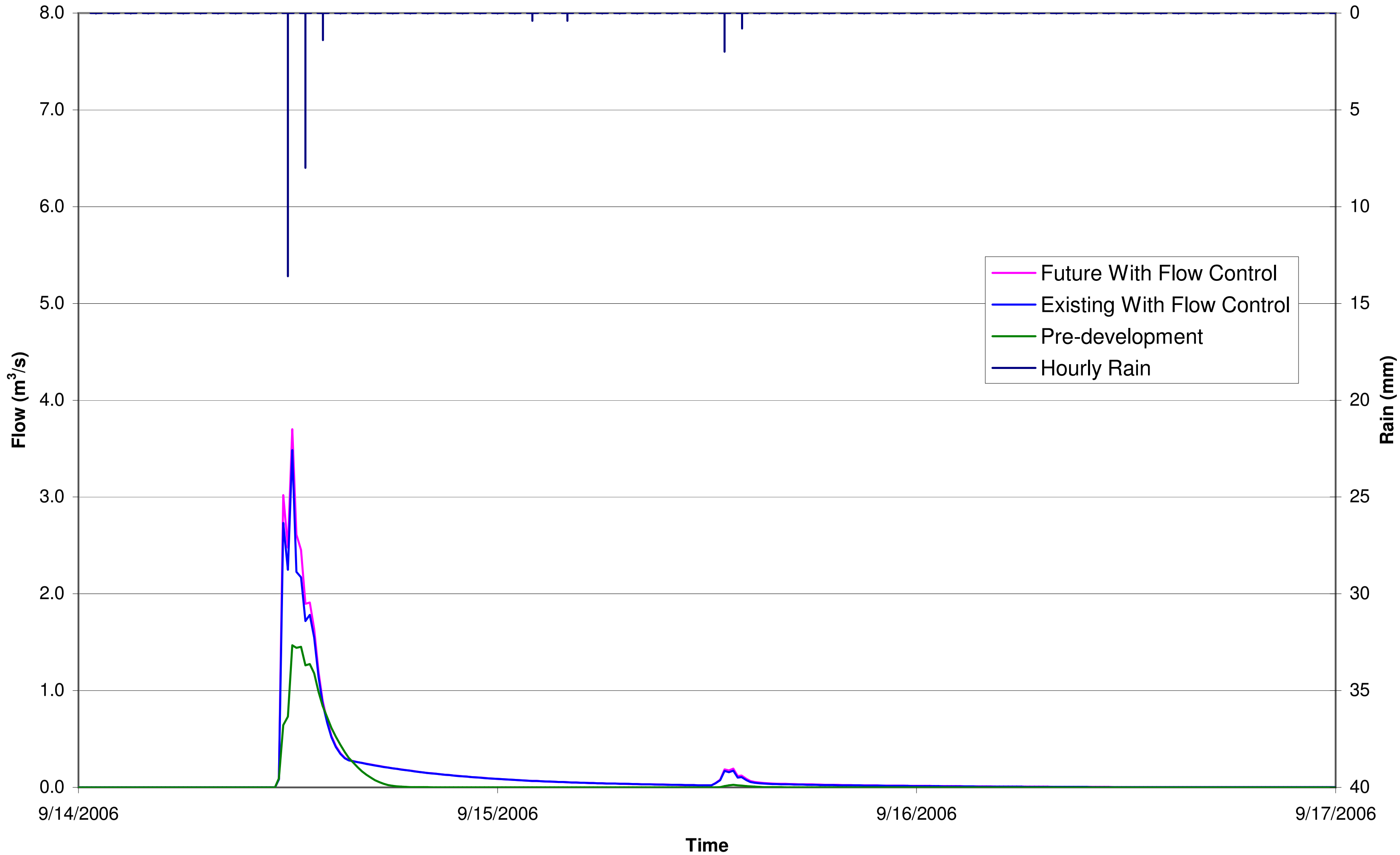

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Figure D-17

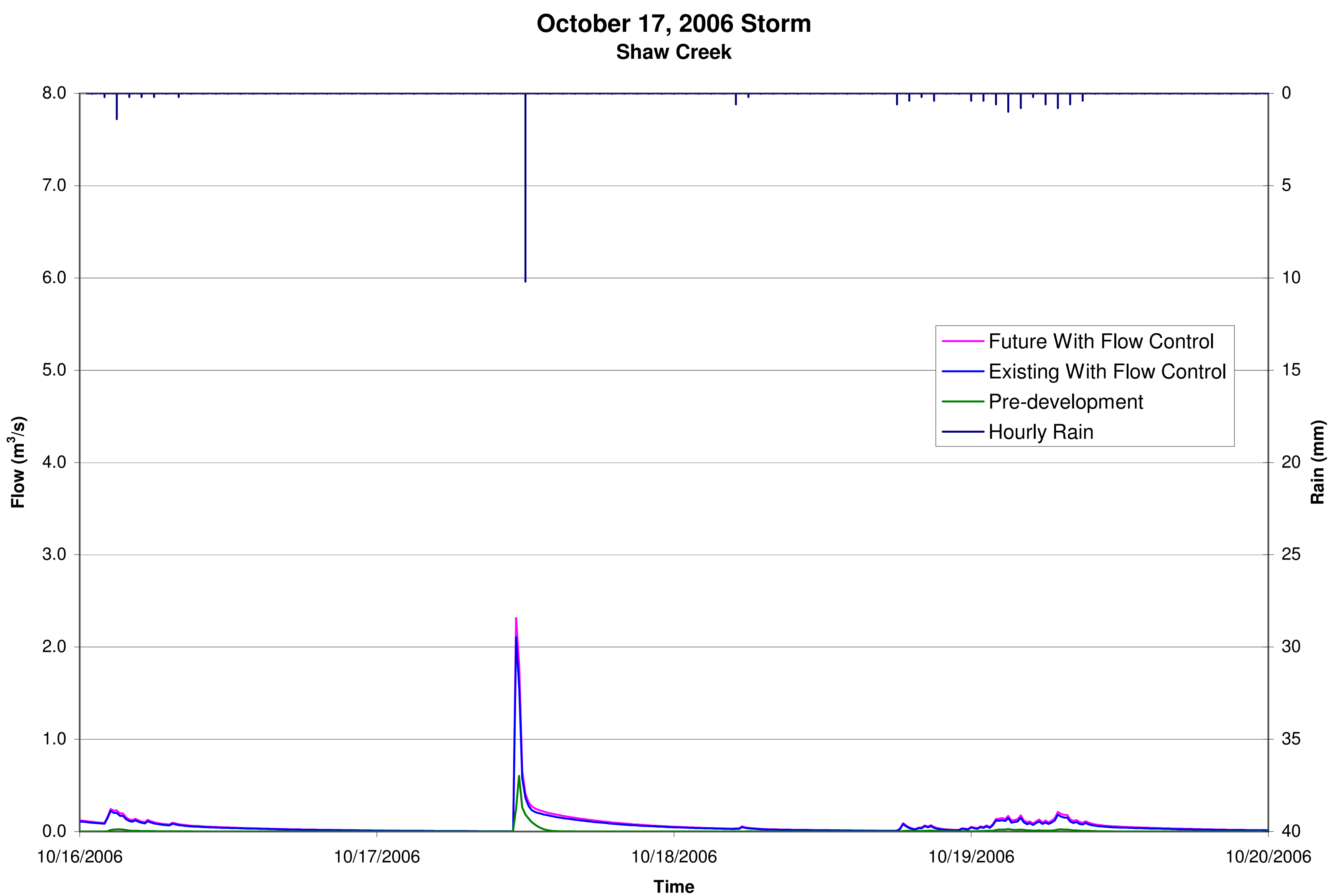

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Figure D-18

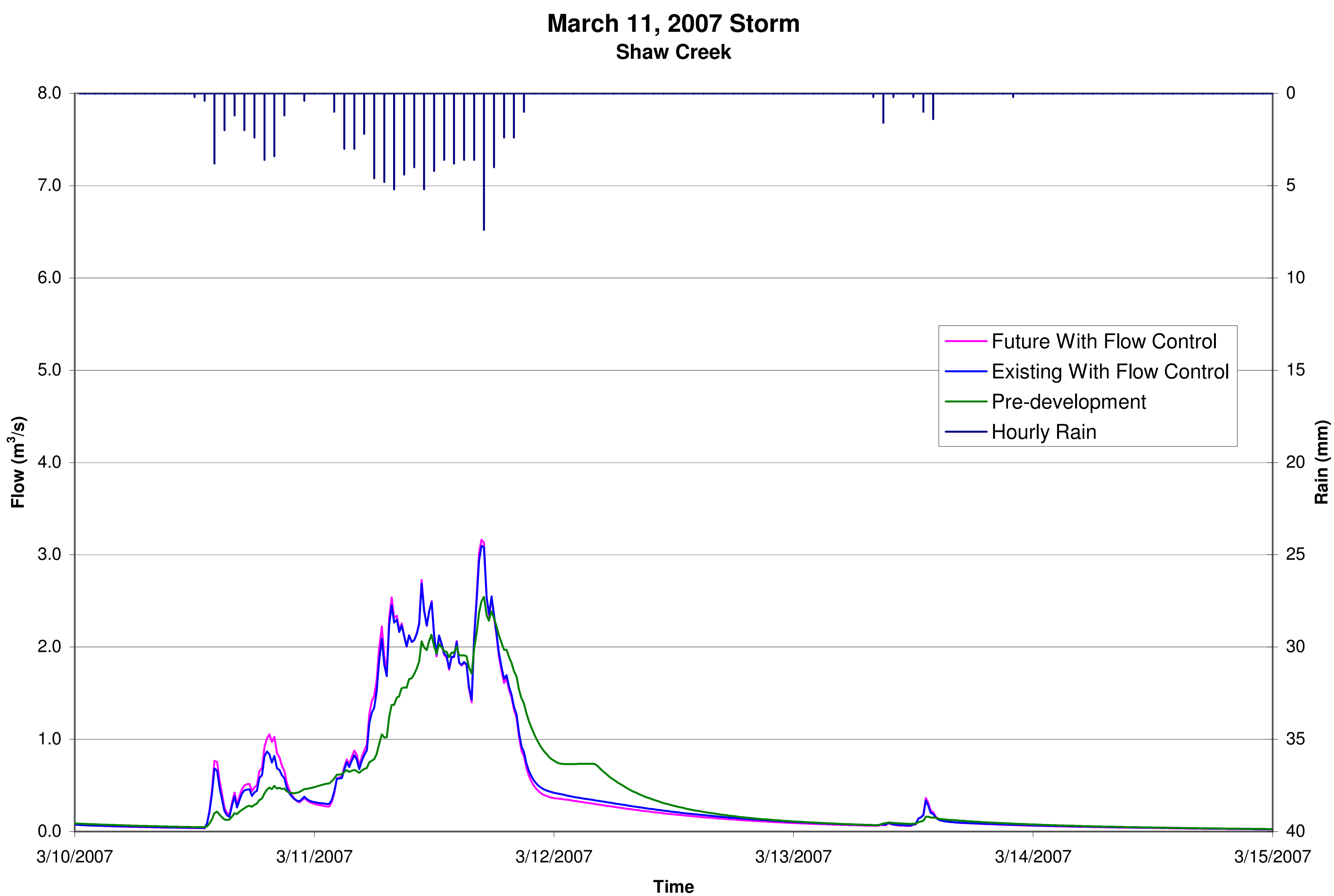

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Figure D-19

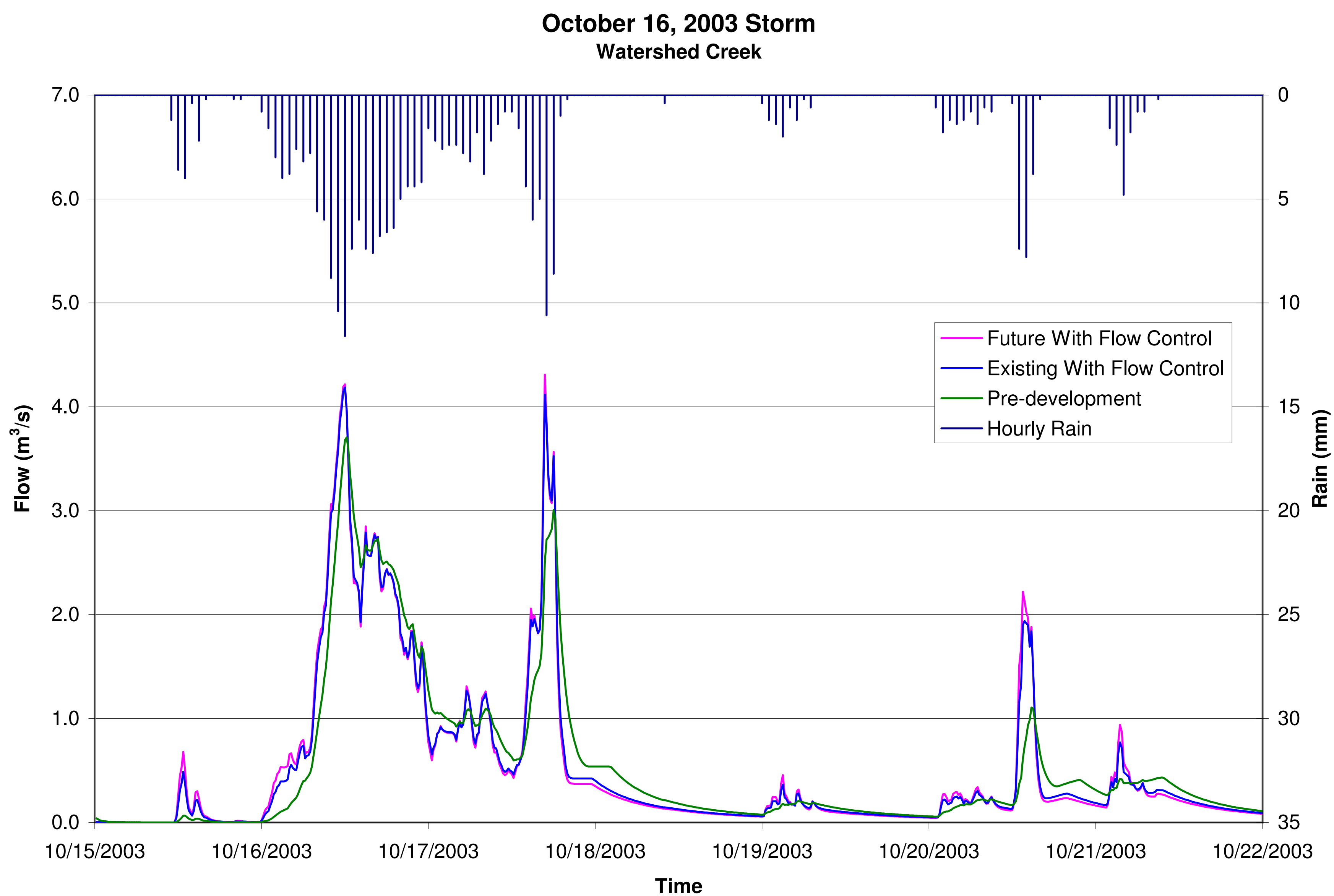

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Figure D-20

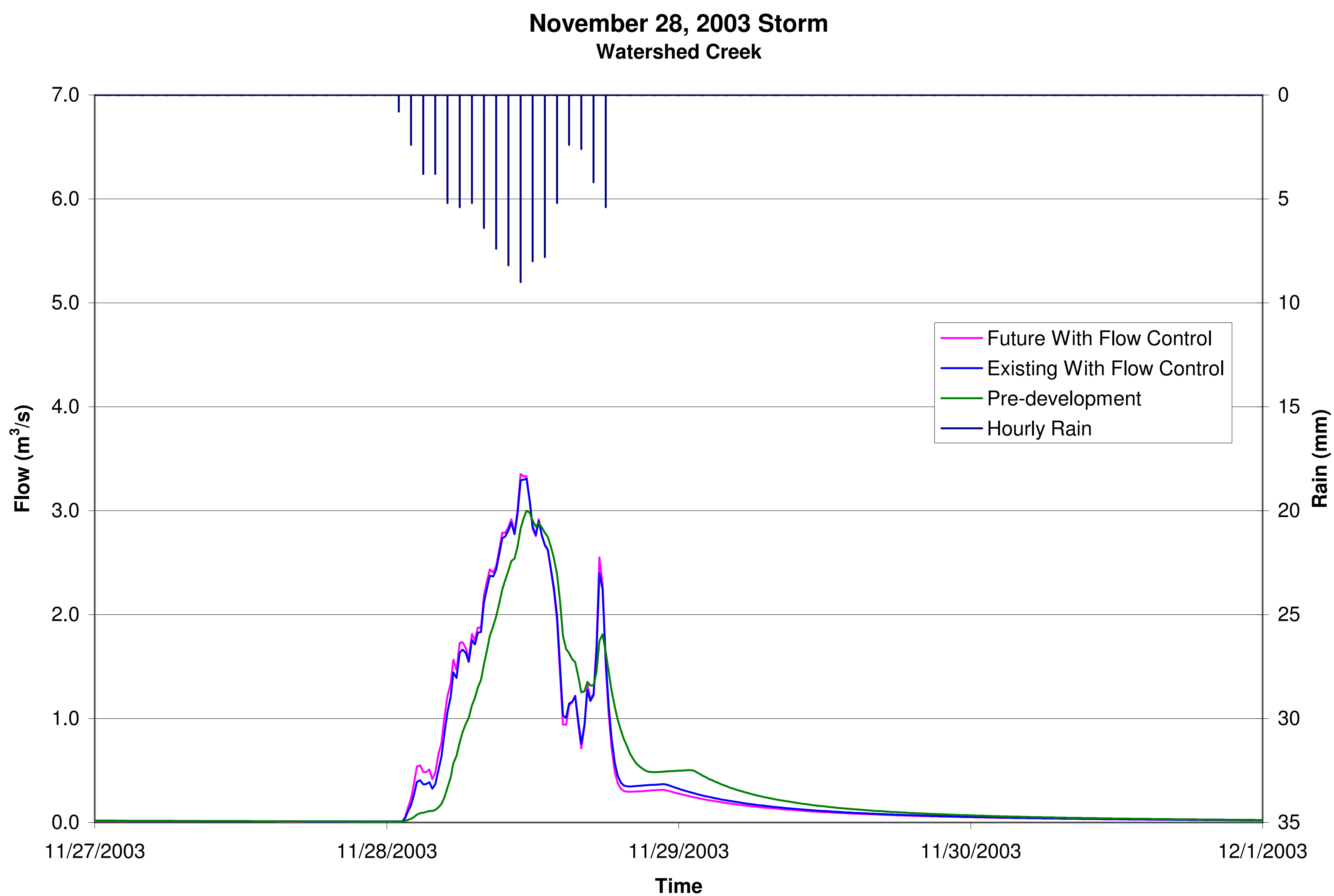

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Figure D-21

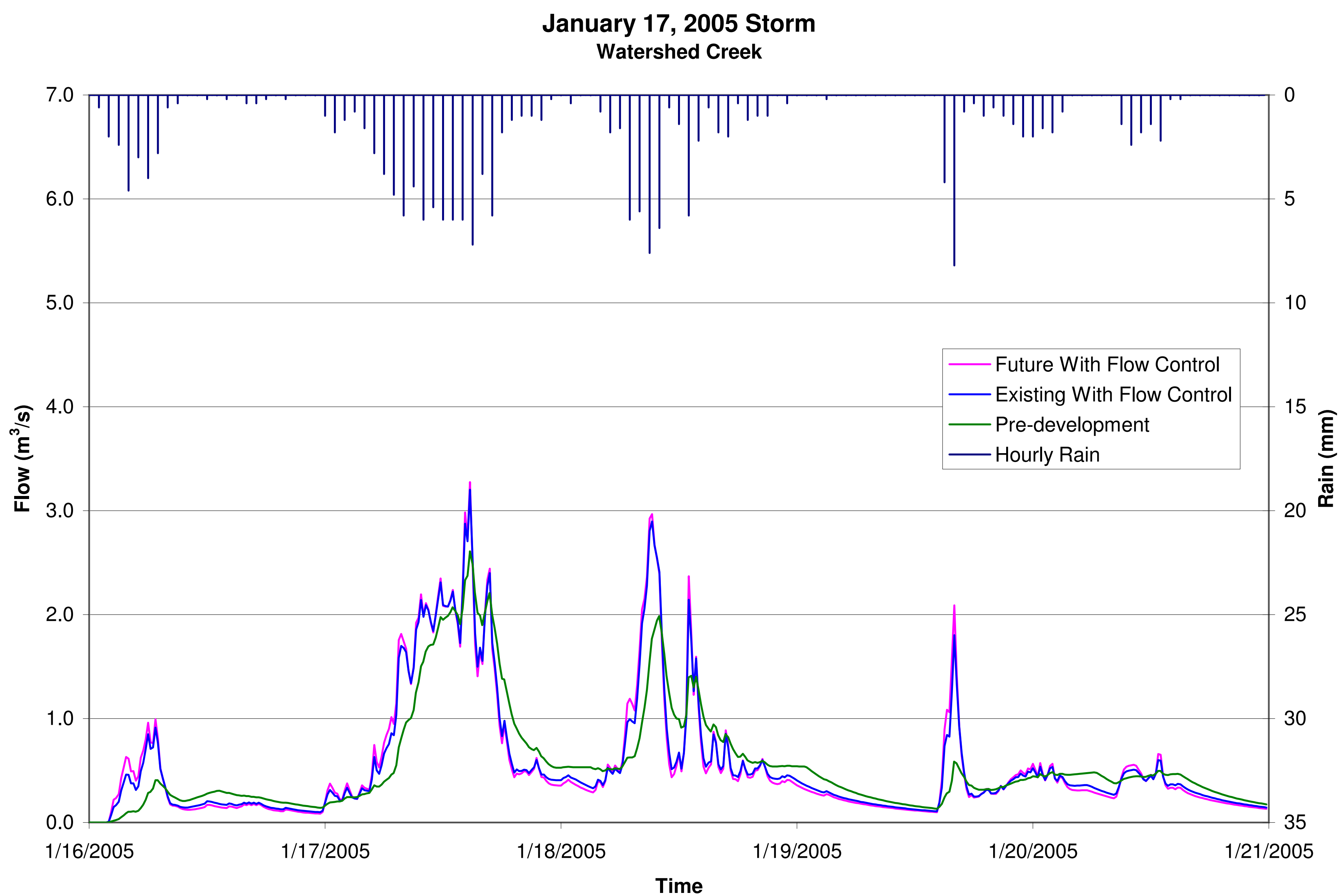

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Figure D-22

September 14, 2006 Storm
Watershed Creek

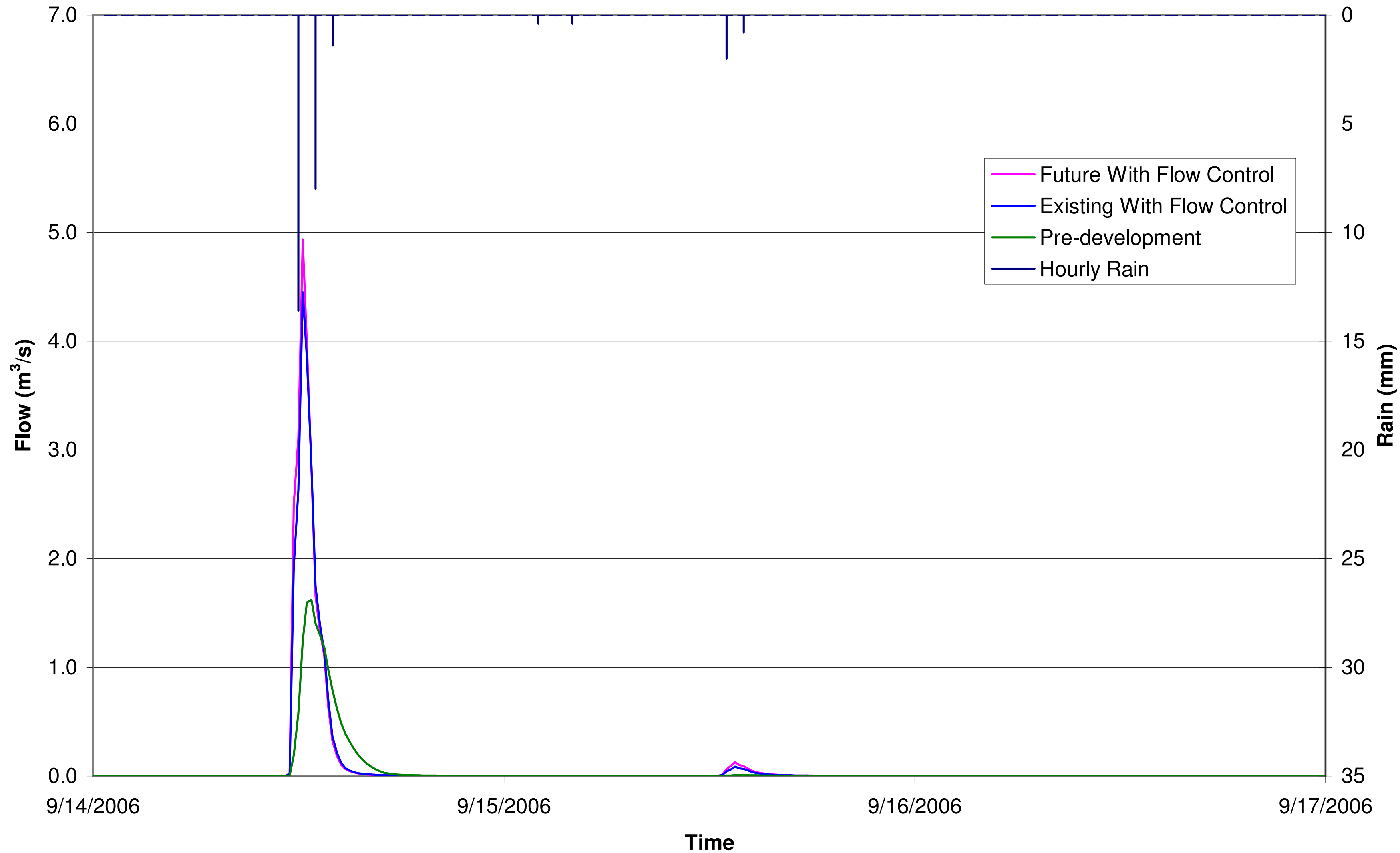

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Figure D-23

October 17, 2006 Storm
Watershed Creek

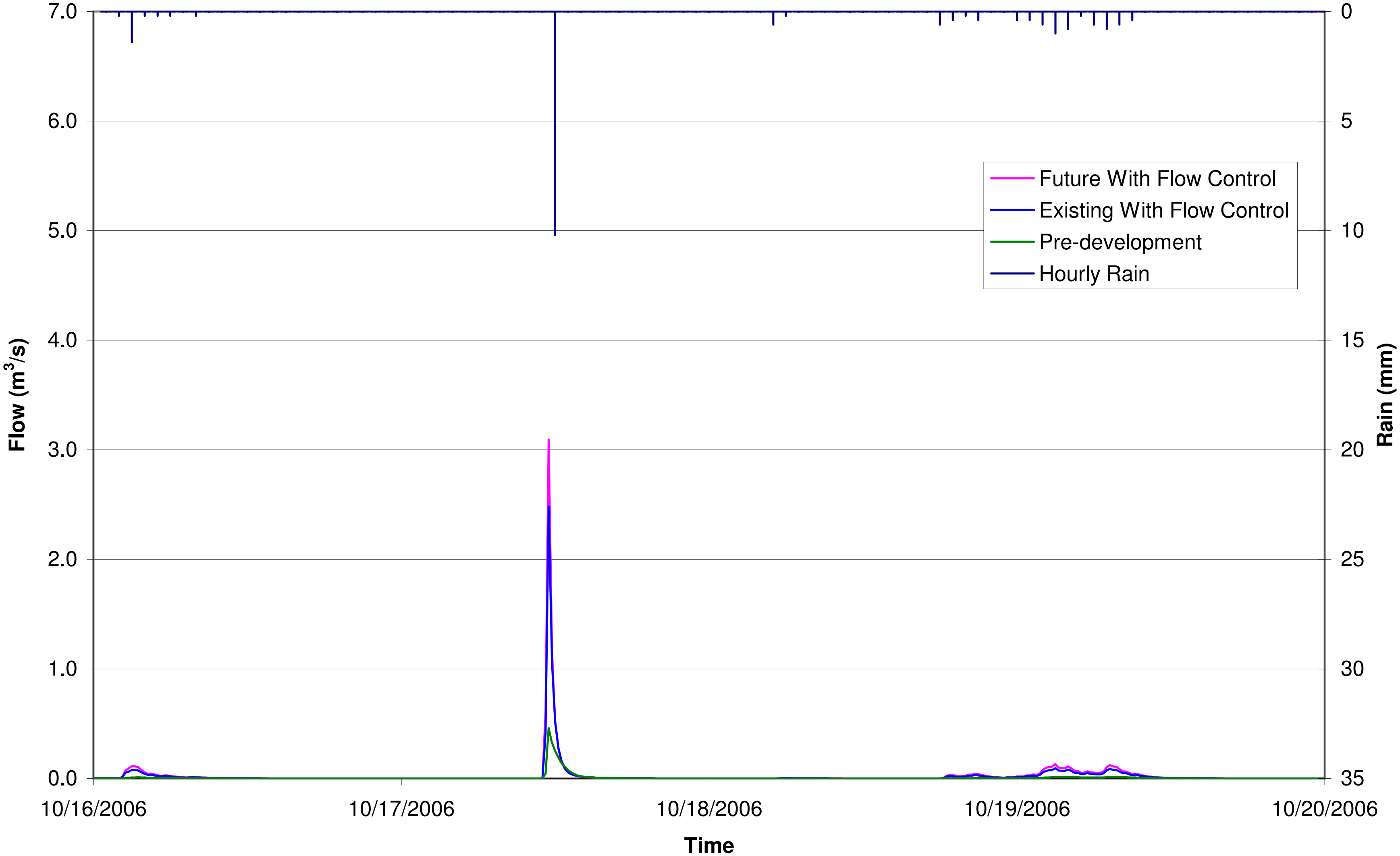

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Figure D-24

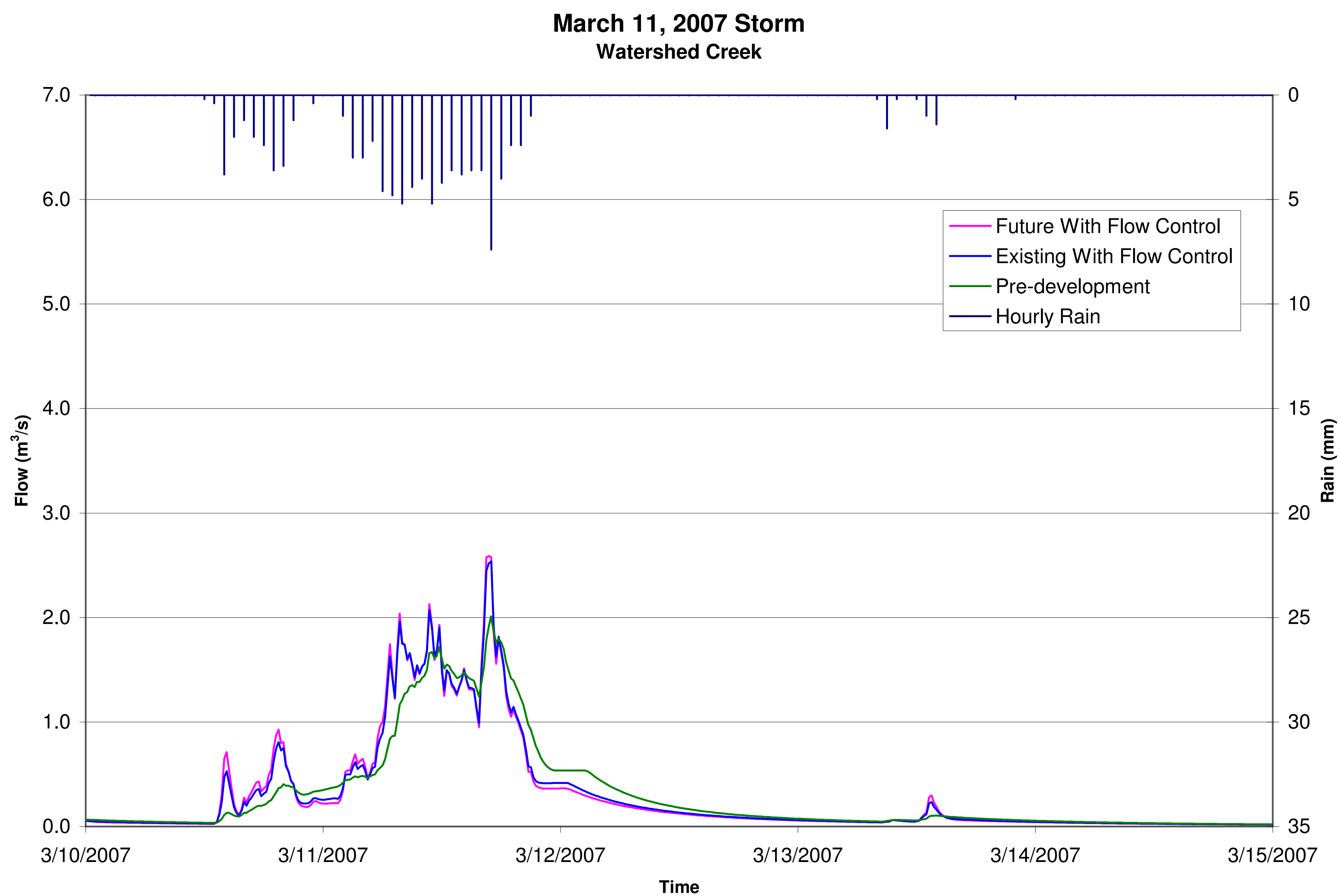

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Figure D-25

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Appendix E

Measures to Mitigate Environmental Hydrologic Impacts of Development

Appendix E – Mitigation Measures

Measures to Mitigate Environmental Hydrologic Impacts of Development

Contents

Appendix E – Mitigation Measures

1. Low Impact Development Practices

Introduction

Low Impact Development (LID) is a design with nature approach that reduces a development's ecological footprint. LID concepts embodied at the planning stage, often affords more opportunities to reduce the overall negative effects of development and reduce costs. Requirements for expensive traditional stormwater infrastructure may also be reduced as less runoff will be generated.

There are many best management practices (BMPs) commonly used in LID, however it is not always possible to incorporate all of them into a development, and even with adoption of all available LID options, there will still be changes to the hydrologic regime relative to the pre-development conditions and some additional measures or facilities will often be required. LID practices are most effective in mitigating adverse stormwater effects when used in combination with other BMPs, such as constructed source controls and detention. The *Puget Sound Action Team's* *LID Technical Guidance Manual*[1] is an excellent resource for LID planning and design.

Reduced Road Widths

Traditional road pavement widths may be larger than they need to be, particularly for streets that are residential access only, and not thoroughfares. Road widths can be narrowed to a minimum that allows necessary traffic flow, but that discourages excess traffic and excess speed, both of which are beneficial in a family- and pedestrian-oriented neighbourhood. Road widths do, however, need to meet the community's needs for utility and emergency vehicle access and these requirements will often determine acceptable minimum road widths.

Reduced Building Footprints

Building footprints, and impervious roof area, may be reduced without compromising floor area by increasing building height. This also allows greater flexibility to develop layouts that preserve naturally vegetated areas and provide space for infiltration facilities. Some relaxation of building height restrictions may be necessary to allow this type of design.

Reduced Parking Standards

Reducing the required number of parking spaces for a development reduces the impervious area and encourages pedestrian and public transit-friendly communities. Reducing the required parking spaces also reduces development costs.

1 Low Impact Development Technical Guidance Manual for Puget Sound, 2005. http://www.psparchives.com/our_work/stormwater/lid.htm

Appendix E – Mitigation Measures

Limiting Surface Parking

Limiting surface parking and restricting parking to below building roof areas, also directly reduces the impervious area in a development.

Pervious Parking Surfaces

Use of pervious paving materials rather than impervious concrete or asphalt can reduce the runoff generated from parking areas. Pervious materials may include pavers, reinforced clean crushed gravel, reinforced turf, or engineered permeable pavements.

Reinforced Clean Crushed Gravel

Pavers

Building Compact Communities

A complete and compact development plan preserves more natural watershed features and significantly reduces imperviousness. In some cases, compact communities have up to 75% less roadway pavement per dwelling unit, and parking needs are reduced because local services are more accessible by pedestrians and via public transit.

Preserving Naturally Significant Features

Preservation of natural areas in a watershed is always an important consideration, which can provide recreational as well as environmental benefits but some natural areas perform special aquatic ecosystem functions and as such are vital to maintaining watershed health. These areas, which include riparian forests, wetlands, floodplains and natural infiltration depressions with highly permeable soils, are particularly important to inventory and protect from alteration.

2. Stormwater Source Control Technologies

Stormwater source controls reduce the runoff that is discharged to the stream network by managing the water balance at the site level. Source controls play a key role in achieving Rainwater Management Criteria for volume reduction, water quality treatment, and runoff control and can be very effective at reducing runoff volumes and peak runoff rates from events smaller than the 50% of 2-year storm. Though they do provide some flow-detention benefits for the 2-year storms, source controls have limited ability to reduce peak runoff rates from large storms and must be designed with adequate overflow

Appendix E – Mitigation Measures

capacity. Additional stormwater infrastructure must be provided to safely convey stormwater offsite for the larger events.

Several standard source control technologies are described below. The *Metro Vancouver Stormwater Source Control Design Guidelines*[2] is an excellent reference for source control BMP design advice.

Absorbent Landscaping

Natural topsoil is generally permeable. The vegetation on topsoil provides a layer of organic matter which is mixed into the soil by worms and micro-organisms, creating voids, which allow rain water to percolate through, and making the soil more structurally capable of providing storage in the void spaces when saturated.

Standard construction practice is often to strip the existing topsoil, compact or excavate a site surface to the desired grade, and then cover it with a thin layer of imported topsoil. Although lawns and other ornamental landscaping will establish a vegetated surface, both the original surface and subsurface flows and storage capacities have been altered and surface runoff will be increased. Instead of stripping and removing, original topsoil it should be replaced on the site and augmented with organic matter and sand to improve soil structure and increase macropore development.

To increase absorbency, surface soils should have a minimum organic content to facilitate plant growth and a soil depth sufficient to meet the 50% of 2-year rainfall capture target. Increased soil depths also provide retention for runoff from adjacent hard surfaces. Surface vegetation should include herbaceous groundcovers with a thickly matted rooting zone, deciduous trees, or evergreens.

Some maintenance over the long term is required for the absorbent landscape to continue to provide stormwater benefits. Maintenance activities may include replacing soils that have eroded and replanting dead or dying vegetation.


Absorbent Landscaping


Absorbent Landscaping

2 Metro Vancouver, Stormwater Source Control Design Guidelines, 2005 http://www.gvrd.bc.ca/sewerage/stormwater_reports.htm

Appendix E – Mitigation Measures

Surface Infiltration Facilities

Rainfall runoff is stored at or near the surface in a layer of absorbent soil, sand, gravel, or rock, and/or on the ground surface in a ponding area. The stored runoff that infiltrates into the soil becomes interflow and augments groundwater in the sub-surface.

Surface infiltration facilities can look like normal vegetated swales or ponds, and can be aesthetically landscaped and integrated into the design of open spaces. They include bioretention facilities and rain gardens. Both surface and sub-surface infiltration facilities can be effective at the lot level, as well as at the neighbourhood level, where individual lot sizes or layouts don't support on-lot facilities or where more permeable soils or groundwater recharge areas are located off-site. Surface infiltration facilities can, depending on their design, provide some level of water quality treatment as well.

Surface infiltration can be combined with detention, where the detention release rate allows sufficient time for infiltration through the pond. Infiltration facilities are highly dependent on the hydrologic properties of the sub-surface soils.

Surface infiltration can also be promoted by the used of permeable pavers or other pervious surfacing materials.

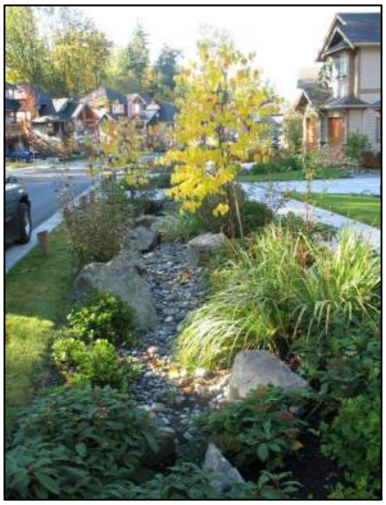
Surface Infiltration Swale

Bio-Retention Facilities

If infiltration rates are low, such as is likely in clay and till soils, bio-retention facilities can be designed to store the volume reduction target in soil and rock trench voids and infiltrate it slowly over time.

Where applicable, a retention facility may also be designed as a baseflow augmentation facility that retains the design capture volume in a tank or pond and releases it at baseflow rates. These rates are very low, and are based on measured summer baseflows in a watercourse divided by the contributing watershed area, and then applied to the area of the site contributing runoff. Baseflow augmentation facilities discharge the capture volume to the downstream stormwater system or watercourse at a maximum of the determined baseflow rates. Any volumes above the capture volume must be allowed to bypass the baseflow augmentation facility.

Appendix E – Mitigation Measures



Bio-Retention Swale

Bio-Retention Swale

Sub-surface Infiltration Facilities

A similar design process is used for sub-surface infiltration as for surface infiltration facilities. The main advantage of sub-surface facilities is that they often have vertical walls and do not require as much dedicated ground area, allowing them to be located beneath paved impervious areas.

Sub-surface facilities must be located at least 0.5 m above the level of the water table so that they can discharge through the sides and bottom of the structure and will not merely store infiltrated groundwater. Generally, the deeper an infiltration facility is located, the less-effective it will be. Subsurface infiltration facilities can be as simple as a trench filled with clean, free-draining rock that is protected from soil by a permeable membrane. There are numerous products available commercially for subsurface infiltration as well.

Sub-Surface Infiltration

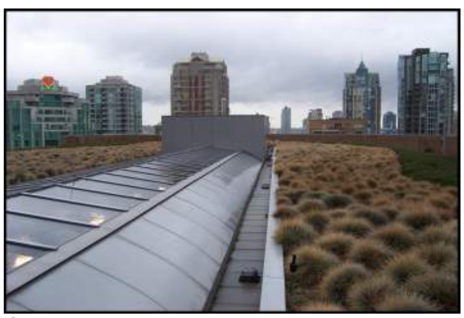
Appendix E – Mitigation Measures

Green Roofs

Installing a green roof rather than a conventional impervious roof can significantly reduce the volume and rate of runoff from a building lot particularly for the smaller, more frequent storm events.

A green roof is essentially a roof with a layer of absorbent soil and vegetation on top of a drainage collection layer or system. Rainfall is absorbed or stored by the soil and vegetation for later evapotranspiration. The green roof has a limited storage capacity, so any excess rainfall percolates through and is collected by a drainage system. The excess rainfall is then routed to the ground for detention and conveyance.

Green roofs are more expensive to build as they have structural costs as well as landscaping costs and do require maintenance to ensure their ongoing functionality. However, when compared with land costs for alternate facilities in high density urban areas, the costs for a green roof may be favourable. Green roofs also have other benefits, in addition to stormwater benefits, that can include heating or cooling cost savings by insulating the building, aesthetic benefits, air quality benefits, and reduced solar gain that decreases the urban heat island effect. Green roofs should only be designed and constructed by qualified professionals as structural engineering, building envelope and landscape design as well as stormwater engineering are all critical components. Green roofs are the preferable source control in areas where ground surface controls are not possible. For more information on green roofs readers are referred to the *Green Roofs for Healthy Cities* website.


Green Roof


Green Roof

Rainwater Re-use

Rainwater re-use is commonly afforded by residential rain barrels which are effectively retention facilities for roof runoff. Limitations of rain barrels are that rainfall is seldom a reliable source for water during the dryer seasons and rain barrels are often not large enough to store the 50% of 2-year capture target. The most significant reductions in runoff volume from re-use are achieved by capturing and re-using rainwater for indoor grey-water uses, or for commercial and industrial applications with high water consumption rates or where water supplies are limited. Recycling rainwater reduces demands from surface waters and reservoirs and can reduce supply infrastructure costs. Rainwater re-use can also be combined with infiltration facilities.

Appendix E – Mitigation Measures

Re-Use Tank

Re-Use Rain Barrel

Water Quality Best Management Practices

Changes in land use, loss of natural biofiltration capacity, increases in impervious area, and pollutant laden runoff associated with urban development can contribute to reduced water quality which impacts fish and fish habitat. BMPs designed to capture and treat runoff need to be incorporated into RWMPs.

Water Quality BMPs are physical, structural or management practices that reduce or prevent water quality degradation. Many of these are the same as, or similar to those used for runoff volume reduction and rate control and but have ancillary benefits for water quality. Source control remains the key means of reducing introduction of toxic and hazardous materials or organic and inorganic contaminants, originating from land and water use or as a result of commercial or industrial spills. Without source control, runoff water quality is limited by the effectiveness of treatment technology.

Treatment controls are point-source water quality management measures. They are generally constructed facilities and are often individual installations incorporated into the stormwater management infrastructure. They should be designed on a site-specific basis, after examining all alternative treatment technologies, and selecting the best available options based on cost and effectiveness. These controls should be designed and constructed by appropriately qualified environmental professionals.

Water Quality Best Practical Technologies

Several technologies have the ability to provide both water quality benefits and runoff control. Water quality benefits are derived from contaminant removal mechanisms that use biological and physical processes. Runoff control is accomplished by improving stormwater detention and retention which reduces peak runoff discharge rates and volumes.

Biofilters

Biofilters are vegetated filter strips, swales and rain gardens that remove deleterious substances, notably particulate contaminants, though some combination of physical (e.g.: adsorption) and biological

Appendix E – Mitigation Measures

(biodegradation) removal mechanisms. Biofilter technology is suitable for sheet flow runoff, typical of large linear impervious developments like roadways and parking lots.

Urban Forests and Leave Strips

Depending on the extent of tree canopy and ground cover retained, runoff reduction and pollutant removal can be achieved by maintaining natural well functioning urban forested areas. The contaminant removal processes forests and natural vegetation provide include: filtration, adsorption, absorption, and biological uptake and conversion by plant life. Urban forests also provide habitat refuges for many species whose habitats have been fragmented while riparian leave strips along watercourses, provide critical fish and wildlife habitat.

Infiltration Systems

Infiltration systems generally require pre-treatment for water quality to prevent clogging and binding-off of the permeable materials and contamination of underlying aquifers. Physical removal of deleterious substances by filtration and adsorption, as well as conversion of soluble pollutants by bacteria, also occurs within the infiltrating soils.

Constructed Wetlands

Physical, biological and chemical processes combine in wetlands to remove contaminants and either surface or subsurface flow wetlands can be constructed specifically to treat stormwater runoff. Constructed wetlands also offer retention benefits and can create preferred habitats for aquatic and terrestrial wildlife species. **The use of existing natural wetlands to treat stormwater however is not an acceptable practice**.

Small Wetland

Wetland

Wet Detention Ponds

Permanent wet ponds remove pollutants and other deleterious substances through physical processes such as sedimentation, filtration, absorption and adsorption and through biological mechanisms such as: uptake and conversion by plants, and microbial degradation. Wet ponds can also detain flows thereby contributing to rate control and volume reduction objectives. General design parameters need

Appendix E – Mitigation Measures

to include: vegetation types (floating, emergent and submergent vegetation), water depth and ponding area, and will often require consideration of detailed pond specific operational parameters.

Wet Detention Pond

Wet Detention Pond

Oil and Grit Separators

Oil and grit separators are suitable for spill control and removal of floatable petroleum-based contaminants as well as coarse grit and sediment from small areas, such as gas stations, automotive service areas and parking lots. Oil and grit separators have limited application in large-scale stormwater runoff applications, and should be limited to small area generation sites.

Oil Grit Separator

Oil Grit Separator

Construction Best Practices

Construction Best Practices for instream stormwater management works include timing of the works to minimize impacts. Timing windows should be adhered to in order to minimize impacts to fish and wildlife and specifically to avoid sensitive periods for certain life history stages of fish (e.g.; adult spawning, egg and alevin intergravel incubation). Where information is available on critical life history stages and timing for any identified Species at Risk, these times should also be avoided. Clearing should only be undertaken immediately in advance of work, and only during vegetation clearing timing windows, where these have been identified for protection of nesting birds. To the extent possible, work should be restricted to cells and undertaken in a systematic manner to limit the area disturbed at any given time. Works should only be undertaken during favourable weather conditions and low water conditions.

Appendix E – Mitigation Measures

Measures must be taken to prevent the release, from any work site, of silt, sediment, sediment-laden water, raw concrete, concrete leachate, or any other *deleterious substance* into any ditch, watercourse, stream, or storm sewer system. The work area should be isolated from flowing water as much as possible and diversions around the site should be provided for overland flow paths. Ensuring that all equipment used on-site is in good working order, and having a ready spill containment kit and staff trained in its use, are also critical measures.

For further information on managing erosion and sediment discharges during construction, see the Erosion and Sediment Control section of the *Land Development Guidelines and the Standards and Best Practices for Instream Works*.[3]

3. Stormwater Detention Systems

The rainwater detention objective is to limit the post-development runoff to the pre-development rate, volume, and approximate shape of the hydrograph for the 50% MAR, and 2-year/24-hour storm events and to maintain, as closely as possible, the natural pre-development flow pattern in the receiving watercourse.

These detention levels have been adopted to address increases in impervious areas in developments and the environmental impacts (e.g. stream erosion, sedimentation; loss of riparian habitat, changes in stream morphology, etc.) that are occurring due to the more frequent, smaller storm events being rapidly conveyed off hard surfaces into fish bearing waters.

4. Infiltration Systems

Stormwater infiltration systems can provide many benefits to urban streams. Infiltration systems can retain runoff, recharge groundwater and control peak flows. The soil, through which the stormwater runoff passes, also acts as a filter removing a large percentage of the common pollutants normally discharged to the stream or creek. Infiltration can recharge local groundwater which in turn feeds smaller streams and creeks through seepage. Groundwater which is slowly discharged back into streams and can constitute all or part of a stream's baseflow. This baseflow can be critical for fish and fish habitat during extended periods of little or no precipitation and runoff. It maintains preferred spawning conditions for several salmon species which key on groundwater seepage areas for spawning and egg incubation.

In areas with well-draining soils, stormwater runoff from a site can be collected and discharged into an infiltration system where there are no conventional stormwater removal systems, or infrastructure, which reduces the costs of providing offsite conveyance.

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[3] BC Ministry of Water, Land and Air Protection's *Standards and Best Practices for Instream Works* (draft March 2004) http://wlapwww.gov.bc.ca/sry/iswstdsbpsmarch2004.pdf.

KERR WOOD LEIDAL
consulting engineers

Appendix F

Capital Cost Estimates

Appendix F: Capital Cost Estimates - Environmental

Item		Costs[1]	Quantity		Unit Cost	Comment
9	High flow pipe to E. Oliver Bypass					
	900mm dia culvert pipe jacked	$176,400	30	m	$3,500	per m supply and install cost
	Ditch creation (2 sq.m. xs area)	$23,100	250	m	$55	per m includes clearing for the ditch
	riprap spillway / sidechannel weir	$16,800	1	ea	$10,000	assume 2 days of machine time and 25 m3 of riprap
	Subtotal	**$220,000**				
14	Highway 10 WQ treatment wetland (1m deep)	**$100,000**	600	m2	$95	per m2 assumes $35/m2 for soil removal, $50/m2 reveg, $10/m2 other
15	Watershed Creek WQ treatment wetland (1m deep)					
	Berm (1.3m high, 2m wide crest, 3:1 slopes)	$231,941	600	m	$230	per m using import pitrun ($30/m3 supply and place)
	storm sewer (750mm)	$184,800	200	m	$550	per m supply and install cost
	manhole (1200mm)	$12,432	2	ea	$3,700	ea supply and install
	outlet headwall	$6,720	1	ea	$4,000	ea supply
	crew for headwall	$13,440	2	days	$4,000	per day
		$450,000				
21	Boundary Park rain garden					
	rain garden	$302,400	600	m	$300	per m labour + material
	storm sewer (300mm)	$33,600	100	m	$200	per m supply and install cost
	outlet headwall	$5,880	1	ea	$3,500	assume a day of machine time and $2000 headwall
	Subtotal	**$340,000**				

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Item		Costs[1]	Quantity		Unit Cost	Comment
27	Stream relocation (0.5 m deep, 0.5 m bottom width, 2:1 slopes)					move 30 m over away from railway and fill and reforest existing channel
	clearing (4 m wide)	$6,720	1000	m2	$4	per m2
	Excavation	$10,500	250	m	$25	per m assumes that material is side case in trees, a small excavator is used for 6 days ($1000/day)
	habitat features	$12,600	1	ea	$7,500	ea supply and install
	Restoration of old channel	$21,000	250	m	$50	per m assumes minimal soil and then light vegetation
	Subtotal	**$50,000**				
28	Remove Shaw Creek fish passage obstruction (weir in creek)					
	weir removal / flow diversion	$12,600	1	ea	$7,500	pumping creek around site and removal of weir (1 day)
	riprap restoration	$8,400	1	ea	$5,000	Supply and place about 20 m3 of riprap ($75/m3) plus 2 days of excavator (1500/day)
	Subtotal	**$20,000**				
	Improve fish passage through culverts					
29	Watershed Creek CUL_14 Under BNSF Railway 1800mm CSP too steep (25 m at 2.5%)	$33,600	1	ea	$20,000	allowance for rock weirs or baffles
30	Shaw Creek CUL_236 Under Hwy 91 1800mm CSP too long (85 m at 0.9%)	$33,600	1	ea	$20,000	allowance for rock weirs or baffles
	Subtotal	**$70,000**				
31	Create Shaw Creek fish habitat					
	create channel (0.5 m deep, 1 m bottom width, 2:1 slopes)	$22,680	150	m	$90	per m assumes material is disposed of off-site and clearing of the channel
	spawning gravel (0.3m deep for 1 m width)	$3,402	45	m3	$45	per m3 supply and place
	habitat features	$12,600	1	ea	$7,500	ea supply and install
	Subtotal	**$40,000**				

Note: 1. Costs include 2% bonding/insurance, 6% mob/demob, 20% engineering, and 40% contingency.

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Appendix F: Capital Cost Estimates - Hydrotechnical

	Item	Costs[1]	Quantity	Unit Cost	Comment
1	Construct bank protection on right bank of Shaw Creek at Highway 10 south side major erosion spot (E-11)	**$40,000**	1 ea	$20,000	assume 4 days of machine time and 50 m3 of riprap
2	Monitor Riprap movement and erosion at the top end of Shaw Creek	**$0**			no capital cost only maintenance
3	Monitor and remove accumulated debris at Briarwood culvert more frequently (perhaps monthly and after storm events)	**$0**			no capital cost only maintenance
4	Upgrade culvert CUL_352 in Watershed Park to 1050mm diameter pipe.	**$40,000**	1 ea	$20,000	per path culvert supply and install
5	Improved inlet and new trash rack at Hwy 10 Shaw Creek with wider bar spacing and debris interceptor upstream.	$60,077	1 ea	$35,760	headwall cost x4 supply and install
		$84,000	1 ea	$50,000	debris interceptor
		$16,800	1 ea	$10,000	sediment basin excavation
	Subtotal	**$100,000**			
6	Complete construction of East Oliver Bypass backwater berms near Delta Golf Course.	**$60,000**	70 m	$500	per lin m using import pitrun ($30/m3 supply and place)
7	Upgrade culvert CUL_274 in Watershed Park to 1350mm diameter pipe.	**$40,000**	1 ea	$20,000	per path culvert supply and install
8	Allow culverts CUL_2, CUL_17, CUL_24, CUL_231, CUL_236, CUL_249, CUL_250, and CUL_370 to surcharge in the near term and replace at end of life with	**$0**			additional cost of larger size not estimated. Replacement cost part of asset management budget.

Note: 1. Costs include 2% bonding/insurance, 6% mob/demob, 20% engineering, and 40% contingency.

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Appendix F: Capital Cost Estimates - Monitoring

Item		Costs[1]	Quantity		Unit Cost	Comment
16	Monitor WQ at top end of Watershed Creek Tributary at former Works Yard outfall (first year cost)					
	new probe	$8,000	1	ea	$8,000	per probe
	data downloading and probe calibration	$3,000	1	yr	$3,000	per yr for data downloading, probe calibration, etc (based on 40 day cycle)
	batteries and solutions	$400	1	yr	$400	per yr for batteries + solutions
	data collation and summary memo	$2,500	1	yr	$2,500	per year for basic yearly data collation, cleaning, and reporting (memo)
		$14,000				
17	Monitor WQ at top end of Briarwood Creek (first year cost)					
	new probe	$8,000	1	ea	$8,000	per probe
	data downloading and probe calibration	$3,000	1	yr	$3,000	per yr for data downloading, probe calibration, etc (based on 40 day cycle)
	batteries and solutions	$400	1	yr	$400	per yr for batteries + solutions
	data collation and summary memo	$2,500	1	yr	$2,500	per year for basic yearly data collation, cleaning, and reporting (memo)
		$14,000				
18	Monitor WQ at top end of Shaw Creek (first year cost)					
	new probe	$8,000	1	ea	$8,000	per probe
	data downloading and probe calibration	$3,000	1	yr	$3,000	per yr for data downloading, probe calibration, etc (based on 40 day cycle)
	batteries and solutions	$400	1	yr	$400	per yr for batteries + solutions
	data collation and summary memo	$2,500	1	yr	$2,500	per year for basic yearly data collation, cleaning, and reporting (memo)
		$14,000				

O:\03 1. Monitoring costs do not include travel time or mileage.

O:\0300-0399\323-059\300-Report\Final Report\AppendixF\[ClassD-cost-ISMP.xlsx]Monitoring

Delta

Tsawwassen Area
Integrated Stormwater Management Plan

Associated Engineering

February 2019

CANADA'S BEST MANAGED COMPANIES Platinum member

ASSOCIATED ENGINEERING

QUALITY MANAGEMENT SIGN-OFF

Signature ....

Date 2019/02/06 (26-19-017)

Date Issued	February 2019

Watershed Overview:

The study area for the Tsawwassen Area Integrated Stormwater Management Plan (ISMP) is located in South Delta and is generally bounded by 28th Avenue to the north; the Strait of Georgia to the west; Boundary Bay to the east; and Point Roberts to the south. The study area is approximately 2,050 ha and has four drainage pump stations; 12th Avenue Pump Station, Brandrith Pump Station, Beach Grove Pump Station, and 3rd Avenue Pump Station. The majority of the study area is serviced by these pump stations.

Existing land uses are predominantly single family residential in the uplands and agricultural in the lowlands. Tsawwassen Town Centre and Tsawwassen Mills make up the majority of the commercial development. The study area is almost fully built out. The main future development will be re-development in Point Roberts to single family residential, and general densification in residential areas.

In general, there is no more natural habitat or water courses in the study area other than Boundary Bay Regional Park and the steep treed bluff areas. Water quality throughout the study area is generally poor. The drainage system consists mainly of stormwater mains draining residential areas and a series of agricultural ditches leading to the pump stations.

Recommendations for City	Description
Infrastructure Upgrades	The drainage system has only a few existing deficiencies, and future development will not have a great impact on the system. However, we expect climate change to have a significant impact on the drainage system and Delta must consider upgrades to the major and minor system over the long-term to contain the additional runoff resulting from the projected increases to precipitation.
Environmental Enhancement Projects/Stormwater BMPs	To conform with updated Metro Vancouver source control guidelines, stormwater best management practices (BMPs) will be required on residential lots, and other BMPs should be implemented during redevelopment of roadways and commercial properties. Treatment wetlands should be installed at both Brandrith Pump Station and 12 Avenue Pump Station in addition to revegetating lowland ditches where possible to improve

Note: This summary sheet summarizes the contents of the ISMP only. Other documents may supersede or complement the guidance found here. The designer should ensure all relevant guidance is followed when designing within the ISMP study area.

	water quality. Altering operation schedules of pump stations to discharge at high tides would improve water quality in receiving water bodies.
Specific BMP Recommendations	Residential Lots: · Ensure all paved areas drain to a permeable surface (pervious pavement can be used as an alternative) and not directly to a roadway. · Limit impervious area to a maximum of 70% on each lot. · Disconnect downspouts from the storm system to drain to a permeable surface. · Increase the minimum absorbent topsoil depth to 450 mm. · Limit runoff to 40% of the 1 in 2-year storm of 24-hour duration as stated in Metro Vancouver's Baseline document (2017). The equivalent rainfall depth for Tsawwassen would be approximately 28 mm with climate change. Commercial/Multifamily Lots: · Require pre-treatment for hydrocarbon and sediment removal of stormwater runoff. · Apply bioswales/rain gardens, green roofs, underground detention, and absorbent soils where possible. · Provide a minimum required storage volume of 120 m^3 / hectare with a maximum allowable release rate (peak flow) of 21 L/s/ hectare.

Executive Summary

1 INTEGRATED STORMWATER MANAGEMENT PLANNING

The fundamental purpose of an Integrated Stormwater Management Plan (ISMP) is to maintain and enhance the overall health of a watershed, and provide effective stormwater management while allowing for future development. An ISMP is a comprehensive planning document that addresses a wide variety of components related to watershed health while considering economic growth.

2 STUDY AREA DESCRIPTION

The study area for the Tsawwassen Area Integrated Stormwater Management Plan (ISMP) is located in South Delta and is generally bounded by 28th Avenue to the north; the Strait of Georgia to the west; Boundary Bay to the east; and Point Roberts to the south. The study area is approximately 2,050 ha and has four drainage pump stations; 12th Avenue Pump Station, Brandrith Pump Station, Beach Grove Pump Station, and 3rd Avenue Pump Station. The majority of the study area is serviced by these pump stations. However, an area of approximately 135 ha on the western bluff above the Strait of Georgia (Roberts Bank) drains directly via gravity outfalls and a significant area drains by gravity to an outfall at 12th Avenue.

3 WATERSHED GOALS AND OBJECTIVES

As outlined in the City of Delta's Terms of Reference, the overall goals for the Tsawwassen Area ISMP are to:

- Compose a future vision for the watershed that marries the interests of Engineering, Planning, Environment and Recreation.
- Prepare a comprehensive inventory of the watershed including confirmation of its boundaries.
- Identify any deficient drainage infrastructure to minimize risk to life and property by flooding.
- Quantify the overall health and natural features of the watershed.
- Protect watercourses and aquatic life.
- Prevent pollution and maintain / improve water quality.
- Protect and enhance the environment, wildlife and habitat corridors.
- Provide a sampling program outline in order to identify and monitor baseline water quality.
- Identify areas of existing and future residential, commercial, recreational and agricultural land uses (as per Delta's OCP).
- Inform stakeholders of the issues and objectives of the ISMP.
- Develop a comprehensive and cost-effective strategy for municipal capital improvements, potential projects for streamkeeper groups and improve community awareness of watershed issues.
- Develop a cost-effective implementation plan.

In consideration of the overall goals identified above, the vision statement developed for the Tsawwassen Area ISMP is presented below.

The Tsawwassen Area watershed is home to both farmers and residents of South Delta, and the marine, estuarine, freshwater, forested and agricultural ecosystems of the region. The ISMP goal for the Tsawwassen Area watershed is to strive for improvement of watershed health, encourage low impact stormwater practices, and maintain resilient drainage infrastructure as it undergoes development over the long-term.

4 IMPLEMENTATION STRATEGY

The Tsawwassen Area ISMP's recommendations include actionable items for the City of Delta to improve stormwater management. In table ES-1 we list the primary actions including recommended drainage upgrades and environmental enhancement opportunities. Following this table is a list of some of the specific changes to Delta's bylaws to enforce these recommendations. Other general recommendations for environmental enhancement opportunities and stormwater Best Management Practices (BMPs) can be found in Section 5 of this report.

The majority of the recommended upgrades are intended to be implemented in an opportunistic manner over the long term in association with broader scope infrastructure projects (such as road or other infrastructure upgrades) or in the context of drainage system renewal as a result of normal life cycle considerations. The identified capacities (e.g. pipe sizes or pumping capacities) of these upgrades address future impacts of climate change in terms of estimated increases in rainfall, and consequently runoff, that are likely to arise during the lifespan of the new components (i.e. 75 years or more). Storm infrastructure upgrades implemented in the future will have expected service lives that extend well into the time horizon of the estimated climate change impacts. While not necessarily required in the immediate time frame, drainage infrastructure projects from this point forward need to recognize these conditions.

Generally, land use changes are minor and are not a driver for most recommended infrastructure upgrades, and the priority ranking reflects whether the identified component is subject to capacity constraints under existing climatic conditions, or under a future time horizon related to climate change. Those indicated with 'High' priority should be prioritized and included in Capital Works projects over the next 5 years. 'Medium' priority should be included in Capital Works projects over the next 20 years. Upgrades and improvements indicated as 'Low' priority items should be upgraded in an opportunistic manner over the next 20-40 years.

Table ES-1
Improvements and Upgrades

ID	Priority	Location	Time Horizon	Description
Minor System Upgrades				
MN-1	Low	Beach Grove Road/17a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-2	High	North portion of 56 Street, 18 Avenue, Spyglass Crescent	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change. Smooth pipe profile to improve hydraulic efficiency.
MN-3	High	Trunk and Storm Siphon along 12 Avenue	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.
MN-4	Low	North side of 50b Street, 51 Street and Western extent of 50a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-5	High	Trunk along 10a Avenue, through Winskill park, and Ferguson Road,	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.

ID	Priority	Location	Time Horizon	Description
MN-6	Low	Pipes through Beach Grove Golf Club and along Boundary Bay Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change (by twinning the pipe).
MN-7	Low	Pipe Outfall from Pacific Drive to Tsawwassen Beach Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-8	Low	Trunk south of 8a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-9	Low	6 Avenue and 54 Street	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-10	Low	3rd Avenue Trunk	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
Major System Upgrades				
MA-1	Low	3rd Avenue Pump Station	Long Term (20-40 years)	Increase 3rd Avenue Pump Station capacity. Outfall pipe capacity should be increased in tandem.

ID	Priority	Location	Time Horizon	Description
MA-2	Low	12th Avenue Pump Station and Ditch along Boundary Bay Road	Long Term (20-40 years)	Increase 12th Avenue Pump Station capacity. Provisions to allow for climate change impacts have already been included in the design. Increase the capacity of the ditch along the west side of Boundary Bay Road and culverts.
MA-3	Low	Brandrith Pump Station and Ditches Upstream of Brandrith Pump Station	Long Term (20-40 years)	Increase ditch capacities upstream of the Brandrith pump station and associated culverts and increase pump station capacity. Alternatively consider building an additional pump station to reroute drainage to a separate location.
Environmental Enhancement Opportunities				
EV-1	Medium	12th Avenue Pump Station	Medium (5 – 20 years)	Expand the proposed wetland at the 12th Avenue Pump Station.
EV-2	Medium	Brandrith Pump Station	Medium (5 – 20 years)	Build a treatment wetland upstream of the Brandrith Pump Station to filter contaminants before discharging to the marine environment.
EV-3	High	3rd Avenue Pump Station/ 12th Avenue Pump Station	Short Term (0-5 years)	Change operation schedule to discharge at High Tides. Consider mechanical/chemical treatment options at 3rd Avenue to improve water quality. Limit flow velocities during discharge events to protect downstream ecosystem.

The City should look for opportunities to implement community scale detention storage to attenuate peak flows from the Tsawwassen uplands. The primary challenge with retrofitting detention storage in the Tsawwassen uplands will be obtaining sufficient open space, at appropriate locations in the drainage system. However, if successfully implemented, detention storage may allow for a reduction in the size and extents of future drainage infrastructure upgrades required to address climate change impacts.

In Table ES-2, we list relevant BMPs and associated performance criteria for residential and commercial/ multi-family lots:

Table ES-2
BMP Recommendations

Residential Lots	Commercial/Multi-Family Lots
• Ensure all paved areas drain to a permeable surface and not directly to a roadway. • Limit impervious area to a maximum of 70% on each lot. • Disconnect downspouts from the storm system to drain to a permeable surface. • Increase the minimum absorbent topsoil depth to 450 mm. • Limit runoff to 40% of the 24 hour, 2-year return period rainfall (equivalent to 28 mm).	• Require pre-treatment of stormwater runoff for hydrocarbon and sediment removal. • Apply bioswales/rain gardens, green roofs, underground detention, and absorbent soils where possible. • Provide a minimum required storage volume of 120 m^3 / ha with a maximum allowable release rate of 21 L/s/ha for a 24-hour duration, 10-year return period event. This release rate reflects the estimated peak flow rate under hypothetical natural conditions.

Infiltration based BMPs and source control strategies should only be employed in areas with suitable soils and with a minimum setback from steep slopes. Geotechnical engineers should be consulted on issues of slope stability and soil infiltration capacity.

5 ENFORCEMENT STRATEGY

To implement projects called out in the Implementation Strategy, the following changes should be made to the **Delta Subdivision and Development Standards Bylaw No. 7162**:

- Soil depth for lawns is recommended to be a minimum of 150 mm. This should be updated to 450 mm to fulfill Metro Vancouver's new guidelines.
- Text should be added to require implementation of BMPs or set a limit to maximum outflow rates from lots to achieve runoff targets ("limiting runoff to 40% of the 1 in 2-year storm of 24 hour duration") as stated in Metro Vancouver's Baseline document (2017). The equivalent rainfall depth for Tsawwassen would be approximately 28 mm with climate change.
- Add in a requirement to disconnect downspouts on existing residential lots.
- Add in a requirement for impervious surfaces to drain to permeable surfaces for residential lots.
- Design minor system components to the 10-year event, including a climate change analysis.
- Update IDF curves for climate change or make a note to design storm systems with consideration for increased rainfall due to climate change.
- Require pre-treatment for hydrocarbon and sediment removal of stormwater runoff from industrial, multi-family, and commercial lots. Minimum required storage volume on these lots should be 120 m^3/hectare and maximum allowable release rate should be 21 L/s/hectare
- Add more specific requirements and criteria on implementing stormwater BMPs (Section 5.2.16 of Drainage Schedule A), outline new requirements for residential properties.
- Reference Metro Vancouver Stormwater Source Control Design Guidelines (2012) for BMP design criteria.

- Provide clear guidance to designers as to how to incorporate climate change impacts into sizing of drainage infrastructure. Incorporation of climate change impacts in the design capacity (sizing) for future infrastructure renewal is critical, and should be carried into asset management and capital plans immediately, even if specific projects are not yet formulated.
- Maximum acceptable runoff rates by land use should be included.
- Source control design criteria, including:
    - Maximum outflow rates per hectare of tributary area.
    - Rainfall capture targets (72% of 2-year return period, 24-hour duration rainfall, as per the draft Land Development Guidelines [DFO/MoE]).
    - Water quality objectives and a list of acceptable mechanisms to achieve these targets (bioswales, manufactured treatment units, constructed ponds/wetlands).
- Update design criteria to lowland ditches to the 1:100 year design standard (including the impacts of climate change.
- Make reference to this ISMP and others in Delta to ensure designers take into account considerations specific to each ISMP study area.

6 FUNDING STRATEGY

A variety of funding sources exist within the City of Delta. These sources include the following:

- Development Cost Charges – Bylaw 7560
- Property Taxes – Bylaw 5751
- Contributions to stormwater management on private lots from land owners and developers
- Incentives (existing and proposed for the City of Delta)
- Federal funding opportunities include the New Building Canada Fund, Eco Action Community Funding Program, and Green Municipal Fund
- Provincial Funding such as the Infrastructure Planning Grant Program

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1 Introduction

1.1 STUDY AREA

The City of Delta engaged Associated Engineering to develop an Integrated Stormwater Management Plan (ISMP) for the Tsawwassen Area. The study area for the Tsawwassen Area Integrated Stormwater Management Plan (ISMP) is located in South Delta and is generally bounded by 28th Avenue to the north; the Strait of Georgia to the west; Boundary Bay to the east; and Point Roberts to the south. The study area is approximately 2,050 ha and has four drainage pump stations; 12th Avenue Pump Station, Brandrith Pump Station, Beach Grove Pump Station, and 3rd Avenue Pump Station. The majority of the study area is serviced by these pump stations. However, an area of approximately 135 ha on the western bluff above the Strait of Georgia (Roberts Bank) drains directly via gravity outfalls and a significant area drains by gravity to an outfall at 12th Avenue.

Map 1-1 provides a general overview of the study area for the Tsawwassen Area ISMP.

1.2 PROJECT PARTICIPANTS

The study team is comprised of personnel from Associated Engineering and our Environmental Sciences division, Associated Environmental. Key team members involved in the development of this ISMP are:

- Jamie Fitzgerald — Project Manager
- Michael MacLatchy — QA/QC Reviewer
- Jenna Lee — Technical Lead
- Jason Kindrachuk — Water Resources Engineer
- Julia Stafford — Water Resources Engineer
- Rob Hoogendoorn — Environmental Lead
- Stacy Boczulak — Environmental Scientist
- Corinna Hoodicoff — Terrestrial Biologist
- Aaron Deane — GIS Specialist

The City of Delta also played a crucial role in the development of this ISMP. The key contributors include:

- Suman Shergill — City of Delta Project Manager
- Hugh Fraser — Deputy Director of Engineering
- Harald Fograscher — Manager or Utilities
- Mike Brotherston — Manager of Climate Action & Environment.

1.3 GOALS AND OBJECTIVES

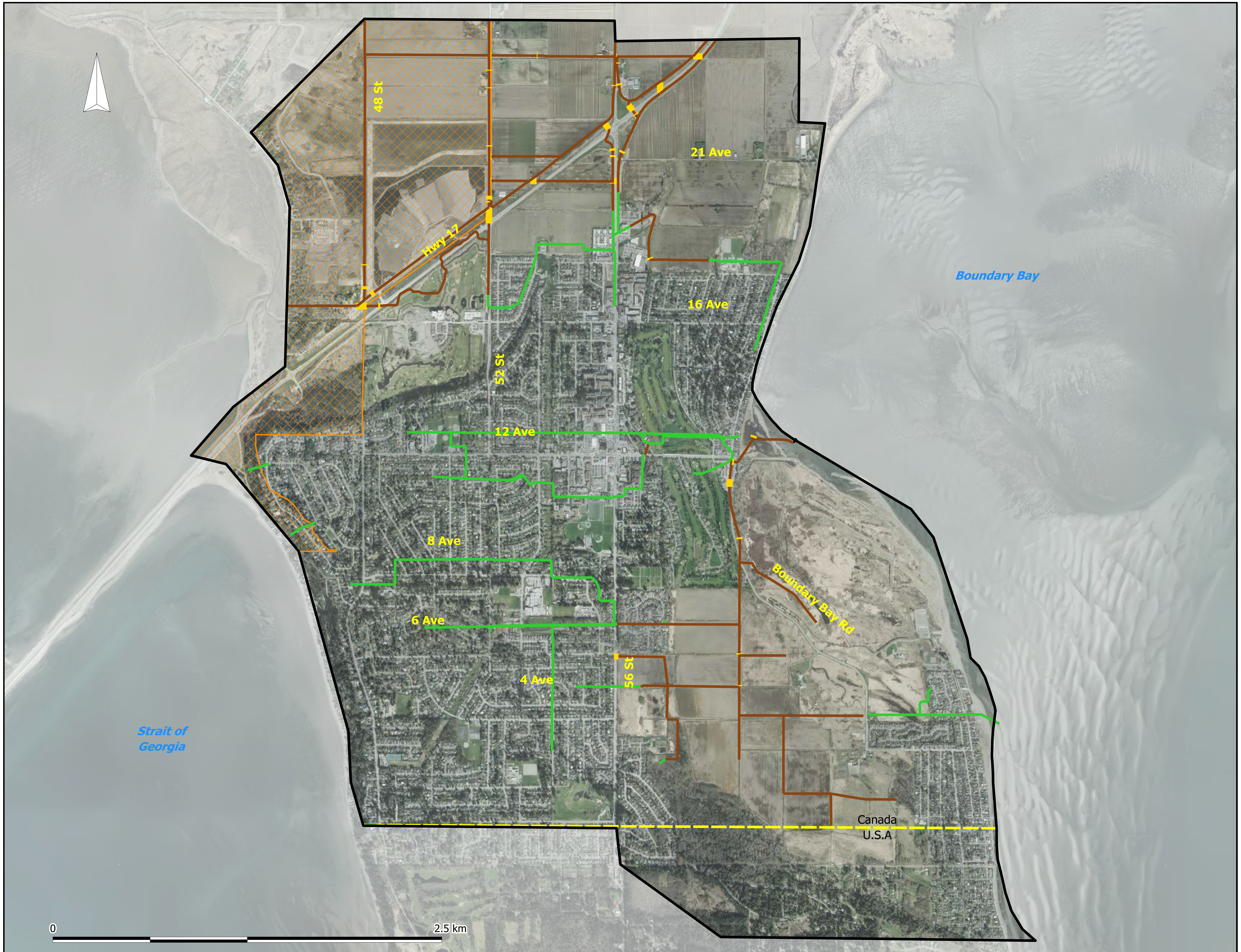
The fundamental purpose of any ISMP is to maintain and enhance the overall health of a watershed while addressing drainage and local flood protection requirements to allow for future development; this is true for the current Tsawwassen Area ISMP.

As outlined in the City of Delta's Terms of References, the overall goals for the Tsawwassen Area ISMP are to:

- Compose a future vision for the watershed that marries the interests of Engineering, Planning, Environment and Recreation.
- Prepare a comprehensive inventory of the watershed including confirmation of its boundaries.
- Identify any deficient drainage infrastructure to minimize risk to life and property by flooding.
- Quantify the overall health and natural features of the watershed.
- Protect watercourses and aquatic life.
- Prevent pollution and maintain / improve water quality.
- Protect and enhance the environment, wildlife and habitat corridors.
- Provide a sampling program outline in order to identify and monitor baseline water quality.
- Identify areas of existing and future residential, commercial, recreational and agricultural land uses (as per Delta's OCP).
- Inform stakeholders of the issues and objectives of the ISMP.
- Develop a comprehensive and cost-effective strategy for municipal capital improvements, potential projects for streamkeeper groups and improve community awareness of watershed issues.
- Develop a cost-effective implementation plan.

In consideration of the overall goals identified above, the vision statement developed for the Tsawwassen Area ISMP is presented below.

The Tsawwassen Area watershed is home to both farmers and residents of South Delta, and the marine, estuarine, freshwater, forested and agricultural ecosystems of the region. The ISMP goal for the Tsawwassen Area is to strive for improvement of watershed health, encourage low impact stormwater practices, and maintain resilient drainage infrastructure as it undergoes development over the long-term.



LEGEND

- CULVERT
- DITCH
- STORM MAIN
- STUDY AREA
- TSAWWASSEN FIRST NATION

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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Delta

THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

STUDY AREA OVERVIEW

DRAWING NUMBER	REV. NO.	SHEET
MAP 1-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

2 Study Area Overview

2.1 LAND USE

2.1.1 Existing Conditions

In the uplands of the study area, the land is predominately developed as Single-Family Residential with some pockets of Medium Density Residential, Institutional, Mixed Use, Commercial and Parks. The lowlands areas are mainly Agricultural.

Major commercial areas include the shopping center at 12th Avenue and 56th Street and the newly built Tsawwassen Mills shopping centre on Tsawwassen First Nation lands near Highway 17 and 52nd Street.

Major park areas in the study area include Boundary Bay Regional Park and two golf courses; Tsawwassen Springs Golf Course and Beach Grove Golf Club. Boundary Bay Regional Park encompasses a significant area in the lowlands and is environmentally sensitive and provincially protected. Other parks include Brandrith Park near 12th Avenue and 52nd Street, Winskill Park near 56th Street and 9th Avenue, Pebble Hill Park west of 52nd Street between Milsom Wynd and 2a Avenue, and Diefenbaker Park near 56th Street and 1st Avenue.

Map 2-1 illustrates the existing land use of the study area.

One of the key parameters required for hydrologic modelling is estimation of the percent of impervious coverage of each subcatchment. In order to do this, percent impervious values are required for each land use type. Table 2-1 summarizes the impervious percent coverage assumed for the different land use types in the study area.

Table 2-1
Impervious Percent by Land Use

Land Use	Impervious Percent
Single-Family Residential	40%
Medium Density Residential	70%
Commercial	80%
Institutional	80%
Parks	20%
Agricultural	20%
Mixed Use	100%

2.1.2 Future Development

Minimal future changes to land use in the study area are anticipated. Development in the TFN lands and the Southlands is already underway, so we considered these to be existing conditions for this study. Minor build out in Point Roberts may occur in the future based on zoning in this area. We also expect residential areas to densify in the future as houses are redeveloped with larger footprints and residents add impervious coverage to their lot. This future densification is reflected in the modelling but not in the land use map.

Map 2-2 illustrates the future land use of the study area.

2.2 DRAINAGE NETWORK

The drainage network for the study area was assembled based on the City of Delta's GIS data and our knowledge of the study area as shown in Map 2-3.

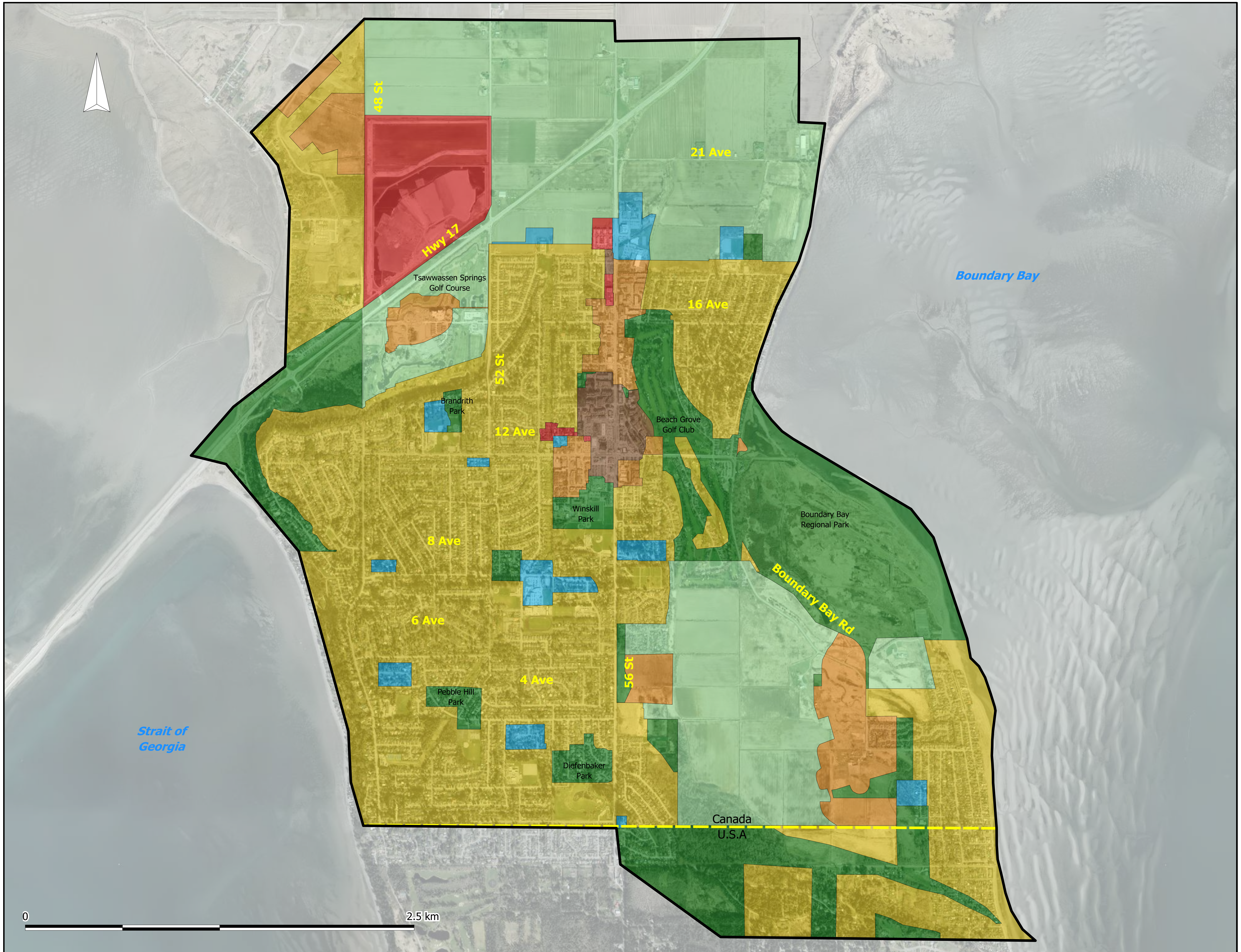
For the purpose of the ISMP, we divided the study area into 60 subcatchments. The subcatchments in the urban areas were delineated based on areas contributing to major storm trunks (450 mm and larger) and a minimum area of approximately 20 ha was used for the majority of the subcatchments, which is an appropriate scale for a planning-level assessment.

Major storm drainage pipes, generally 450 mm diameter and larger, were identified and included as part of the model for this planning level study. These storm pipes are predominantly located in the 12th Avenue catchment, and the remaining are in the 3rd Avenue catchment and Strait of Georgia catchment.

Using available data and mapping, we identified 39 culverts in the study area. Of these culverts, 29 culverts are Delta's responsibility and 10 culverts are the Ministry of Transportation and Infrastructure's (MoTI) responsibility (i.e. Highway 17). The culvert inventory is presented in Appendix A. We note that the GIS data provided by Delta for Highway 17 did not reflect the recent changes associated with the TFN developments. We updated the culvert data based on our IFC design drawings for the Highway 17 Tsawwassen Drive to 56th Street project (AE, 2014).

The study area has four pump stations; Brandrith Pump Station, Beach Grove Pump Station, 12th Avenue Pump Station and 3rd Avenue Pump Station. Pump stations are critical for draining the lowland system, only the 12th Avenue system (portion not connected to the pump station) and the English Bluff sub-catchments are drained by gravity.

See Appendix A for more details of the stormwater network.



LEGEND

LANDUSE TYPE

- AGRICULTURAL
- COMMERCIAL
- INSTITUTIONAL
- MEDIUM DENSITY RESIDENTIAL
- MIXED-USE
- PARKS
- SINGLE FAMILY RESIDENTIAL

SCALE:	AS SHOWN		
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DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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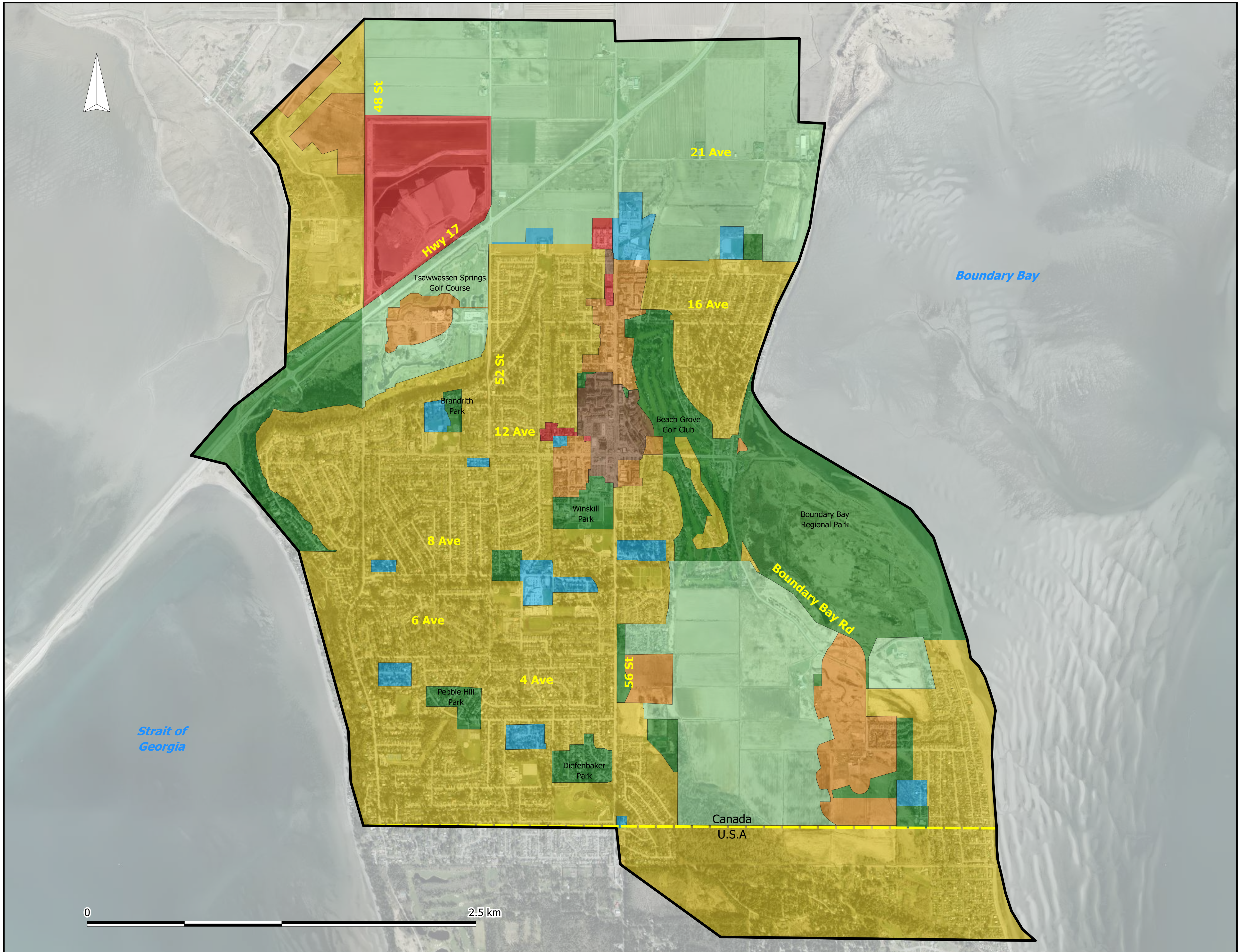
THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

EXISTING LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map



LEGEND

LANDUSE TYPE

- AGRICULTURAL
- COMMERCIAL
- INSTITUTIONAL
- MEDIUM DENSITY RESIDENTIAL
- MIXED-USE
- PARKS
- SINGLE FAMILY RESIDENTIAL

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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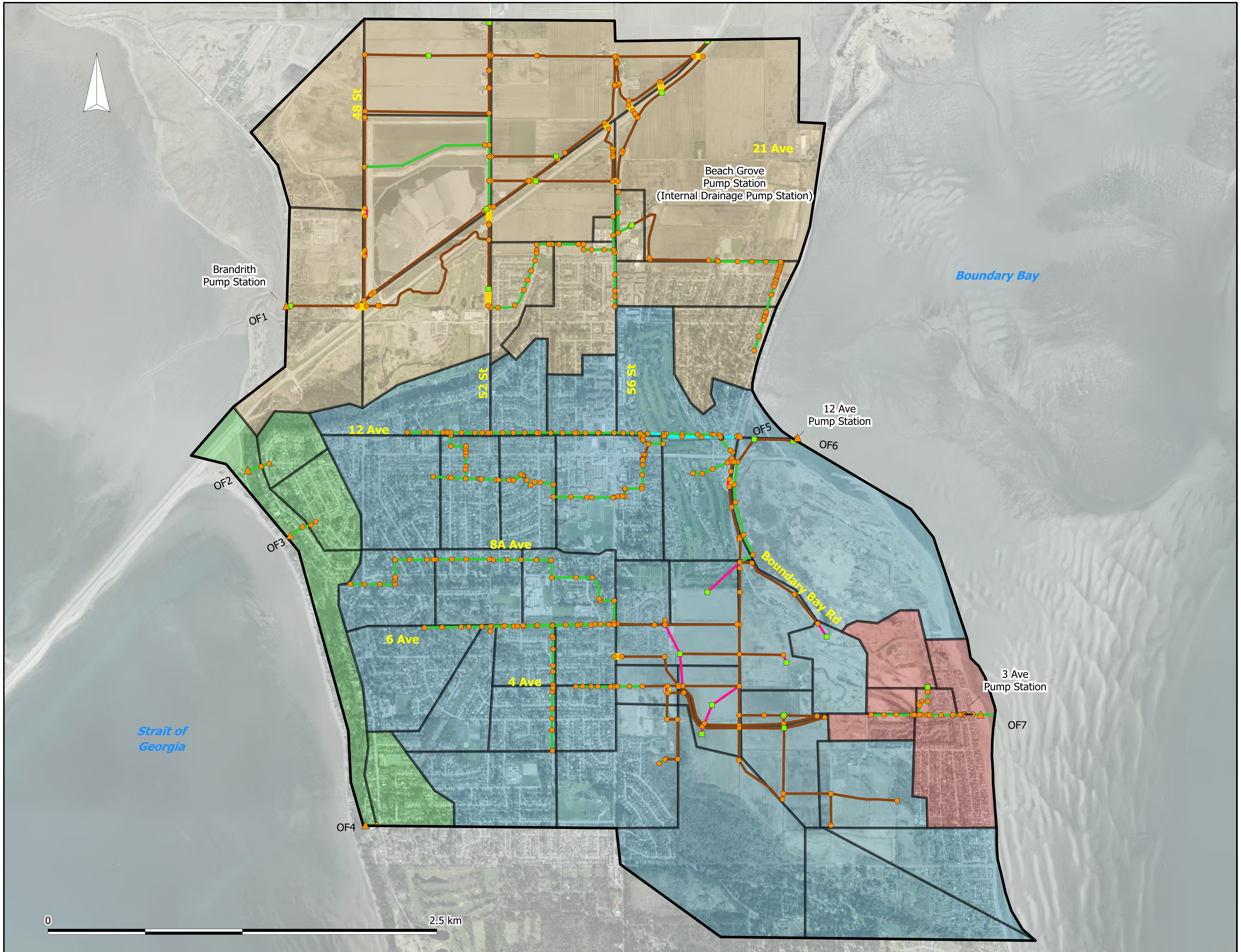
THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

FUTURE LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-2		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map



LEGEND

	STORAGE NODES
	NODES
	OUTFALLS
OF1	OUTFALL ID
	MODEL CONNECTION
	CULVERT
	DITCH
	STORM MAIN GRAVITY
	PRESSURIZED STORM MAIN
	SUBCATCHMENTS
	12 AVE
	3 AVE
	BRANDRITH
	STRAIT OF GEORGIA

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		JS	21-04-17
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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THE CITY OF DELTA
TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MODEL NETWORK

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-3		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

3 Aquatic and Terrestrial Habitat

3.1 AQUATIC ENVIRONMENT

The Tsawwassen Integrated Stormwater Management Plan study area includes numerous ditches and drainage channels, and unnamed watercourses in the various sub-watersheds (i.e. Brandrith, 12th Avenue, 3rd Avenue, and Strait of Georgia catchments) that function as a drainage network for the surrounding residential and commercials lands and road systems, and as irrigation and drainage for the lowland agricultural areas. The study area is bound by the marine ecosystems of Boundary Bay to the east, and the Strait of Georgia (Pacific Ocean) to the west.

The aquatic habitat of watercourses in the study area includes man-made, highly modified, and disturbed drainage ditches, channels and riparian areas, and very little remaining undeveloped, natural watercourses. Many of the ditches in the study area are semi-permanent or temporal and not connected to fish bearing streams. Historic land development (residential, agricultural, and commercial) in the study area has resulted in aquatic habitat loss and degradation through channel re-alignment, flow alteration and water quality degradation.

Due to low base flows, the ditches in the study area typically have poor water quality characteristics for fish (i.e. low levels of dissolved oxygen, elevated total suspended solids), and exceeded several water quality parameters for the protection of aquatic life, notably for fecal coliform bacteria within the 12th and 3rd Avenue catchment [1,2] and within the Brandrith catchment[3]. These conditions are common in lowland agricultural areas.

For more detailed information on freshwater and marine habitat, please refer to Appendix A. Map 3-1 following this section illustrates the distribution of aquatic and terrestrial habitat.

The City of Delta has developed a classification system for watercourses, tributaries and ditches[4] that indicates fish and amphibian presence and provides timing windows for when work can be completed in the watercourse, as described in Table 3-1. Watercourses classified according to this system are indicated on Map 3-1.

[1] City of Delta. 2013. BBAMP Field Data.
[2] City of Delta. 2009-2010. Pump Station Results.
[3] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.
[4] City of Delta. 2003. Watercourse Classification System. Available at: http://www.delta.ca/environment-sustainability/plants-wildlife/fish-frogs. Accessed Aug 2016.

Table 3-1
City of Delta Watercourse Classification System

Classification	Map Symbol	Description
Schedule A	Red	Salmonid presence (no works from October 1 to July 1)
Schedule B	Orange	Special fish/amphibian sensitive zone (no works from March 1 to August 15)
Schedule C	Yellow	Standard fish/amphibian work window (no works from May 1 to August 15)

None of the watercourses in the study area are considered Schedule A under Delta's Classification System. The majority of the study area watercourses and lowland ditches are Schedule C; however, a number of watercourses are listed as Schedule B as shown on Map 3-1, and include:

- The ditch along agricultural fields north of 17a Avenue and east of the South Delta Recreation Centre.
- The ditch along 16 Avenue from 56 Street to Gillespie Road, and south on Gillespie Road to Beach Grove Golf Club access.
- The ditch running from north end of Boundary Bay Road to where the ditch separates from the road.
- Watercourses B and C in the uplands of the study area.

3.2 TERRESTRIAL ENVIRONMENT

The study area includes a variety of forested, naturalized, disturbed, and herb dominated ecosystems. The terrestrial assessment of the study area uses the same catchment boundary delineation as the aquatic assessment for discussion (i.e. the Brandrith, 12th Avenue, 3rd Avenue, and Strait of Georgia catchments). The Brandrith catchment is characterized by moderate urbanization, while the 12th Avenue catchment is almost entirely urbanized with residential and commercial development in the uplands and is largely old field agriculture in the lowlands. Patches of green space and hedgerows are common in the uplands of the 12th Avenue catchment. This catchment contains the Boundary Bay Regional Park and intertidal area, a globally significant stopover for migratory birds along the Pacific Flyway. The 3rd Avenue catchment in the southeast is mainly residential development. The Strait of Georgia catchment is largely undeveloped except at the top of bank, as it is a steep coastal bluff, and is highly influenced by the climatic conditions of the Pacific Ocean.

For more detailed information on terrestrial habitat, visit Appendix A.

3.3 WATERSHED HEALTH ASSESSMENT

Metro Vancouver's 2005 ISMP Template proposed a methodology for a qualitative assessment of watershed health. The methodology requires three inputs:

- Total impervious area (TIA), representing the level of development and disturbance in the watershed relative to natural conditions. When such information is available, the effective impervious area (EIA) is often used instead. The EIA provides a better indicator of the degree of disturbance the watershed's development has by accounting for hydraulic disconnection of development from the receiving system. However, without significant data collection and interpretation, EIA is highly subjective and prone to uncertainty.
- Riparian forest integrity (RFI), representing the intactness of forest along the banks of natural watercourses.
- Benthic index of Biological Integrity (B-IBI), used as an indicator for ecological health of a stream.

The characteristics of the Tsawwassen area watersheds largely preclude the use of this methodology. The RFI of the study area is essentially zero, which would severely skew the watershed health assessment. Further, B-IBI scores, which are used to calibrate the tool are not available for the study area because the index is intended as a metric for high-gradient, coarse substrate, natural streams. There are no such streams within the study area.

We adapted the principles of the tool to conduct a qualitative assessment of the ecological health of the watersheds in the study area. It provides an overview of the current state of the watershed, and identifies how the ecological health could change in the future, in relation to development.

Watercourse Disturbance

No significant natural watercourses are present in the uplands. Lowland watercourses have generally been modified to serve agricultural purposes. The lowland ditches generally have a very narrow, or non-existent, vegetative buffer to the adjacent agricultural lands.

The upper watersheds in the study area therefore collect and convey runoff rapidly down the slopes via pipes and into the lowland agricultural watercourses. In the lowlands, generally slow moving drainage causes the water to stagnate within the ditches during low flow periods, and limited vegetative cover allows the temperature to increase during the summer. This results in poor water quality, particularly in the summer months when stagnation and temperature influences are the highest. Runoff from agricultural lands introduces organics, sediment and nutrients.

Degree of Development

Our assessment has taken the baseline 'existing' development condition to include the full build-out of the Southlands and Tsawwassen First Nation lands, in accordance with their respective land use plans. Against this baseline, the degree of anticipated additional future development is relatively low, and restricted primarily to sporadic densification of the residential neighbourhoods in the uplands and renewal of housing stock. To estimate land use conditions for future development, we assumed a 10 percent increase in impervious surfaces for single family residences.

Table 3-2
Total Impervious Coverage under Existing and Future Development Conditions

Catchment	Existing Development Condition	Future Development Condition
Brandrith	41%	44%
12th Avenue	46%	54%
3rd Avenue	56%	58%
Strait of Georgia	53%	61%
Total Study Area	**45%**	**51%**

Overall Ecological Health of the Watersheds
Qualitatively, we interpret that the overall ecological health of the watersheds within the study area to be relatively poor. This interpretation is applied because of the following factors:

- Extensive development and near-full build-out in the uplands, and disturbance to the lowlands.
- A lack of natural watercourses through the study area.
- Poor water quality and very low riparian integrity in the lowland ditches.

Under future development conditions, there is some potential for watershed health to further degrade if development and densification occurs without mitigative measures for both ecological health, and hydrologic function. Mitigative measures are discussed in Section 5.

3.4 ENVIRONMENTALLY SENSITIVE AREAS AT RISK

As previously discussed, most of the significant new development was included as part of our existing condition as it is already underway. The remainder of anticipated impacts due to development will come from long-term general densification and redevelopment, the majority of which is not yet planned. We expect the forested area in Point Roberts that drains to our study area will also be developed into single family residential homes in the future which will significantly increase the impervious area in those sub catchments. However, activities in this area are not under Delta's control.

In our aquatic and terrestrial assessment, we identified environmentally sensitive areas across the study area. In general, the majority of inland Tsawwassen has previously been developed and does not have many sensitive areas. The environmental corridors along the few natural or ditched open channel watercourses, forested areas in the uplands area of Southlands, forested areas along the western perimeter of Tsawwassen, and Boundary Bay Park have the most current terrestrial ecological value. Additionally, the majority of marine habitat along the foreshore areas may also be sensitive to the water quality of storm runoff at outfalls. In particular, poor water quality has been recorded at the outfall of the 3rd Avenue Pump Station during low tide in the summer months.

Map 3-2 presents anticipated increases to impervious coverage to inform risk of development on environmentally sensitive areas.

Table 3-2 summarizes the risk that development poses to sensitive areas and to downstream features for each subcatchment. We briefly discuss each watershed in the context of development risk below.

Table 3-3
Estimated Risk of Development on Environmentally Sensitive Areas and Downstream Features

Subcatchments	Development Risk[1] to Terrestrial Habitats	Development Risk[1] to Downstream Watercourses
Point Roberts (48 & 49)	High	High
English Bluffs (17)	Moderate	Moderate
Tsawwassen Central and Surrounding Residential Neighborhoods (11-13,18-24, 26-37)	Low	Moderate
North Tsawwassen and Beach Grove (9, 10, 14 & 16)	Low	Moderate
Tsawwassen First Nation Lands (1-3)	Low	Moderate

[1] Risk refers to the potential impact of development absent of mitigative measures (improved development setbacks from watercourses and key environmental areas / stormwater source controls).

Point Roberts

If development of the natural forested lands to single family large lot residential housing occurs, it could significantly affect the terrestrial habitat in this area. Additionally, an increase from 20% impervious to 40-50% impervious area possible under the zoning for rural residential could cause a large increase in peak runoff and total flows draining from the area into the Southlands/Boundary Bay area. Water quality of the receiving watercourses could also be negatively impacted by the increase in contaminants from urban runoff. The City does not have direct control over development activities in this area so they may want to discuss these impacts with Whatcom County in Washington State.

English Bluffs

Densification of the single-family residential areas in the English bluffs neighborhood may cause a nominal increase to the runoff into the Strait of Georgia. Opportunities for improving water quality through BMPs should be considered in this area, as storm runoff is directly discharged into the foreshore environment without treatment.

Tsawwassen Central and Surrounding Residential Neighborhoods/ North Tsawwassen and Beach Grove

These areas are already greatly impacted by residential development and therefore the effect of further densification will be minimal. It is important for redevelopment in this area to take advantage of the resulting opportunities to enhance watershed health by employing restorative stormwater management measures or environmental reclamation approaches. Increased impervious area may contribute to poorer water quality downstream with less pervious surfaces to filter potential contaminants and greater peak flows in the system.

Tsawwassen First Nation Lands

Similar to the English Bluffs area, opportunities to improve water quality should be considered in this area as storm runoff will be directly discharged into the foreshore environment without prior treatment. Development/densification in this area could lead to increase stormwater runoff and discharge into the foreshore environment impacting the sensitive habitats such as marsh lands, eel grass, and mudflats that currently exist.

3.5 WATER QUALITY ASSESSMENT

Water quality sampling conducted in the first stages of the ISMP identified that the lowland ditches are prone to poor water quality. Water quality sampling results can be found in Appendix B. Many of the parameters exceeded water quality guidelines and were at levels of concern relative to Metro Vancouver's Adaptive Management Framework classifications.

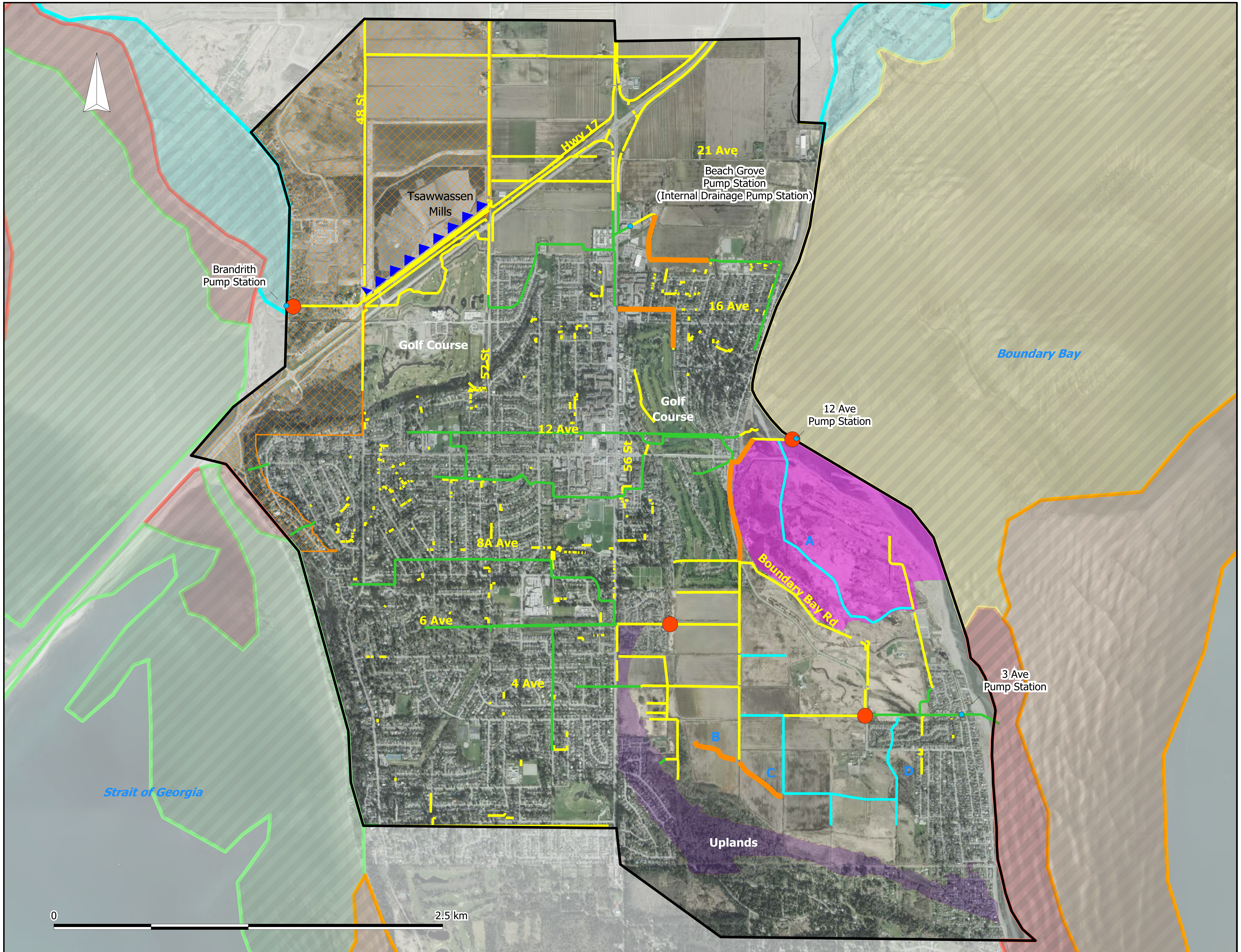
The poor water quality is likely attributed to a combination of:

- Contaminants originating from the upland developed areas, as well as those entering the ditches from the agricultural areas.
- Stagnant water within the ditches, particularly during the summer months so that temperatures also increase drastically and oxygen concentrations are depressed.
- Wildlife and waterfowl use.

Of the sites sampled, there was a distinct difference in water quality nearer the uplands than towards the discharge points of the lowlands near the pump stations where water quality was much poorer. This suggests that much of the degradation of the water quality is occurring within the lowland ditches and is related to stagnation and inputs from agricultural activities.

The City of Delta expressed particular concern with pumps discharging water with poor quality in Boundary Bay during low tide in the summer months while there are recreational users of the beaches. Alterations in pump station operation for the 3rd Avenue Pump Station, such that drainage discharges take place at night during the summer, could address this issue and will be discussed in Section 5.

In the context of the ISMP, it is important to address these water quality issues through a combination of enhancement measures. These measures will be discussed in detail in Section 5.



LEGEND

DRAINAGE FEATURES

- WATER QUALITY SAMPLING SITES
- PUMP STATION
- HABITAT COMPENSATION AREA
- AREA BOUNDARIES
- STORM MAIN

WATERCOURSE

- SCHEDULE B
- SCHEDULE C
- UNCLASSIFIED

TERRESTRIAL FEATURES

- TSAWWASSEN FIRST NATION
- BOUNDARY BAY REGIONAL PARK

FORESHORE HABITATS

- EEL-GRASS
- MARSH
- MUDFLAT
- SAND
- SAND/EEL-GRASS

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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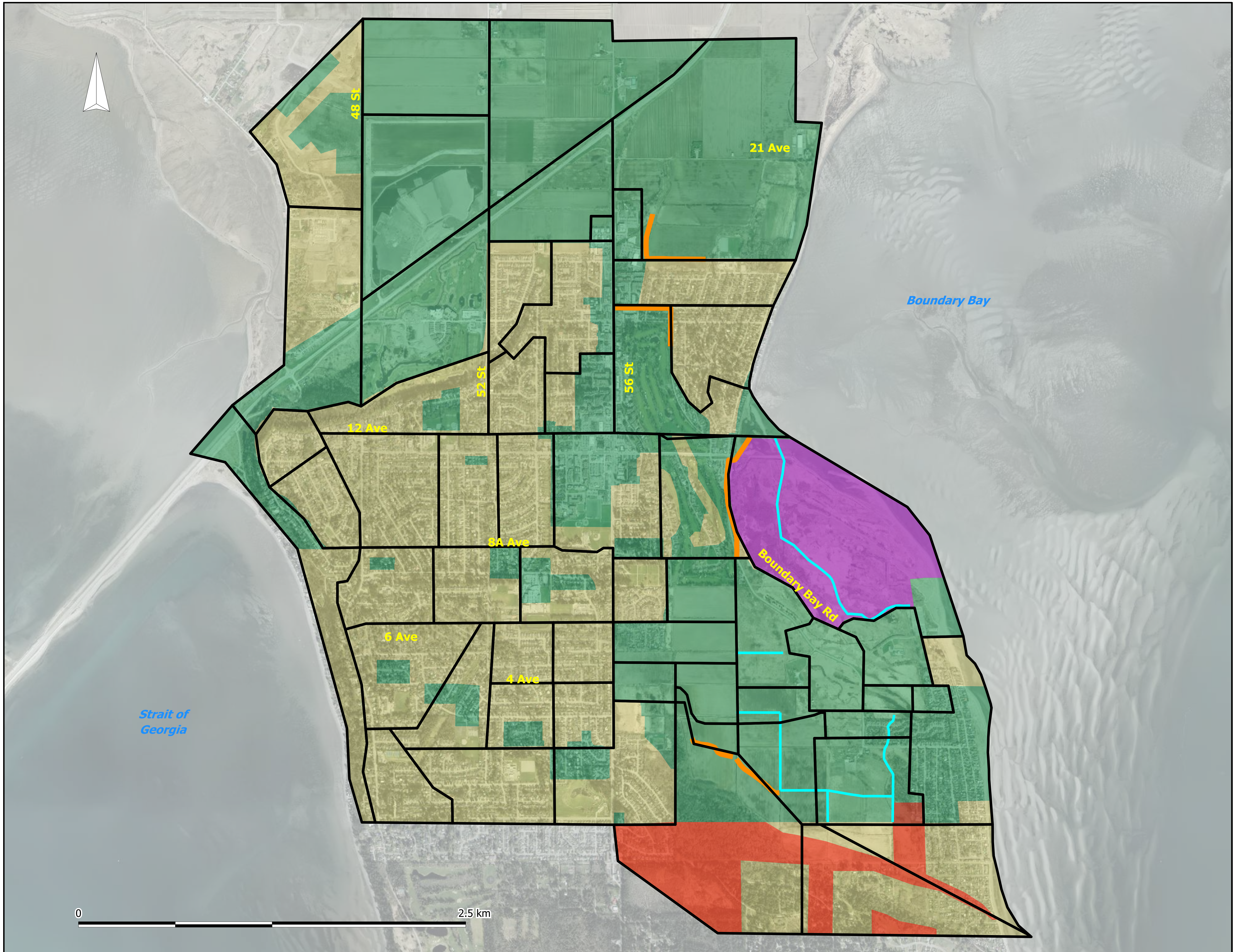
THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

ENVIRONMENTAL &
HABITAT CONTEXT

DRAWING NUMBER	REV. NO.	SHEET
MAP 3-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map



LEGEND

UNDER FUTURE DEVELOPMENT
- MINIMAL INCREASE, 0-10%
- MODERATE INCREASE, 10%
- SIGNIFICANT INCREASE, >30%

WATERCOURSE
- SCHEDULE B
- UNCLASSIFIED

TERRESTRIAL FEATURES
- BOUNDARY BAY REGIONAL PARK

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		JS	21-04-17
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

ANTICIPATED INCREASES TO IMPERVIOUS COVERAGE

DRAWING NUMBER	REV. NO.	SHEET
MAP 3-2		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

4 Hydrologic and Hydraulic Event-Based Modelling

4.1 EXISTING CONDITION MODEL AND CALIBRATION

We built a hydrologic and hydraulic model based on data from Delta's GIS mapping of drainage network components and information from the OCP on land use. Only major storm drainage trunks, 450 mm and above, and significant ditches were included in the model at this planning level study.

We developed design rainfall events using the SCS Type 1A curve and IDF data for the Pebble Hill Reservoir rain gauge (DT61) operated by Metro Vancouver.

We calibrated the model based on flow monitoring data collected by SFE in storm mains collected near the intersection of 56 Street and 6 Avenue. Flow monitoring data can be found in Appendix C. Calibration of the model allows us to more closely mimic the actual watershed response to precipitation in our model based on recorded flows in the storm system.

More details on model development can be found in Appendix D.

4.2 FUTURE CONDITION MODEL AND CLIMATE CHANGE

Our future condition modelling included updates to the system based on the expected densification of residential areas as well as build out of the area in Point Roberts which drains to Tsawwassen.

We applied a 50% percent increase to the total rainfall volume for the 24-hour storm which was based on similar lower bound increases found in a recent climate change study from the City of Surrey[5] through year 2080. In the study, computational routines were used to downscale global climate / circulation models to a local resolution for the Kwantlen rain gauge in Surrey for various climate change scenarios. Given the similar climatic conditions between Tsawwassen and Surrey, using Surrey's updated IDF curves allows us to take advantage of data based on detailed regional downscaling. Climate change projections should be reconfirmed when infrastructure upgrades are being advanced through planning and design.

Sea level rise and storm surge will both influence the shoreline of the Tsawwassen area and should be looked at in more detail. However, these aspects are beyond the scope of this ISMP. Gravity outfalls at the current Brandrith Pump Station, and the upland 12th Avenue system will become less effective as they will not be able to open as often or for as long with higher sea levels, combined with storm effects. Increased pump station capacify may be required, both in terms of total flow as well as static lift, to address the greater emphasis on drainage pumping. We referenced the *Southlands Area – Coastal Flood Modelling*

[5] Dillon Consulting on Behalf of City of Surrey. 2015. Development of Future IDF Statistics for the City of Surrey.

and Flood Construction Level Assessment [6] when estimating high tide events given climate change to apply values to boundary conditions in our model.

4.3 MODELLING STRATEGY

We created scenarios utilizing the 10- and 100-year return period 24-hour storm to assess the performance of the storm drainage network by reviewing peak hydraulic grade lines (HGL) and peak flow at significant locations within the study area.

The following criteria were used to evaluate locations with deficient infrastructure:

- Minor system storm pipes surcharging or showing significant head loss under the 10-year return period 24-hour storm.
- Major system culverts and ditches overflowing or showing significant head loss under the 100-year return period 24-hour storm.

All of the piped flows (with the exception of culverts within the study area and the under construction the 12th Avenue Stormwater Improvements project peak flow diversion pipe) are minor drainage system components and are therefore assessed based on the 10-year return period criteria.

The major drainage system is defined as overland flow paths, major open channels, and culverts that convey flows up to and including the 100-year return period design event. The major drainage system components we modelled for this ISMP were the major watercourses and their associated culverts, as well as the 12th Avenue Stormwater Improvements project peak flow diversion pipe. Overland flow paths were not modelled.

4.4 SYSTEM DEFICIENCIES

The results from our hydraulic modelling were used to identify deficiencies in the storm gravity mains, culverts, and ditches based on surcharging under either the 10-year (minor system) or 100-year (major system) return period design event as applicable. We assessed the deficiencies within the system under existing and future development conditions, and future development conditions with climate change.

4.4.1 Deficiencies under Existing and Future Conditions

Table 4-1 describes the location and nature of each identified deficiency under existing development and climatic conditions. Map 4-1 highlights the locations of deficient infrastructure in the existing condition. Long profiles indicating the system deficiencies for both existing and climate change conditions can be found at the end of Appendix D.

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[6] Associated Engineering on Behalf of City of Delta. 2012. Southlands Area – Coastal Flood Modelling and Flood Construction Level Assessment.

We found no significant deficiencies in the major system based on the criteria listed above for the existing and future conditions.

Table 4-1
List of Deficiencies in the Minor System

MINOR SYSTEM		
Deficiency ID (Map 4-1)	**Location**	**Description**
D-2 (See Figure D-2 for 10-year peak HGL profile)	Storm main trunk extending along 18th Avenue to Spyglass Crescent	Some of the 1200 mm and 1500 mm diameter storm pipes along this roadway are undersized and surcharge in the 10-year return period event. These pipes are causing backwater effects and surcharged manholes upstream.
D-3 (See Figure D-3 for 10-year peak HGL profile)	Storm siphon along 12 Avenue	The storm siphon (varied pipe size) is undersized causing backwater effects and surcharged manholes upstream.
D-4 (See Figure D-4 for 10-year peak HGL profile)	Storm pipes along 10A Avenue and Ferguson Road	The storm mains (varied pipe size) are undersized along this profile. These pipes are causing backwater effects and surcharged manholes upstream.

Figures D-6 through D-8 show the same deficiencies under climate change.

In areas where pipes are surcharging to surface, there is a risk of overland flooding. Areas at risk of flooding under existing conditions include the North Tsawwassen residential areas, much of the central Tsawwassen single family residential neighborhoods, and the 3rd Avenue Pump Station service area.

These areas drained by the minor system storm mains could experience significantly more flooding overtime with climate change effects. We cannot quantify this risk with a 1D PCSWMM model. We recommend that more detailed 1D-2D modelling with coupled major and minor systems (including overland flow) be completed to assess the surficial flooding extents and severity. The lowland major drainage system appears to have adequate capacity during the existing and future scenarios. More detailed field reconnaissance and modelling could be completed to confirm these assumptions.

In the future development scenario, the same deficiencies remain apparent, and are exacerbated. No additional deficiencies were noted at this stage.

4.4.2 Deficiencies under Future Conditions with Climate Change

When modelling a rainfall scenario that includes the impacts of climate change, the problems listed in Table 4-1 are further exacerbated, and new problems are created in the system. Map 4-1 highlights the locations of deficient infrastructure during the future development condition with climate change scenario. Areas within the system that are deficient under both the existing and climate change scenario are indicated on the map in red. Long profiles comparing the deficiencies under the climate change event which are also deficient in the existing scenarios can be found in Appendix D, Figures D6-D8.

As discussed in Section 4.2 above, we estimate that Tsawwassen could experience a 50% increase in precipitation under the RCP 8.5 emissions scenario, by the year 2080. Storm mains typically have a design life of 50 years or more depending on their level of service, and over their service life, newly upgraded pipes will be subject to a significant increase in peak flows due to climate change. We expect that installing larger pipes sized for climate change will only have an incremental impact on the total replacement cost. This is likely more cost effective than undertaking a new replacement cycle before the end of the service life of a pipe. As such, our recommended pipe upgrades in Section 5 below are sized accounting for the estimated impacts of climate change on precipitation and the resulting peak flows.

In determining required pipe upgrades in the urban system, we assumed that new pipes would be graded in relatively smooth profiles, in contrast to portions of the existing network that vary widely in slope over short distances. Maintaining consistent pipe slopes is more hydraulically efficient, which allows for the use of smaller pipes for identified upgrades. See Figure 4-1 for an example of a pipe profile along Spyglass Crescent in its existing state, and after we made changes to both pipe diameters and inverts. The City should ensure that new pipe upgrades maintain a consistent downward slope when completing any pipe designs and installations.

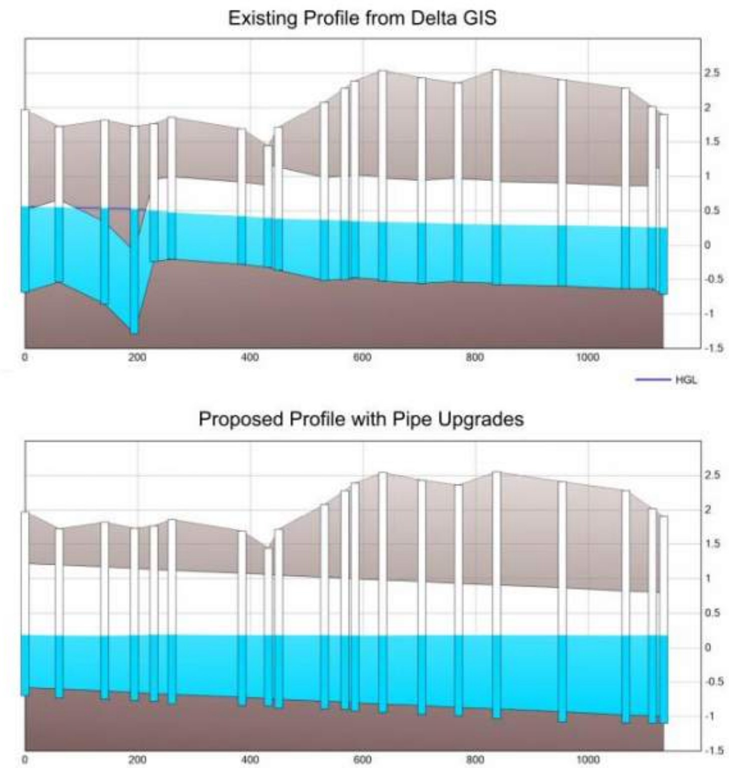
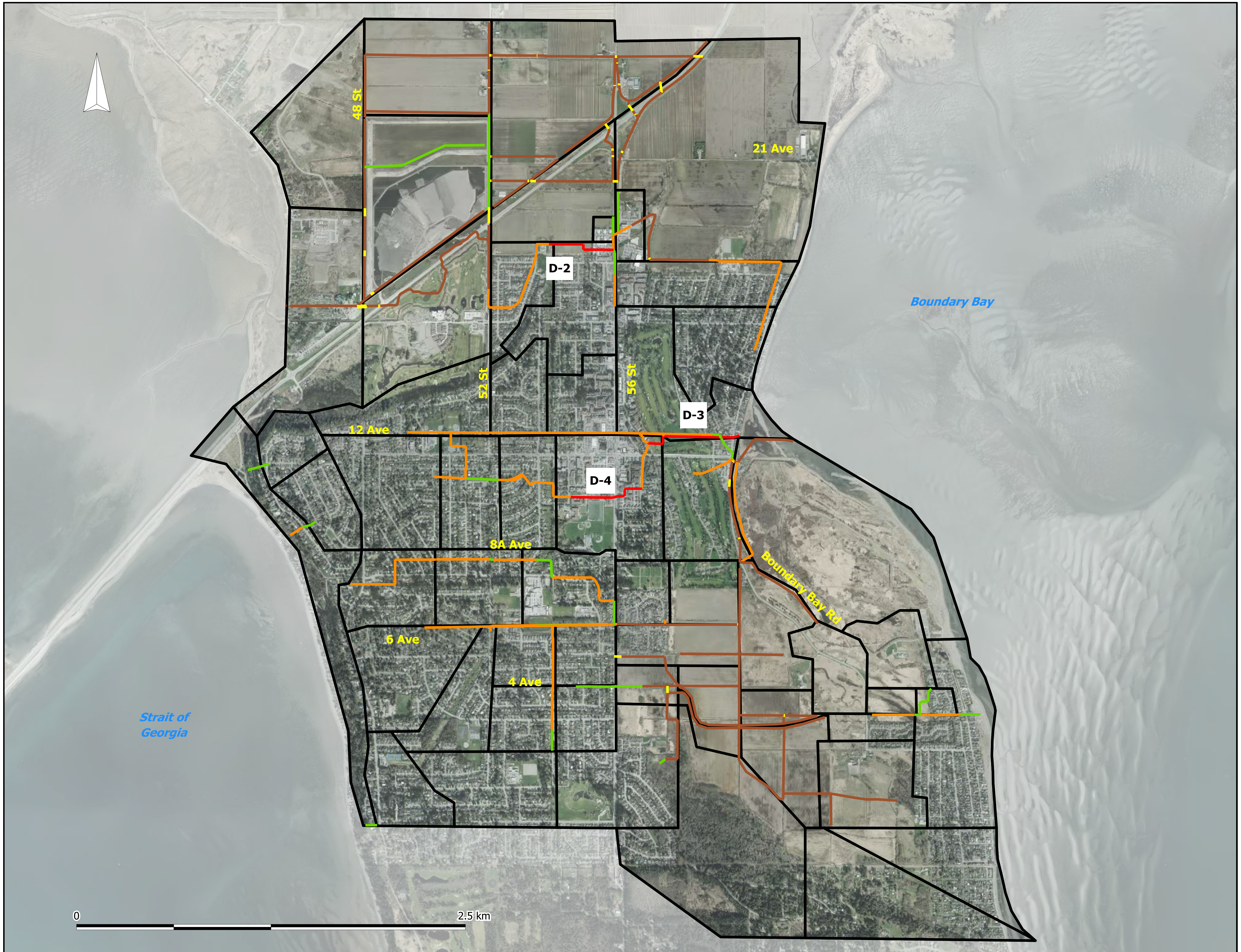


Figure 4-1
Example of Existing and Proposed Pipe Profiles

In addition to the deficiencies in the minor system, some of the downstream extents of the piped system are backwatered during the climate change scenario for the 100-year design storm due to a lack of ditch capacity downstream, or a lack of pump capacity. We identified these issues and other problems with capacity in the major system for the 100-year event with the impacts of climate change:

- Backwatering of the 3rd Avenue system upstream of the pump station.
- Backwatering of the minor system upstream of 12th Avenue Pump Station.
- Ditches upstream of Brandrith Pump Station are exceeding capacity and causing backwater effects upstream in the North Tsawwassen and Beach Grove catchments.
- Ditches downstream of the Southlands Development exceeding the 1.4 m HGL boundary condition stated for the development.

We will identify options to fix the issues in the minor and major system to mitigate the impacts of climate change in Section 5.



LEGEND

Red line	DEFICIENT UNDER EXISTING CONDITIONS AND CLIMATE CHANGE
Orange line	DEFICIENT UNDER CLIMATE CHANGE
Yellow line	CULVERT
Brown line	DITCH
Green line	STORM GRAVITY MAIN
Cyan line	PRESSURIZED STORM MAIN
Outline	SUBCATCHMENTS
x-X	DEFICIENCIES ID

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	04-27-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

LOCATION OF DEFICIENCIES

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

5 Implementation Strategy

In this section of the report, we present comprehensive recommendations to maintain or improve watershed health while allowing managed development to occur in the watershed. These recommendations include rainwater management measures, necessary and potential infrastructure upgrades, and environmental enhancement opportunities.

5.1 SPECIFIC IMPROVEMENTS TO STORMWATER MANAGEMENT

Table 5-1 outlines the proposed drainage upgrades and enhancement opportunities within the study area, and Map 5-1 shows the location of each specific recommendation. Of the minor system upgrades, Delta should prioritize areas noted in Section 4 as deficiencies in the existing condition. The LID and BMP measures as well as additional environmental enhancement options, which will be applied in general areas rather than specific locations, are discussed in subsequent sections. Upgrades to the major system (upgrades to ditches and culverts) have been developed for conveyance of the 100-year design flow with climate change effects.

The majority of the recommended upgrades are intended to be implemented in an opportunistic manner over the long term in association with broader scope infrastructure projects (such as road or other infrastructure upgrades) or in the context of drainage system renewal as a result of normal life cycle considerations. The identified capacities (e.g. pipe sizes or pumping capacities) of these upgrades address future impacts of climate change in terms of estimated increases in rainfall, and consequently runoff, that are likely to arise during the lifespan of the new components (i.e. 75 years or more). Storm infrastructure upgrades implemented in the future will have expected service lives that extend well into the time horizon of the estimated climate change impacts. While not necessarily required in an immediate sense, drainage infrastructure projects from this point forward need to recognize these conditions.

Generally, land use changes are minor and are not a driver for most recommended infrastructure upgrades, and the priority ranking reflects whether the identified component is subject to capacity constraints under existing climatic conditions, or under a future time horizon related to climate change. Those indicated with 'High' priority should be prioritized and included in Capital Works projects over the next 5 years. 'Medium' priority should be included in Capital Works projects over the next 20 years. Upgrades and improvements indicated as 'Low' priority items should be upgraded in an opportunistic manner over the next 20-40 years.

The upgrades within the system are high-level estimates primarily for planning purposes. It is expected that the City would complete further analysis of the system prior to any detailed design should they consider upgrading any components of the drainage system. Climate change projections should be reconfirmed when infrastructure upgrades are being advanced through planning and design.

In Appendix E we provide a detailed list of pipe upgrades for each group upgrade listed in the table below along with maps for each group. Cost estimates follow the pipe upgrades in Appendix E. Without detailed survey of ditch geometries throughout Tsawwassen, the existing dimensions provided in the tables in Appendix E are estimated from general observations of average ditch dimensions within the system.

Table 5-1
Improvements and Upgrades

ID	Priority	Location	Time Horizon	Description	Cost Estimate
Minor System Upgrades					
MN-1	Low	Beach Grove Road/17a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$4,900,000
MN-2	High	North portion of 56 Street, 18 Avenue, Spyglass Crescent	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change. Smooth pipe profile to improve hydraulic efficiency.	$15,500,000
MN-3	High	Trunk and Storm Siphon along 12 Avenue	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.	$12,200,000
MN-4	Low	North side of 50b Street, 51 Street and Western extent of 50a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$1,500,000
MN-5	High	Trunk along 10a Avenue, through Winskill park, and Ferguson Road,	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.	$7,500,000

ID	Priority	Location	Time Horizon	Description	Cost Estimate
MN-6	Low	Pipes through Beach Grove Golf Club and along Boundary Bay Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change (by twinning the pipe).	$3,700,000
MN-7	Low	Pipe Outfall from Pacific Drive to Tsawwassen Beach Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$400,000
MN-8	Low	Trunk south of 8a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$5,600,000
MN-9	Low	6 Avenue and 54 Street	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$6,300,000
MN-10	Low	3rd Avenue Trunk	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$1,900,000
Major System Upgrades					
MA-1	Low	3rd Avenue Pump Station	Long Term (20-40 years)	Increase 3rd Avenue Pump Station capacity. Outfall pipe capacity should be increased in tandem.	$5,800,000
MA-2	Low	12th Avenue Pump Station and Ditch along Boundary Bay Road	Long Term (20-40 years)	Increase 12th Avenue Pump Station capacity. Provisions to allow for climate change impacts have already been included in the design. Increase the capacity of the ditch along the west side of Boundary Bay Road and culverts.	$31,700,000

ID	Priority	Location	Time Horizon	Description	Cost Estimate
MA-3	Low	Brandrith Pump Station and Ditches Upstream of Brandrith Pump Station	Long Term (20-40 years)	Increase ditch capacities upstream of the Brandrith pump station and associated culverts and increase pump station capacity. Alternatively consider building an additional pump station to reroute drainage to a separate location.	$35,600,000
Environmental Enhancement Opportunities					
EV-1	Medium	12th Avenue Pump Station	Medium (5 – 20 years)	Expand the proposed wetland at the 12th Avenue Pump Station.	$400,000
EV-2	Medium	Brandrith Pump Station	Medium (5 – 20 years)	Build a treatment wetland upstream of the Brandrith Pump Station to filter contaminants before discharging to the marine environment.	$400,000
EV-3	High	3rd Avenue Pump Station/ 12th Avenue Pump Station	Short Term (0-5 years)	Change operation schedule to discharge at High Tides. Consider mechanical/chemical treatment options at 3rd Avenue to improve water quality. Limit flow velocities during discharge events to protect downstream ecosystem.	N/A – Change operation schedule.

**Note: Cost Estimates were rounded up to the nearest $100,000 as these are high level estimates.*

Culvert upgrades for the major system projects can be found in Appendix E as part of MA-2 and MA-3. However, we included a summary table of all culvert upgrades for quick reference for the City in Table 5-2 below:

Table 5-2
Culvert Upgrades

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
MA-2				
C-1364	435180	1050 x 1050	2400	13
C-1365	434761	1200	Two 2400 Culverts	49
C-1366	426617 / 426618	1200	Two 2400 Culverts	11

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
MA-3				
C-1251	Culvert below Highway 17 from 16th Avenue to Eagle Way	1200	1800	63
C-1250	Culvert below Highway 17 from 16th Avenue to Eagle Way	1800	2750	64
C-1361	Culvert below Highway 17 from 16th Avenue to Eagle Way	1050	1500	70
C-1201	Culvert Along 16th Avenue	1500	2400	13
C-1344	Culvert parallel to Highway 17	1800	2750	28
C-1248	Culvert parallel to Salish Sea Drive	1500	2400	38
C-1249	Culvert below Blue Heron Drive	1500	2400	53

5.2 STORMWATER BMPS

5.2.1 Recommended Residential BMPs

In addition to the specific drainage upgrades outlined above, Stormwater Best Management Practices (BMPs) should be implemented to mitigate the potential hydrologic impacts of development within the study area and improve water quality. As discussed, the majority of the study area is already fully developed with no new "green-field" developments planned in the foreseeable future. However, we assume that as the housing stock is renewed overtime, houses will be built with bigger footprints and will have correspondingly greater impervious areas. Additionally, an area in Point Roberts which drains into the study area is currently sparsely developed but is zoned for future rural single family residential housing.

Currently, Delta has wording in their design criteria manual stating, "Stormwater BMPs shall be incorporated where applicable to improve quality of stormwater runoff from the developed properties and reduce stormwater volumes in accordance with provincial and federal guidelines" (Bylaw 7162). Metro Vancouver has recently released the "Region-wide Baseline for On-site Stormwater Management" providing minimum requirements for BMPs on single family lots (Metro Vancouver, 2017). As we expect most of the redevelopment in the future will be on single family lots, we assume that the baseline measures as stated in the Metro Vancouver report will be implemented to mitigate impacts of development:

- Ensure all paved areas drain to a permeable surface (pervious pavement can be used as an alternative) and not directly to a roadway.
- Limit total impervious area to a maximum of 70% on each lot.
- Disconnect downspouts from the storm system to drain to a permeable surface.
- Increase the minimum absorbent topsoil depth to 450 mm.

- Limit maximum outflow rates from lots to 40% of the 1 in 2 year storm of 24 hour duration as stated in Metro Vancouver's Baseline document (2017). For Tsawwassen this translates to approximately 28 mm of rainfall in 24 hours with climate change.

We assume that these BMPs will be applied in areas of future densification (single family lots) and redevelopment. This reflects the fact that future development activities will provide the City with an opportunity to enforce BMP measures as densification occurs. Conversely, it is more challenging to retrofit BMPs on existing development, but the City should consider incentives to encourage implementation of BMPS on existing lots where possible. The majority of the upland areas in Tsawwassen are single family residential, so implementing BMPs on these lots to reduce a major source of runoff and capture contaminants will contribute to improving downstream water quality and reducing peak flows. The BMPs recommended above are easier to implement by homeowners in comparison to rain gardens or infiltration trenches which require proper installation and maintenance. Pervious pavement does require long term maintenance, however, so options such as grading driveways to drain to pervious surfaces or using paved strips for driveways to minimize impervious coverage may be simpler alternatives. Encouraging use of rain barrels or planter boxes will also improve on lot stormwater retention. Of note, these two measures can be applied on existing properties without requiring residents to significantly alter their lots.

As with pipe upgrades, BMPs should be implemented on an opportunistic basis, whenever new or re-development plans are created or when roadways and housing developments are renewed. Taking advantage of new construction will help build the cost of BMPs into the redevelopment costs at a fraction of the amount than if they were installed retroactively. In general, detention systems should be considered as alternatives to pipe upgrades in areas with sufficient space to fit above or below ground detention systems. Controlling peak flows may reduce the required pipe sizes downstream. Surface detention can be considered in parks or green spaces, and underground detention on larger commercial and multi-family developments.

The City of Delta should consider hosting an education program for residents to inform them of the positive impacts of implementing BMPs on their lots and provide support to make these changes. Public buy in is essential to meet the above stated targets.

It is important to note that infiltration based source controls (BMPs) and runoff retention features such as raingardens and growing medium prescriptions are generally only effective over the spectrum of small, frequently occurring, rainfall events. Their ability to address large rainfall events of a design magnitude, such as a 10- or 100- year rainfall event is generally very limited, i.e. minor proportions of the overall rainfall volume. Additionally, consideration must be given to the likelihood that large events are often proceeded by wet antecedent conditions, reducing or nullifying the efficacy of these measures. Accordingly, at least in the context of the Lower Mainland, it is not realistic to expect that these systems will reliably reduce the total runoff volumes and peak flow rates that must be conveyed in conventional drainage systems. Also, as the estimates of climate change driven increases in precipitation continue to move upward, the benefit in using rainwater management approaches to reduce runoff volumes from design storm events becomes relatively minor. While there a great many environmental and ecological reasons why rainwater management of small storm events is beneficial and desirable, addressing capacity constraints and overland flooding risk from major storms, both with and without climate change, is not one of them.

The City should look for opportunities to implement community scale detention storage to attenuate peak flows from the Tsawwassen uplands. The primary challenge with retrofitting detention storage in the Tsawwassen uplands will be obtaining sufficient open space, at appropriate locations in the drainage system. However, if successfully implemented, detention storage may allow for a reduction in the size and extents of future drainage infrastructure upgrades required to address climate change impacts.

Infiltration based BMPs and source control strategies should only be employed in areas with suitable soils and with a minimum setback from steep slopes. Geotechnical engineers should be consulted on issues of slope stability and soil infiltration capacity.

5.2.2 Additional Recommended BMPs

BMPs should also be implemented on commercial/multifamily/industrial lots and roadways, where possible during redevelopment or upgrades.

Commercial (and Multi Family/Industrial) Lots

In Appendix F, we described a number of potential BMPs that can be applied on commercial and multi-family lots. These include bioswales/rain gardens, green roofs, underground detention, and absorbent soils.

Rain garden adjacent to parking lot.

We recommend implementing bioswales along the edges of parking lots, while rain gardens can be located to receive runoff from parking lots and/or rooftops. Based on Metro Vancouver's Stormwater Source Control Design Guidelines (2012), bioswales and rain gardens should both be sized to at least 5% of the impervious area they service. This represents a 20:1 ratio of impervious area to bioswale/rain garden footprint. The guidelines provide additional recommendations regarding the detailed design and application of these BMPs.

Rain garden adjacent to buildings.

Where buildings have flat roofs, and occupy a large fraction of the total lot area, we recommend that green roofs be implemented. The standard range for green roof soil depths is 150 mm to 600 mm, as noted in the Stormwater Source Control Design Guidelines.

Absorbent soils should be implemented at a minimum depth of 450 mm as discussed in Metro Vancouver's recent Region-Wide Baseline for On-site Stormwater Management document (2017). In a typical commericial lot, medians between parking stalls and areas around the perimeter of buildings are good locations to add absorbant landscaping and rain gardens. Grading impervious surfaces to drain to pervious surfaces is recommended to help attenuate peak flows for small storm events.

Water quality treatment should be implemented for commercial or industrial lots that may generate higher levels of contaminants, to provide treatment before stormwater is discharged to the main system. Underground stormwater detention tanks can be implemented in conjuction with treatment devices to improve water quality and attenuate runoff.

Source controls implemented by The City should meet the release targets and storage requirements outlined in Table 5-3 to reduce stress on the storm sewer system. The release rates and storage requirements are estimated to mimic hypothetical natural peak runoff rates for a the 24 hour duration, 10-year period storm event (for current climatic conditions).

Table 5-3
Source Control Release Targets and Storage Targets

Minimum Required Storage Volume	Maximum Allowable Release Rate
120 m^3 / hectare	21 L/s / hectare

Roadways

There are a variety of road classifications within the study area, including local, collector, and arterial roadways consisting of 18 m, 20 m, and 24 m right-of-way widths respectively. As noted previously, road rights-of-ways present significant opportunities to implement BMPs because they are linear and are within the City's control. Further, since the City already has funding committed to road projects, these projects present an opportunity to incorporate BMP measures in a cost-effective manner. Rather than planning and funding Stormwater Low Impact Development projects in isolation, existing road projects under Delta's Neighborhood Road Improvements Plan can be modified to achieve LID goals. Road rights-of-way can incorporate a variety of BMPs depending on their width, including:

- Bioswales,
- Pervious pavement,
- Rain gardens,
- Absorbent landscaping combined with street trees, and
- Structural porous soils.

Where space allows, we recommend bioswales and rain gardens be built on the edges of local and collector roads, and in the center of arterial roads, to receive and treat runoff. Rather than using raised road medians on arterial roads to separate traffic, linear bioswales, depressed below the road surface, can be built to collect the runoff from the roadways, while providing aesthetic value. On streets with low traffic volumes, curb bulges, in which curbs are extended into the roadway for placement of rain gardens, can be effective in decreasing the impervious area of roadways while contributing to traffic calming measures. These BMPs will both filter out contaminants from the roadway runoff and attenuate peak flows. Pervious pavement is best used for sidewalks, as runoff on sidewalks has less total suspended solids content than roadways which can clog pavement pores and require increased maintenance.

BMPs should be encouraged on all projects as part of Delta's Neighborhood Road Improvements Plan. Details on roadside swale and rain garden design can be found in Delta's Design Guidelines Bylaw 7162 as well as Metro Vancouver's Stormwater Source Control Design Guidelines (2012).

For a full list of applicable BMPs to the study area and descriptions of each, see Appendix F.

Infiltration BMPs should not be considered above areas which exhibit potential slope stability hazards, such as the English Bluffs. We recommend infiltration BMPs be offset from the western and northern bluff areas by a minimum of 100 m. A qualified geotechnical or hydrogeological professional should confirm acceptability of proposed BMP locations for all cases, and confirm required setbacks from all slopes. In areas where infiltration is not feasible or practical, flow through (non-infiltration) BMPs can be used as an alternative, where all drainage from these systems is eventually directed back into the stormwater system. Flow through BMPs will not provide runoff volume reduction but will attenuate peak flows.

5.2.3 Summary of Recommended BMPs

Table 5-4 summarizes the recommended BMPs from Section 5.2.1 and 5.2.2 for quick reference for the City.

Table 5-4
BMP Recommendations

Residential Lots	Commercial/Multi-Family Lots
• Ensure all paved areas drain to a permeable surface and not directly to a roadway. • Limit impervious area to a maximum of 70% on each lot. • Disconnect downspouts from the storm system to drain to a permeable surface. • Increase the minimum absorbent topsoil depth to 450 mm. • Limit runoff to 40% of the 24 hour, 2-year return period rainfall (equivalent to 28 mm).	• Require pre-treatment of stormwater runoff for hydrocarbon and sediment removal. • Apply bioswales/rain gardens, green roofs, underground detention, and absorbent soils where possible. • Provide a minimum required storage volume of 120 m3 / ha with a maximum allowable release rate of 21 L/s/ha for a 24 hour duration, 10-year return period event. This release rate reflects the estimated peak flow rate under hypothetical natural conditions.

5.2.4 Impacts of BMPs in Tsawwassen

We completed an Extended Period Simulation (EPS) to assess the impacts of densification and development in the Tsawwassen area. For more details on this assessment of existing and future conditions, without application of mitigative measures, refer to Appendix F. This analysis provides information on the distribution of high flows and illustrates attenuation of runoff when comparing results between different model scenarios. In general, without application of source controls, future densification will decrease infiltration leading to increased runoff and peak flows. To assess the effectiveness of our recommended BMP measures in mitigating future densification, we updated our EPS model to account for these BMPs on single family lots and on commercial properties/roadways throughout the study area by altering the internal routing and storage parameters. We did not model BMPs in the sub-catchments in the English Bluffs area as they are not applicable due to potential risks of slope stability hazards arising due to excess infiltration, as noted in Delta's Design Guidelines. For this updated modelling exercise, we used one year of extended rainfall data (Summer 2010-2011).

Using the results from the EPS models, we created flow-duration-exceedance curves for the future condition with the application of BMPs. The results are presented on Figures 5-1 and 5-2, which also includes the flow-duration-exceedance curves for both the existing development condition and the future development conditions without BMPs. The reporting location for each curve is indicated on Map 5-2.

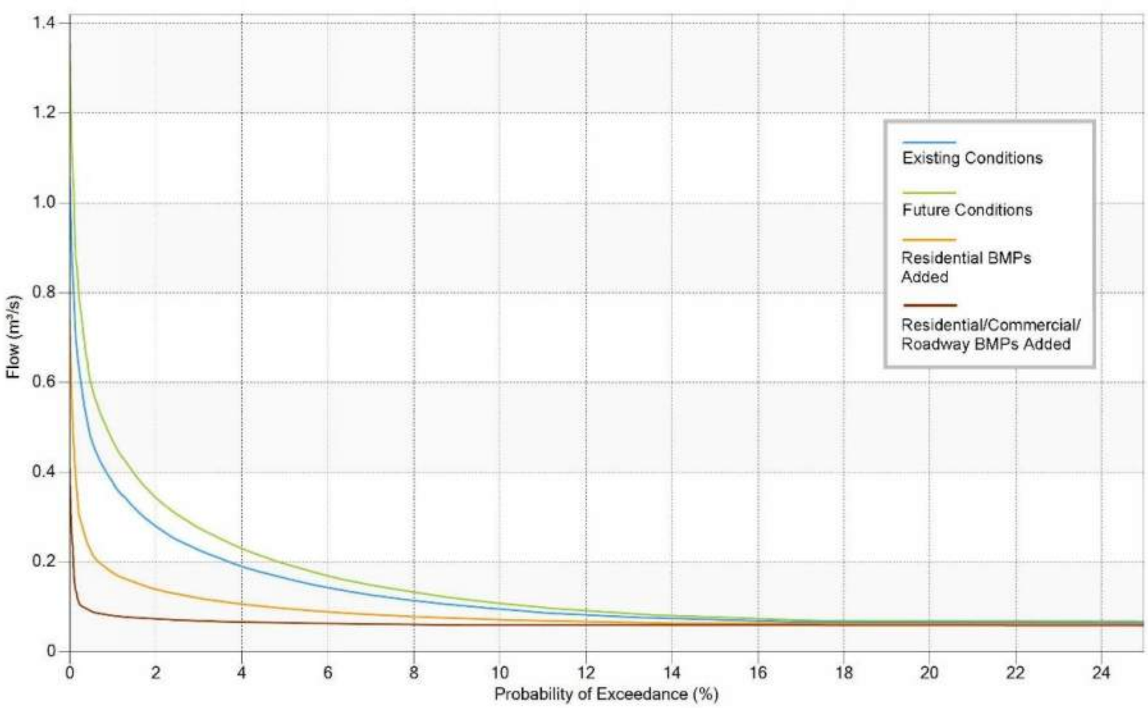


Figure 5-1
Outfall Ditch at 56 Street and 6 Avenue- D-1393

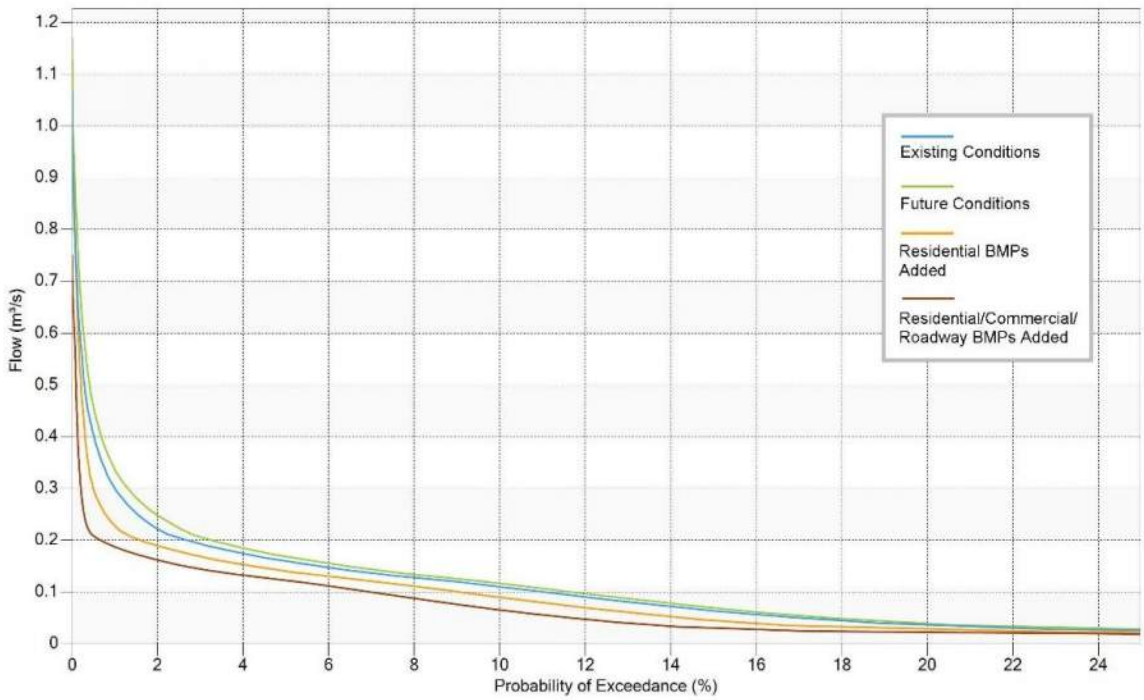


Figure 5-2
Outfall Ditch at Spyglass Crescent and 52 Street – D-1437

For both locations, it is clear from the EPS that the addition of BMPs reduce the duration and magnitude of high flows. For the outfall at 56 Street, flows in the 95th percentile (5% probability of exceedance) move from approximately 0.2 m^3/s in the future scenario to 0.07 m^3/s with all BMPs added. For the outfall at Spyglass Crescent, flows in the 95th percentile move from approximately 0.17 m^3/s in the future scenario to 0.12 m^3/s with all BMPs added. Even with future densification, implementing BMPs can have a net positive impact on the runoff conditions in the Tsawwassen area in comparison to existing conditions. Figure 3-3 illustrates example hydrographs for a sample rainfall event during the EPS scenario run for D-1393.

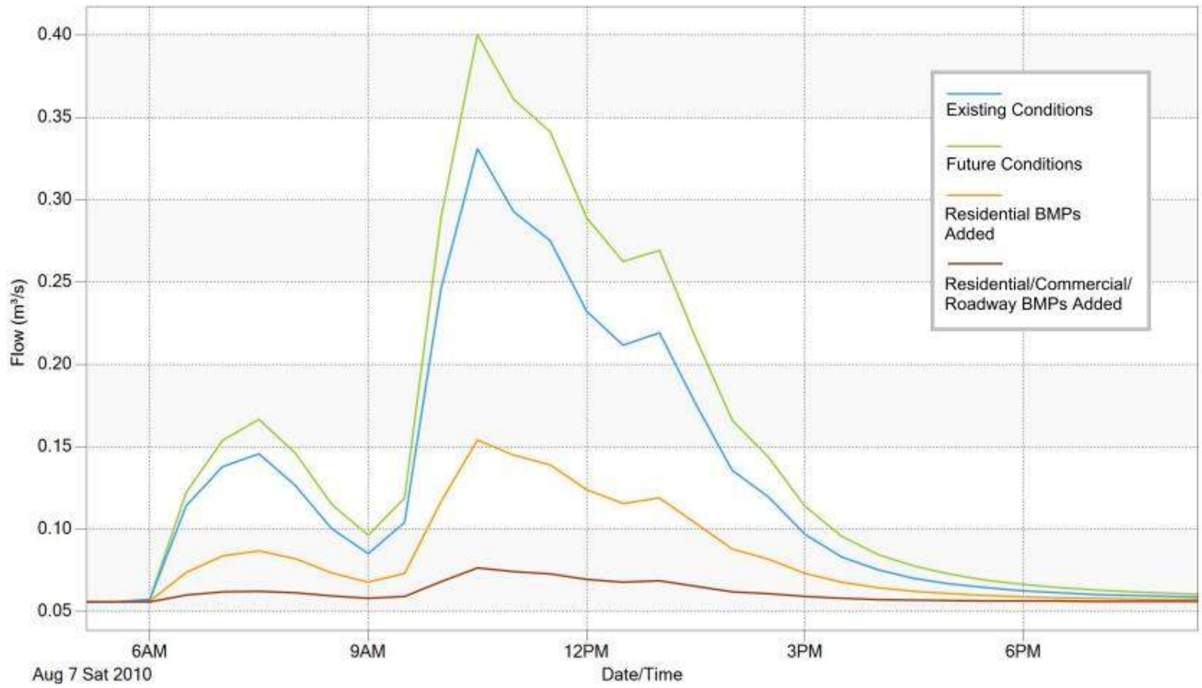


Figure 5-3
Example Hydrographs for D-1393

Figure 3-3 shows a significant decrease in flow volume (area under the curve) between future scenarios and scenarios with BMPs, illustrating the positive impact of adding BMPs to the system. BMPs allow for increased infiltration throughout the study area removing a large portion of runoff which would otherwise be routed downstream through the storm system.

5.3 ENVIRONMENTAL ENHANCEMENT OPPORTUNITIES

5.3.1 Water Quality Improvements

Upland Water Quality

Contaminants contained within urban runoff may be managed by stormwater BMPs (rain gardens, bioswales, infiltration facilities). However, the uplands are mostly built-out and are predominantly residential properties. It is very difficult to enforce or monitor the performance of stormwater management systems on residential lots. Therefore, the City should watch for opportunities involving larger-scale redevelopments in the uplands and apply rainwater management features to these developments.

The City's Tsawwassen Area Plan highlights policies and objectives that directly relate to improved water quality in runoff. For example, one such policy identifies the desire to maintain a 'garden theme' throughout Tsawwassen to promote the use of native vegetation on road rights-of-way and private developments. As a condition of redevelopment within the 'small town' centre, the plan encourages the development of parking lots that are aesthetically pleasing. This provides an opportunity to consider pervious pavers, as well as vegetated rain gardens, bioswales, or similar green infrastructure with attenuation, runoff reduction and water quality benefits.

Lowland Water Quality

The characteristics of the lowlands, including lack of shade and stagnant water conditions, will continue to cause water quality issues in the ditches. To address water quality issues associated with runoff from adjacent agricultural lands, a vegetated buffer strip should be provided along the ditches in the lowlands. This buffer will help filter contaminants, including nutrients and fecal coliforms from the agricultural fields, will shade the ditches to help moderate temperature, help prevent growth of instream aquatic vegetation, and will also serve as a corridor for small wildlife.

As noted in the table of enhancement projects (Section 5.1), further polishing of the water should be applied near the pump stations in the form of treatment wetlands. This would provide a final polishing of the water prior to discharge into the marine receiving environment, particularly at the 12th Avenue Pump Station and Brandrith Pump Station. Treatment wetlands are not feasible at the 3rd Avenue Pump Station given space constraints, however mechanical/chemical treatment options should be considered. Alternatively, we recommend changing the operation procedures of the pump station to discharge at high tides to increase flushing and dilution and reduce any aesthetic concerns on adjacent beaches.

5.3.1 Additional Enhancement Opportunities

During the review of existing information as part of the first stages of this ISMP, several potential opportunities to enhance and restore the environmental conditions in the study area were identified. Pursuing these opportunities whenever feasible will contribute to the general overall improvement of the watercourse / watershed health in the study area. These include:

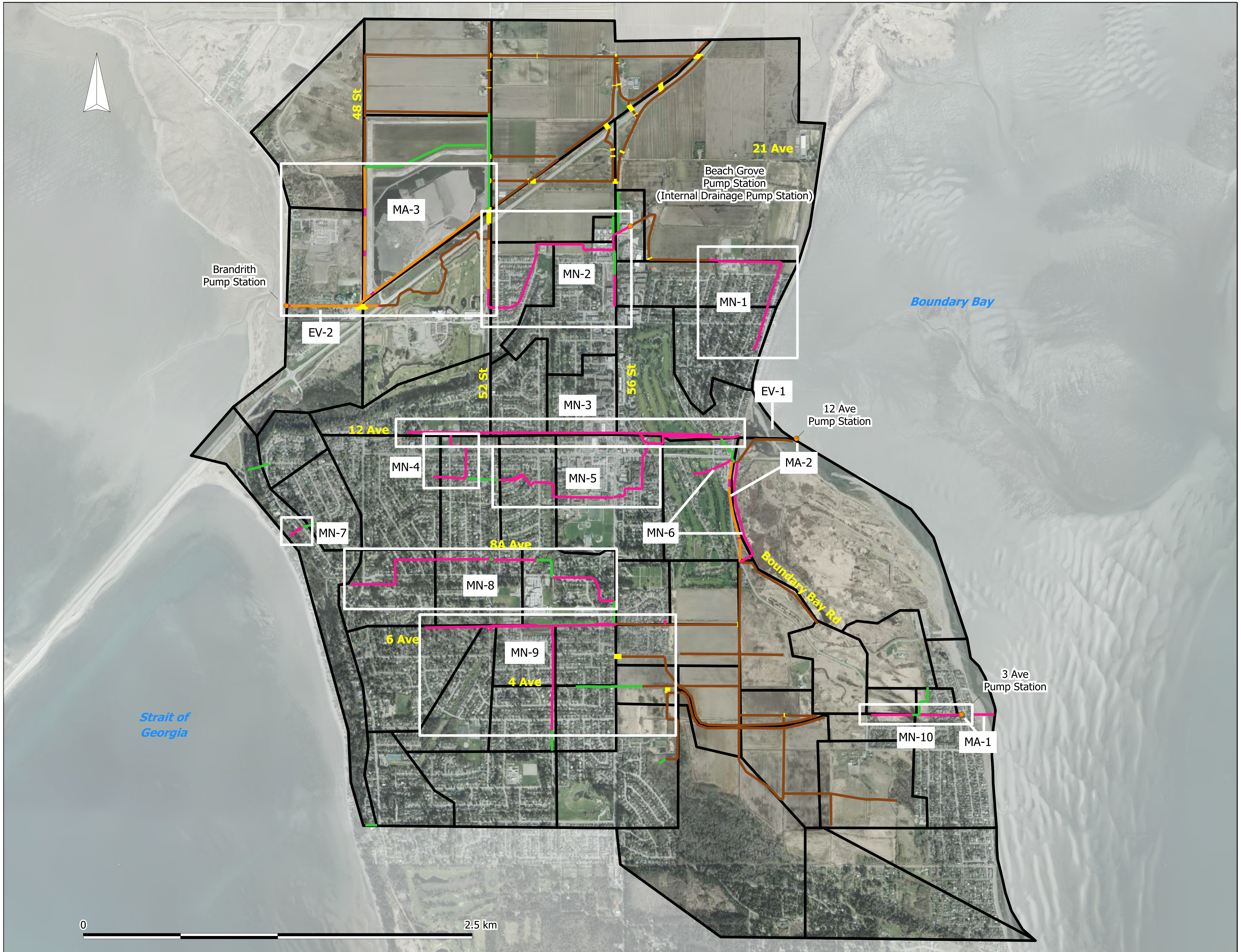
- Maintain aquatic habitat where possible to provide habitat and nutrients for aquatic and semi-aquatic wildlife.
- Maintain ditch, watercourse, intertidal and marine habitat functionality (i.e. maintain or improve: flow, water levels, connectivity, riparian and intertidal vegetation).
- Complete any construction works within designated least harm/risk timing windows.
- Implement Best Management Practices including:
  - Standards and Best Practices for Instream Works[7].
  - Land Development Guidelines for the Protection of Aquatic Habitat[8].

[7] B.C. Ministry of Water, Land and Air Protection. 2004. Standards and Best Practices for Instream Works. Available at: http://www.env.gov.bc.ca/wld/documents/bmp/iswstdsbpsmarch2004.pdf (accessed July 2016).

[8] Fisheries and Oceans Canada (DFO). 1993. Land Development Guidelines for the Protection of Aquatic Habitat. Available at: http://www.dfo-mpo.gc.ca/Library/165353.pdf (accessed July 2016).

  - Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia[9].
- Maintain and enhance structure and diversity of treed and shrubby ecosystems by:
  - Re-vegetating newly built areas to reduce surface runoff and improve rainwater retention.
  - Decreasing impermeable surfaces where possible and finding opportunities to reduce or mitigate hard surfaces.
  - Incorporating invasive species management, where necessary.
- Maintain riparian linkages to connect environmental areas by:
  - Considering green space corridor connectivity to enhance or restore wildlife habitat corridors.
  - Maintaining existing wildlife movement corridors.
- Plan and develop landscape as part of a sustainable ecological system by:
  - Considering the effects of climate change on the natural and built environment.
  - In new built-environments, directing surficial water flow to natural environments such as wetlands, green space corridors, or multi-storey forested habitat.
  - Constructing "catchment" ecosystems that will reduce runoff and retain rainwater and improve capacity for biodiversity.
  - Maintaining the health and vigour of existing vegetation and considering the occurrence or potential for spread of invasive plant species.
  - Incorporating habitat values for fish and wildlife, including species at risk, and maintaining habitat capacity for wildlife.
  - Managing topsoil to preserve existing topsoil condition to support vegetation and maintain rainwater infiltration.
  - Incorporating permeable surfaces (e.g., pathways) and planting vegetation to promote structural complexity and accommodate surface runoff.
- Building new green spaces where possible for recreational purposes. Protect areas adjacent and connected to the Boundary Bay Regional Park to protect the ecosystem in this area.

[9] B.C. Ministry of Environment. 2014. Develop with Care 2014. Environmental Guidelines for Urban and Rural Land Development in British Columbia. Available at: http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare/#Main (accessed September 2016).



LEGEND

- CULVERT
- DITCH
- STORM MAIN
- UPGRADED PIPE
- UPGRADED DITCH
- SUBCATCHMENTS
- xx-X UPGRADES ID

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	05-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering
GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

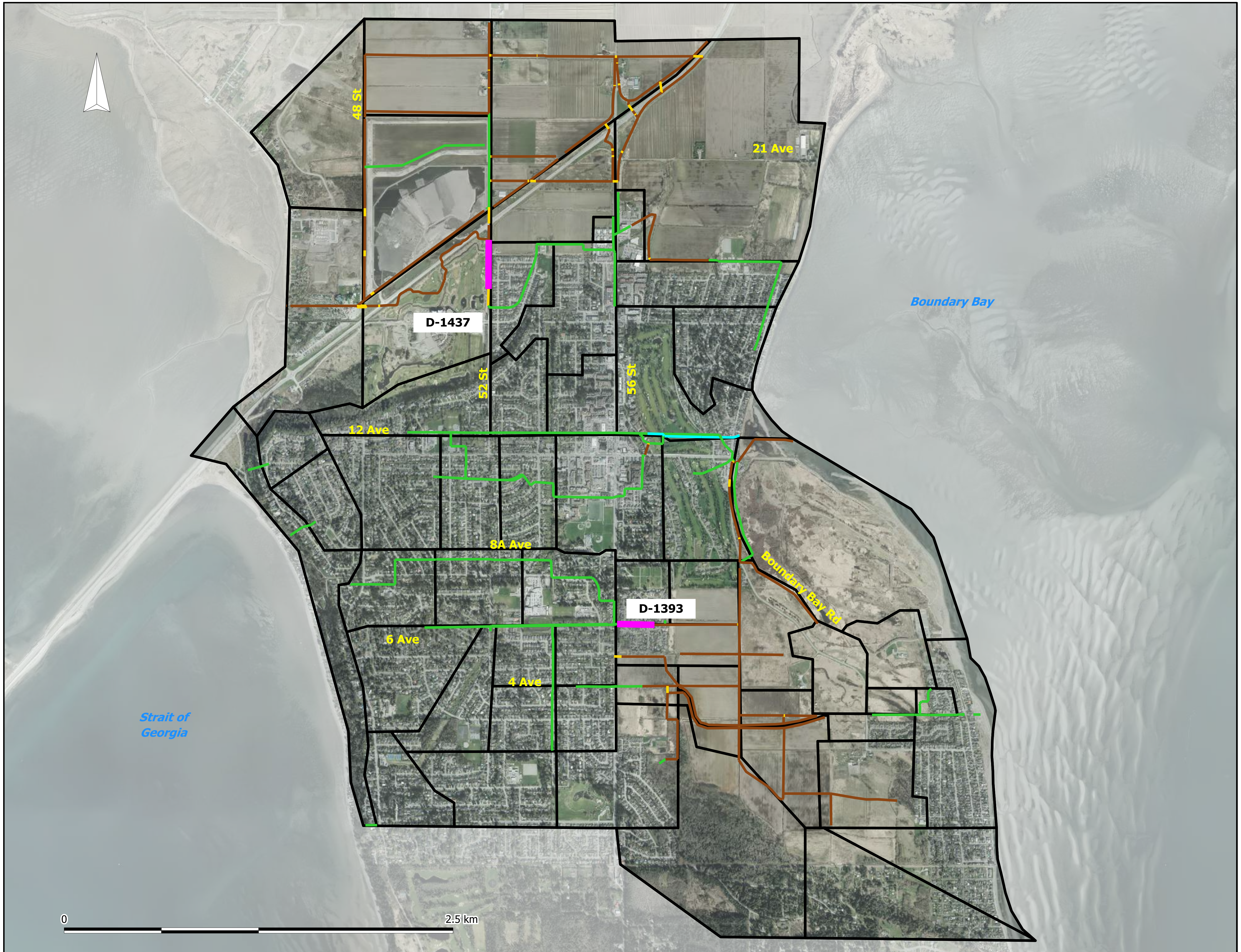
THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

LOCATION OF IMPROVEMENTS
AND UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP 5-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map



LEGEND

- REPORTING LOCATIONS
- CULVERT
- DITCH
- STORM GRAVITY MAIN
- PRESSURIZED STORM MAIN
- SUBCATCHMENTS

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		AM	14-06-17
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

REPORTING LOCATIONS
FOR FDE CURVES

DRAWING NUMBER	REV. NO.	SHEET
MAP 5-2		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

6 Enforcement, Funding, and Monitoring Strategy

6.1 ENFORCEMENT STRATEGY

The City's implementation of the Tsawwassen ISMP's recommendations will require proactive and effective enforcement of the policy and regulatory aspects of the ISMP. We believe this requires both an enforceable regulatory framework, and community motivation to actively improve watershed health.

Several of the ISMP recommendations critical for supporting watershed health and responsible stormwater management are not supported or enforceable under the City's current bylaws, policies and design guidelines. For enforcement to be effective, we recommend the City update its existing policies, bylaws, and manuals to provide the necessary regulatory framework to support the implementation of these various measures in the study area.

We note that these documents are typically City-wide, and our recommendations must be considered in the context of recommendations arising from other City studies and plans.

To implement projects called out in the Implementation Strategy in Section 5.1, the following changes should be made to the **Delta Subdivision and Development Standards Bylaw No. 7162**:

- Soil depth for lawns is recommended to be a minimum of 150 mm. This should be updated to 450 mm to fulfill Metro Vancouver's new guidelines.
- Text should be added to require implementation of BMPs or set a limit to maximum outflow rates from lots to achieve runoff targets ("limiting runoff to 40% of the 1 in 2 year storm of 24 hour duration") as stated in Metro Vancouver's Baseline document (2017). The equivalent rainfall depth for Tsawwassen would be approximately 28 mm with an allowance for future climate change.
- Add in a requirement to disconnect downspouts on residential lots where infiltration capacity of the receiving soil has been confirmed to be sufficient for proper drainage.
- Add in a requirement for impervious surfaces to drain to permeable surfaces for residential lots.
- Design minor system components to the 10 year event, including a climate change allowance.
- Update IDF curves for climate change or make a note to design storm systems with an allowance for increased rainfall due to climate change.
- Require pre-treatment for hydrocarbon and sediment removal of stormwater runoff from industrial, multi-family, and commercial lots. Minimum required storage volume on these lots should be 120 m^3/hectare and maximum allowable release rate should be 21 L/s/hectare.
- Add more specific requirements and criteria on implementing stormwater BMPs (Section 5.2.16 of Drainage Schedule A), outline new requirements for residential properties.
- Reference Metro Vancouver Stormwater Source Control Design Guidelines (2012) for BMP design criteria.
- Provide clear guidance to designers as to how to incorporate climate change impacts into sizing of drainage infrastructure. Incorporation of climate change impacts in the design capacity (sizing) for

future infrastructure renewal is critical, and should be carried into asset management and capital plans immediately, even if specific projects are not yet formulated.

- Maximum acceptable runoff rates by land use should be included.
- Source control design criteria, including:
  - Maximum outflow rates per hectare of tributary area.
  - Rainfall capture targets (72% of 2-year return period, 24-hour duration rainfall, as per the draft Land Development Guidelines [DFO/MoE]).
  - Water quality objectives and a list of acceptable mechanisms to achieve these targets (bioswales, manufactured treatment units, constructed ponds/wetlands).
- Update design criteria for all open channel conveyance components, such as lowland ditches, to the 1:100 year design standard (including an allowance for climate change).
- Make reference to this ISMP and others in Delta to ensure designers take into account considerations specific to each ISMP study area.

In addition to the changes called out in this bylaw, the following bylaws in Delta will need to be revised to be consistent with the implementation strategy:

- **Delta Zoning Bylaw No. 2750:** Update to reflect new land use and development standards to minimize impervious coverage on lots and maintain native vegetation. More detailed and specific requirements should be included for areas which drain to the 12th Avenue or 3rd Avenue outfall to protect the Boundary Bay Regional Park and connected ecosystems.
- **Storm Sewers Regulation and Connection Charge Bylaw 5786:** Ensure language is provided such that downspouts can be disconnected from the storm system on existing lots and for development/redevelopment.
- **Official Community Plan Bylaw No. 3950:** Refer to ISMPs and include specific requirements on protecting against climate change impacts and implementing stormwater BMPs.
- **Soil Deposit and Removal Bylaw No. 7221:** Refer to ISMPs, ensure soil deposition is carried out in a manner to prevent stream contamination.
- **Pesticide Use Control Bylaw No. 6788:** Reference ISMPs and goals related to preventing contamination of downstream watercourses.
- Delta should create an erosion and sediment control bylaw to control releases of sediment to downstream areas and prevent negative impacts especially in the sensitive habitats of Boundary Bay Regional Park.

All bylaws related to stormwater management in Tsawwassen should refer to the ISMPs such that area specific recommendations can be enforced. See Appendix A, for descriptions of relevant content to stormwater management in these bylaws.

Delta should ensure building inspectors are trained to identify proper implementation of stormwater BMPs. For example, inspectors should identify lot grading is effectively routing runoff onto pervious surfaces and the required depth of topsoil is present.

6.1.1 Provincial

There are provincial acts which may affect the regulatory framework of stormwater management or watershed health within the study area. Those acts include the following:

- Agricultural Land Commission Act
- Dike Maintenance Act
- Drainage, Ditch, and Dike Act
- Drinking Water Protection Act
- Environment and Land Use Act
- Environmental Assessment Act
- Environmental Management Act
- Fish Protection Act
- Fisheries Act
- Integrated Pest Management Act
- Public Health Act
- Riparian Areas Protection Act
- Water Sustainability Act
- Water Protection Act

6.1.2 Federal

There are federal acts that might influence stormwater management or watershed health in the study area. Those acts include the following:

- Canada Marine Act
- Canada Water Act
- Canada Wildlife Act
- Canadian Environmental Protection Act
- International Boundary Waters Treaty Act
- Fisheries Act
- Pest Control Products Act
- Species at Risk Act

Delta should work with the Tsawwassen First Nation to develop and implement consistent stormwater management planning strategies as responsibility for the Tsawwassen area drainage encompasses both jurisdictions. Similarly, drainage from Point Roberts ends up in the study area necessitating the City liaise and coordinate with Whatcom County Authorities.

6.2 FUNDING STRATEGY

A variety of funding sources exist within the City of Delta. Applicable funding sources are discussed in more detail above.

6.2.1 Municipal Funding

Development Cost Charges (DCC) Bylaw 7560

Provides provisions for Delta to implement development cost charges to provide funds for drainage upgrades for people who obtain approval for a subdivision or building permit. Table 6-1 below outlines the DCC allotted to drainage effective January 1, 2018:

Table 6-1
Development Cost Charges Allocated to Drainage

Type of Property	Portion Allotted to Drainage	DCC Rates
Low Density	$1,643	Per dwelling units
Townhouse	$890	Per dwelling units
Apartment	$548	Per dwelling units
Congregate Care	$546	Per sleeping unit
Commercial	$5.28	Per m^2 gross floor
Industrial	$36,959	Hectare gross site
Agriculture - Intensive	$10,266	Hectare gross site

Property Taxes (Outlined in Bylaw 5751)-

Property taxes contribute to funds available for drainage related expenditures. Table 6-2 below outlines the tax rates which pertain to each property class:

Table 6-2
Portion of Tax for Drainage

Property Class	Drainage Tax Rates (dollars of tax per $1000 taxable value)
Residential	0.1253
Utilities	2.1476
Supportive Housing	0.1253
Major Industry (Excludes eligible port properties)	1.5785
Light Industry	0.4664
Business and Other	0.4824
Recreation Property/Non-profit Organization	0.4063
Farm	1.0277

Land Owners and Private Developers

Land owners and private developers do not receive City funding to implement stormwater BMPs on private property. The cost of constructing, operating and maintaining source controls, riparian area buffers, stormwater detention or retention facilities, and off-site system upgrades necessitated as part of the development is the responsibility of land owners and developers. To promote widespread application of source controls throughout the study area, the City could offer incentives to encourage the application of BMPs.

6.2.2 Incentives

One-Time Rebates

While incentive programs are relatively low-cost to the City, they do result in lost revenue that would be otherwise used on capital projects. As such, we recommend that rebate-centered incentive programs be offered on a one-time basis to promote the initial establishment of source controls and awareness of their benefits.

We recommend that the City create a Stormwater Management Rebate Program to encourage land owners and developments to construct stormwater source control measures and detention and retention systems on their properties. In the initial stages of the project the approval process for rebates should be relatively easy to meet and administer. For example, a fixed rebate of a monetary value set by the City of Delta can be offered to participating land owners who show proof of on-site stormwater management control measures. Proof can take the form of a photo or receipt for constructed works. For the program to be effective, it will be important for the City to promote the inter-related benefits of stormwater management features, such as reduced municipal water requirements for landscaping and the insulation benefits of a green roof for industrial and commercial property owners.

Once the program is established, we recommend that the approval process for rebates be more thorough to ensure proper design and installation of works. The procedure will require more effort from both the City and the participant. Rebates should no longer be fixed, but be based on compliance with the approval process and projected reduction in total annual runoff volume. For example, participants could have to satisfy a sequence of steps as follows:

1. Submit to the City the conceptual design, including design drawings, engineering calculations and/or computer modelling of the proposed works.
2. Submit to the City detailed design drawings of the proposed works.
3. Submit to the City operation and maintenance plans of the proposed works.
4. Provide the City with a construction plan and schedule.
5. Facilitate inspection and monitoring by City of Delta inspectors.

Successful completion of the program will require proper introduction to developers and a thorough understanding of the approval process by those City of Delta staff administering or involved in the program.

Community Stormwater Programs
Delta has several community based programs already in place to promote stormwater management. Delta's rain garden program focuses on installing rain gardens in and around Delta roadways and at several elementary schools (The City of Delta, 2016a, Water Sustainability Action Plan for British Columbia, 2015). The Delta School Rain Garden Program has constructed, or is in the process of constructing, rain gardens at all 14 elementary schools in Delta (Fraser Basin Council, 2016)[10]. The rain gardens are constructed with the assistance of the School District and local community groups. There is a complementary rain gardener program targeted at students in grades 4 and 5 and supported by Delta's engineering department. The school rain gardens are maintained with the assistance of local streamkeeping groups (Fraser Basin Council, 2016)[17]. Delta also allows residents to adopt a rain garden in order to improve rain garden maintenance. The City should implement these programs in Tsawwassen schools.

Delta allows residents to sign out storm drain marking kits to paint yellow fish beside storm drains (The City of Delta, 2016e)[11]. The storm drains are marked with painted fish to improve awareness among residents that pollutants flowing into the storm drains can have a negative ecological impact. This program is also supported by Fisheries and Oceans Canada (Government of Canada, 2016)[12].

Delta makes rain barrels (including screen, faucets, overflow pipe and plug) available for residents to purchase for $70 each (The City of Delta, 2016b)[13].

Finally, Delta also runs tree planting programs. The Trees for Tomorrow program allows homeowners to request that one or two trees be planted on municipal land immediately adjacent to the side or front of their properties (The City of Delta, 2016c)[14]. Urban reforestation in Delta receives capital investment. The urban reforestation project plans to plant 5000 trees in Delta parks, boulevards, and medians over 5 years (The City of Delta, 2016d)[15]. The program recognizes the role trees play in helping to reduce the amount of pollution entering creeks and irrigation ditches through runoff, as well as the important role they play in erosion control.

6.2.3 Federal Funding

The federal government provides funding for infrastructure and environmental projects primarily through Infrastructure Canada and Environment Canada.

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[10] Fraser Basin Council. (2016). *Showcasing Successful Green Stormwater Infrastructure: Lessons from Implementation.* Metro Vancouver and Victoria: Fraser Basin Council.
[11] The City of Delta. (2016e). *What You Can Do*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/green-living/what-you-can-do
[12] Government of Canada. (2016). *Fisheries and Oceans Canada*. Retrieved September 13, 2016, from pac.dfo-mpo.gc.ca: http://www.pac.dfo-mpo.gc.ca/sep-pmvs/sci-icp/stormdrain-collecteur-eng.html
[13] The City of Delta. (2016b). *Rain Barrel Program*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/services/water-sewer/water-conservation/rain-barrel-program
[14] The City of Delta. (2016c). *Trees for Tomorrow*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/trees-for-tomorrow
[15] The City of Delta. (2016d). *Urban Reforestation Project*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/urban-reforestation-project

Although typically not as readily available as municipal funding sources, we highlight below some of the programs most applicable to the type of works recommended in this ISMP.

New Building Canada Plan

The New Building Canada Plan (NBCP) is a federal government program intended to support infrastructure projects across Canada. Much of the funding is intended for projects of national, regional, or local significance, and therefore may not be accessible for the projects associated with this ISMP; however, part of the NBCP is the Federal Gas Tax Fund, intended to provide municipalities with stable and predictable funding over the next ten years to support infrastructure projects. It is allocated on a per-capita basis to all municipalities across Canada and could be used for infrastructure upgrade projects in the study area.

We anticipate that within municipal governments such as the City of Delta, competition for these funds may not allow a significant investment in independent drainage projects. We strongly recommend the City push to have stormwater BMPs included in all infrastructure projects, where practical.

EcoAction Community Funding Program

The EcoAction Community Funding Program provides funds to non-profit community-based groups.

While the City of Delta is not eligible to apply for funding, community-based groups are. Community or environmental groups may apply for funding for various environmental enhancement projects. Minor terrestrial or riparian enhancement projects, such as the removal of debris jams and management of invasive species are the most likely types of projects to have success under this arrangement, and should be promoted by the City, and encouraged where possible to improve watershed health.

Green Municipal Fund

The Green Municipal Fund (GMF) is distributed through the Federation of Canadian Municipalities (FCM), but funded by the Government of Canada. The GMF funds municipal environmental initiatives, including plans, studies, and projects. Projects in the energy, transportation, waste and water sectors undergo a competitive process and are ultimately reviewed for approval or denial by the GMF Council.

The stormwater management projects supported by the fund must manage the majority of rainfall events for a community, which is the shared objective of source controls and stormwater BMPs. The funding is therefore directly relevant to the goals of this ISMP and should be applied for as applicable.

6.2.4 Provincial Funding

The British Columbia provincial government provides funding for community and stormwater management projects through the Ministry of Community, Sport and Cultural Development. Currently, the only applicable funding source is the Infrastructure Planning Grant Program, as the funds from all other relevant programs are fully allocated.

The Infrastructure Planning Grant Program provides grants up to $10,000 to assist in the development or improvement of long-term comprehensive plans. Existing projects (such as this ISMP) are ineligible for the funding. However, further studies in particular locations of concern within the study area, could be eligible.

6.3 MONITORING AND ADAPTIVE MANAGEMENT PLAN

In order to assess the effectiveness of stormwater management within with study area, the City should monitor key metrics that indicate the condition of the watershed. These metrics will track the condition of the watershed and identify areas of improvement as well as areas of degradation. This will indicate where enhancement projects and upgrades have been successful and will also highlight areas where additional mitigation is required.

In consultation with its members, Metro Vancouver has developed a Monitoring and Adaptive Management Framework (September 2014), which provides guidance on the minimum monitoring activities and response mechanisms for ensuring that ISMPs stay "on track" in meeting their objectives. This framework does not preclude the possibility of additional monitoring effort if the particulars of a watershed make it advisable.

Tsawwassen has no significant natural watercourses, upland drainage consists of an entirely piped system, and lowland drainage is predominantly through agricultural/road side ditches. As such, Metro Vancouver recommends monitoring water quality and in the piped system and lowland ditches only. However, we think it would be advisable to monitor flow in the piped system at key locations as well to assess the effectiveness of residential BMPs. These parameters will be the key performance indicators for the watershed.

We note the currently recommended sampling interval of 5 years will make it difficult to establish norms or trends on any particular watercourse. Acquiring sufficient data to establish norms will take many sampling periods, and the significance of individual measurements will be uncertain until the degree of variability has been established.

Accordingly, we recommend that hydrometric monitoring be carried out on a continuous basis on at least one of the major storm trunks. The advantage of a continuous monitor is the ability to record the response to large and infrequent events that may be missed with a periodic monitoring program.

Grab sampling for water quality offers similar concerns. Individual samples can miss specific events, such as the first flush during the onset of a storm, or long-term averages. Continuous sampling, preferably coinciding with flow monitoring on the same watercourse, will provide a more useful data record. However, in the case of water quality sampling, periodic installation of a portable sampling device may provide sufficient data.

Metric 1 – Continuous Hydrometric Monitoring

Hydrometric data provides insight into the actual response of the watersheds to rainfall events, which in turn will provide information on the effectiveness of recommended BMPs over time. Frequent monitoring periods are required to establish a reliable record for making representative assessments. We recommend installing a permanent flow monitoring station at the outflow of the piped stormwater system at 56 Street and 6 Avenue to collect continuous data.

Measurement: Continuous water level and flow data:

Timing/Triggers: Data to be collected continuously on a permanent basis. Once every five years, data should be analysed to assess if goals are being met and parameters recommended in the AMF, as applicable to piped systems.

Goals: Mean annual flow/volumes – decrease
Peak flows and runoff volumes – decrease

Cost: $30,000 for initial setup and $5,000 annually for data collection, and maintenance.

Metric 2 – Water Quality Monitoring

Monitoring the water quality at key locations within the watersheds can provide insight into the success of the ISMP and identify areas of concern where mitigative measures may be required.

Metro Vancouver's AMF suggests water quality monitoring be done in low gradient, high gradient, and piped systems, with samples taken two periods per year – once in the dry season (July to August) and once in the wet season (November to December). The recommended sampling procedure is to collect 5 samples over a 30 day period on a weekly basis. The AMF recommends testing dissolved oxygen, temperature, turbidity, pH, conductivity, nitrate, E. coli, fecal coliforms, total iron, total copper, total lead, total zinc, and total cadmium.

Water quality monitoring should be completed at the inlet to the Brandrith Pump Station and 12th Avenue Pump Station to assess water quality in the lowland systems as well as the stormwater outlet at 56 Street and 6 Avenue to assess impacts of BMPs.

In addition to the primary constituents outlined above, Total Suspended Solids (TSS) should be monitored. Most water quality source controls are designed based on TSS removal efficiency. Therefore, information on TSS loading and removal efficiencies can assist in selecting source controls on future projects.

Testing for polycyclic aromatic hydrocarbons (PAH) is beneficial to monitor the performance of water quality devices, such as oil-water separators, but is relatively costly to implement. Without mandating stormwater source controls as a way of addressing historic contamination, the presence of PAH may not be actionable by the City. We recommend that PAH testing be completed at locations where distinct concerns are noted in the field (e.g. oily sheen on the surface of ditches, evidence of spills).

Measurement: Water quality monitoring of the following parameters:

- Dissolved oxygen
- Temperature
- Turbidity

- Total suspended solids
- pH
- Conductivity
- Nitrate
- *E. coli*
- Fecal coliforms
- Total iron, total copper, total lead, total zinc and total cadmium

Timing / Triggers: Two sampling periods per year (wet season and dry season) as per the AMF on a maximum repeated cycle of five years.

Cost: $8,000 per site per sampling period (including analysis and reporting).

Goals: Long term stability or improvement in water quality.

If the goals of the two metrics are not being met, the City should identify which stormwater and environmental BMPs have been put in place during the monitoring period. Depending on the BMPs that have been put in place, the City could review the items in the ISMP and take action on those which have not been completed, assess the enforceability of stormwater language in their bylaws, or complete an inspection program to assess degree of compliance of implementing BMPs throughout the study area.

Closure

This report was prepared for the City of Delta to identify areas in the Tsawwassen Area in which stormwater management can be enhanced or improved. The assessment of drainage and environmental conditions in the watershed as well as recommendations for best management practices and drainage upgrades forms part of the broader Integrated Stormwater Management Plan for Tsawwassen.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
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Appendix A - Background Information

This appendix contains information from the Stage 1/2 and report. The appendix is organized as follows:

Section A1 outlines aquatic and terrestrial habitat.
Section A2 outlines the drainage network components.
Section A3 outlines stormwater regulations in delta.
Section A4 outlines plans and policies related to stormwater in Delta.

A1 AQUATIC AND TERRESTRIAL HABITAT

A1.1 FRESHWATER SYSTEM

Aquatic Habitat

The Brandrith catchment consists of a major agricultural irrigation-ditch network which collects water from upland residential and commercial (i.e. golf course, mall) areas. Fish habitat quality is poor as these ditches were constructed on estuarine lands with brackish water and have been developed for agricultural purposes[3]. Ditches in this catchment have varied flows, are often stagnant, and are prone to flooding and dewatering especially at the intertidal interface[3]. Furthermore, the catchment drains to the Brandrith Pump Station, which is a barrier to upstream fish migration. A habitat assessment in this area recently concluded that there was limited value fish habitat (lack of habitat and substrate diversity) and no characteristic features of salmonid-bearing stream habitat[3]. The South Fraser Perimeter Road (SFPR) Fish Habitat Impact Assessment, assessed the 64th Street ditch in this catchment and determined that it has low to moderate productive capacity, but has potential to contribute (e.g. food nutrients and water) to downstream habitats[16].

Aquatic habitat in the 12th Avenue catchment consists primarily of a major agricultural irrigation-ditch network in the lowland which receives drainage from a primarily piped drainage system in the large upland residential and commercial area with few ephemeral channels (Watercourse B) (Map 4-1). Flows from the agricultural lowlands drain through connecting ditches and channels to the 12th Avenue Pump Station located in Boundary Bay Park which is located in the northeast corner of the catchment and encompasses a large portion of the lowland. The 12th Avenue Pump Station outlets to Boundary Bay and is not passable to fish. A natural watercourse (Watercourse A) flows through Boundary Bay Regional Park and wildlife reserve (the Park) and drains to the pump station. Watercourse A has limited value fish habitat (fine substrate, dense vegetation growth in watercourse, poor water quality[2]).

[16] Coast River Environmental Services Ltd. 2006. South Fraser Perimeter Road Fish Habitat Impact Assessment. Prepared for the Ministry of Transportation. Available Online at http://www.delta.ca/docs/default-source/downloads/tfn/south-fraser-perimeter-road-fish-habitat-impact-assessment-.pdf?sfvrsn=8. Accessed Aug 2016.

The 3rd Avenue catchment also consists of major agricultural irrigation-ditches that flow from ephemeral watercourses (Watercourses C and D). Fish habitat quality is expected to be poor as these ditches flow into piped residential areas, have poor water quality [1,2], and drain out the 3rd Avenue Pump Station (*i.e.* a barrier to fish migration) to Boundary Bay.

The Strait of Georgia catchment is almost entirely piped underground or consists of small ephemeral ditches (swales). The catchment contains no notable fish habitat characteristics.

Riparian vegetation along ditch networks and watercourses is grass or shrub dominated with remnant trees along watercourses. Common riparian species include the introduced: Reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus armeniacus*), cutleaf evergreen blackberry (*Rubus lacinatus*), hard hack (*Douglas spirea*), English ivy (*Hedera helix*), and the native Nootka rose (*Cytisus scoparius*), red osier dogwood (*Cornus sericea*), cherry (*Prunus spp.*), red alder (*Alnus rubra*), willow (*Salix spp.*), and Douglas fir (*Pseudotsuga menziesii*)[3]. Although aquatic habitats are generally of poor or very poor quality to fish, riparian vegetation improves water quality, and provides habitat for amphibians, birds and other wildlife.

Fish Species

Fish observations and capture information is sparse for the study area. Within the Brandrith catchment, the brassy minnow (*Hybognathus hankinsoni*), redside shiner (*Richardsonius balteatus*), threespine stickleback (*Gasterosteus aculeatus*), common carp (*Cyprinus carpio*), peamouth chub (*Mylo cheilus*), brown catfish (*Ameiurus nebulosus*), and longnose sucker (*Catostomus catostomus*) have been documented[17]. Within the 12th Avenue catchment, common carp, threespine stickleback, brassy minnow and redside shiner have been documented[3]. Within Watercourse A, threespine stickleback has been documented in the vicinity of the 12th Avenue pump station[18] and brassy minnow has been documented further upstream west of Boundary Bay Road, approximately 150 m north of 8th Avenue[19]. In the 3rd Avenue catchment, the only fish presence documented was the threespine stickleback[7], and no fish have been documented within the Strait of Georgia catchment.

A1.2 MARINE SYSTEM

Marine Habitat

The study area is surrounded by a marine ecosystem including Boundary Bay with its foreshore to the east, and the Strait of Georgia (Pacific Ocean) with its foreshore (generally referred to as Roberts Bank) to the west. A variety of habitats are present in these marine ecosystems and are distributed based primarily on tidal and wave action. Habitats have been mapped by the Fraser River Estuary Management Plan and

[17] City of Delta. 2003. Fish and Amphibian in Delta British Columbia: Species Occurrence and Habitat Utilization Study. 2001-2003 Data Report.
[18] British Columbia Ministry of Environment (MOE). 2016. Habitat Wizard database. Available at: www.env.gov.bc.ca/habwiz. Accessed Aug 2016.
[19] Community Mapping Network. 2015. Fraser River Estuary Management Program – Burrard Inlet Environmental Action Program. Available at: http://www.cmnbc.ca/atlas_gallery/fremp-bieap-habitat-atlas. Accessed Aug 2016.

Burrard Inlet[8] (Map 4-1). The marine ecosystems surrounding the study area include the following intertidal habitat types at the community level:

- Marsh (Brandrith catchment, 12th Avenue catchment)
- Sandflats (All catchments)
- Eelgrass (All catchments)
- Mudflats (12th Avenue catchment)

In addition to these habitat types, marsh habitats in the Brandrith and 12th Avenue catchments include several dendritic, tidally influenced channels connecting nearshore areas to other habitat types further offshore.

Eelgrass and sandflats are the most abundant habitat type and are present along most of the shoreline areas bordering the study area. Eelgrass is particularly abundant along the western coastline in offshore area adjacent to the Brandrith Pump station, and Strait of Georgia catchment.

The distribution and variety of these habitats form a marine ecosystem which provides highly diverse and valuable habitats for numerous fish and wildlife species. For example, eelgrass provides habitat for a variety of marine invertebrates and fish that are dependent on eelgrass beds for shelter, foraging and breeding habitat. These species, in turn, provide a food source for marine birds, migrating and wintering shorebirds, larger fish species, and marine mammals, and form an integral part of the larger ecosystem. Because of this, Boundary Bay and Roberts Bank have been designated as Wildlife Management Areas (WMA[20]) by the province of BC.

Fish Species

Marine fish documented in the Roberts Bank subtidal and intertidal habitats include at least 72 different species[6]. An intertidal forage fish spawning habitat study for the Boundary Bay Park beach determined that the beach was high quality spawning habitat for surf smelt (*Hypomesus pretiosus*) and Pacific sand lance (*Ammodytes hexapterus*)[21]. Surf smelt are an important part of the diet of the provincially blue-listed coastal cutthroat trout (*O. clarkii clarkii*) and bull trout (*Salvelinus confluentus*), and Pacific sand lance makes up a considerable proportion of the essential diet for juvenile salmon and the majority of the diet of Chinook salmon (*Onchorynchus tshawytscha*)[7]. Salmonid species previously documented in the marine habitat include juvenile pink (*O. gorbuscha*), chum (*O. keta*), Chinook, and cutthroat trout[4,6].

A1.3 TERRESTRIAL ENVIRONMENT

A summary of the terrestrial wildlife and vegetation in the study area is provided in this section. This includes the identification of typical wildlife and vegetation species and a list of rare or endangered wildlife

[20] Ministry of Environment. 2011. Parks and Protected Areas. Available at http://www.env.gov.bc.ca/lower-mainland/wildlife/recreation/park_areas.htm Accessed Aug 2016

[21] de Graaf, R.C. 2008. Boundary Bay Intertidal Forage Fish Spawning Habitat Project. Prepared for Friends of Semiahmoo Bay Society. Prepared by Emerald Sea Research & Consulting.

and plants that are known to occur in the area. This section is based on a desktop review of existing terrestrial conditions in the community of Tsawwassen and the Tsawwassen First Nation reserve, and incorporates terrestrial planning objectives from relevant documents to support the ISMP.

Information presented for the terrestrial environment was assembled from the following sources:

- *Tsawwassen First Nation Integrated Rain Water Management Plan – Environmental Overview*[22];
- *The City of Delta Official Community Plan – Schedule D.1: Tsawwassen Area Plan*[23];
- B.C. Conservation Data Centre Species and Ecosystems Explorer for potential occurrence of listed species[24]; and
- Government of British Columbia iMapBC database for known occurrences of listed species[25].

Land Use and Vegetation

The study area is located within the Moist Maritime Coastal Douglas-fir (CDFmm) biogeoclimatic zone[26], and is characterized by warm, dry summers and mild, wet winters. The study area has been altered from its natural condition by agricultural activities, community development, and municipal infrastructure. The vegetation in the area is heavily influenced by the maritime climate of the region. In general, the terrestrial environment of the study area can be defined under the following ecosystem classes:

- Agricultural;
- Forest, hedgerow, and riparian;
- Intertidal / mudflats; and
- Commercial / residential.

Agricultural lands in the study area are found in the Brandrith, 12th Avenue, and 3rd Avenue catchments. These lands are either fallow (dormant) or cropped and consist of tilled fields of grains, cereals, or vegetables[27] . Fallow fields are commonly dominated by grass and forb species. Although these areas are disturbed from their natural condition, they provide a permeable landscape for water and are often large in size.

Forest, hedgerow, and riparian areas in the study area are found in the Brandrith and 12th Avenue catchments, and consist of forest, shrub, or forb dominated lands. Forest areas are surrounded by agricultural, urban area, or commercial / residential development, and are fragmented from one another unless connected by a riparian corridor. Riparian corridors in the study area are often treed, with a dense shrub and forb dominated understorey. Hedgerows, typically trees and shrubs, are found alongside roads, ditches, and between fields. Common tree species in this ecosystem type include Douglas-fir, red alder,

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22 Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.
23 Schedule D.1: Tsawwassen Area Plan. Available on the internet at: https://delta.civicweb.net/filepro/documents/37999
24 BC Conservation Data Centre available online at: http://a100.gov.bc.ca/pub/eswp/
25 iMapBC available online at: http://maps.gov.bc.ca/ess/sv/cdc/
26 Meidinger, D.V., and J. Pojar. 1991. *Ecosystems of British Columbia*. Research Branch. Special Report Series. Available on the Internet at: https://www.for.gov.bc.ca/hfd/pubs/Docs/Srs/Srs06.htm
27 Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.

paper birch, and western redcedar. Common shrub species include salal, tall Oregon grape, Himalayan blackberry, hard hack, English ivy, re-osier dogwood, willow, red elderberry and salmonberry. Common herb layer species include reed canarygrass, lady fern (*Athyrium filix-femina*), spiny wood fern (*Dryopteris expansa*), and skunk cabbage (*Lystichiton americanus*) in wetter sites. Forest, hedgerow, and riparian ecosystems are important in surface water flow and ground water retention as they capture and slow surface and ground water flow across the landscape.

Intertidal / mudflats are found on the shoreline of Boundary Bay and Roberts Bank. These areas are sparsely vegetated and heavily influenced by the changing tides. Ecosystems associated with the intertidal / mudflat areas are herb and forb dominated meadows, beach dunes, and saltgrass marsh. Common species found in the intertidal / mudflat areas include saltgrass species, salal, and reed canarygrass. A small wetland ecosystem is situated just south of Tsawwassen Drive South (UTM Zone 10U 492594, 5430288). Intertidal / mudflat ecosystems are important in water capture because they provide large expanses of permeable ground surface. Wetland ecosystems are important because they capture, retain, and improve water quality through natural filtration processes.

Commercial / residential areas are prominent and fragment the continuity of vegetated ecosystems across the study area. They are found throughout the study area, and are most highly concentrated in the 12th and 3rd Avenue catchment areas. Commercial / residential areas are characterized by hard surface development (i.e., roads, buildings) and are commonly impermeable, with patchy, fragmented green space along road sides and on private properties. Trees and shrubs growing in commercial / residential areas are a mix of native and cultivated species, within manicured lawns. These areas provide some connectivity of green space, but typically only in the tree canopy layer (i.e., ground cover is highly fragmented by roads and buildings). Two golf courses occur in the study area (Beach Grove Golf Course and Tsawwassen Springs Golf Course) and have patchy forest and shrubs with extensive areas of grass. Commercial / residential areas are largely hard surface, promoting surface water runoff and concentrating flows to ditches and storm water systems; however, green spaces with permeable surfaces within these areas capture water and return it to the ground water system.

Because of the mild and moist maritime climate, the study area has potential to support 104 provincially listed plant species. Two of those species have been identified near the study area and are federally listed under Schedule 1 of the Species at Risk public registry (Table A-1).

Table A-1
Federally Listed Plant Species Known to Occur Within 20 km of the Study Area

Common Name	Scientific Name	Habitat	BC List	SARA List
Streambank lupine	*Lupinus rivularis*	Along creeks and streambanks in sandy/gravelly substrates	Red	1- E (2002)
Vancouver Island beggarticks	*Bidens amplissima*	Wetland and shoreline areas with fluctuating water levels	Blue	1-SC (2001)

Source: Conservation Data Centre iMapBC database. available online at: http://a100.gov.bc.ca/pub/eswp/

[1] Red-listed species are indigenous species that are Extirpated, Endangered, or Threatened in B.C. Blue-listed species are indigenous species considered to be of Special Concern in B.C.

[2] E = Endangered: species facing imminent extirpation or extinction; T = Threatened: species that is likely to become endangered if limiting factors are not reversed; SC = Special Concern: species of special concern because of human activities or natural events.

Wildlife

The study area is rich in wildlife biodiversity, most notably for birds. Located along the Pacific Flyway, a major migratory corridor for birds, the study area has been described as part of a vital link for birds migrating on the Pacific Flyway. Habitat in the area provides suitable nesting, foraging, breeding, and overwintering habitat requirements for many species.

The Fraser River delta has been designated an Important Bird Area because it provides habitat for globally threatened bird species, birds with restricted breeding ranges, or globally limited breeding, wintering, and/or migratory bird habitat. The delta is important for its value in providing critical life requisites for species such as: trumpeter swans (*Cygnus buccinators*), tundra swans (*C. columbianus*), lesser snow geese (*Chen caerulescens*), Brandt's cormorant (*Phalacrocorax penicillatus*), and Atlantic brandt (*Branta bernicla*). Great blue herons (*Ardea herodias*) and shorebirds such as western sandpipers (*Calidris mauri*), dunlins (*Calidris alpina*), and black-bellied plovers (*Pluvialis squatorola*) are also reliant on these intertidal areas. Table 4-3 summarizes the list of birds observed during field surveys conducted near the study area[28].

The Boundary Bay Regional Park (on the foreshore of Boundary Bay in the 12th Avenue catchment) is an area that has provincial protection as a wildlife management area (WMA). No public access is permitted in this WMA, and it is an area important to migratory birds and for its value to overwintering birds. Similarly, the Roberts Bank WMA is an area of intertidal and nearshore subtidal habitat in the Fraser River delta. Intertidal habitats attract large numbers of shorebirds, ducks, gulls, herons, and birds of prey.

[28] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.

Table A-2
Bird Species Observed in the Study Area

Common Name	Scientific Name	Common Name	Scientific Name
Mallard	Anas platyrhynchos	American pipit	Anthus rubescens
Ring-necked pheasant	Phasianus colchicus	Orange-crowned warbler	Oreothlypis celata
Great blue heron	Ardea herodias	Spotted towhee	Pipilo maculatus
Bald eagle	Haliaeetus leucocephalus	Savannah sparrow	Passerculus sandwichensis
Northern harrier	Circus cyaneus	Fox sparrow	Passerella iliaca
Cooper's hawk	Accipiter cooperii	Song sparrow	Melospiza melodia
Red-tailed hawk	Buteo jamaicensis	Lincoln's sparrow	Melospiza lincolnii
Rough-legged hawk	Buteo lagopus	White-crowned sparrow	Zonotrichia leucophrys
Black-bellied plover	Pluvialis squatarola	Golden-crowned sparrow	Zonotrichia atricapilla
Killdeer	Charadrius vociferus	Dark-eyed junco	Junco hyemalis
Dunlin	Calidris alpina	Red-winged blackbird	Agelaius phoeniceus
Downy woodpecker	Picoides pubescens	Western meadowlark	Sturnella neglecta
Northern flicker	Colaptes auratu	Brewer's blackbird	Euphagus cyanocephalus
Northwestern crow	Corvus caurinus	House finch	Carpodacus mexicanus
Black-capped chickadee	Poecile atricapillus	American finch	Spinus tristis
Bewick's wren	Thryomanes bewickii	House sparrow	Passer domesticus
Winter wren	Troglodytes troglodytes	American wigeon	Anas americana
Marsh wren	Cistothorus palustris	Black-headed grosbeak	Pheucticus melanocephalus

Common Name	Scientific Name	Common Name	Scientific Name
Golden-crowned kinglet	Regulus satrapa	Green-winged teal	Anas crecca
American robin	Turdus migratorius	Short-eared owl	Asio flammeus
European starling	Sturnus vulgaris	Trumpeter swan	Cygnus buccinator

Source: *Tsawwassen First Nation Integrated Rainwater Management Plan*

Wildlife habitat in the study area is also suitable for small-to-large mammals, amphibians, reptiles, and turtles. Mice, voles, and adult amphibians will use habitats in the fallow or cropped agricultural fields and riparian areas in the 12th and 3rd Avenue and Brandrith catchments for forage or cover. These areas provide good hunting opportunities for birds of prey in the area, such as Cooper's hawk or red-tailed hawk in search of small mammals. Agricultural fields also provide good forage and cover opportunities for deer (*Odocoileus sp.*) and deer may be found throughout the study area, including the commercial / residential areas of the 12th Avenue catchment.

Forest, hedgerow, and riparian ecosystems provide suitable habitat for deer, as well as nesting and perching habitat for raptors, owls, and song birds. Riparian corridors are important habitats for wildlife movement across the landscape because they provide good cover and suitable forage for a wide range of species. The Pacific water shrew (*Sorex bendirii;* listed as Endangered under Schedule 1 of SARA) is known to occur within 20 km of the study area, and may be found in riparian or wetland habitats. Reptiles and amphibians will both occupy riparian habitats. The federally listed northern red-legged frog (*Rana aurora*) and painted turtle (*Chrysemys picta*) are known to occur within 20 km of the study area, and may be found in riparian or wetland ecosystems. Racoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) are known to use forested, hedgerow, riparian, and residential habitats for forage, cover, and movement. There is critical habitat under the Species at Risk Act for the Oregon forest snail (*Allogona townsendiana)* in the Southlands forest area.

Based on a search of the Conservation Data Centre Species and Ecosystems Explorer[29], 91 provincially listed wildlife species have potential to occur in the study area. The results of the Conservation Data Centre search for occurrences of federally listed wildlife species within 20 km of the study area is presented in Table A-3.

[29] Search query was area based for CDF biogeoclimatic zone and habitats found in the Study Area.

Table A-3
Federally Listed Wildlife Species Known to Occur Within 20 km of the Study Area

Species Group	Common Name	Scientific Name	Habitat	BC List	SARA List
Birds	Great blue heron, fannini subspecies	Ardea herodias fannini	Estuarine, Riparian	Blue	1-SC (2008)
Mammal	Pacific water shrew	Sorex bendirii	Riparian, Wetland	Red	1-E (2016)
Amphibian	Northern red-legged frog	Rana aurora	Riparian, Meadow, Wetland	Blue	1-SC (2015)
Turtle	Painted turtle – Pacific coast population	Chrysemys picta pop. 1	Riparian, Wetland	Red	1-E (2006)
Invertebrate	Dun skipper	Euphyes vestris	Forest, Agricultural, Meadow	Red	1-T (2013)
	Oregon forestsnail	Allogona townsendiana	Forest, Riparian, Wetland	Red	1-E (2005)

Source: Conservation Data Centre iMapBC database.

[1] Red-listed species are indigenous species that are Extirpated, Endangered, or Threatened in B.C. Blue-listed species are indigenous species considered to be of Special Concern in B.C.

[2] E = Endangered: species facing imminent extirpation or extinction; T = Threatened: species that is likely to become endangered if limiting factors are not reversed; SC = Special Concern: species of special concern because of human activities or natural events.

A2 DRAINAGE NETWORK

The drainage network for the study area was assembled based on the City of Delta's GIS data and our knowledge of the study area.

A2.1 CATCHMENTS

The study area is divided into four catchments based on the areas contributing to Brandrith Pump Station, 12th Avenue Pump Station and 3rd Avenue Pump Station and the areas discharging to the Strait of Georgia.

For the purpose of this stormwater system analysis within ISMP, we divided the study area into 60 subcatchments (Map 2-3). The subcatchments in the urban areas were delineated based on areas contributing to major storm trunks (450 mm and larger) and a minimum area of approximately 20 ha for the majority of the subcatchments, which is an appropriate scale for a planning-level assessment.

A2.2 STORM DRAINS

Major storm drainage pipes, generally 450 mm diameter and larger, were identified and are shown on Map 2-3. These storm drains are predominantly located in the 12th Avenue catchment, and the remaining are in the 3rd Avenue catchment and Strait of Georgia catchment.

During model assembly, we made reasonable assumptions for the invert elevations of pipes with missing information based on nearby pipe inverts for hydraulic modelling. We took the following approach for missing data:

- If a pipe outlet invert elevation is missing and its downstream pipe inlet elevation is known, we used the downstream pipe inlet invert elevation for the missing invert data.
- If the above approach could not be taken, we assumed the pipe inverts based on the ground elevation (1-1.5 m below ground).

12th Avenue Catchment

On the north of 8a Avenue, two major drainage pipe alignments run east to west; along 12th Avenue and generally along 10a Avenue. These two lines interconnect at 50b Street via 51st Street and Ferguson Road. The 12th Avenue drainage pipes generally collect runoff from the 12th Avenue subcatchments north of 12th Avenue, and the 10a Avenue storm trunk collects runoff from the 12th Avenue subcatchments between 12th Avenue and 8a Avenue.

The storm network at the intersection of 12th Avenue and Ferguson Road where the two trunk lines tie in is complex. Downstream of the two lines, the flow is split into a gravity line which discharges into the channel upstream of the 12th Avenue Pump Station and a siphon line of varying pipe diameters from 750 mm to 1,350 mm which discharges to the foreshore. The 8a Avenue storm trunk discharges to open channel before it enters the storm pipe on 12th Avenue.

On the south of 8a Avenue, two major storm pipe alignments run east to west; generally, along immediately south of 8a Avenue and 6th Avenue. The 8a Avenue storm trunk generally collects runoff from the catchment area between 8a Avenue and 6th Avenue. The 6th Avenue storm trunk generally collects runoff from the catchment area south of 6th Avenue.

A storm main along 4th Avenue collects runoff from the area between 4th Avenue and 2nd Avenue and discharges to the Southlands area via 56th Street.

A storm trunk along Boundary Bay Road is currently proposed as part of our 12th Avenue Drainage Improvements project for The City of Delta.

3rd Avenue Catchment

The main storm trunk in the 3rd Avenue catchment follows the road alignment of 3rd Avenue. The storm drains to the 3rd Avenue Pump Station and discharges to Boundary Bay via 750 mm diameter CSP and HDPE drainage pipe.

Strait of Georgia

The Strait of Georgia catchment has three stormwater outfalls. They include the two outfalls north of 8a Avenue on TFN lands that drain the catchment area west of 48 and north of 8a Avenue, and the outfall at the US boarder that drains the area in the vicinity of English Buff Rd and US boarder.

In addition to the drainage outfalls, the hillside area west of English Buff Road drain directly to Strait of Georgia.

A2.3 CULVERTS

Using available data and mapping, we identified 39 culverts in the study area. Of these culverts, 29 culverts are Delta's responsibility and 10 culverts are within the Ministry of Transportation and Infrastructure's (MoTI) jurisdiction (i.e. Highway 17). The culvert inventory is presented as Table A-4 below. We note that the GIS data provided by Delta in the Highway 17 did not reflect the recent changes associated with the TFN developments and we updated the culvert data based on our IFC design drawings for the Highway 17 Tsawwassen Drive to 56th Street project (AE, 2014).

Table A-4
Culvert Inventory for Study Area

Culvert ID	Dimension (mm)	Number	Material	Road or local	Catchment	Notes/Description
1	1,800	1	HDPE	48th Street	Brandrith	
2	1,500	1	concrete	48th Street	Brandrith	
3	200	1	concrete	48th Street	Brandrith	
4	900	1	concrete	52nd Street	Brandrith	
5	400	1	concrete	52nd Street	Brandrith	
6	1,200	1	HDPE	52nd Street	Brandrith	
7	900	1	CSP	52nd Street	Brandrith	driveway
8	600	1	CSP	52nd Street	Brandrith	driveway
9	525	1	CSP	52nd Street	Brandrith	driveway
10	600	1	CSP	52nd Street	Brandrith	driveway

Culvert ID	Dimension (mm)	Number	Material	Road or local	Catchment	Notes/Description
11	600	1	CSP	52nd Street	Brandrith	driveway
12	1200	1	CSP	56th Street	Brandrith	north of Highway 17
13	900	1	concrete	56th Street	Brandrith	south of Highway 17
14	525	1	concrete	56th Street	Brandrith	driveway culvert
15	900	1	CSP	56th Street	Brandrith	driveway culvert
16	900	1	CSP	56th Street	Brandrith	driveway culvert
17	600	1	concrete	56th Street	Brandrith	driveway culvert
18	600	1	concrete	56th Street	Brandrith	driveway culvert
19	600	1	concrete	56th Street	Brandrith	
20	600	1	concrete	56th Street	Brandrith	crosses 21st Avenue at 56th Street
21	750	1	concrete	56th Street	12th Ave.	
22	1,200	1	HDPE	Highway 17	Brandrith	
23	1,800	1	CSP	Highway 17	Brandrith	
24	1,200	1	CSP	Highway 17	Brandrith	
25	600	1	CSP	Highway 17	Brandrith	
26	900	1	CSP	Highway 17	Brandrith	
27	900	1	CSP	Highway 17	Brandrith	
28	600	1	CSP	Highway 17	Brandrith	
29	600	1	CSP	Highway 17	Brandrith	
30	500 X 1200	2	concrete box	Boundary Bay Road	12th Ave.	east of 56th Street.
31	1,200	1	concrete	Boundary Bay Road	12th Ave.	utility access on west ditch
32	1,200	1	concrete	Boundary Bay Road	12th Ave.	utility access on west ditch
33	1,200	1	CSP	Miscellaneous Lowlands	Brandrith	
34	1,500	2	concrete	Miscellaneous Lowlands	Brandrith	
35	1,050	1	concrete	Miscellaneous Lowlands	Brandrith	

Culvert ID	Dimension (mm)	Number	Material	Road or local	Catchment	Notes/Description
36	600	1	PVC	Miscellaneous Lowlands	Brandrith	
37	2,200	3	CSP	Miscellaneous Lowlands	12th Ave.	discharge directly to Boundary Bay
38	1,200	1	concrete	Miscellaneous Lowlands	12th Ave.	on the current Southlands central ditch
39	1,200	1	concrete	Miscellaneous Lowlands	12th Ave.	on the current Southlands central ditch

48th Street

48th Street runs north-south on TFN lands and has 1 crossing culvert and 2 driveway culverts. A 1,800 mm diameter HDPE (Culvert 1) crosses the new 48th Street at Highway 17. The two driveway culverts are located north of Highway 17 and include a 1,500 mm diameter concrete culvert (Culvert 2) and 1,200 mm diameter concrete culvert (Culvert 3).

52nd Street

52nd Street between 12th Avenue and 28th Avenue is classified as Collector Road and it is one of the major roads in the study area. There are 3 crossing culverts; 900 mm diameter concrete (Culvert 4) and 400 mm diameter concrete (Culvert 5) and 1,200 mm diameter HDPE (Culvert 6), and 5 driveway culverts along 52nd Street; 900 mm diameter CSP (Culvert 7), 600 mm diameter CSP (Culvert 8), 525 mm diameter CSP (Culvert 9), 600 mm diameter CSP (Culvert 10) and 600CSP (Culvert 11).

56th Street

56th Street is the largest road in the study area, classified as Arterial Road, after Highway 17, and runs north-south from 28th Avenue to U.S. border.

In the Brandrith catchment, 56th Street has two crossing culverts; 1200 mm CSP (Culvert 12) north of Highway 17 and 900 mm concrete (Culvert 13) south of Highway 17. There are three driveway culverts along 56th Street north of Highway 17; 525 mm diameter concrete (Culvert 14) on the west side of 56th Street and two 900 mm CSP culverts (Culverts15 and 16) in series on the east side of 56th St.

There are two 600 mm diameter concrete driveway culverts in series (Culverts 17 and 18) along 56th Street south of Highway 17 on the west side of 56th Street. A 600 mm concrete diameter culvert (Culvert 19) along 56th Street provides continuity of the ditch around a fire hydrant. Another 600 mm diameter concrete culvert (Culvert 20) crosses 21st Avenue south of Highway 17. In the 12th Avenue catchment, a 750 mm diameter concrete culvert (Culvert 21) crosses 56th Street between 4th Avenue and 6th Avenue.

Highway 17

Highway 17 bisects the Brandrith catchment diagonally. The highway has seven culvert crossings. They include a 1,200 mm diameter HDPE (Culvert 22) and a 1,800 mm diameter CSP (Culvert 23) in parallel at 48th Street, a 1200 mm diameter CSP culvert (Culvert 24) at 52nd Street, a 600 mm diameter CSP (Culvert 25) between 52nd Street and 56th Street, a 900 CSP (Culverts 26) immediately west of 56th Street, a 900 CSP (Culvert 27), 600 CSP (Culvert 28) and 600 CSP (Culvert 29) east of 56th Street.

We note that the GIS data provided by Delta in the Highway 17 area is outdated and we updated the culvert data based on our IFC design drawings for the Highway 17 Tsawwassen Drive to 56th Street project (AE, 2014).

Boundary Bay Road

Boundary Bay Road defines the west boundary of Boundary Bay Regional Park and has one culvert crossing near 12th Avenue which consists of twin 500 mm x 1,200 mm box culverts (Culvert 30). This culvert conveys the majority of runoff from the 12th Avenue catchment area.

Along the west ditch of Boundary Bay Road, there are two culverts, 1,200 mm diameter concrete (Culvert 31) and 1,200 mm diameter concrete (Culvert 32) between 8a Avenue and 12th Avenue. They are not driveway culverts and we suspect they were constructed to maintenance access to utilities.

Lowlands

In addition to the culverts at major streets and highway, we identified culverts that are located in the lowlands.

In the Brandrith catchment, the lowland culverts include a 1200 mm diameter CSP (Culvert 33) north of Highway 17 between 52nd Street and 56th Street, a 1,500 mm diameter concrete (Culvert 34) crosses Springs Blvd south of Highway 17 and east 48th Street, 1,050 mm diameter concrete (Culvert 35) downstream of highway crossing culvert (Culver 27) and twin 600 PVC culverts (Culvert 36) north of 17A Avenue and east 56th Street.

In the 12th Avenue catchment, triplet 2,200 mm CSP culverts (Culvert 37) discharge directly to Boundary Bay. Other culverts include two 1,200 mm diameter concrete culverts (Culverts 38 and 39) along the main ditch that runs south to north in Southlands.

A2.4 PUMP STATIONS

The study area has four pump stations; Brandrith Pump Station, Beach Grove Pump Station, 12th Avenue Pump Station and 3rd Avenue Pump Station.

Brandrith Pump Station

The Brandrith pump station was originally built to accommodate runoff from a predominantly agricultural area in the mid-1980s. The station was upgraded in 1999 to increase pumping capacity. Until recently, the Brandrith pump station contained two vertically arranged 1.4 m^3/s submersible axial-flow pumps and one 0.3 m^3/s jockey pump, delivering a total capacity of approximately 3 m^3/s. The Brandrith Pump station has recently been upgraded to a total capacity of 5.4 m^3/s in order to accommodate increased flows from the TFN developments.

Beach Grove Pump Station

Beach Grove pump station located on 19th Avenue near 56th Street receives runoff from a portion of the Beach Grove subdivision, east of 56th Street between 12th Avenue and 17A Avenue. The pump station is an internal drainage pump station within the Brandrith catchment. The pump station discharges to a 1,200 mm concrete storm pipe. Record drawing indicates that the pump starts at 2.04 m and shuts off at 1.01 m. The capacity of this pump station is unknown at this time.

12th Avenue Pump Station

12th Avenue Pump Station, located on 12th Avenue at Boundary Bay, receives runoff from a significant portion of the uplands area. The pump station discharges to Boundary Bay via 600 mm diameter steel pipe. The outlet of the pipe has a flap gate.

The existing 12th Avenue Pump Station consists of two 0.35 m^3/s capacity pumps and one 0.95 m^3/s capacity pump, resulting in the existing total pump capacity of 1.65 m^3/s.

Under the parallel 12th Avenue Drainage Improvements project, Associated Engineering is currently engaged with Delta to upgrade the 12th Avenue Pump station to a proposed initial total capacity of 4.5 m^3/s.

3rd Avenue Pump Station

3rd Avenue Pump Station is located on the northwest corner of the intersection of 3rd Avenue and 67A Street. The pump station receives runoff via a 900 mm diameter concrete pipe and dischargers into 750 mm diameter pipe via a 1200 mm x 3050 mm (H x V) culvert.

The pump station was upgraded to a pumping capacity of 0.8 m^3/s in 2002.

A3 STORMWATER REGULATIONS IN DELTA

Several bylaws, acts, and regulations influence stormwater management and watershed health within the study area. Delta and Metro Vancouver bylaws apply throughout the study area with the exception of the Tsawwassen First Nation (TFN) lands. Tsawwassen First Nation's plans, policies and regulations apply within their lands. TFN is also a member of Metro Vancouver and if they complete an entry agreement with the Metro Vancouver Sewerage and Drainage District (MVS&DD) then Metro Vancouver bylaws would apply within TFN lands.

The Fraser River Estuary Management Program (FREMP) previously had jurisdiction over the receiving water bodies and shorelines of the study area; however, FREMP was shut down in 2013. Many of FREMP's responsibilities were transferred to the Vancouver Fraser Port Authority (Port Vancouver). However, the study area is not in their jurisdiction.

Delta's 1989 Stormwater Management Design Manual[30] has been replaced by more recent regulations and policy such as Delta Subdivision and Development Standards Bylaw No. 7162. Finally, many federal and provincial acts have bearing on stormwater management in the Tsawwassen area.

A3.1 CITY OF DELTA

Delta Official Community Plan Bylaw No. 3950[31], 1985, Consolidated March 2015
This bylaw sets out policies for future development within Delta. Schedules A, D, and E are of particular importance to this ISMP and are discussed at length in section 0.

Delta Development Permit Area to Establish Streamside Protection and Enhancement Areas Bylaw No. 6349[32], 2005
This bylaw amends The City of Delta Official Community Plan bylaw (it is an addition to Schedule E) to establish protection areas for watercourses or sources of water. This bylaw is designed to "preserve, protect, restore, and enhance fish and wildlife, and their habitats, in and along streams." This is achieved by setting development standards that protect riparian areas and natural drainage patterns. The protection extends to ponds, lakes, rivers, creeks, brooks, ditches, springs, and wetlands. Watercourses may be considered whether or not they usually contain water. The streamside protection and enhancement area can extend anywhere from 5 to 30 m from the stream bank or top of a ravine depending on the streamside vegetation conditions.

Delta Subdivision and Development Standards Bylaw No. 7162[33], 2015
This bylaw sets development and design standards. Section 6 as well as Schedules A, B, and C are important components of the stormwater policy framework.

Section 6 pertains to water, sanitary sewers and drainage works and services. It includes an allowance for open ditch drainage systems in areas with agricultural zoning.

Schedule A specifies many design standards for the stormwater system, including storm mains (5.2.4), ditches (5.2.8), and culverts (5.2.9).

[30] Dayton & Knight Consulting Engineers. (1989). City of Delta Stormwater Management Design Manual. Delta: City of Delta.
[31] The City of Delta. (1985). The City of Delta Offifical Community Plan Bylaw No. 3950. Consolidated March 2015.
[32] The City of Delta. (2005). Delta Development Permit Area to Establish Streamside Protection and Enhancement Areas Bylawy No. 6349.
[33] The City of Delta. (2015b). Delta Tree Protection and Regulation Bylaw No. 7415.

- Clause 5.2.3 includes the regulation that the design of a drainage system should not cross the boundaries shown on Delta's master drainage plan.
- Clause 5.2.12 in Schedule A states that all proposals for works affecting natural watercourses must be forwarded to the British Columbia Ministry of Environment (Fish and Wildlife Branch and Water Management Branch) as well as other applicable provincial and federal (e.g. Fisheries and Oceans Canada) agencies. Schedule A also encourages the use of stormwater best management practices (BMPs) to improve the quality of stormwater runoff, prevent surface drainage from flowing to adjacent lands, and reduce stormwater volumes.
- Clause 5.2.17 specifies design standards for many BMPs including absorbent landscapes, pervious paving, green roofs, on-site rain gardens, roadside swales, roadside rain gardens, roadside infiltration trenches, and street edge alternatives (Note: The use of stormwater BMPs is also discussed in Kerr Wood Leidal (2005)[34]. There are also several restrictions on the use of BMPs in the Tsawwassen area. Pervious paving, roadside swales, roadside rain gardens, and roadside infiltration trenches are not permitted in Tsawwassen English Bluff unless approved by the director of engineering. Roadside swales and roadside infiltration trenches are not recommended for Tsawwassen Central or Tsawwassen Boundary Bay Flat unless soil infiltration rates are demonstrated to be greater than 5 mm/hr or they are otherwise approved by the director of engineering).

Schedules B and C of the Delta Subdivision and Development Standards Bylaw contain supplementary specifications and supplementary drawings and maps respectively.

Delta Zoning Bylaw No. 2750[35], 1977, Consolidated December 2015
The Delta Zoning Bylaw sets standards for land use and development in the Tsawwassen area for each zoning category. It includes regulations pertaining to land use, landscaping, and construction including the types of facilities that may be constructed and how they are to be sited (including setback requirements). There are also regulations related to parking requirements and lot coverage. The zoning regulations have a significant impact on development density and the resulting impervious coverage.

Delta Storm Sewers Regulation and Connection Charge Bylaw No. 5786[36], 2000
This bylaw pertains to the use of storm sewers and applies connection charges to defray the cost of constructing piped drainage systems. The bylaw also states only unpolluted drainage waters should be discharged into the storm system.

Delta Soil Deposit and Removal Bylaw No. 7221[37], 2014
The Soil Deposit and Removal Bylaw identifies soil as an important resource in Delta. It imposes a permit requirement for the deposit or removal of soil on lands from Delta with some specified exemptions.

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[34] Kerr Wood Leidal. (2005). *Stormwater Best Management Practices Integration Plan.* The City of Delta.
[35] The City of Delta. (1977). Delta Zoning Bylaw No. 2750. *Consolidated December 2015*.
[36] The City of Delta. (2000). Delta Storm Sewers Regulation and Connection Charge Bylaw No. 5786.
[37] The City of Delta. (2014). Delta Soil Deposit and Removal Bylaw No. 7221.

Delta Tree Protection and Regulation Bylaw No. 7415[38], 2015
With specified exceptions, this bylaw sets a permit requirement for any person to cut or otherwise cause the death of a tree. The bylaw also prohibits tree damaging activities and specifies measures for tree protection during development and construction.

Delta Pesticide Use Control Bylaw No. 6788[39], 2009
With specified exemptions, this bylaw prohibits the use of pesticides for the purpose of maintaining outdoor trees, shrubs, flowers or other ornamental plants, and turf on private or public lands within Delta.

A3.2 METRO VANCOUVER

Metro Vancouver bylaws apply to the study area; however, Metro Vancouver's role in governance related to stormwater management is generally more limited than that of the municipalities. Metro Vancouver most commonly provides policy guidance and assists the member municipalities with planning. The Stormwater Interagency Liaison Group (SILG) assists municipalities with sharing knowledge and experience related to sustainable stormwater management (Metro Vancouver, 2016b)[40]. Metro Vancouver also enforces the Integrated Liquid Waste Resource Management Plan (ILWRMP) to its member municipalities. This plan is the underlying mechanism for reviving development and implementation of ISMP.

Greater Vancouver Regional District Bylaw No. 1136[41], 2010
A bylaw to adopt a regional growth strategy for the Greater Vancouver Regional District (GVRD). The regional growth strategy for Metro Vancouver places a high level of importance on sustainability and maintaining a healthy natural environment. The plan outlines the following five goals:

- Create a compact urban area
- Support a sustainable economy
- Protect the environment and respond to climate change impacts
- Develop complete communities
- Support sustainable transportation choices

The regional growth plan links with other GVRD plans for housing, air quality, solid waste, finance, water, food systems, liquid waste, and parks and greenways. The development and expansion of sewerage services is discouraged in rural, agricultural, or conservation and recreation areas. The regional growth strategy promotes the development of integrated stormwater management plans.

Greater Vancouver Regional District Regional Parks Regulation Bylaw No. 1177[42], 2012, Consolidated April 2015

[38] The City of Delta. (2015b). Delta Tree Protection and Regulation Bylaw No. 7415.
[39] The City of Delta. (2009). Delta Pesticide Use Control Bylaw No. 6788.
[40] Metro Vancouver. (2016a). *Minimum Requirements for Stormwater Management on Single-lot Residential Developments*. Retrieved September 13, 2016, from metrovancouver.org: http://www.metrovancouver.org/services/liquid-waste/consultations/stormwater-management-baseline/Pages/default.aspx
[41] Metro Vancouver. (2010a). Greater Vancouver Regional Distrrict Bylaw No. 1136.
[42] Metro Vancouver. (2012). Greater Vancouver Regional District Parks Regulation Bylaw No. 1777. Consolidated April 2015.

This bylaw is a consolidation of the regional parks bylaws for reference purposes. Those bylaws regulate the use of regional parks. Regional parks regulation is important because Boundary Bay Regional Park is an important conservation and recreation site located in the study area.

Greater Vancouver Sewerage and Drainage District Sewer Use Bylaw No. 299[43], 2007

This bylaw is a consolidation of the sewer use bylaw (299) and associated amendments. The bylaw regulates the use of both storm and sanitary sewers for members of the Greater Vancouver Sewerage and Drainage District (GVS&DD).

Minimum Requirements for Stormwater Management on Single Lot Residential Developments

Metro Vancouver is in the process of implementing new regulations regarding single lot residential developments (Metro Vancouver, 2016a)[44]. These regulations are to apply to single detached, duplex, and triplex homes. This regulation will apply where member municipalities do not have comparable regulations in place. The proposed regulations would require the use of a best management practice to improve runoff quality onsite and capture and infiltrate 40% of the 2-year, 24-hour storm. The requirements also stipulate that most developments shall not exceed 70% imperviousness, have a minimum topsoil depth of 450 mm and disconnect downspouts.

A3.3 TSAWWASSEN FIRST NATION

Land Use Planning and Development Act

This act outlines the zoning and building regulations for Tsawwassen First Nation. The zoning regulation includes minimum setbacks from watercourses. Also included are subdivision and development regulations that stipulate that parcel holders provide surface and underground drainage works (including collection, conveyance, and treatment) which are designed by a professional engineer.

Community Governance Act

The Community Governance Act provides regulation for public works, dikes and flood protection, and forest resources. It also governs soil deposit and removal under the Soil Deposit and Removal Regulation.

A4 PLANNING AND POLICIES

A4.1 OFFICIAL COMMUNITY PLAN

The City of Delta Official Community Plan (OCP), Bylaw No. 3950, establishes a vision for the future of Delta and describes related policy decisions. This ISMP should work within these policies and the OCP to enhance the vision outlined in the OCP. The OCP contains three sections of primary importance to the study area: Schedule A, Schedule D (Tsawwassen Community Plan), and Schedule E (Development Permit Area Guidelines and Requirements). This section will highlight the community development objectives and related policies that are most likely to influence stormwater management and watershed health in the study area.

[43] Metro Vancouver. (2007). Greater Vancouver Sewerage and Drainage District Sewer Use Bylaw No. 299.
[44] Metro Vancouver. (2010a). Greater Vancouver Regional Distrrict Bylaw No. 1136.

Schedule A

Objective: "Protect shoreline and riparian areas and maintain high standards for water quality."
The policy framework designed to meet water quality objectives includes the following:

- Work with other agencies to manage and monitor point source pollution and non-point source pollution into streams and Boundary Bay and Georgia Strait.
- Maintain water quality in groundwater aquifers.
- Develop an ISMP consistent with the regional Integrated Liquid Waste Resource Management Plan.

Objective: "Protect and enhance watercourses, ravines, forested uplands, wetlands, foreshore and marine areas as habitat for wildlife." This objective relates strongly to the wildlife components of the ISMP. The policies designed to meet this objective include the following:

- Take physical and environmental resource inventories of environmental assets.
- Implement streamside protection measures.
- Minimize habitat loss and fragmentation.
- Promote naturescaping to create new habitats for wildlife.
- Encourage the protection and reopening of natural watercourses.

Objective: "Balance the interests of agriculture, the protection of the environment and the co-operative management of the Fraser River delta ecosystem." Policies related to balancing agriculture and the environment will influence watershed health. The following policy is included under this objective:

- Encourage initiatives, including BMPs, to maintain water quality, hydrological, and soil conditions on agricultural land.

Objective: "Provide, maintain and renew a sustainable storm and sanitary sewer network to support the community's needs." The following policies related to this objective have the potential to affect stormwater management in the study area:

- Encourage the development and application of BMPs including limiting and mitigating impervious area, appropriate siting of buildings, and applying infiltration devices, open ditches and alternative street edge design.
- Support pilot projects for innovative and sustainable infrastructure design and explore the use of alternative development standards to reduce stormwater runoff.
- Encourage the preservation and enhancement of watercourses and riparian areas.
- Mitigate negative impacts of stormwater runoff from roads.
- Maintain and upgrade the agricultural irrigation system.

Objective: "Minimizing and planning for the impacts of climate change." Climate change will have a significant impact on the hydrological conditions in the study area; therefore, policy related to climate change adaptation is important to consider when creating an ISMP. On the subject of climate change, a report has been published on adapting to expected sea level rise in Delta[45]. The following policies are included in the OCP as means to meet this objective:

- Participate in senior government programs and initiatives that address climate change impacts and that help municipalities plan for local-scale impacts of climate change.
- Promote community awareness of climate change among all sectors and the public.

Objective: "Ensure that land use and development are undertaken in a manner consistent with municipal objectives for environmental sustainability." Implementing land use in an environmentally sustainable manner will include achieving stormwater management objectives. Some important policies related to this objective include the following:

- Require development applicants to complete a sustainability checklist.
- Plan for concentrated growth that discourages urban sprawl and minimizes impervious area.

Schedule D - Tsawwassen Community Plan
Schedule D sets out policy guidelines that will impact future land use in the Tsawwassen area. The following are some of the stated objectives and related policies which may influence stormwater management and/or watershed health.

Objective: "Preserve the semi-rural atmosphere of Tsawwassen, and protect and promote the identity of Tsawwassen." This objective should influence future land use. Some policies related to this objective are:

- Limit land use to farming and "open space" in the areas surrounding those which have already been developed.
- Promote the use of indigenous vegetation in road rights-of-way and private developments.
- Encourage the retention of special natural features and utilize semi-rural engineering practices for roads in the Beach Grove and Boundary Bay areas.
- Permit only single family residential development in the Highlands area.

Objective: "To create an attractive, viable, and cohesive town centre, with a "small town" atmosphere, that reflects the unique characteristics and varying lifestyles of the community, and which has a pedestrian environment and includes commercial, institutional and multiple family residential uses." The following policies are related to this objective:

- Focus growth, including the development of medium density housing, in and around the Tsawwassen town centre.
- Establish boundaries to limit the size of the town centre.

[45] Metro Vancouver. (2015). *Biennial Report: 2013-2014.* Intergrated Liquid Waste and Resource Management. Metro Vancouver.

Objective: "To provide a transition between the town centre and surrounding single family neighbourhoods, and to create an identifiable commercial focus in the town centre." This objective, closely related to the previous one, promotes development around the Tsawwassen town centre.

Objective: "To preserve the farmlands within the Southlands for agricultural uses…" The majority of the Southlands area, in the south-east corner of the study area, is to remain agricultural land.

Objective: "To enhance public enjoyment of the natural environment and to protect important habitat types." There are several policies related to this objective that may have significant influence on stormwater management or watershed health:

- Retain as many trees as possible and require two for one replacement of trees removed during development in zoning classified as commercial, multi-family residential, or more than two single-family units.
- Support the creation of nature parks in the Tsawwassen area and the expansion of Boundary Bay Regional Park.
- Protect farms, existing developments, wildlife habitat and other properties from deterioration caused by changes in drainage patterns or water table level.

There are additional relevant policies related to objectives for road works and engineering services:

- Limit the widths of major roads (56th St.).
- Avoid further intrusion of roads and highways into farms to the north and east of the developed areas of Tsawwassen.
- Upgrade the drainage system as required to accommodate new development.

Schedule E – Development Permit Area Guidelines and Requirements

Schedule E of Delta's OCP sets out development criteria for specific regions within Delta. Within the study area the Entrance to Tsawwassen, Tsawwassen Town Centre, English Bluff, Boundary Bay Foreshore and the Southlands, and the Tsawwassen Golf and Country Club are all subject to Schedule E. Some of the guidelines and requirements relate to flood protection and protecting the natural environment. Schedule E also encourages the use of stormwater BMPs for some areas and contains the Streamside Protection and Enhancement Permit Area regulation.

Regulations for improvements to Tsawwassen Town Centre offer opportunities for the use of permeable pavers in pedestrian walkways and parking lots. There are requirements for the inclusion of trees in streetscaping and parking lots. The guidelines and regulations for the entrance to Tsawwassen borrow some of the guidelines from Tsawwassen Town Centre with additional requirements for flood protection, particularly north of 17A Avenue.

The guidelines for English Bluff focus on preventing damage to the natural environment and protecting development from hazardous conditions (such as mud flows, erosion, land slip, and subsidence) through siting and design control. Regulations prevent changes to density and encourage the preservation of existing natural drainage and vegetation.

The objectives for Boundary Bay Foreshore and the Southlands are to prevent damage to the natural environment and to protect development. The guidelines for these regions require any changes to natural drainage to be minimized. Flood protection regulations (based on the regulations established by the BC Ministry of Environment) prevent construction within 7.5 m of the natural boundary of any tidal area and within 6 m of any swamp, slough, pond, or ditch.

The development permit area regulations for the Tsawwassen Golf and Country Club (TG&CC) designate it as a buffer between the more developed lands to the south and more agricultural lands to the north. It should be noted that the land immediately to the north of the TG&CC has since been developed into the Tsawwassen Mills mall. The Tsawwassen Golf and Country club has also undergone development and is now the Tsawwassen Springs Golf Club. Significant residential development has occurred in the area around the course. Guidelines for the TG&CC include the preservation of mature trees, inclusion of plant material and landscape features, considering the use of green roofs, and maximizing the amount of landscaped area and permeable surfaces.

A4.2 TSAWWASSEN FIRST NATION

Tsawwassen First Nation policies and development initiatives will have a significant impact on stormwater management and watershed health within the study area. TFN lands are currently undergoing significant development, including the Tsawwassen Mills commercial development, the Enterprise Area residential development and future industrial development. The following documents are relevant to the development planning in TFN lands:

- TFN Land Use Plan (2009)
- TFN Zoning Regulation (2013)
- TFN South Neighbourhood Plan (2015)
- TFN Neighbourhood Plan (2016)

Future development and its impact on stormwater management is covered in detail in the TFN Integrated Rainwater Management Plan (IRMP) (Urban Systems, 2013). The IRMP expects much less development (and related changes in hydrology) in the Tsawwassen area outside of TFN lands. This is consistent with current Delta planning documents. There are also service agreements between Delta and TFN relating to drainage and irrigation services and dike maintenance Urban Systems, 2013, The City of Delta[46].

Notably, the City of Delta does not have authority on the TFN lands.

[46] Urban Systems. (2013). *Tsawwassen First Nation Integrated Rainwater Magement Plan.* Tsawwassen First Nation.

A4.3 POINT ROBERTS

The Southlands in the Tsawwassen area receives some drainage from uplands Point Roberts, U.S.A (Associated Engineering, 2014). Therefore, policy in Point Roberts has the potential to affect stormwater management in the Tsawwassen area. Significant development would have the potential to impact the volume of water draining into the Southlands; therefore, development policy is of particular concern. Whatcom County Chapter 20.72 – Point Roberts Special District establishes zoning bylaws for Point Roberts. This bylaw indicates an intention for Point Roberts to remain a rural area.

A4.4 INTEGRATED LIQUID WASTE RESOURCE MANAGEMENT PLAN

The Integrated Liquid Waste Resource Management Plan (ILWRMP) applies to Metro Vancouver and its member municipalities and outlines responsibilities and requirements for each. Requirements for the development of ISMPs are included in the ILWRMP. The ILWRMP is the evolution of the previously published Liquid Waste Management Plan (LWMP) which was first established in 2001 and included commitments by municipalities to create ISMPs. It was developed in accordance with the Canada-wide Strategy for the Management of Municipal Wastewater Effluent. The three primary goals of the ILWRMP are as follows:

- Protect public health and the environment
- Use liquid waste as a resource
- Effective and collaborative management

The ILWRMP discusses the development and implementation of infiltration management plans to ensure that wet weather inflows and infiltration are within targeted levels. As a part of the plan Metro Vancouver commits to working with municipalities to develop knowledge of watershed-based stormwater management approaches and identify improvements to related bylaws. The bylaws will require on-site rainwater management that meets either criteria from municipal ISMPs or regional criteria. The performance measures for the ILWRMP include beach closures and stream health indicators. The ILWRMP requires biennial reports from member municipalities, the latest of which was published in June 2015 (Metro Vancouver, 2015).

A4.5 COMMUNITY STORMWATER PROGRAMS

Delta has several community based programs. Delta's rain garden program focuses on installing rain gardens in and around Delta roadways and at several elementary schools (The City of Delta, 2016a; Water Sustainability Action Plan for British Columbia, 2015). The Delta School Rain Garden Program has constructed, or is in the process of constructing, rain gardens at all 14 elementary schools in Delta (Fraser Basin Council, 2016)[47]. The rain gardens are constructed with the assistance of the School District and local community groups. There is a complementary rain gardener program targeted at students in grades 4 and 5 and supported by Delta's engineering department. The school rain gardens are maintained with the

[47] Fraser Basin Council. (2016). *Showcasing Successful Green Stormwater Infrastructure: Lessons from Implementation.* Metro Vancouver and Victoria: Fraser Basin Council.

assistance of local streamkeeping groups (Fraser Basin Council, 2016)[17]. Delta also allows residents to adopt a rain garden in order to improve rain garden maintenance.

Delta allows residents to sign out storm drain marking kits to paint yellow fish beside storm drains (The City of Delta, 2016e)[48]. The storm drains are marked with painted fish to improve awareness among residents that pollutants flowing into the storm drains can have a negative ecological impact. This program is also supported by Fisheries and Oceans Canada (Government of Canada, 2016)[49].

Delta makes rain barrels (including screen, faucets, overflow pipe and plug) available for residents to purchase for $70 each (The City of Delta, 2016b)[50].

Finally, Delta also runs tree planting programs. The Trees for Tomorrow program allows homeowners to request that one or two trees be planted on municipal land immediately adjacent to the side or front of their properties (The City of Delta, 2016c)[51]. Urban reforestation in Delta receives capital investment. The urban reforestation project plans to plant 5000 trees in Delta parks, boulevards, and medians over 5 years (The City of Delta, 2016d)[52]. The program recognizes the role trees play in helping to reduce the amount of pollution entering creeks and irrigation ditches through runoff as well as the important role they play i

[48] The City of Delta. (2016e). *What You Can Do*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/green-living/what-you-can-do
[49] Government of Canada. (2016). *Fisheries and Oceans Canada*. Retrieved September 13, 2016, from pac.dfo-mpo.gc.ca: http://www.pac.dfo-mpo.gc.ca/sep-pmvs/sci-icp/stormdrain-collecteur-eng.html
[50] The City7 of Delta. (2016b). *Rain Barrel Program*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/services/water-sewer/water-conservation/rain-barrel-program
[51] The City of Delta. (2016c). *Trees for Tomorrow*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/trees-for-tomorrow
[52] The City of Delta. (2016d). *Urban Reforestation Project*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/urban-reforestation-project

Appendix B – Water Quality Report

Date:	May 7, 2018	**File:**	2016-2283.020.003
To:	Corporation of Delta		
From:	Stacy Boczulak M.Sc., P.Ag., Rob Hoogendoorn, R.P.Bio.		
Project:	Tsawwassen ISMP		
Subject:	Water Quality Sampling		

MEMO

1 BACKGROUND

The aquatic habitat of watercourses in the Tsawwassen Integrated Stormwater Management Plan (ISMP) Study Area (Map 1) includes man-made drainage ditches and their associated riparian areas, and very few undeveloped, natural watercourses. Most of the ditches in the Study Area are disturbed, temporal, and not connected to fish-bearing streams. The ditches in the Study Area typically have poor water quality for fish, and fecal coliform bacteria are high within the 12th Avenue, 3rd Avenue[1], and Brandrith catchments[2].

The objective of the water quality sampling was to characterize current water quality conditions in a representative sub-sample of ditches within the Study Area for the Tsawwassen ISMP. Water quality information is useful for comparing to water quality objectives and criteria (i.e. for aquatic life), flagging threats to recreational water quality objectives, or providing baseline data for before-after development studies or climate change adaptation[3].

2 METHODS

Associated Engineering conducted water quality sampling in accordance with Metro Vancouver's Monitoring and Adaptive Management Framework for Stormwater (the AMF)[3]. Water quality sampling was conducted at four sites in open flowing ditches (Map 1) during two seasons: dry (July to August, 2016) and wet (November to December, 2015). During each season, 5 samples were collected from each site. Sites were located down-gradient within the catchments of the ISMP Study Area, with the exception of the Strait of Georgia catchment that had no open flowing channel or ditches available to sample. This site was moved up-gradient into the 12th Avenue catchment at the interface of residential and agricultural areas. The 12th Avenue catchment was chosen as it is the largest and most developed catchment within the Study Area.

Water quality sampling included in situ hand-held meter measurements and laboratory measurements of the following parameters:

- Water temperature (in situ);
- Dissolved oxygen (in situ);
- pH (in situ);
- Conductivity (in situ);
- Turbidity (in situ);
- Total metals (laboratory-measured);
- Nitrate-N (laboratory-measured);
- *Escherichia coli* (laboratory-measured); and
- Fecal coliforms (laboratory-measured).

[1] Corporation of Delta. 2009-2010. Pump Station Results and Corporation of Delta. 2013. BBAMP Field Data.
[2] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.
[3] Metro Vancouver. 2014. Monitoring and Adaptive Management Framework for Stormwater.

3 RESULTS

We compared the in situ measurements and analytical sample results to federal or provincial approved and working water quality guidelines and criteria for the protection of freshwater aquatic life and to the AMF, as discussed below. The applicable water quality guidelines are as follows:

- Canadian Council of Ministers of the Environment (CCME). 2007. Canadian Water Quality Guidelines for the Protection of Aquatic Life (the CCME Guidelines)[4];
- B.C. Ministry of Environment. 2010. Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture (the MOE Approved Guidelines)[5];
- B.C. Ministry of Environment. 2001. Water Quality Guidelines for Temperature[6]; and
- B.C. Ministry of Environment, Lands and Parks. 1998. Guidelines for Interpreting Water Quality Data[7].

3.1 General Parameters

Below we report the findings of water quality sampling from the dry and wet seasons, noting where there were exceedances of water quality guidelines. In some cases, we attempt to explain the cause of elevated concentrations.

pH

The pH ranged from 7.3 to 8.3 at the four sites within the Study Area (Table 1). All values were within the CCME Guidelines and the MOE Approved Guidelines for the protection of aquatic life. There were no trends in pH between sites or seasons.

Nitrate-N

The concentrations for Nitrate-N were low or below detection limit at all sites except the 12th Avenue up-gradient site in the wet season (Table 2). During the wet season, values at this site approached but did not exceed any guidelines. This site is in the vicinity of agricultural fields, and fertilizer runoff may explain the detectable nutrient levels.

Water Temperature

Water temperatures in the Study Area ranged from 15.1°C to 22.2°C in the dry season and from 6.8°C to 13.7°C in the wet season (Table 1). There were exceedances of the MOE Approved Guidelines and "unsatisfactory" temperatures according to the AMF for the dry season at all sites. Dry season temperatures were higher than the optimal temperature ranges for salmonid species and often above extreme temperature tolerances, as indicated in the MOE Water Quality Guidelines for Temperature. Salmonids are not expected in any catchments as there are barriers to fish passage (i.e. flap

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4 http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/
5 http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines
6 http://www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperature.html
7 https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/intrptoc.htm

gates on pump stations). However, if the barriers to fish passage are removed in the future, warm summer temperatures may have an impact on rearing salmonids in the Strait of Georgia or Boundary Bay.

Conductivity

Conductivity values ranged between sites and seasons (Table 1). Conductivity was generally lowest in the 12th Avenue up-gradient site (100 – 261 µS/cm) and was very high at all other sites (350 – 24299 µS/cm). Conductivity at all sites were of the “needs attention” level according to the AMF. The Guidelines for Interpreting Water Quality Data (MELP 1998) indicate that natural waters normally vary between 50 and 1500 µS/cm. The elevated conductivity values found at all sites here may be due to an anthropogenic input of ions (dissolved metals or other dissolved solids) or to the salinity of lowland groundwater due to ocean influences in the Study Area.

Dissolved Oxygen

Concentrations of dissolved oxygen (DO) were low (i.e. <12.2 mg/L) at every site except the up-gradient site within the 12th Avenue catchment (Table 1). DO is essential to the respiratory metabolism of most aquatic organisms, like fish and aquatic invertebrates. DO affects the solubility and availability of nutrients (MOE 1998); therefore, low concentrations of DO can have negative implications on the productivity of aquatic ecosystems.

Concentrations were generally higher in the wet season at all sites, with values ranging from 2.9 to 12.2 mg/L, whereas dry season measurements ranged from 0.4 to 9.1 mg/L (Table 1). The higher concentrations in the wet season are partly due to the colder water temperatures, as oxygen is more soluble in colder water.

Turbidity

Turbidity was high within the Brandrith and 3rd Avenue catchments (ranging from 10 – 57 NTU and 12 – 2339 NTU respectively) (Table 1). In these catchments, most of the wet season turbidity readings were “of concern” according to the AMF. High turbidity increases the total available surface area of solids that bacteria can grow on, and can interfere with respiration of fish and invertebrates. The Guidelines for Interpreting Water Quality Data indicate that high turbidity reduces light penetration and photosynthetic abilities of submerged vegetation and algae and, in turn, may suppress secondary productivity.

Within the 12th Avenue catchment, turbidity was low and more favourable for aquatic life up-gradient (1.0 – 2.8 NTU) but increased further down-gradient (9– 15 NTU) (Table 1). Increased turbidity down-gradient is likely due to erosion causing an accumulation of sediment or dissolved solids down-gradient.

3.2 Microbiological Parameters

Water quality exceeded microbiological guidelines at every site. *E. coli* and total fecal counts were highest in the Brandrith catchment and, to a lesser extent, in the 3rd Avenue catchment (Table 2). Within the 12th Avenue catchment, *E. coli* and total fecal counts were lower up-gradient (only one exceedance) than down-gradient. High counts (i.e. >200 MPN/100 mL) are likely due to stagnant water at pump stations when the gates are closed and/or due to wildlife (i.e. duck) and dog use within Boundary Bay Park. High fecal and microbiological counts can have negative implications on any recreational users of the watercourses or downstream waterbodies that receive this water (i.e. Boundary Bay)[8]. Average values for microbiological parameters are presented below.

Site	Season	*E. coli* (MPN/100mL)	Total Fecal Coliforms (MPN/100mL)
Brandrith	Dry	8758*	48784*
	Wet	2132	3140
12th Avenue (up-gradient)	Dry	32	506*
	Wet	16	21
12th Avenue (down-gradient)	Dry	682	922*
	Wet	62	66
3rd Avenue	Dry	1633	1674*
	Wet	5038*	18509

* Mean is calculated from an unknown value (e.g. >24196 MPN/100mL)

3.3 Total Metals

Total antimony, arsenic, barium, beryllium, calcium, chromium, cobalt, lithium, magnesium, mercury, molybdenum, nickel, potassium, selenium, sodium, thalium, titanium, uranium and vanadium met the CCME Guideline and MOE Approved Guidelines for the protection of aquatic life (Table 2). There were very few exceedances of aquatic life guidelines for total boron, manganese, and silver.

Total aluminum concentrations ranged from 0.035 to 66.2 mg/L in the Study Area (Table 2). Total aluminum concentrations often exceeded the CCME Guideline and the MOE Approved Guideline at all sites in all seasons. As stated in the Guidelines for Interpreting Water Quality Data, aluminum is not considered a serious threat to aquatic health, except in aquatic ecosystems with low pH.

Total cadmium concentrations ranged from below detection limits (<0.000050 mg/L) to 0.00345 mg/L (Table 2). Concentrations in the 3rd Avenue catchment frequently exceeded the CCME Guidelines and at the “needs attention” level

[8] Note that the water quality testing done within Boundary Bay itself has shown no issues with bacterial counts to date.

according to the AMF. There were also CCME Guideline exceedances in the Brandrith catchment, and two exceedences (wet season) in the 12th Avenue catchment at the down-gradient site. As stated in the Guidelines for Interpreting Water Quality Data, cadmium can bioaccumulate and can cause toxic effects on aquatic life, if elevated. Other co-occurring heavy metals such as zinc and copper (discussed below) may increase cadmium's toxicity.

Total copper concentrations ranged from below detection limit (<0.0050 mg/L) to 0.1460 mg/L in the Study Area (Table 2). Total copper concentrations consistently exceeded the CCME Guidelines and the MOE Approved Guidelines at all sites in all seasons. Total copper in the 3rd Avenue and Brandrith catchments was found at a level that "needs attention" according to the AMF. In the 12th Avenue catchment there were only two concentrations at a level that "Needs attention" according to the AMF.

Total iron concentrations ranged from 0.233 to 158.0 mg/L within the Study Area (Table 2). Concentrations consistently exceeded the CCME Guideline at all sites except for sites within the12th Avenue catchment (only two exceedences at the down-gradient site). Many of the concentrations within the 3rd Avenue and Brandrith catchments were at levels classified as "needs attention", according to the AMF.

Total lead concentrations ranged from below the detection limit (<0.0010 mg/L) to 0.0429 mg/L within the Study Area (Table 2). Concentrations exceeded CCME Guidelines and the MOE Approved Guideline, in three samples of the 3rd Avenue catchment. Two of these samples also were at the "need attention" level, according to the AMF.

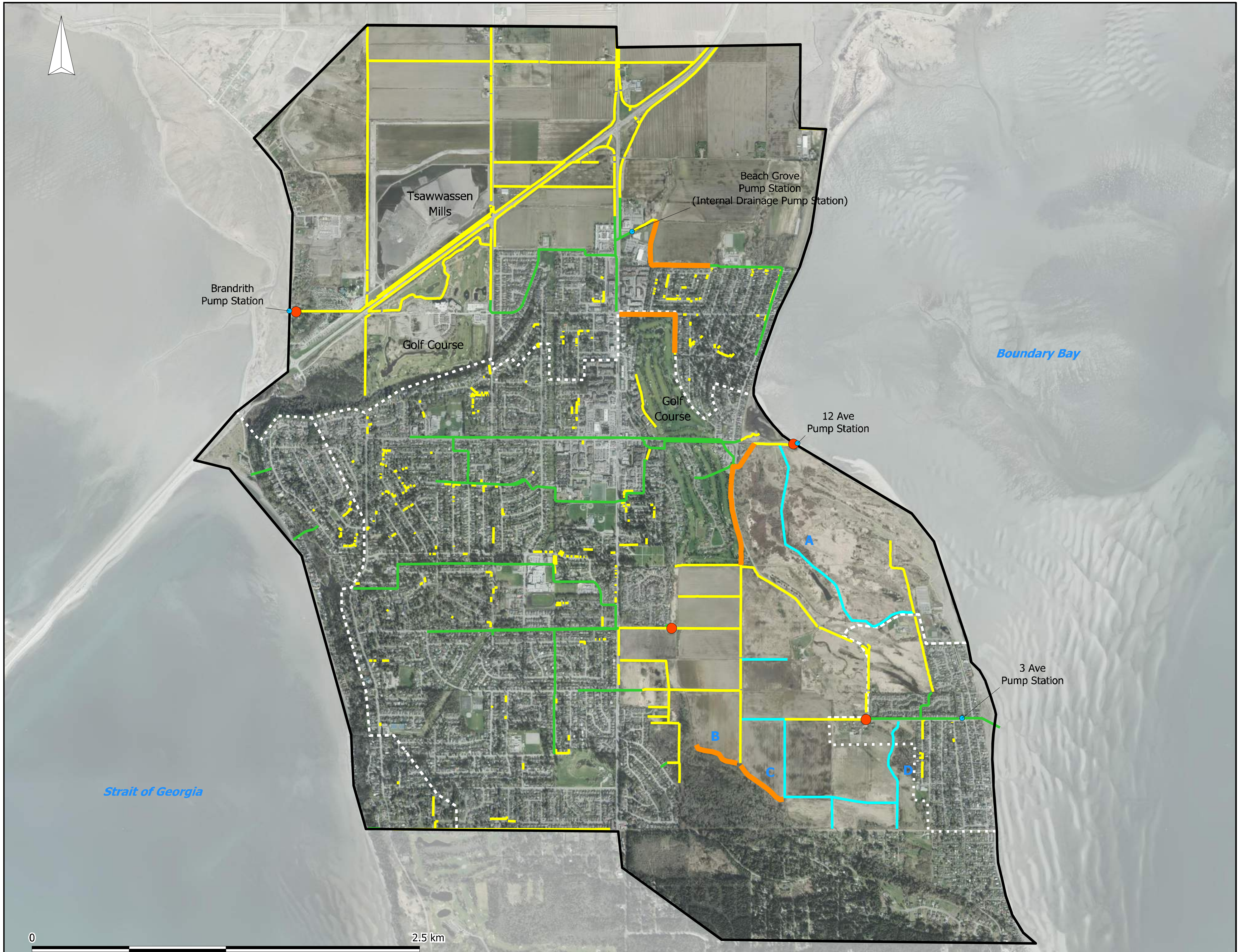
Total zinc concentrations ranged from below the detection limit (0.025 mg/L) to 0.751 mg/L in the Study Area (Table 2). Concentrations exceeded CCME Guidelines within the 3rd Avenue and Brandrith catchments. Concentrations within the 3rd Avenue catchment exceeded MOE Approved Guidelines and were at a level classified as "needs attention", according to the AMF. Within the 12th Avenue catchment, there were a few exceedances of the MOE Approved Guidelines. As stated in the Guidelines for Interpreting Water Quality Data, zinc can be toxic to aquatic organisms, particularly fish.

4 CONCLUSION

The ditches in the Study Area often have poor water quality for fish (i.e., high temperatures in the dry season, high conductivity, low dissolved oxygen, high turbidity, and high concentrations of certain metals) and may have implications on downstream areas of recreational use (i.e. high concentrations of fecal coliforms enter Boundary Bay). Many parameters exceeded several water quality guidelines (CCME and MOE Approved) and/or were at a levels classified by AMF as "needs attention", "unsatisfactory", or "of concern".

Contributing factors to poor water quality include:

- Land development (residential, agricultural, and commercial) in the Study Area (increased nutrients, dissolved substances, microbiological growth, and metals);
- Stagnant water at pump stations of the Study Area (increased microbiological growth, reduced DO);
- Shallow, low-flowing ditches (increased temperatures, reduced DO); and
- Wildlife or waterfowl use (introduce fecal coliforms).



LEGEND

DRAINAGE FEATURES

- WATER QUALITY SAMPLING SITES
- PUMP STATION
- HABITAT COMPENSATION AREA
- SUBCATCHMENTS
- CULVERT
- STORM MAIN
- STORM SIPHON

WATERCOURSE

- SCHEDULE B
- SCHEDULE C
- UNCLASSIFIED

SCALE:	1:23,500		
PROJECT NO.	BUR_P_2016-2283	INITIAL	DATE
DRAWN		AD	13-12-16
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

THE CORPORATION OF DELTA

TSAWWASSEN
INTEGRATED STORMWATER
MANAGEMENT PLAN

WATER QUALITY
SAMPLING SITES

DRAWING NUMBER	REV. NO.	SHEET
MAP 1		

Map File: \\s-bur-fs-01\projects\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_figures_20160807_ad.map

Table 2. Water Quality Monitoring Results (Laboratory Measured Parameters) Tsawwassen ISMP 2016

				Microbiology				Total Metals (mg/L)																											
		Hardness ($CaCO_3$; mg/L)	Nitrate- N (mg/L)	*E. coli* (MPN/100mL)	Mean	Total Fecal Coliforms (MPN/100mL)	Mean	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Magnesium (Mg)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Potassium (K)	Selenium (Se)	Silver (Ag)	Sodium (Na)	Thallium (Tl)	Titanium (Ti)	Uranium (U)	Vanadium (V)	Zinc (Zn)
CCME Guideline[c]		-	3	-	-	-	-	0.1	-	0.005	-	-	1.5	0.00009	-	0.001	-	***variable***	3	***variable***	-	-	-	0.00026	0.073	***variable***	-	0.001	0.00025	-	0.0008	-	-	-	0.03
BC Guideline[d]		-	3	77	-	200	-	0.05	-	0.005	-	-	1.2	***variable***	-	-	0.004	0.002	-	***variable***	-	-	***variable***	***variable***	2	-	-	2	***variable***	-	-	-	-	-	***variable***
AMF Guideline[e]		-	3	-	-	200	-	-	-	-	-	-	-	0.00034	-	-	-	0.011	5	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
Brandrith Catchment																																			
Dry Season	16-Aug	2070	<0.50	649		>2419.6		0.072	<0.0020	0.0020	0.104	<0.025	1.19	<0.00010	180.0	<0.0020	<0.0020	<0.0100	1.37	<0.0010	<0.050	393	0.942	<0.00020	0.0020	<0.010	89.0	<0.0010	<0.00020	2940	<0.00020	<0.050	0.00038	<0.150	<0.025
	19-Aug	2370	<0.50	>2419.6		1600		0.286	<0.0020	0.0021	0.117	<0.025	1.44	<0.00010	197.0	<0.0020	<0.0020	<0.0100	2.05	<0.0010	<0.050	457	0.831	<0.00020	0.0031	<0.010	109.0	<0.0010	<0.00020	3670	<0.00020	<0.050	0.00052	<0.150	<0.025
	23-Aug	2090	<0.50	2420	8758	7900	48784	0.180	<0.0010	0.0030	0.104	<0.025	1.23	<0.000050	168.0	<0.0010	0.00110	<0.0050	2.82	<0.0010	<0.050	405	0.814	<0.00020	0.0015	<0.0050	94.0	<0.0010	<0.00010	3150	<0.00020	<0.050	0.00039	<0.150	<0.025
	26-Aug	761	<0.10	14100		92000		0.565	<0.00050	0.0094	0.067	<0.015	0.48	0.000101	69.0	0.0019	0.00171	0.0055	7.23	0.0015	<0.050	143	1.100	<0.00020	0.0014	<0.0050	36.3	<0.0010	<0.000050	992	<0.00020	<0.050	0.00021	<0.090	0.113
	30-Aug	1330	<0.50	24200		140000		0.586	<0.0010	0.0024	0.075	<0.015	0.78	<0.000050	118.0	0.0018	0.00140	<0.0050	1.78	<0.0010	<0.050	252	0.544	<0.00020	0.0014	<0.0050	60.1	<0.0010	<0.00010	1940	<0.00020	<0.050	0.00034	<0.090	0.018
Wet Season	4-Nov	246	<0.50	3080		7900		3.180	<0.00050	0.0048	0.036	<0.005	0.16	0.000121	50.0	0.0077	0.00370	0.0185	6.56	0.0020	<0.050	29.4	0.311	<0.00020	0.0046	0.0206	17.5	<0.0010	<0.000050	143	<0.00020	0.119	0.00091	<0.030	0.037
	10-Nov	253	0.815	4610		2400		1.650	<0.00050	0.0051	0.027	<0.005	0.19	0.000121	48.7	0.0050	0.00398	0.0161	5.21	0.0012	<0.050	31.9	0.324	<0.00020	0.0058	0.0212	18.1	<0.0010	<0.000050	160	<0.00020	0.075	0.00081	<0.030	0.026
	18-Nov	264	0.912	480	2132	2400	3140	2.220	<0.00050	0.0047	0.027	<0.005	0.19	0.000123	51.2	0.0054	0.00363	0.0175	5.61	0.0012	<0.050	33.1	0.310	<0.00020	0.0053	0.0206	15.8	<0.0010	<0.000050	179	<0.00020	0.069	0.00095	<0.030	0.031
	25-Nov	175	0.710	1190		1300		3.770	<0.00050	0.0043	0.028	<0.005	0.11	0.000147	37.3	0.0086	0.00382	0.0182	6.29	0.0022	<0.050	19.7	0.206	<0.00020	0.0047	0.0218	12.3	<0.0010	<0.000050	105	<0.00020	0.144	0.00096	<0.030	0.034
	1-Dec	284	1.130	1300		1700		1.380	<0.00050	0.0038	0.029	<0.005	0.18	0.000070	51.6	0.0038	0.00267	0.0110	3.97	<0.0010	<0.050	37.6	0.353	<0.00020	0.0042	0.0151	16.4	<0.0010	<0.000050	218	<0.00020	<0.050	0.00093	<0.030	0.019
12th Avenue Catchment (upgradient)																																			
Dry Season	16-Aug	37	0.366	26		>2419.6		0.050	<0.00050	0.0010	<0.020	<0.005	<0.10	<0.000050	11.2	<0.0005	<0.00050	0.0047	0.186	<0.0010	<0.050	2.24	0.012	<0.00020	<0.0010	<0.0050	<2.0	<0.0010	<0.000050	6	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	19-Aug	34	0.309	7		8		0.035	<0.00050	<0.0010	<0.020	<0.005	<0.10	<0.000050	10.2	<0.0005	<0.00050	0.0034	0.184	<0.0010	<0.050	1.98	0.024	<0.00020	0.0013	<0.0050	<2.0	<0.0010	<0.000050	6	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	23-Aug	49	0.560	6	32	5	506	0.071	<0.00050	0.0011	<0.020	<0.005	<0.10	<0.000050	15.3	<0.0005	<0.00050	0.0040	0.228	<0.0010	<0.050	2.71	0.030	<0.00020	<0.0010	<0.0050	3.0	<0.0010	<0.000050	12	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	26-Aug	45	0.644	49		46		0.053	<0.00050	0.0011	<0.020	<0.005	<0.10	<0.000050	13.5	<0.0005	<0.00050	0.0051	0.202	<0.0010	<0.050	2.75	0.020	<0.00020	<0.0010	<0.0050	<2.0	<0.0010	<0.000050	9	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	30-Aug	39	0.363	72		49		0.046	<0.00050	0.0011	<0.020	<0.005	<0.10	<0.000050	11.9	<0.0005	<0.00050	0.0121	0.169	<0.0010	<0.050	2.16	0.014	<0.00020	<0.0010	<0.0050	<2.0	<0.0010	<0.000050	8	<0.00020	<0.050	<0.00020	<0.030	<0.0050
Wet Season	4-Nov	80	0.344	4		13		0.065	<0.00050	0.0013	0.026	<0.005	<0.10	<0.000050	22.9	0.0006	<0.00050	0.0049	0.193	<0.0010	<0.050	5.47	0.038	<0.00020	<0.0010	<0.0050	2.9	<0.0010	<0.000050	16	<0.00020	<0.050	<0.00020	<0.030	0.009
	10-Nov	77	2.510	9		13		0.062	<0.00050	0.0012	0.024	<0.005	<0.10	<0.000050	21.5	0.0005	<0.00050	0.0059	0.185	<0.0010	<0.050	5.58	0.042	<0.00020	<0.0010	<0.0050	3.0	<0.0010	<0.000050	14	<0.00020	<0.050	<0.00020	<0.030	0.008
	18-Nov	73	2.420	14	16	4	21	0.111	<0.00050	0.0014	0.024	<0.005	<0.10	<0.000050	20.6	0.0006	<0.00050	0.0052	0.320	<0.0010	<0.050	5.25	0.072	<0.00020	<0.0010	<0.0050	2.7	<0.0010	<0.000050	13	<0.00020	<0.050	<0.00020	<0.030	0.009
	25-Nov	71	2.350	49		70		0.359	<0.00050	0.0019	0.026	<0.005	<0.10	<0.000050	20.0	0.0012	<0.00050	0.0268	0.504	<0.0010	<0.050	5.09	0.070	<0.00020	<0.0010	<0.0050	3.0	<0.0010	<0.000050	16	<0.00020	<0.050	<0.00020	<0.030	0.014
	1-Dec	76	2.390	5		5		0.068	<0.00050	0.0012	0.024	<0.005	<0.10	<0.000050	21.8	0.0006	<0.00050	0.0070	0.194	<0.0010	<0.050	5.2	0.043	<0.00020	<0.0010	<0.0050	2.6	<0.0010	<0.000050	37	<0.00020	<0.050	<0.00020	<0.030	0.007
12th Avenue Catchment (downgradient)																																			
Dry Season	16-Aug	890	<0.25	1050		>2419.6		0.084	<0.00050	0.0110	<0.020	<0.010	0.65	<0.000050	95.6	0.0009	0.00131	<0.0025	1.160	<0.0010	<0.050	158	0.387	<0.00020	0.0011	<0.0050	49.1	<0.0010	<0.000050	1260	<0.00020	<0.050	0.00045	<0.060	<0.010
	19-Aug	49	0.493	365		170		0.106	<0.00050	0.0025	<0.020	<0.005	<0.10	<0.000050	13.4	<0.0005	<0.00050	0.0076	0.233	<0.0010	<0.050	3.62	0.028	<0.00020	<0.0010	<0.0050	2.1	<0.0010	<0.000050	10	<0.00020	<0.050	<0.00020	<0.030	0.014
	23-Aug	1410	<0.25	387	682	350	922	0.632	<0.0010	0.0127	<0.050	<0.025	1.15	0.000054	122.0	0.0020	0.00250	<0.0050	2.660	<0.0010	<0.050	270	0.736	<0.00020	0.0013	<0.0050	85.0	<0.0010	<0.00010	2240	<0.00020	<0.050	0.00137	<0.15	<0.025
	26-Aug	366	<0.10	1550		1600		0.768	<0.00050	0.0394	0.031	<0.005	0.29	<0.000050	47.8	0.0022	0.00720	0.0032	5.710	<0.0010	<0.050	59.8	3.720	<0.00020	0.0014	<0.0050	23.1	<0.0010	<0.000050	495	<0.00020	<0.050	0.00034	<0.030	0.008
	30-Aug	306	<0.10	60		70		0.403	<0.00050	0.0118	<0.020	<0.005	0.23	<0.000050	40.3	0.0011	0.00165	0.0019	1.670	<0.0010	<0.050	49.9	0.472	<0.00020	0.0010	<0.0050	16.7	<0.0010	<0.000050	392	<0.00020	<0.050	0.00021	<0.030	0.006
Wet Season	4-Nov	227	<0.10	28		13		1.200	<0.00050	0.0047	0.020	<0.005	0.15	0.000132	40.2	0.0038	0.00252	0.0087	3.070	0.0011	<0.050	30.8	0.161	<0.00020	0.0021	0.0129	14.6	<0.0010	<0.000050	192	<0.00020	0.051	0.00036	<0.030	0.021
	10-Nov	209	0.947	29		33		0.393	<0.00050	0.0036	<0.020	<0.005	0.13	0.000084	41.5	0.0018	0.00315	0.0052	1.910	<0.0010	<0.050	25.5	0.277	<0.00020	0.0023	0.0143	13.0	<0.0010	<0.000050	139	<0.00020	<0.050	0.00030	<0.030	0.015
	18-Nov	272	0.768	96	62	79	66	0.533	<0.00050	0.0034	<0.020	<0.005	0.18	0.000079	45.1	0.0021	0.00242	0.0052	2.010	<0.0010	<0.050	38.7	0.144	<0.00020	0.0024	0.0142	15.0	<0.0010	<0.000050	247	<0.00020	<0.050	0.00036	<0.030	0.009
	25-Nov	190	0.784	122		170		1.030	<0.00050	0.0029	<0.020	<0.005	0.11	0.000096	37.8	0.0029	0.00214	0.0065	2.050	<0.0010	<0.050	23.2	0.125	<0.00020	0.0018	0.0132	10.6	<0.0010	<0.000050	150	<0.00020	<0.050	0.00037	<0.030	0.013
	1-Dec	240	0.798	34		33		0.633	<0.00050	0.0036	<0.020	<0.005	0.15	0.000129	43.2	0.0024	0.00270	0.0056	2.060	<0.0010	<0.050	32.1	0.168	<0.00020	0.0021	0.0127	12.5	<0.0010	<0.000050	182	<0.00020	<0.050	0.00045	<0.030	0.013
3rd Avenue Catchment																																			
Dry Season	16-Aug	138	0.011	17		>2419.6		0.501	<0.00050	0.0085	<0.020	<0.005	<0.10	<0.000050	35.6	0.0015	0.00077	0.0055	2.650	<0.0010	<0.050	12	0.060	<0.00020	<0.0010	<0.0050	4.2	<0.0010	<0.000050	19	<0.00020	<0.050	0.00030	<0.030	0.006
	19-Aug	149	0.008	411		350		6.350	<0.00050	0.0134	0.048	<0.005	<0.10	0.000357	36.7	0.0142	0.00845	0.0142	17.1	0.0044	<0.050	14	0.226	<0.00020	0.0013	0.0152	4.8	<0.0010	<0.000050	19	<0.00020	0.274	0.00087	<0.030	0.054
	23-Aug	163	0.009	727	1633	1600	1674	6.390	<0.00050	0.0128	0.042	<0.005	<0.10	0.000316	40.3	0.0147	0.00776	0.0163	15.1	0.0049	<0.050	15.1	0.260	<0.00020	0.0014	0.0152	4.8	<0.0010	<0.000050	21	<0.00020	0.251	0.00089	<0.030	0.067
	26-Aug	411	<0.025	5790		1600		62.6	<0.00050	0.0504	0.297	<0.005	0.24	0.002480	95.5	0.1340	0.07250	0.1190	126.0	0.0348	0.078	41.9	1.770	0.00022	0.0032	0.1210	22.0	0.0015	0.000294	99	0.00037	1.740	0.00476	0.179	0.361
	30-Aug	486	<0.025	1220		2400		66.2	0.00055	0.0404	0.360	<0.005	0.34	0.003450	110.0	0.1540	0.08390	0.1460	158.0	0.0429	0.098	51.5	2.210	<0.00020	0.0039	0.1440	26.0	0.0018	0.000364	108	0.00042	2.180	0.00498	0.257	0.517
Wet Season	4-Nov	395	<0.025	>24196		92000		7.140	0.00091	0.0254	0.101	<0.005	0.42	0.001180	89.2	0.0310	0.03320	0.0925	151.0	0.0158	<0.050	41.8	1.600	<0.00020	0.0104	0.0565	34.1	<0.0010	0.000123	249	<0.00020	0.218	0.00289	0.107	0.751
	10-Nov	329	0.182	866		490		2.190	<0.00050	0.0118	0.039	<0.005	0.41	0.000362	68.8	0.0108	0.01070	0.0165	46.1	0.0043	<0.050	38.2	0.625	<0.00020	0.0053	0.0221	32.6	<0.0010	0.000062	234	<0.00020	0.095	0.00107	0.040	0.212
	18-Nov	311	0.332	29	5038	17	18509	4.200	<0.00050	0.0041	0.031	<0.005	0.39	0.000190	62.4	0.0105	0.00588	0.0131	14.8	0.0024	<0.050	37.7	0.324	<0.00020	0.0025	0.0177	33.4	<0.0010	<0.000050	237	<0.00020	0.148	0.00069	<0.030	0.060
	25-Nov	248	0.306	93		31		5.490	0.00107	0.0053	0.033	<0.005	0.26	0.000174	51.6	0.0104	0.00666	0.0157	10.4	0.0025	<0.050	29	0.358	<0.00020	0.0073	0.0211	29.0	<0.0010	0.000064	141	<0.00020	0.185	0.00098	<0.030	0.041
	1-Dec	274	0.453	5		8		2.380	<0.00050	0.0039	0.022	<0.005	0.32	0.000128	54.4	0.0077	0.00440	0.0094	8.6	0.0014	<0.050	33.7	0.232	<0.00020	0.0039	0.0148	30.5	<0.0010	<0.000050	179	<0.00020	0.107	0.00061	<0.030	0.027

Notes:

a) Dry season is defined as July-August and wet season is November-December according to Metro Vancouver's Monitoring and Adaptive Management Framework for Stormwater (MetroVan 2014).

b) See Map 1 for site locations and catchment boundaries

c) CCME guidelines for the protection of Aquatic Life

d) BC MOE Approved Water Quality Guidelines Aquatic Life, Wildlife and Agriculture

e) Based on Monitoring and Adaptive Management Framework

variable Guideline is a range of values based on calculation that relies on hardness, temperature and/or pH

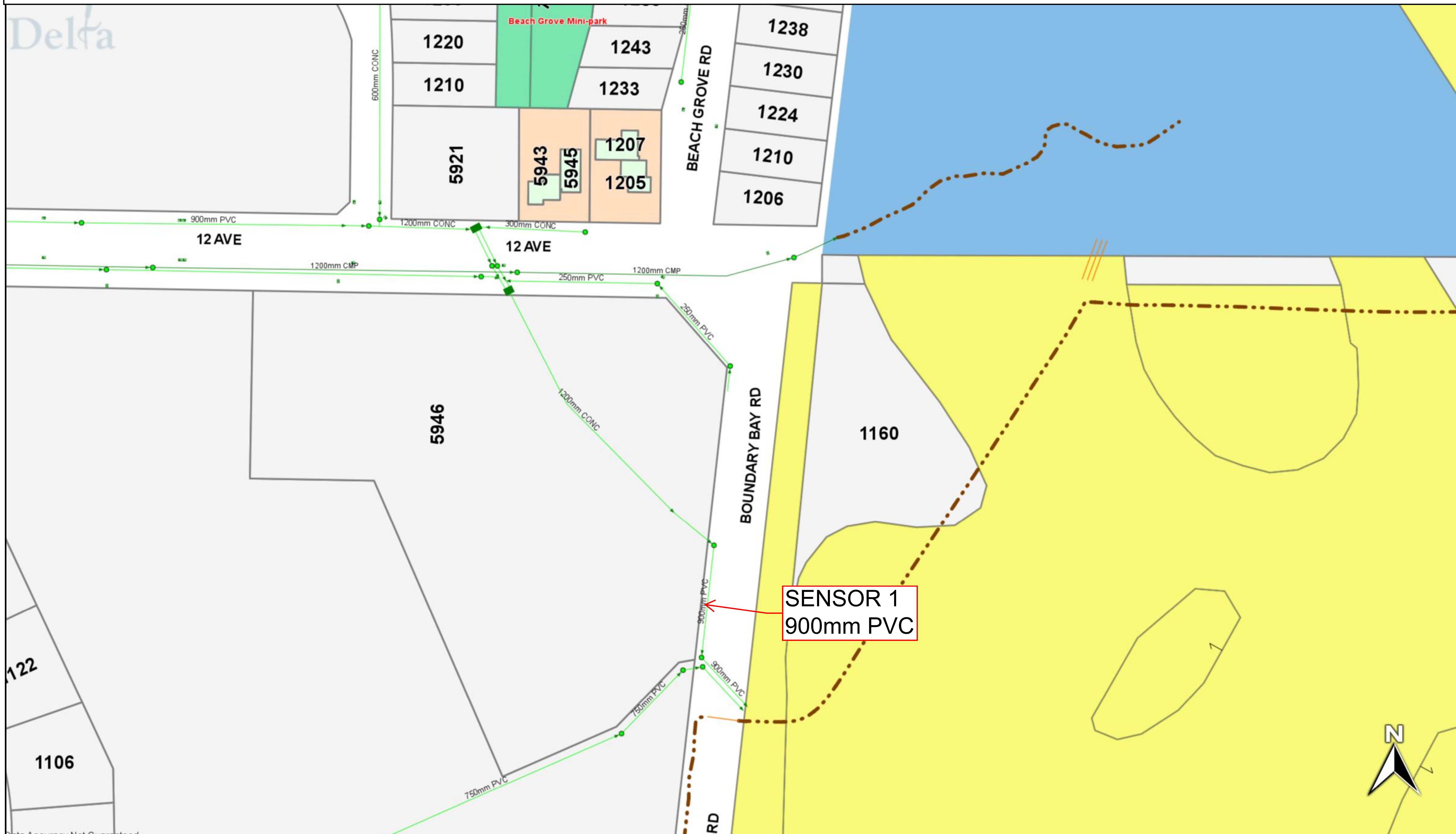
text Value Exceeds CCME Guidelines

text Value Exceeds BC Guidelines

text Value is "Unsatisfactory" , "of Concern" or "Needs Attention" as per the Adaptive Management Framework

Appendix C – Flow Monitoring

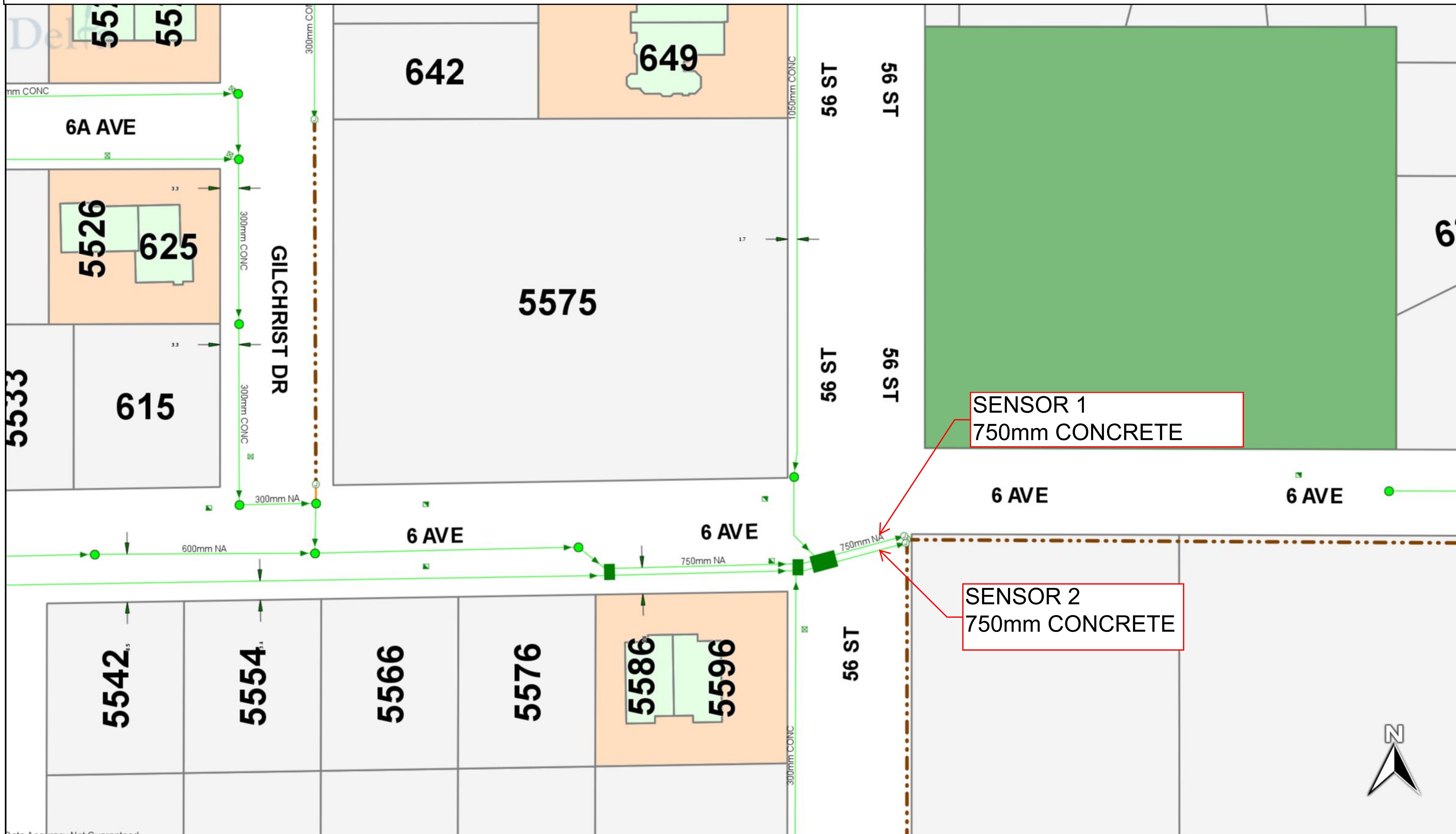
STREET MAP
SITE 1



40 m
100 ft

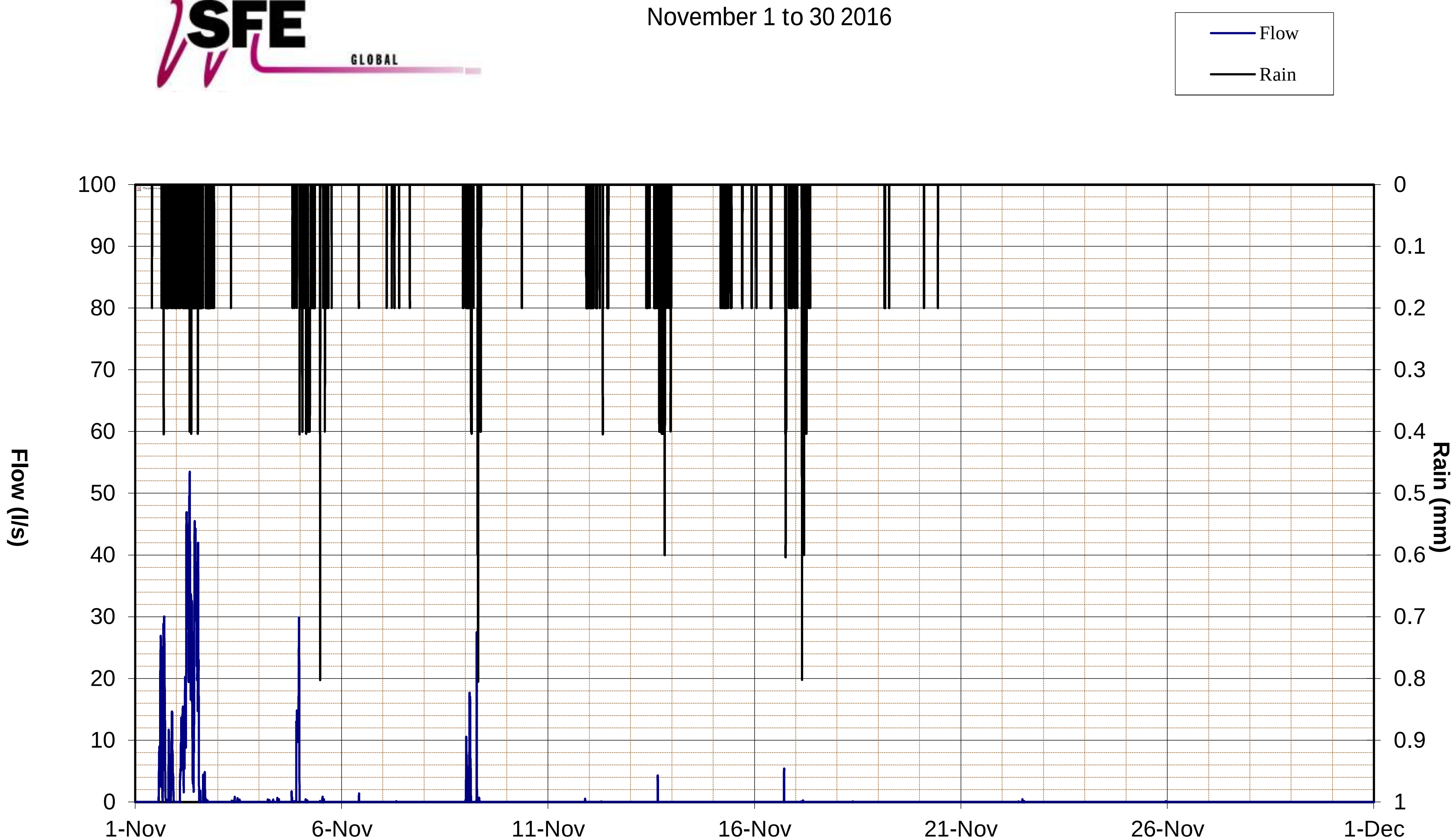
Oct/19/2016
Scale 1:1946

STREET MAP
SITE 2

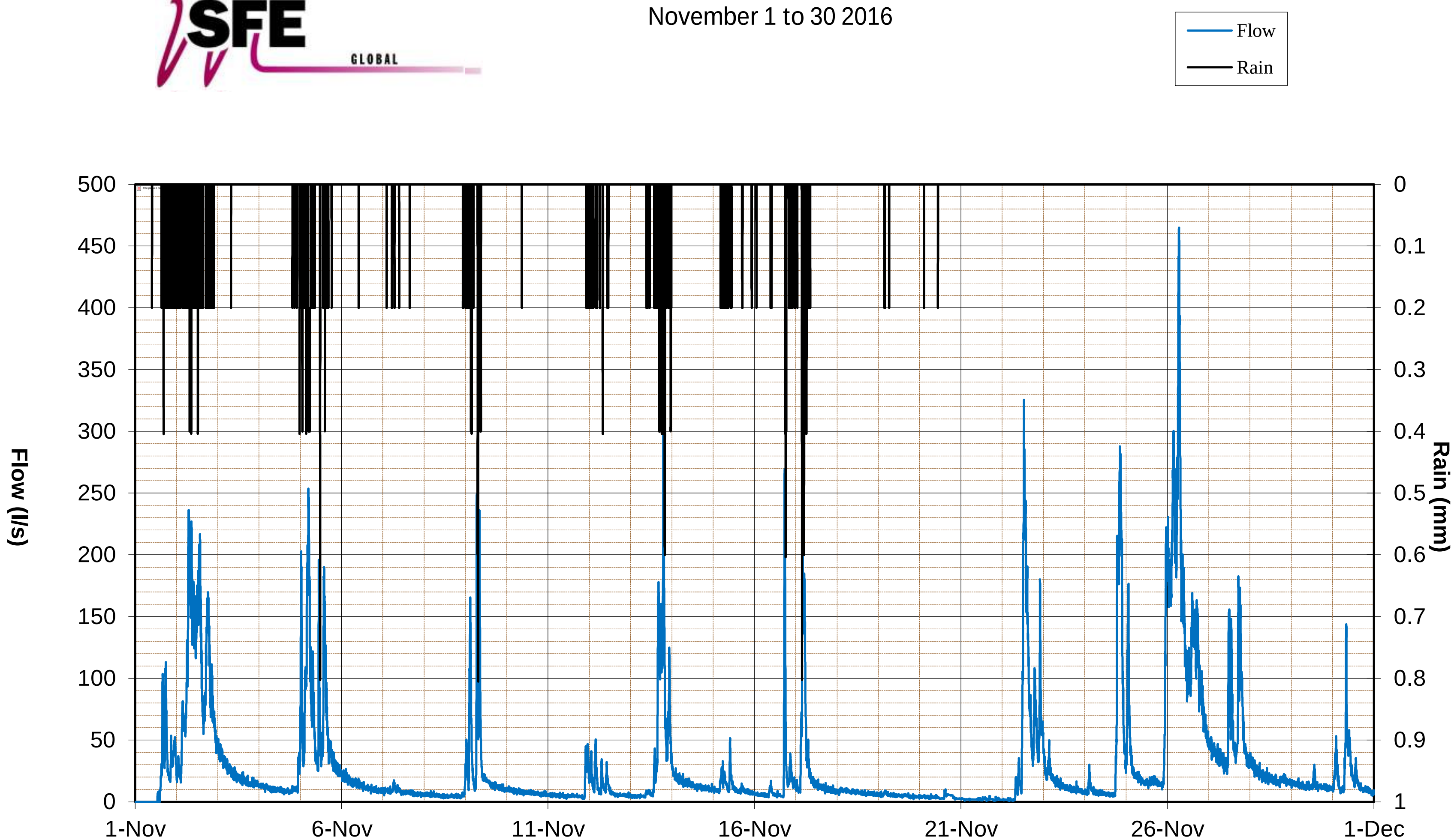


20 m
60 ft
Oct/19/2016
Scale 1:973

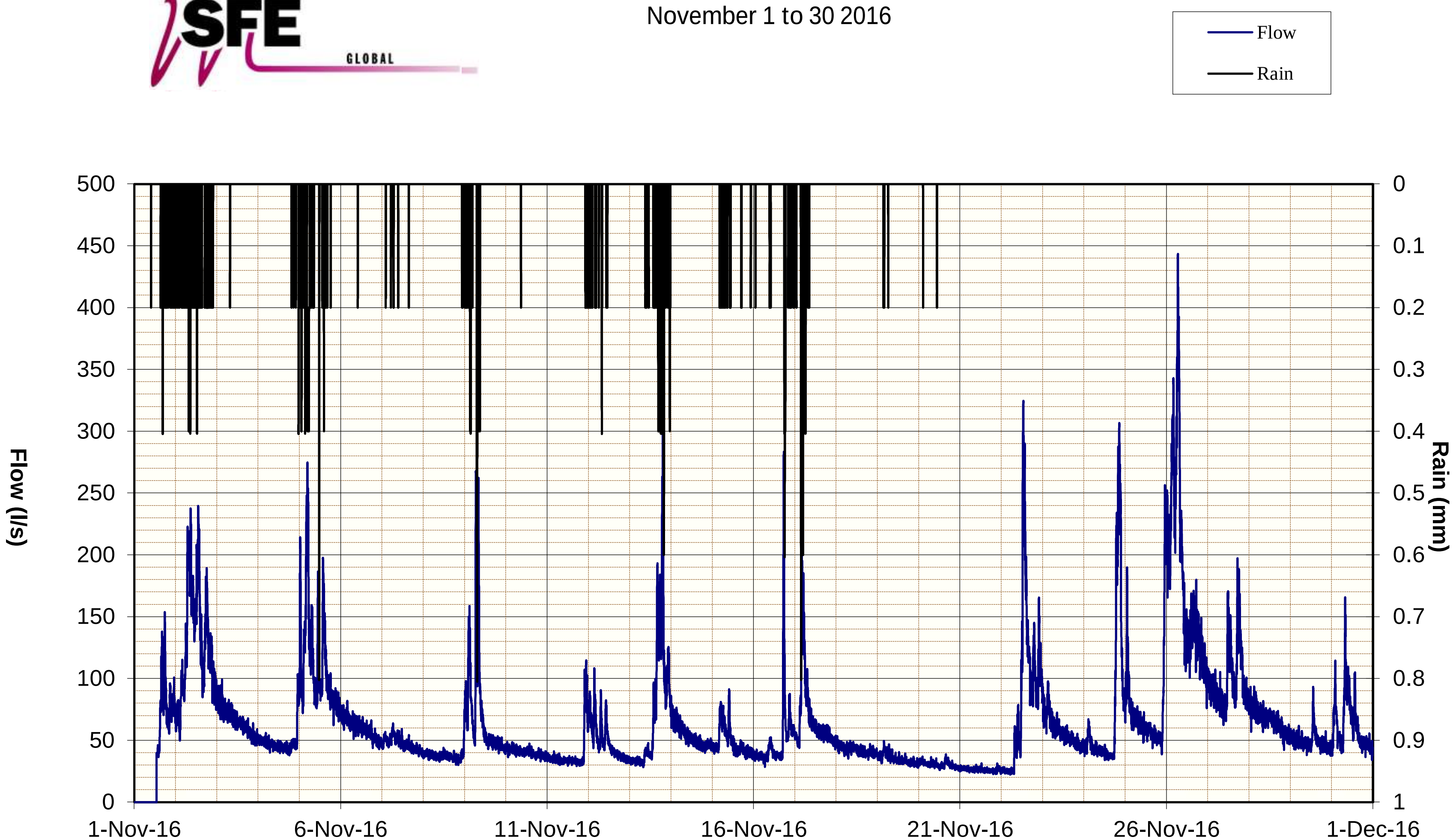
City of Delta (Tsawassen)
SFE Site #068F - 1 - 12th and Boundary Bay Road
November 1 to 30 2016



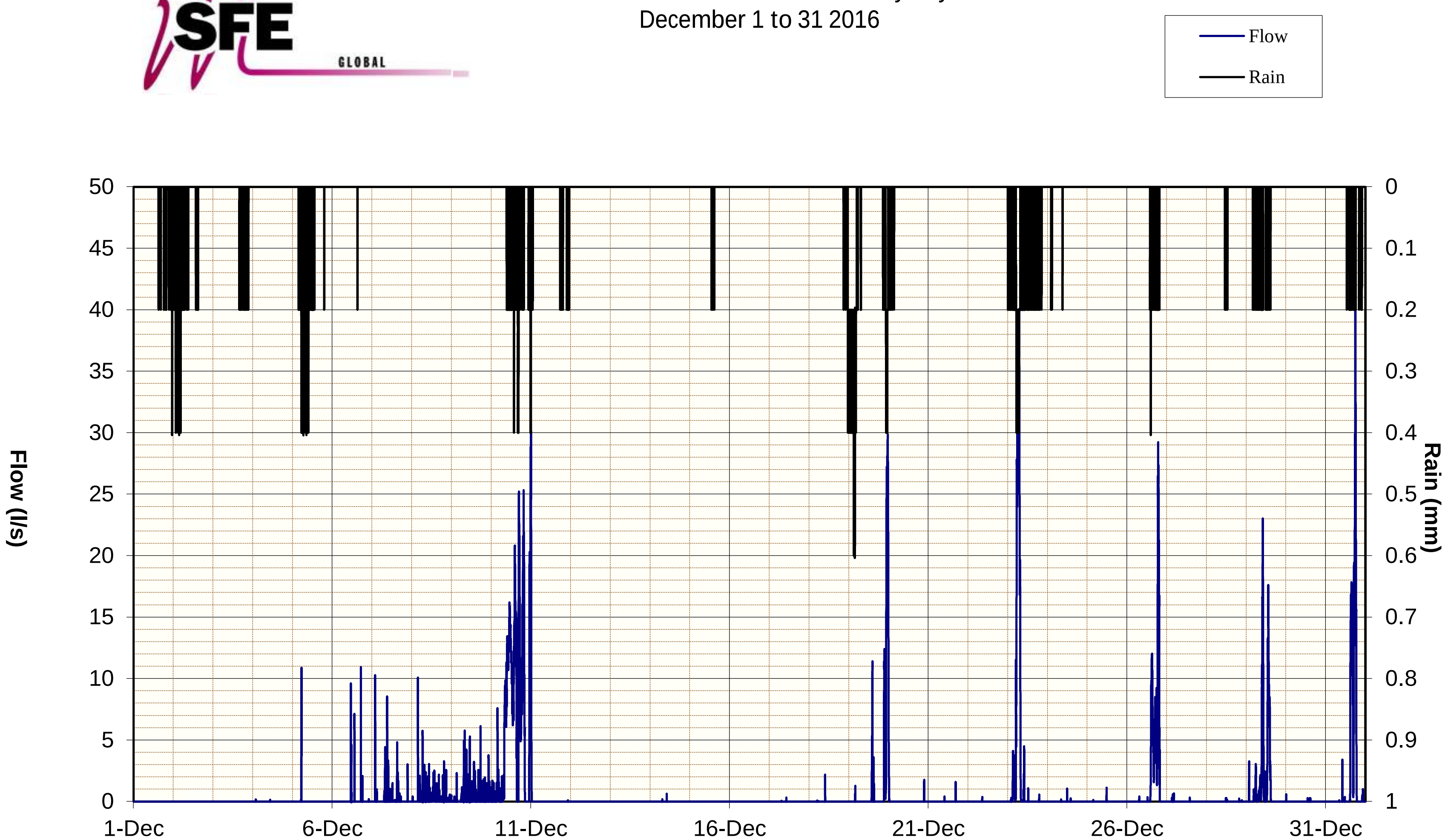
City of Delta (Tsawassen)
SFE Site #068F - 2 Left - 56th and 6th
November 1 to 30 2016



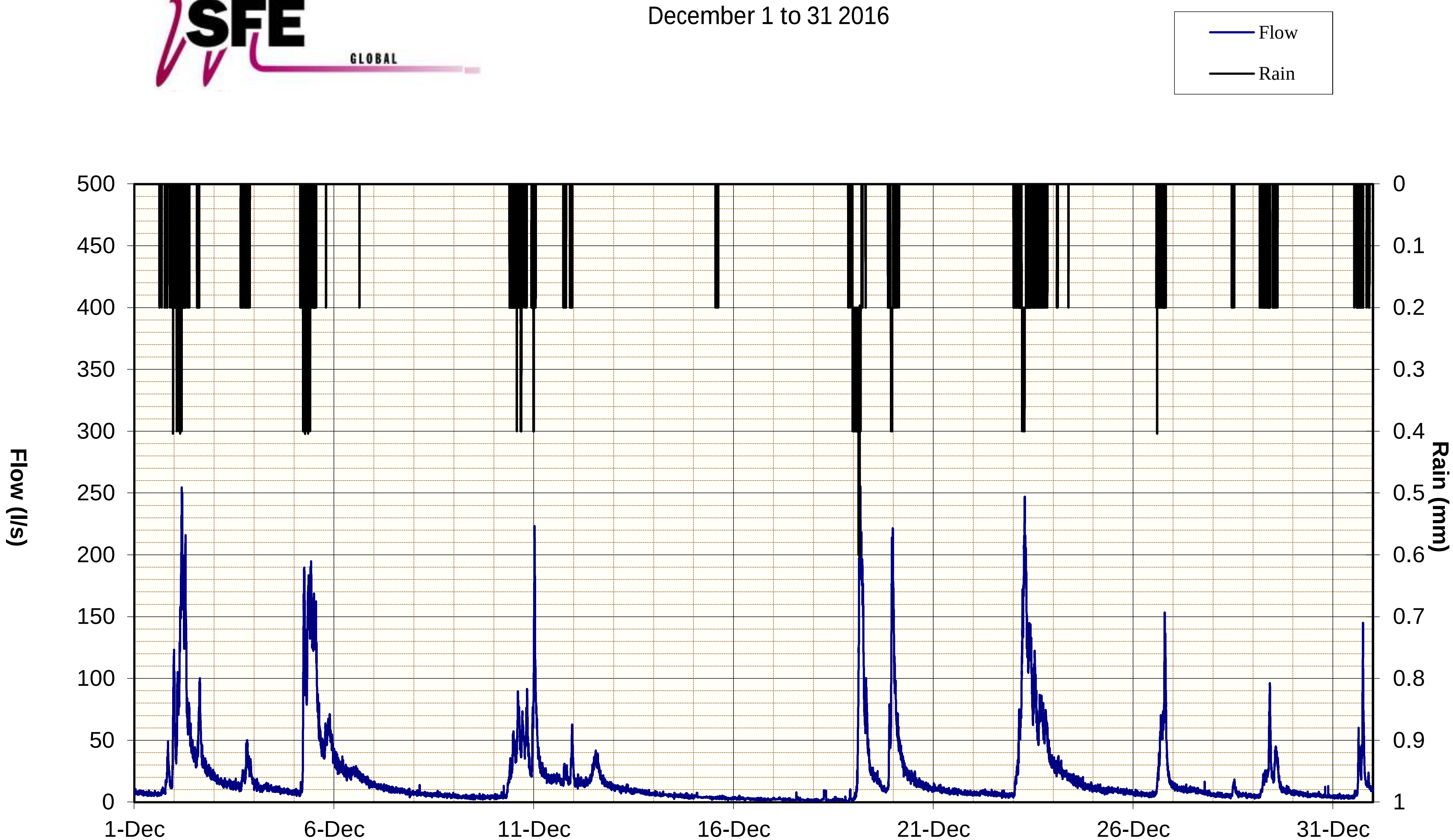
City of Delta (Tsawassen)
SFE Site #068F - 2 Right - 56th and 6th
November 1 to 30 2016



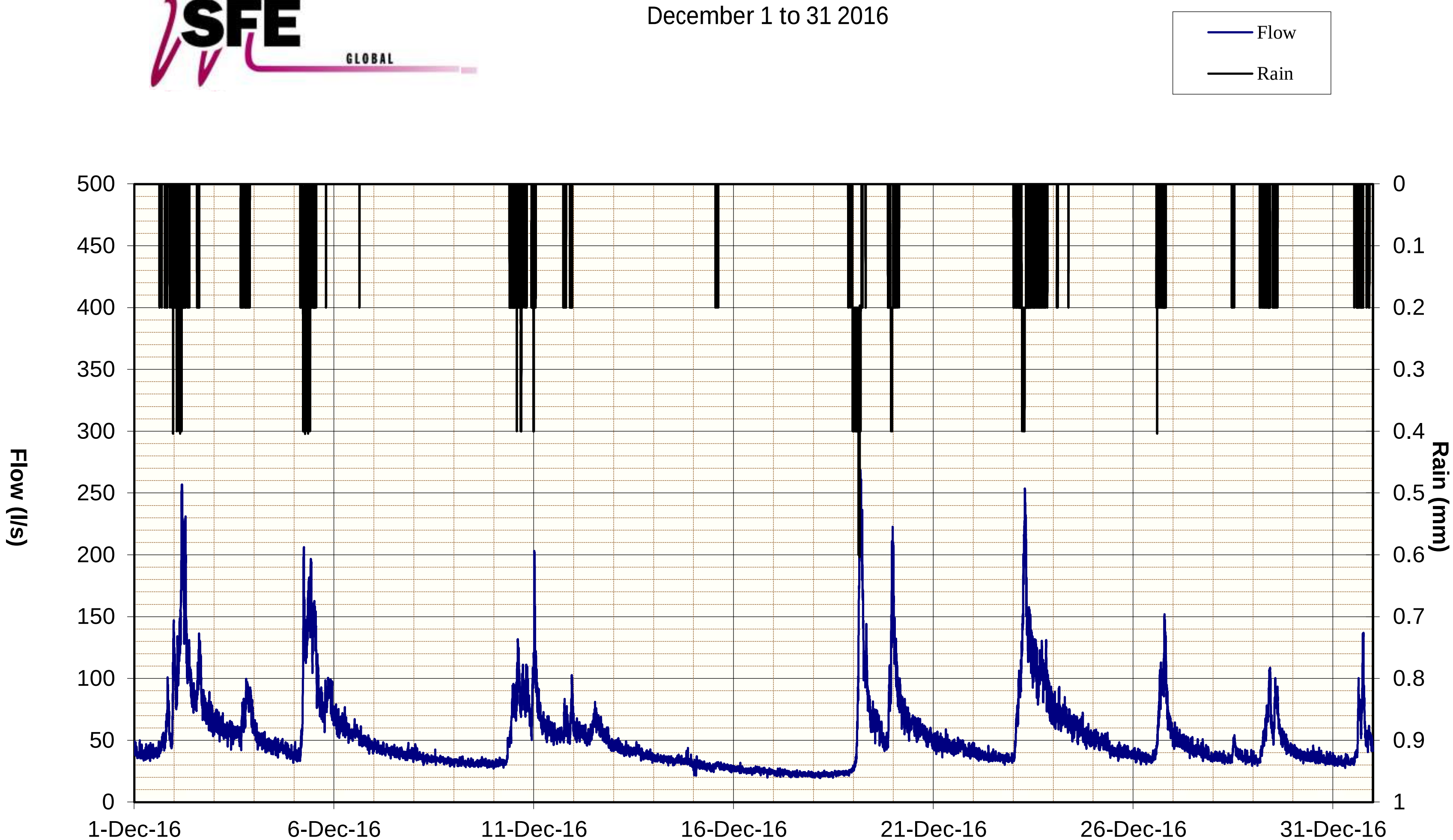
City of Delta (Tsawassen)
SFE Site #068F - 1 - 12th and Boundary Bay Road
December 1 to 31 2016



City of Delta (Tsawassen)
SFE Site #068F - 2 Left - 56th and 6th
December 1 to 31 2016



City of Delta (Tsawassen)
SFE Site #068F - 2 Right - 56th and 6th
December 1 to 31 2016



Appendix D – Hydrologic and Hydraulic Modelling

This appendix contains information from the Stage 3 report. The appendix is organized as follows:

D1 outlines the hydraulic modelling assessment.
D2 outlines the extended period simulation.
Following D1 and D2 we include long profiles illustrating system deficiencies (Figures D-1-D-8).

D1 HYDRAULIC MODELLING

D1.1 EXISTING CONDITION MODEL

Model Parameters

Subcatchment parameters including Horton infiltration rates, average slope, Manning's Roughness Coefficients for overland flow and depression storage were established based on air photos, LiDAR data, site visits and previous modelling efforts in the region. Table D-1 summarizes the key hydrologic parameters used in the model.

Table D-1
Hydrologic Model Parameters

Horton Infiltration Parameters	
Maximum Infiltration Rate (mm/hr)	3 (Lowlands) 5 (Uplands)
Minimum Infiltration Rate (mm/hr)	1 (Lowlands), 2.5 (Uplands)
Decay Constant (hr -1)	4.14
Drying Time (days)	7
Manning's Roughness Coefficient, n, for Overland Flow	
Impervious Surface (overland flow)	0.013
Pervious Surface (overland flow)	0.24
Depression Storage	
Impervious Surface (mm)	2.5
Pervious Surface (mm)	5

Table D-2 presents the hydraulic parameters assigned to the conduits within the model.

Table D-2
Conduit Properties

Manning's Roughness Coefficient, n, for Conduit Flow	
PVC	0.013
HDPE	0.013
Steel	0.013
Concrete	0.013
Corrugated Steel Pipe (CSP)	0.024
Ditches / Watercourses	0.035*

*Note: A Manning's n of 0.035 was chosen rather than 0.05 which would normally be applied to natural water courses. The majority of the open channels in this area are maintained agricultural ditches with fewer roughness features such as logs or boulders.

Rainfall Data

We developed design rainfall events for the 2-, 5-, 10-, 25-, 50-, and 100-year return period using the SCS Type IA curve and the IDF data for the Pebble Hill Reservoir rain gauge (ID:DT61) operated by Metro Vancouver. This rain gauge was selected due to its proximity to the study area and the period of record available. It is located in the southwest corner of the study area at an elevation of 51 m. The IDF data includes 13 years of data (from 1998 to 2010). The IDF curve is presented in in Figure D1-1.

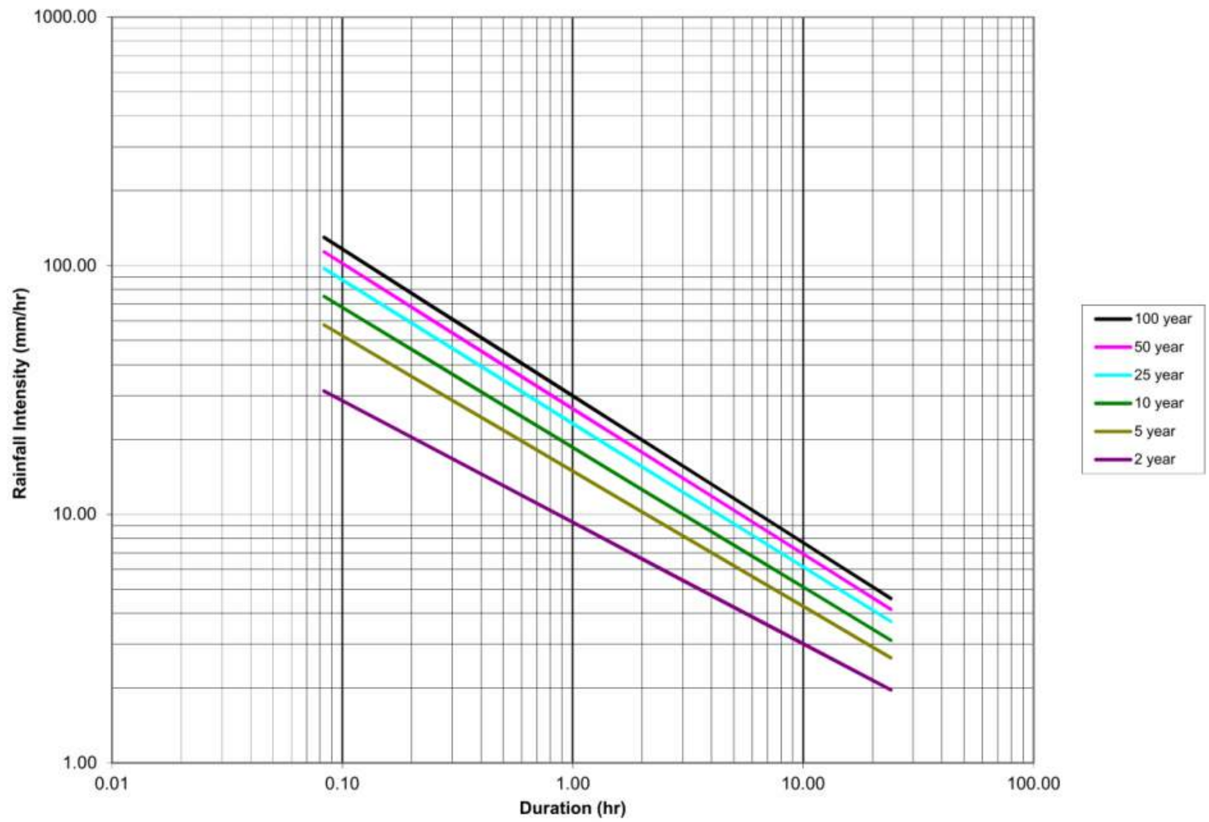


Figure D1-1
Pebble Hill Reservoir IDF Curves

Table D-3 presents the relevant coefficients for the Pebble hill IDF Curve.

Table D-3
Coefficient A and Exponent B for Pebble Hill Reservoir IDF Curve

	10-Year Return Period	100-Year Return Period
Coefficient A	18.598	29.948
Exponent B	-0.562	-0.590

We include an example of the 100-year storm event developed from this IDF curve for use in the model in Figure D1-2:

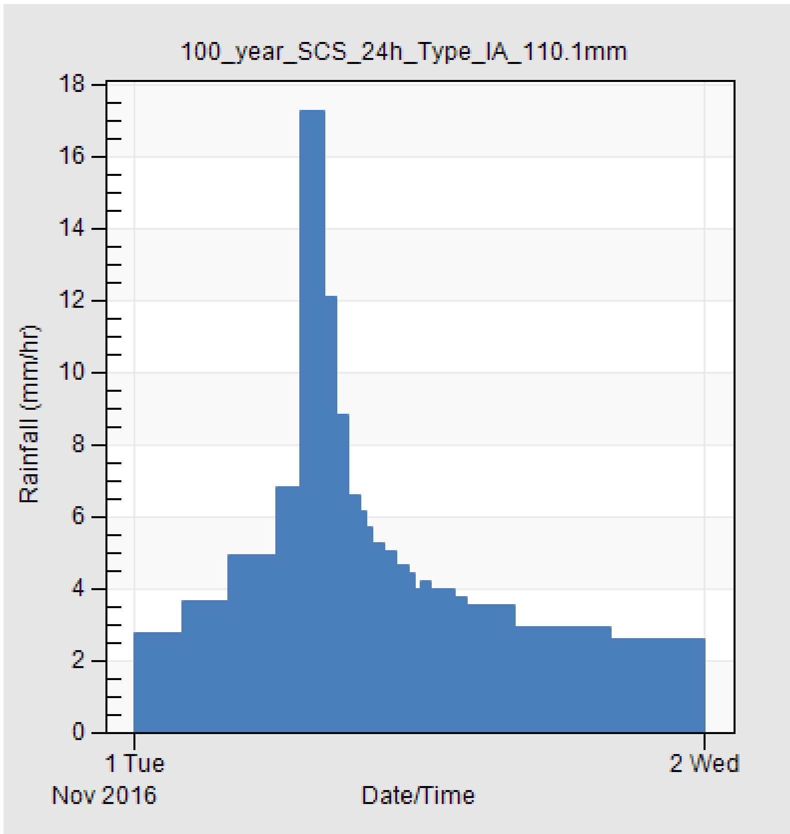


Figure D1-2
100-year, 24-hour Rainfall Event

Boundary Conditions and External Inflows

We added two subcatchments in the northern area of the model to account for the runoff that can be expected to contribute to the drainage along the north boundary of the study area. At the outfalls at the floodbox at Brandrith Pump Station (OF1) and the end of the storm siphon along 12 Avenue (OF5), we assumed fixed tidal conditions of high tide (1.8 m) to represent the worst-case tidal condition for the study area. The tidal information was taken from the Fisheries and Oceans Canada database. We assumed only free outfalls not controlled by pump stations would be affected by tides. The outfalls along English Bluffs (OF2, OF3, OF4) would not be significantly affected due to their steep gradient. We assume pump stations will be upgraded overtime to overcome future high tide conditions (OF6 and OF7).

Model Calibration

SFE completed flow monitoring near the intersection of Boundary Bay Road and 12 Avenue at the 900 mm PVC pipe (Site 1) and both of the 750 mm twinned concrete pipes at the intersection of 56 Street and 6 Avenue (Site 2). The figures in Appendix B show these locations in more detail. The flow monitoring was completed from November 1 to December 31, 2016. During this time, the peak flows measured during he storm events ranged from 50 L/s to 500 L/s. Associated Engineering processed the data and calibrated the existing condition model to match the flow distributions recorded at the flow monitoring locations. We used the sum of the two pipes at 56 Street for calibration as the other location did not have complete records over the monitoring period.

Figures D1-3 and D1-4 show the flow results from the model compared to the measured flows before and after calibration.

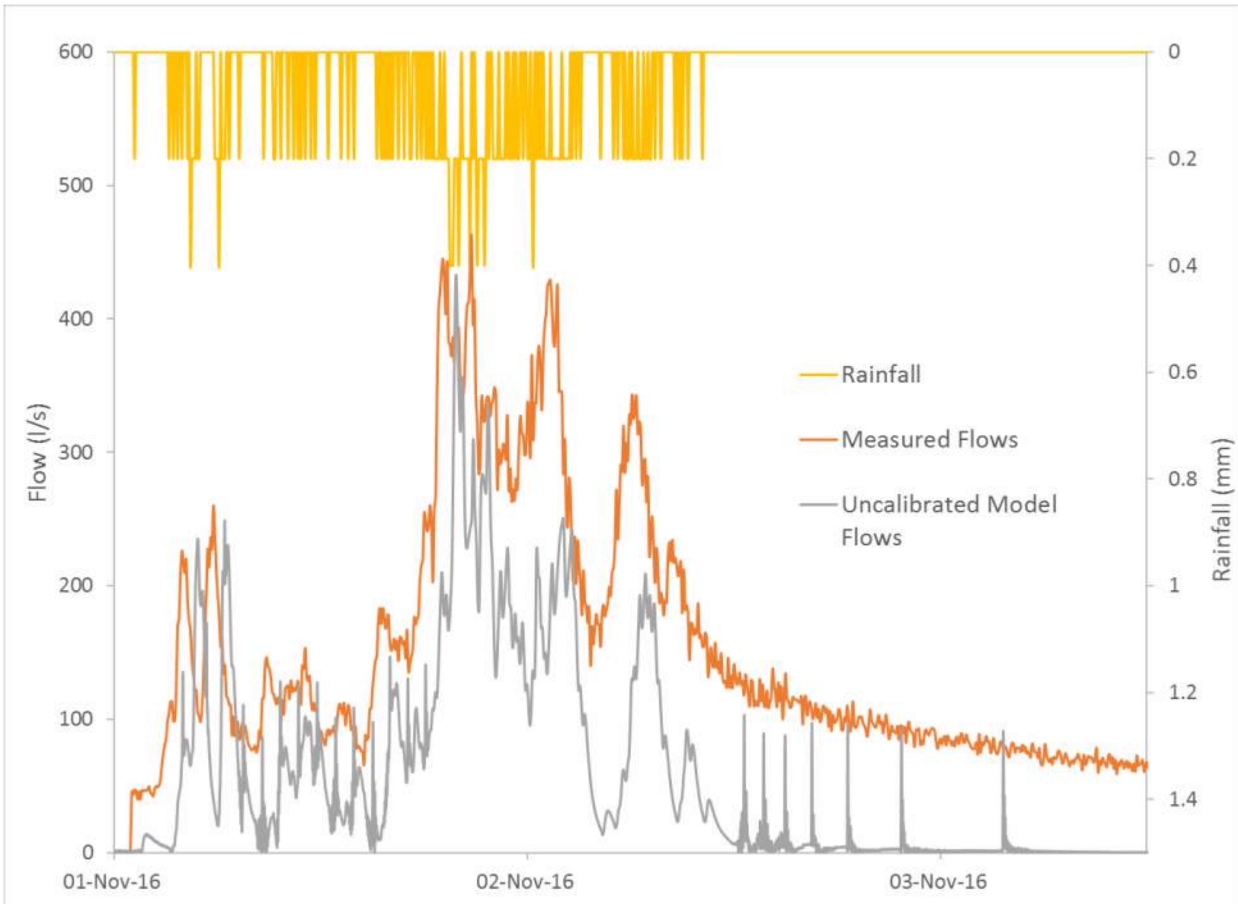


Figure D1-3
Comparison of Measured and Uncalibrated Model Flows (Site 2)

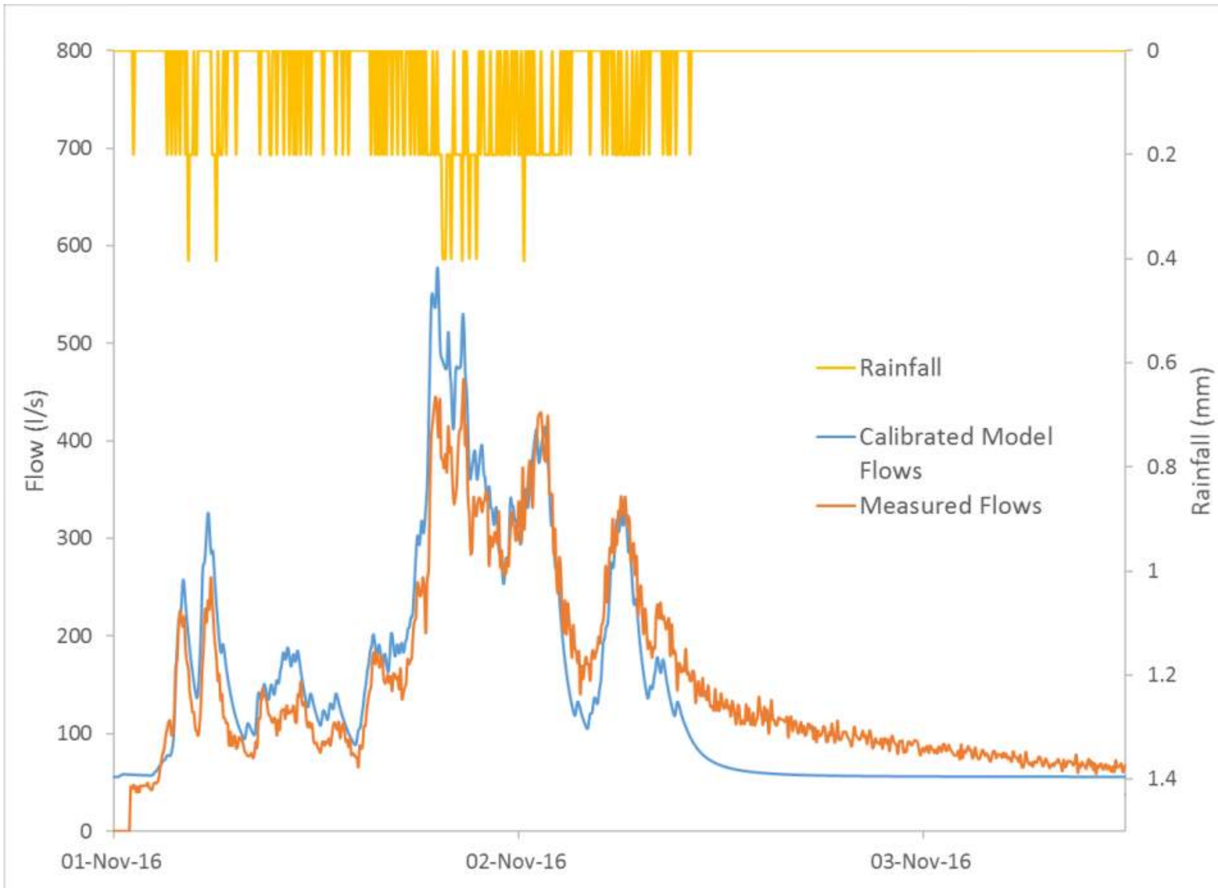


Figure D1-4
Comparison of Measured and Calibrated Model Flows (Site 2)

The uncalibrated model flows have significantly sharper, but lower peaks than the measured flows and underestimates the runoff volume. Additionally, the measured flows exhibit a base flow while the uncalibrated model does not.

To calibrate the model, we adjusted the hydrologic parameters affecting subcatchment runoff, most notably the effective impervious area. Although we originally assume single family residential areas to have 60% impervious cover, we changed this value to 40% to better correspond to the measured flows. To compensate for the resulting net decrease in surface runoff, we lowered the rates of infiltration for pervious surfaces to better replicate the watershed response during large storms. Additionally, we assigned base flows of approximately 0.6 L/s throughout the model to correspond the base flow measured by SFE. The calibrated hydrograph now closely replicates the measured flow events. Although the calibrated flow is overestimating the measured flows at the peaks, we did not feel that further reducing runoff rates was justifiable give the calibration event was relatively small. Runoff response does not scale linearly with the magnitude of an event.

Our calibrated model will give us more confidence in our model results for the smaller events. For larger events, however, additional calibration to larger storm events closer to the modeled event return period would be required to create an accurate representation of the watershed response.

D1.2 FUTURE CONDITION MODEL

We updated our Existing Condition Model to reflect future developments expected to occur within the study area. The purpose of this model is to identify the hydraulic impacts of future development. New deficiencies may occur as a result of future development, and existing deficiencies may be exacerbated.

Densification

In the existing condition model, we modelled all developments which were already approved and underway, including the Onni development in the TFN lands and the Southlands development. For the future condition, no new developments are planned, so for the most part, our land use condition and associated impervious values stayed the same. However, we assumed that as the housing stock is replenished overtime, houses will be built with bigger footprints and will have correspondingly greater impervious areas. To update our model to reflect this future densification, we increased the impervious percentage associated with the single family residential land use category from 40% to 50%.

Additionally, there is a portion of the northern point of Point Roberts which drains to the Tsawwassen Southlands area. As this area is zoned to be developed into rural residential housing, we modeled this area as fully developed into single family residential housing in our future condition.

Climate Change

The Lower Mainland can expect an increase in the frequency of storms as well as an increase in storm severity in the future due to climate change (Metro Vancouver[53], 2016). This increase in precipitation could have a significant effect on the drainage system performance in the Tsawwassen area. As such, we completed a screening level assessment of the effects of climate change on the rainfall in the area. We applied a percent increase to the total rainfall volume for the 24-hour storm proportional to increases found in a recent climate change study from the City of Surrey[54]. Given the similar climatic conditions between Tsawwassen and Surrey, using results of Surrey's updated IDF curves allows us to take advantage of data based on detailed regional downscaling. In the year 2080, Tsawwassen could experience a 50% increase in precipitation depending on the emissions scenarios we follow globally. We modelled this 50% increase for both the 10-year and 100-year event to assess the response of the current major and minor system to climate change.

[53] Metro Vancouver. 2016. Climate Projections for Metro Vancouver. Available at: http://www.metrovancouver.org/services/air-quality/AirQualityPublications/ClimateProjections ForMetroVancouver.pdf (accessed February 2017).
[54] Dillon Consulting on Behalf of City of Surrey. 2015. Development of Future IDF Statistics for the City of Surrey.

Results are presented in Section 4.3. Figure D1-5 presents a comparison of our rainfall event adjusted for climate change to the original modelled event representing present day conditions.

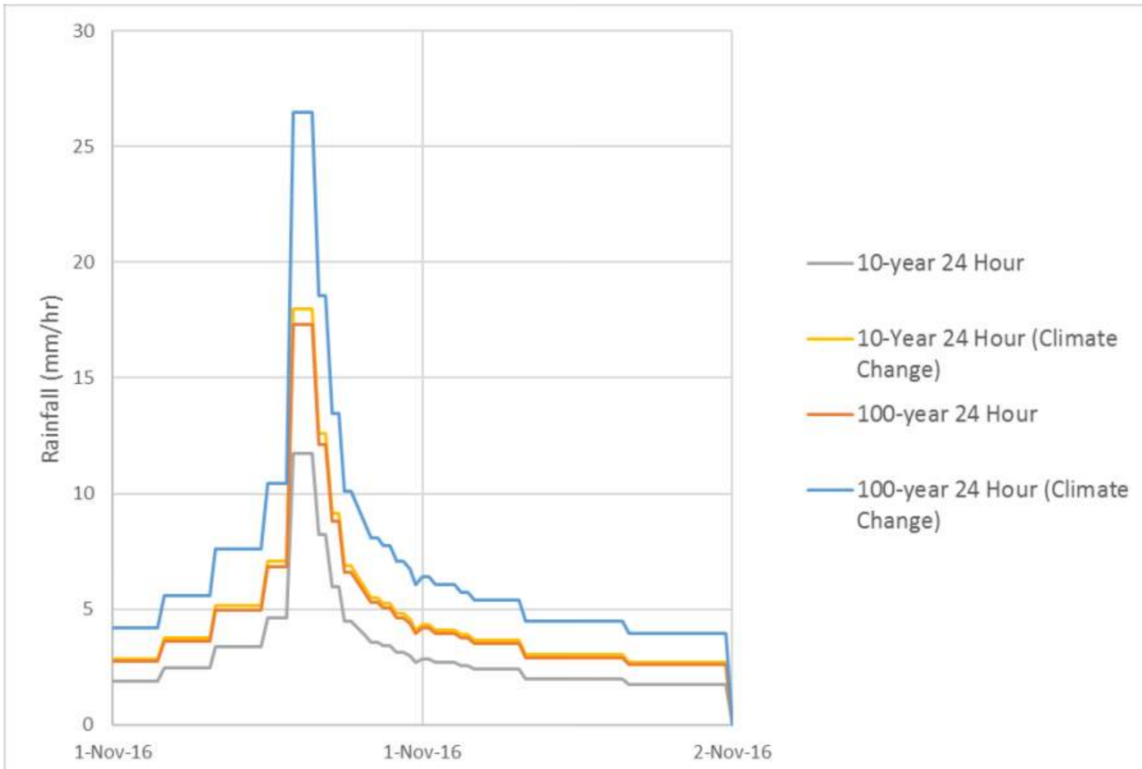


Figure D1-5
Comparison of Rainfall Events (with/without Climate Change)

D2 ASSESSMENT OF POTENTIAL IMPACTS

We ran a three-year continuous simulation of the drainage network to compare the existing and future conditions in the watershed. This allows us to analyze the potential impacts of development and densification in the Tsawwassen study area. The purpose of the simulation is to assess the impact of development on the hydrologic regime in natural watercourses. This provides an indication of changes in flow-duration characteristics following development.

D2.1 EXTENDED PERIOD RAINFALL DATA

We completed Extended Period Simulation (EPS) modelling for two scenarios. The first scenario was based on existing land use, while the second scenario was based on future land use. The modifications to the land use under future development conditions are the same as those used for the event-based models.

For both scenarios, the same hydraulic network and rainfall data were applied to the model. We used rainfall data spanning from June 1, 2010 to June 1, 2013 from the firehall rain gauge, as shown in Figure D2-1.

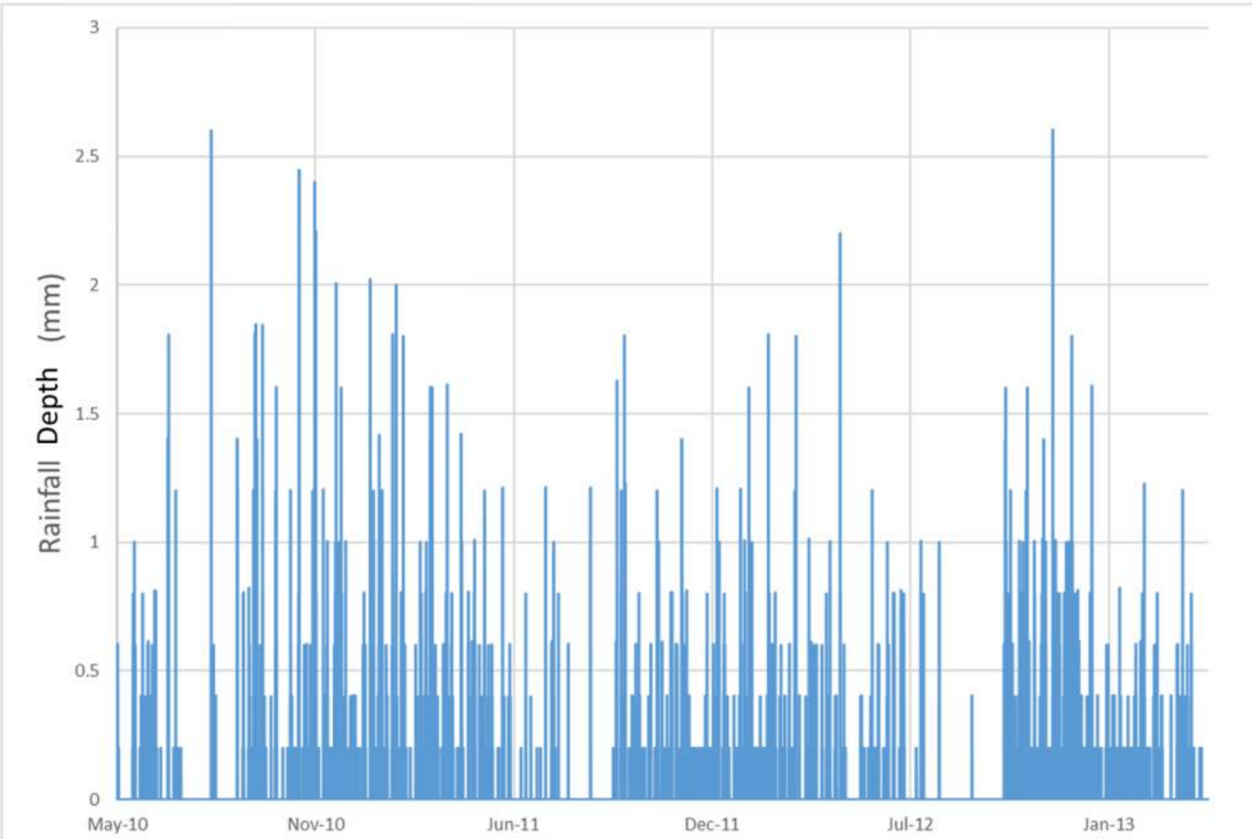


Figure D2-1
EPS Rainfall Data

D2.2 POTENTIAL IMPACTS OF DEVELOPMENT

Hydrological Impacts

The EPS modelling is based on recorded rainfall data over an extended period, not on synthetic design events. As such, it is representative of the typical rainfall events that occur within the study area, and therefore provides quantitative insight into the study area's response to development/densification, absent any mitigation measures such as source controls or BMPs.

The key hydrologic results from the EPS model are summarized in Table D-4.

Table D-4
Hydrologic Results from Extended Period Simulation Model

	Existing Development	Future Development	Change
Average Impervious Percent of Subcatchments (%)	39%	44%	14%
Total Runoff Volume (10^7 m^3)	1.4	1.6	12%
Average Total Infiltration of Subcatchments (mm)	1681	1585	-6%

The increased impervious area associated with the future development condition results in an increase in the total runoff volume. The increase in impervious area within the study area also reduces the total infiltration, as there is an increase in hard surfaces which cannot accommodate infiltration. These effects during the future development condition will cause formerly infiltrated water in the uplands single family residential areas to concentrate in downstream watercourses more quickly, if not managed with feasible source controls or BMPs.

We created flow-duration-exceedance curves at two locations in agricultural ditches to illustrate changes in flow regimes: one at the outlet of the storm main system at Spyglass Crescent and 52 Street (D-1437), and one at the outlet of the storm system at 56 Street and 6 Avenue (D-1393). The curves are presented in Figures D2-2 and D2-3, and the reporting location for each curve is indicated on Map 5-2. These curves represent the fraction of the total simulation time that a particular flow rate is exceeded in each watercourse.

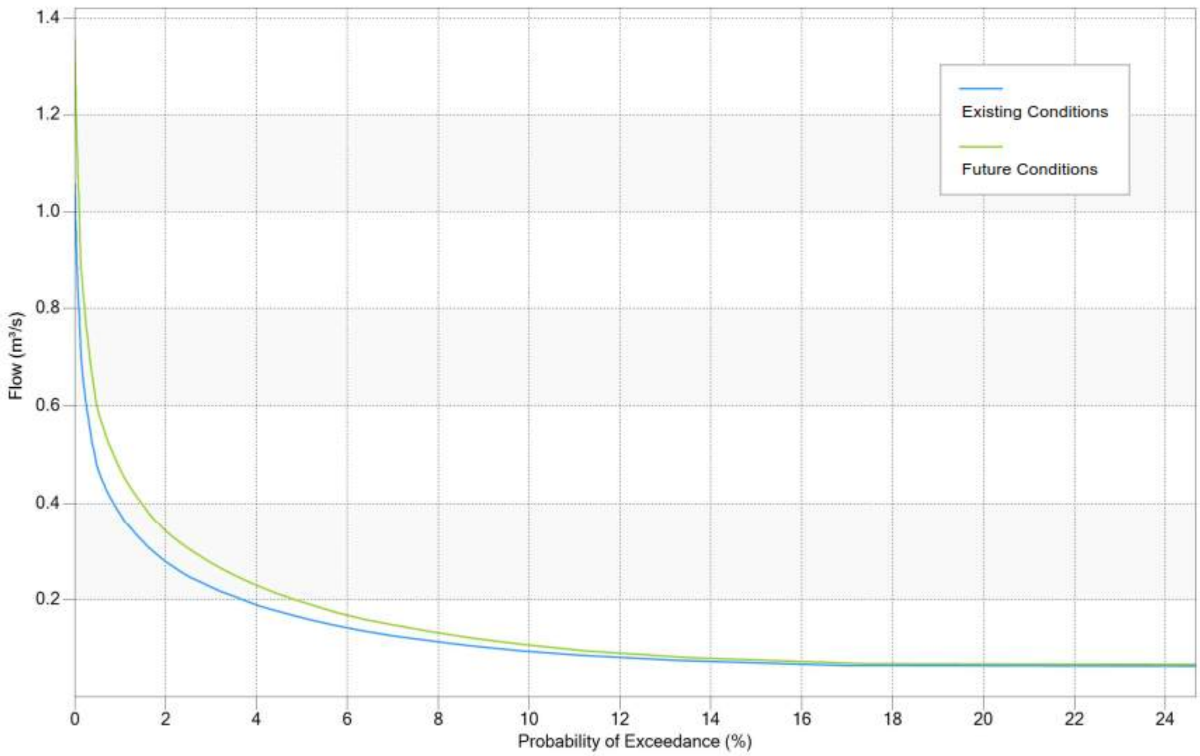


Figure D2-2
Flow Duration Exceedance Curve for D-1393

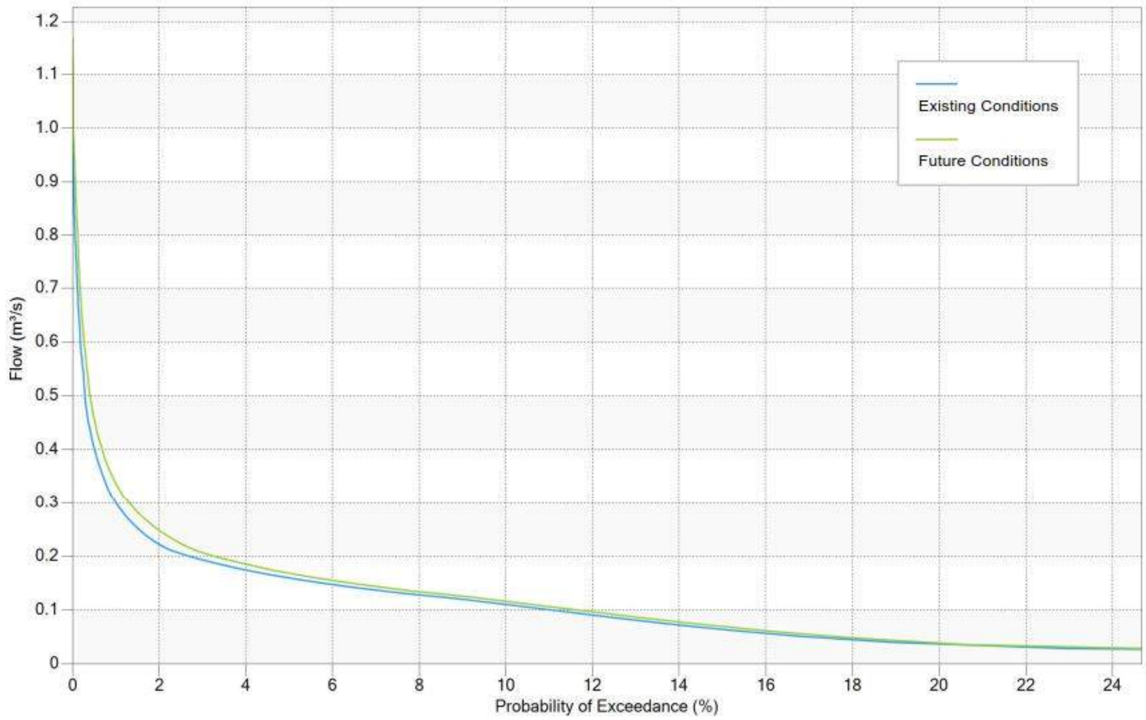
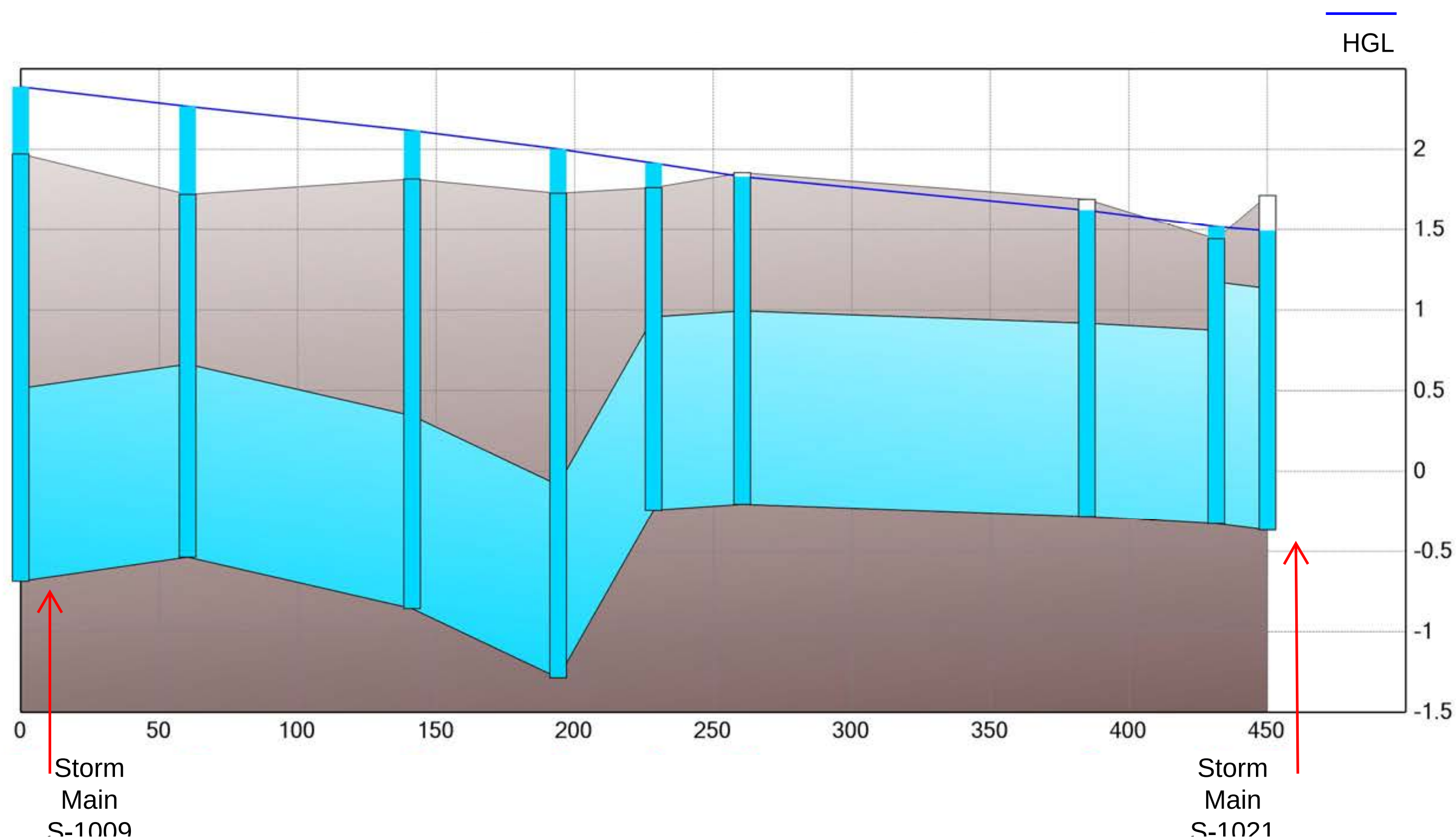


Figure D2-3
Flow Duration Exceedance Curve for D-1437

Under future development conditions, both ditches are subject to an increase in the occurrence of high frequency and duration flows. This is reasonable for both, given that a significant portion of the area draining into both ditches will be subject to densification and an increase in impervious area in the future conditions. We did not observe any significant change in the base/low flow conditions between the exiting and future development conditions.



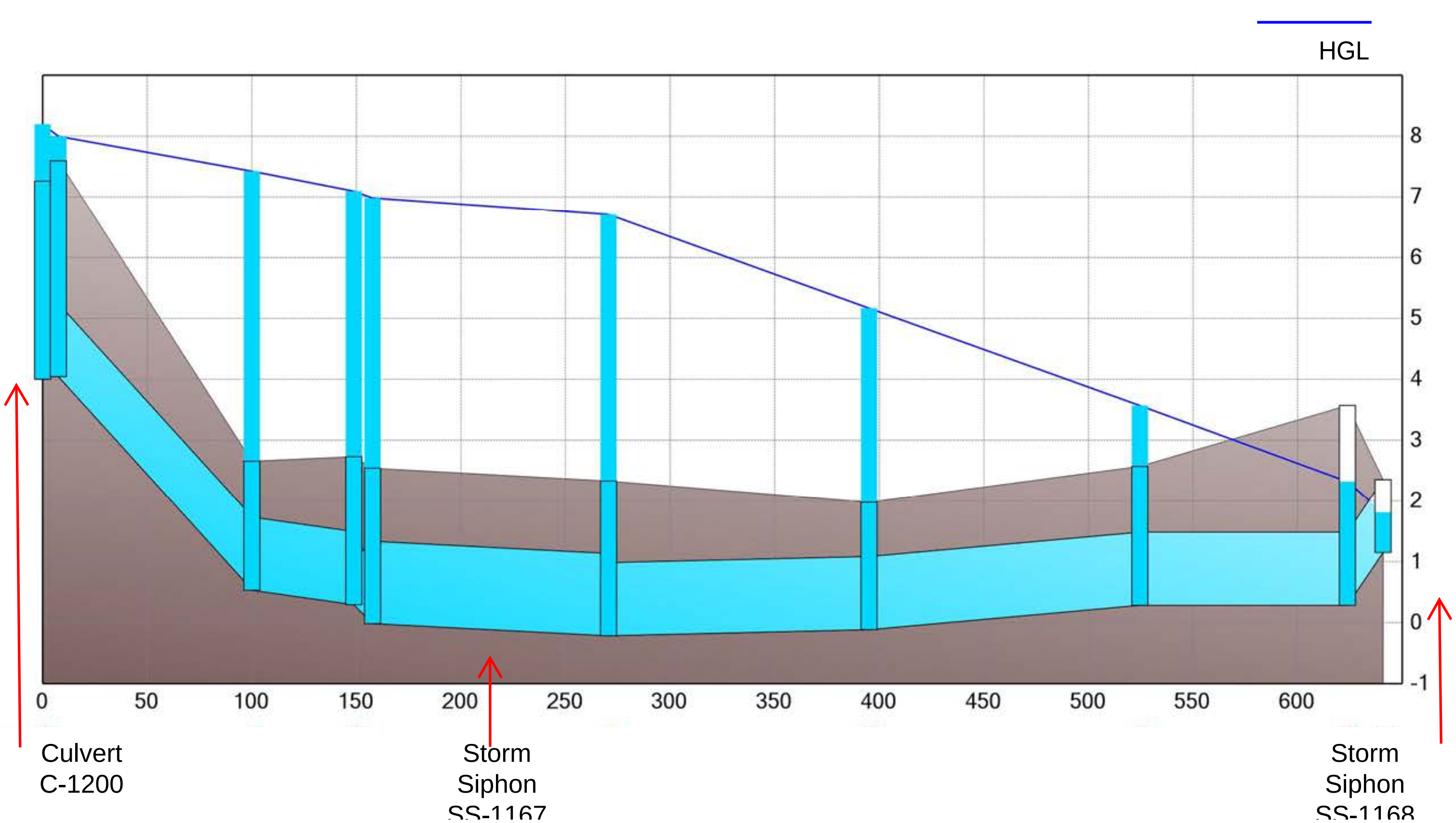
PREPARED BY: Associated Engineering

PREPARED [FOR:] Delta

Figure D-2:
Existing Condition Deficiency D-2
Peak HGLs for 10-Year Design Event

PROJECT No: 20162283

DATE: APRIL 2018



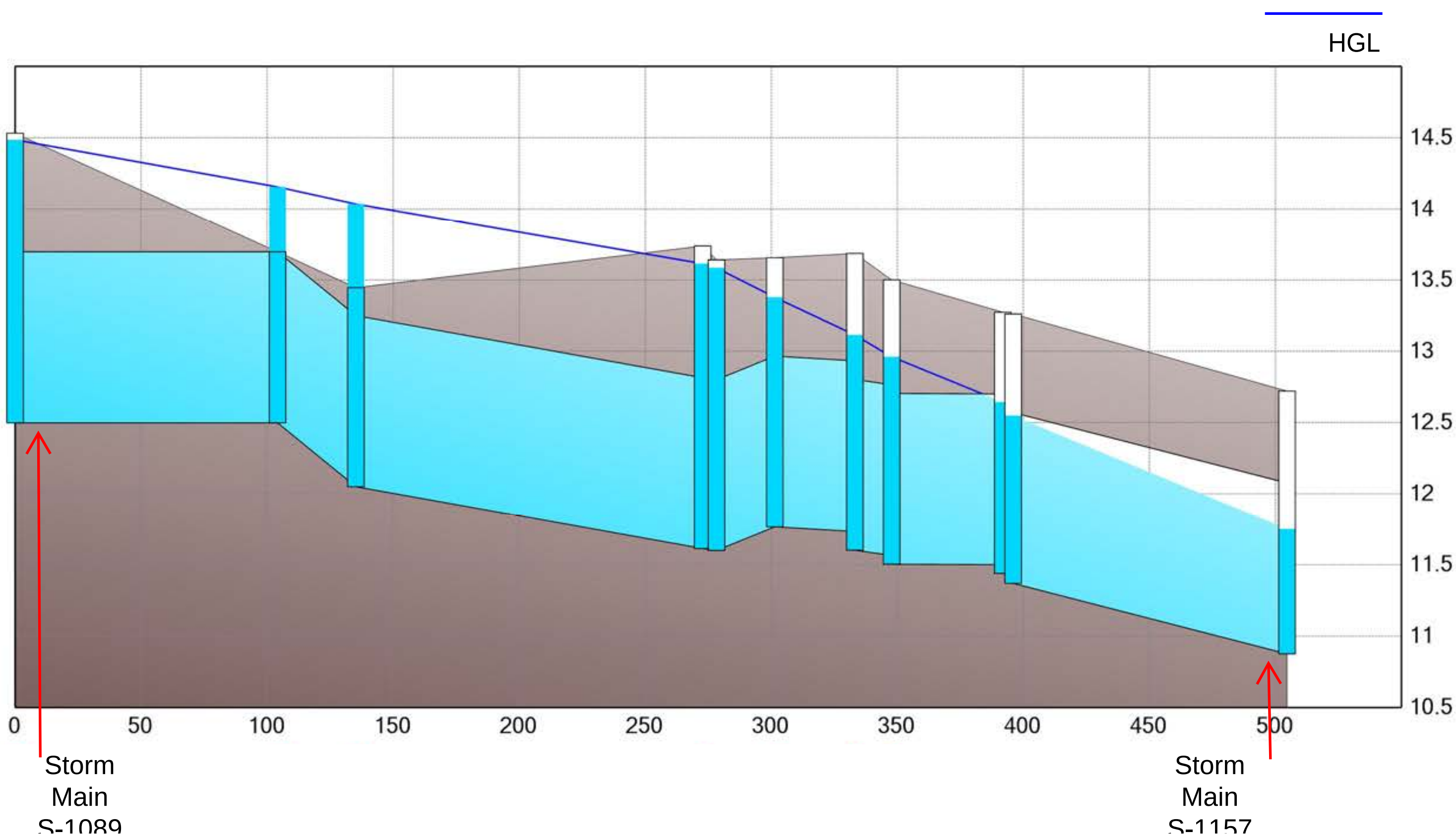
PREPARED BY: Associated Engineering

PREPARED Delta

Figure D-3:
Existing Condition Deficiency D-3
Peak HGLs for 10-Year Design Event

PROJECT No: 20162283

DATE: APRIL 2018



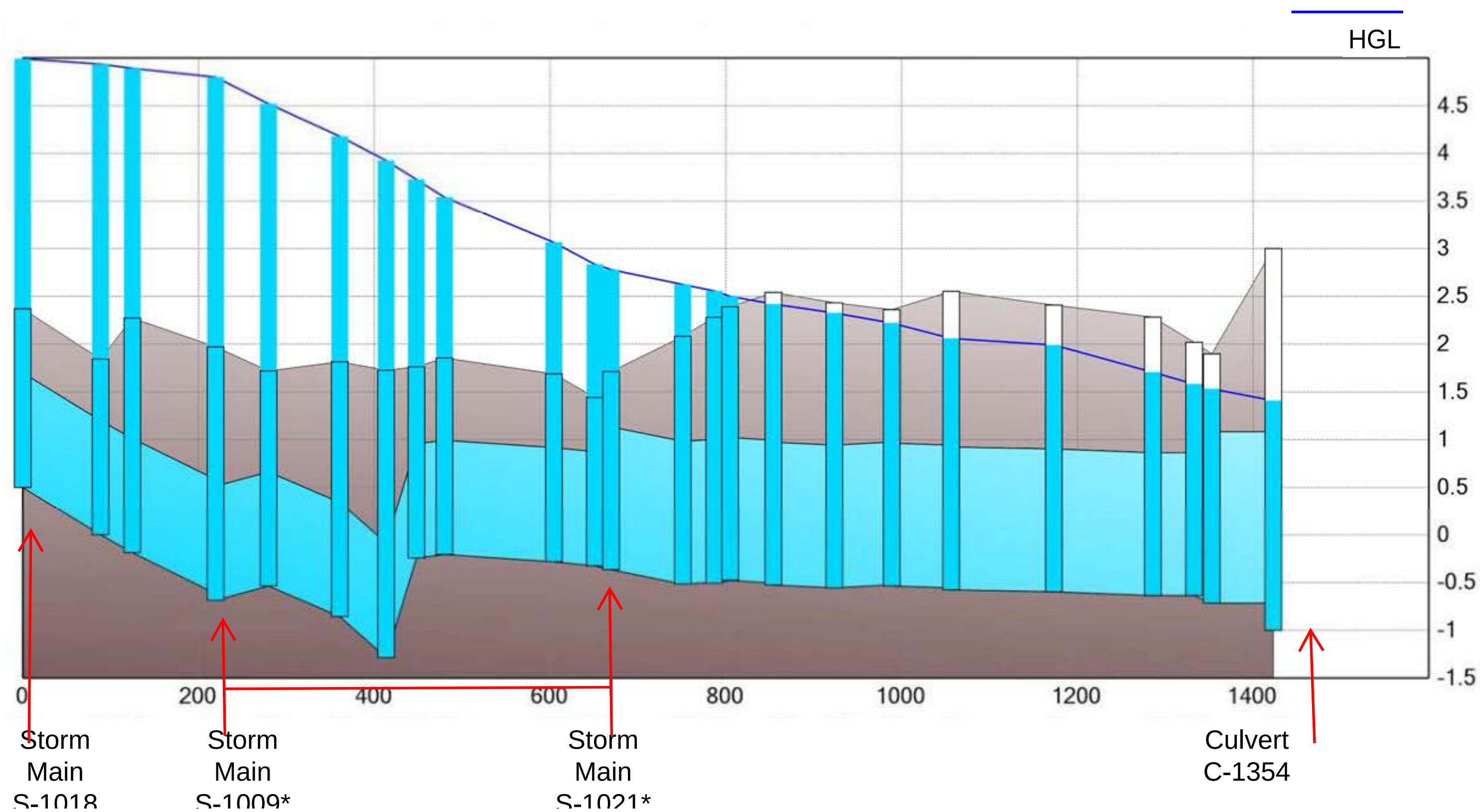
PREPARED BY:

PREPARED

Figure D-4:
Existing Condition Deficiency D-4
Peak HGLs for 10-Year Design Event

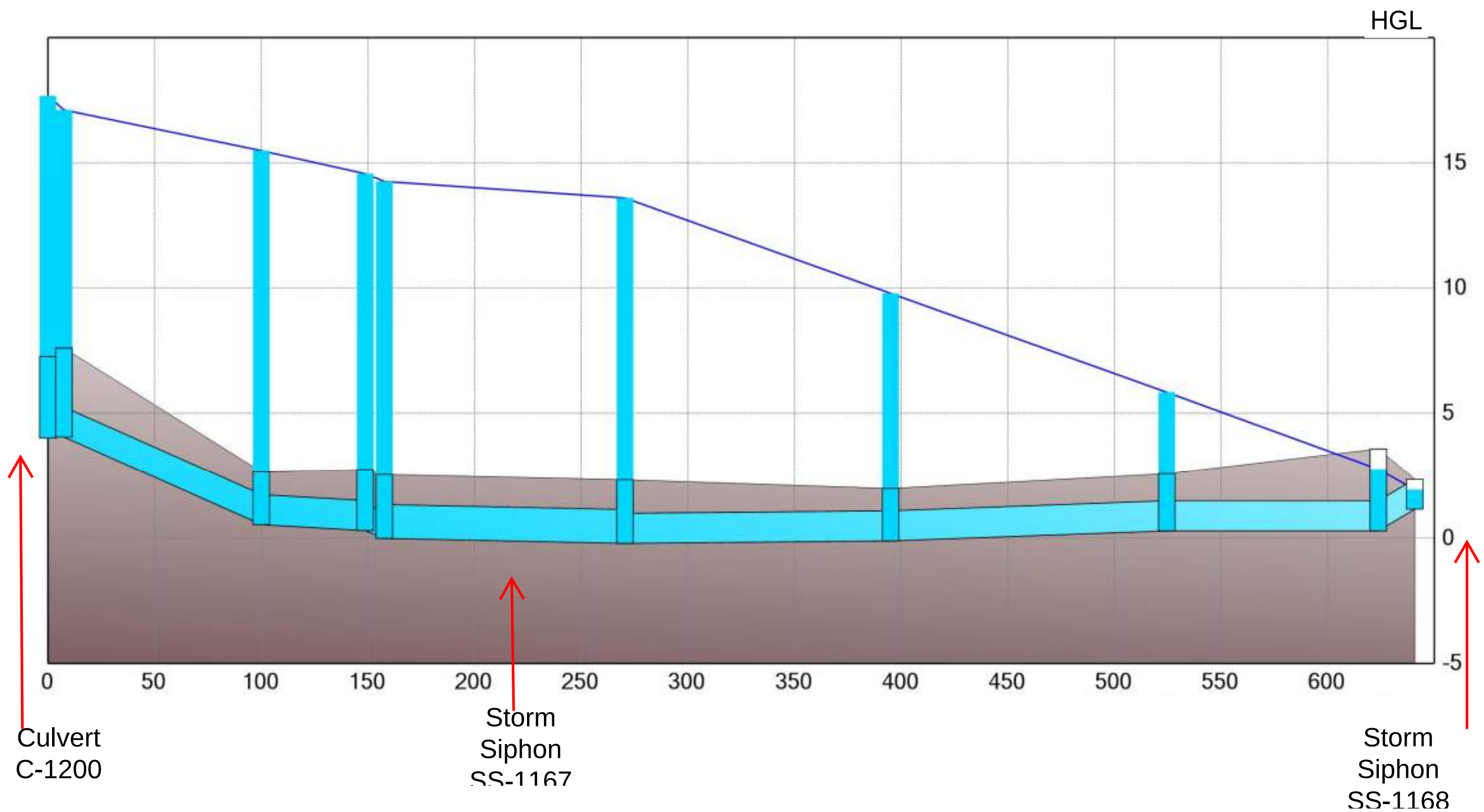
PROJECT No: 20162283

DATE: APRIL 2018



*Deficient under existing development

PREPARED BY:	PREPARED	Figure D-6: Peak HGLs for 10-Year Design Event Under Climate Change	PROJECT No: 20162283
Associated Engineering	Delta		DATE: APRIL 2018



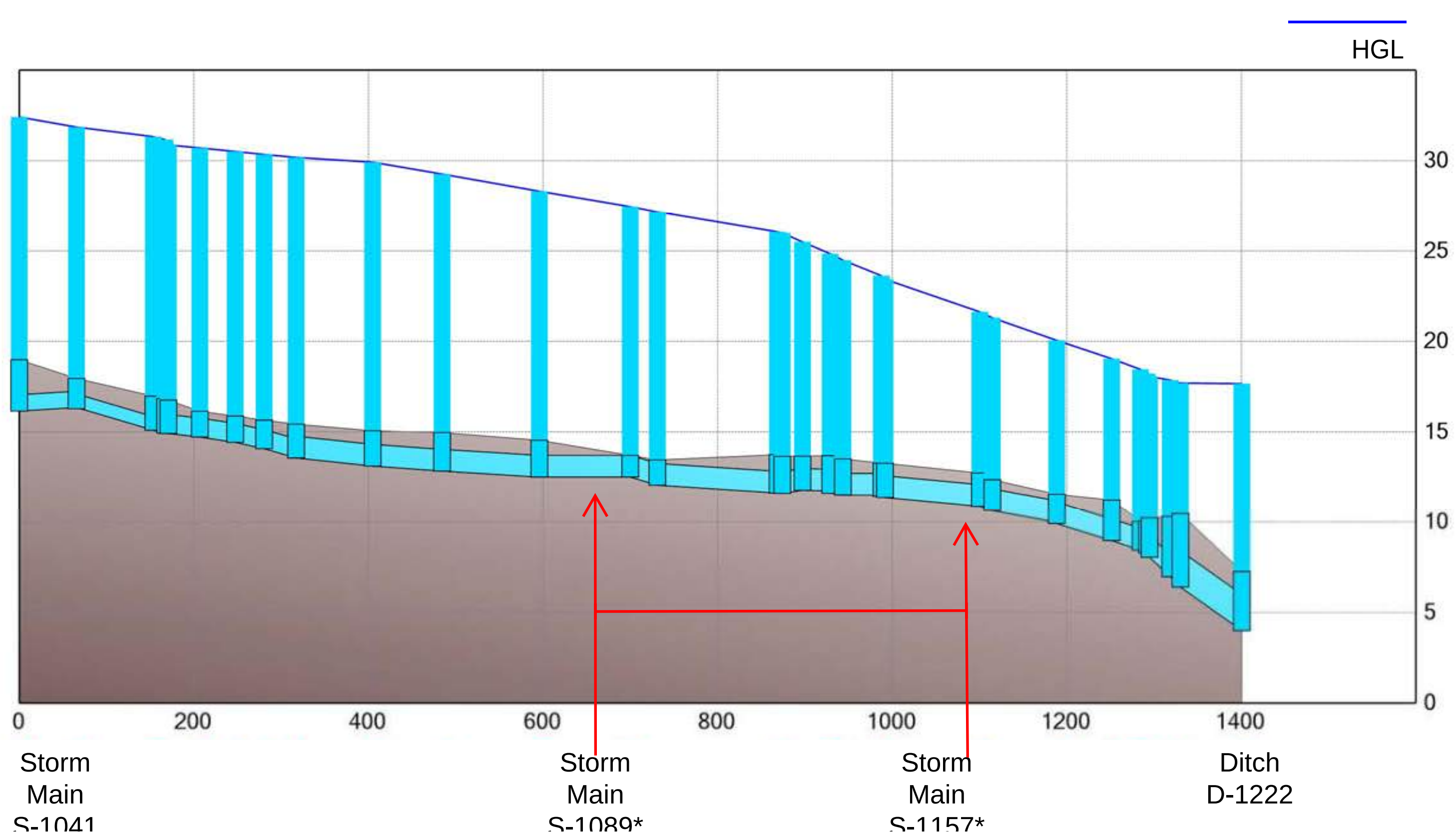
PREPARED BY: Associated Engineering

PREPARED Delta

Figure D-7:
Peak HGLs for 10-Year Design Event
Under Climate Change

PROJECT No: 20162283

DATE: APRIL 2018



*Deficient under existing development

PREPARED BY:	PREPARED	Figure D-8: Peak HGLs for 10-Year Design Event Under Climate Change	PROJECT No: 20162283 / DATE: APRIL 2018

Appendix E - System Upgrades

Table E-1
Minor System Upgrades

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
MN-1				
S-1297	427342	450	1200	15
S-1298	427343	450	1200	20
S-1299	427467	450	1200	106
S-1300	427468	450	1200	96
S-1301	427618	525	1200	9
S-1314	427344	450	1200	117
S-1316	427341	450	1200	20
S-1302	427621	525	1350	16
S-1303	427620	525	1350	2
S-1304	427619	525	1350	16
S-1305	427726	525	1350	13
S-1306	427730	525	1350	16
S-1307	427732	525	1350	13
S-1308	427731	525	1350	23
S-1309	427727	525	1350	16
S-1310	427729	525	1350	3
S-1311	427728	525	1350	23
S-1312	427725	525	1350	16
S-1313	427724	525	1350	55
S-1315	427617	525	1350	95
S-1317	427610	600	1350	90
S-1318	427609	600	1350	92

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1319	427599	600	1350	125
S-1320	427597	600	1350	56
S-1321	427598	600	1500	9
MN-2				
S-1006	1217146	685	750	37
S-1007	1217147	685	750	64
S-1005	427683	900	1050	104
S-1000	427490	1500	1200 x 1800	117
S-1001	427484	1500	1200 x 1800	47
S-1002	427485	1500	1200 x 1800	113
S-1003	427758	1200	1200 x 1800	53
S-1009	427557	1200	1200 x 1800	60
S-1010	427556	1200	1200 x 1800	81
S-1011	427745	1500	1200 x 1800	18
S-1012	427746	1500	1200 x 1800	49
S-1013	427649	1500	1200 x 1800	69
S-1014	427648	1500	1200 x 1800	65
S-1015	427647	1500	1200 x 1800	68
S-1018	434188	1200	1800	89
S-1020	427623	1200	1200 x 1800	36
S-1021	427750	1500	1200 x 1800	18
S-1022	427751	1200	1200 x 1800	47
S-1023	427756	1200	1200 x 1800	124
S-1024	427551	1200	1200 x 1800	32
S-1025	427749	1500	1200 x 1800	81
S-1026	427553	1200	1200 x 1800	34
S-1027	427560	1200	1200 x 1800	95
S-1028	427744	1500	1200 x 1800	36

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
C-1354	C-1218315	1200 x 1800	1200 x 2400	70
S-1247	C-1218315	1200 x 1800	1800 x 2100	20
MN-3				
S-1062	427023	450	675	43
S-1063	427014	450	675	107
S-1060	427029	600	750	16
S-1051	427055	600	900	69
S-1052	427056	600	900	80
S-1053	427057	600	900	14
S-1054	427039	450	900	38
S-1055	427046	450	900	46
S-1056	427044	450	900	87
S-1059	427030	450	900	69
S-1061	427028	450	900	22
S-1064	427024	450	900	81
S-1065	427021	450	900	27
S-1075	427053	600	900	73
S-1078	427086	750	900	15
S-1079	427084	750	900	78
S-1138	426900	480	900	102
S-1139	426909	600	900	18
S-1076	427093	750	1200	4
S-1077	427072	750	1200	74
S-1080	427092	750	1200	72
S-1081	427095	900	1200	12
S-1082	427091	750	1200	80
S-1119	427107	900	1200	59
S-1122	427105	900	1200	97

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1123	427103	900	1200	6
S-1125	427102	900	1200	82
S-1126	427101	900	1200	55
S-1136	427110	900	1200	57
S-1137	427112	900	1200	52
S-1140	426884	900	1200	15
S-1141	426894	750	1200	15
S-1144	426891	900	1200	27
S-1145	426890	900	1200	3
S-1146	426888	900	1200	39
S-1162	427209	900	1200	94
S-1164	427207	900	1200	99
S-1166	426901	900	1200	103
S-1244	936198	600	1200	47
SS-1245	426899	750	1200	114
C-1200	C-434907	1200	1500	8
S-1143	426905	1050	1500	9
S-1147	426898	1200	1500	93
S-1148	426886	1200	1500	49
SS-1142	936196	525	1800	4
SS-1161	427214	1200	2100	130
SS-1165	427208	1200	2100	125
SS-1167	426902	1350	2100	113
SS-1174	427213	1200	2100	99
SS-1168	427231	1200	2400	17
MN-4				
S-1043	426704	600	750	71
S-1044	427049	600	750	21

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1045	427051	600	750	22
S-1046	427050	600	750	15
S-1048	426703	600	750	21
S-1049	426697	600	750	58
S-1057	427035	450	750	97
S-1058	427026	600	750	73
S-1325	426686	600	750	93
S-1326	426872	450	750	102
S-1343	426684	500	750	13
MN-5				
S-1041	426712	900	1200	66
S-1042	426720	600	1200	31
S-1083	426738	1050	1200	41
S-1084	426739	1050	1200	36
S-1085	426742	750	1200	4
S-1086	426743	750	1200	13
S-1087	426721	750	1200	69
S-1088	426713	750	1200	88
S-1093	426745	1050	1200	37
S-1094	434166	1050	1200	33
D-1222	Ditch along Ferguson Road Leading into Pressurized system- Make into a Pipe	2 m wide ditch	1350	70
S-1120	426795	1200	1350	23
S-1133	426792	1200	1350	44
S-1134	426793	1200	1350	15
S-1135	426794	1200	1350	32

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1149	426887	1200	1350	12
S-1150	426929	1200	1350	24
S-1151	426928	1200	1350	3
S-1152	426927	1200	1350	8
S-1153	426925	1200	1350	33
S-1154	426933	1200	1350	63
S-1155	426806	1200	1350	74
S-1156	426807	1200	1350	14
S-1157	426796	1200	1350	109
S-1158	434220	1200	1350	4
S-1089	426773	1200	1500	104
S-1090	426771	1200	1500	111
S-1091	426772	1200	1500	79
S-1092	426750	1200	1500	88
S-1124	426776	1200	1500	31
S-1132	426777	1200	1500	138
MN-6				
S-1163	426939	750	900	60
S-1160	426951	750	900	74
S-1184	426953	750	900	103
S-1173	426950	750	900	31
S-1171	426957	750	900	7
S-1169	426958	750	900	23
S-1417	Crosses Boundary Bay Road near 8th avenue	1200	1200 (Add additional pipe beside existing 1200mm pipe)	98
S-1418	Along Boundary Bay Road near Jackson Way	1200	1200	216

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
			(Add additional pipe beside existing 1200mm pipe)	
S-1419	426310	1200	1200 (Add additional pipe beside existing 1200mm pipe)	141
S-1420	Along Boundary Bay Road near Jackson Way	1200	1200 (Add additional pipe beside existing 1200mm pipe)	114
S-1421	Along Boundary Bay Road near Jackson Way	1200	1200 (Add additional pipe beside existing 1200mm pipe)	147
MN-7				
S-1038	426311	600	1200	95
MN-8				
S-1071	426260	750	900	99
S-1277	426225	600	900	99
S-1278	426226	600	900	99
S-1279	426215	600	900	90
S-1280	426429	750	900	3
S-1281	426428	750	900	14
S-1282	426431	750	900	42
S-1283	426416	750	900	112
S-1284	426252	750	900	33
S-1285	426410	750	900	14
S-1286	426411	750	900	112
S-1287	426417	750	900	93
S-1288	426257	750	900	95
S-1290	426443	750	900	149

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1291	426441	750	900	93
S-1292	426440	750	900	100
S-1293	426258	750	900	84
S-1096	426354	900	1050	89
S-1097	426352	900	1050	15
S-1098	426351	900	1050	148
S-1099	426276	900	1050	155
S-1100	426263	900	1050	106
MN-9				
S-1030	426129	450	600	84
S-1031	426140	450	600	69
S-1032	426132	450	600	8
S-1033	426133	450	600	81
S-1034	426130	450	600	55
S-1035	426139	450	600	85
S-1067	426153	450	600	102
S-1069	426151	450	600	82
S-1070	426145	450	600	93
S-1072	426146	450	600	42
S-1073	426141	450	600	23
S-1074	426131	450	600	117
S-1294	426128	450	600	50
S-1322	426135	450	600	30
S-1264	425612	600	750	66
S-1265	425611	600	750	74
S-1267	425905	600	750	38
S-1268	426020	525	750	85
S-1269	426014	525	750	19

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1270	426016	525	750	18
S-1271	426015	525	750	9
S-1276	426053	600	750	106
S-1427	426207	450	750	14
S-1428	426206	450	750	16
S-1272	425608	600	750	106
S-1110	426195	600	750	7
S-1102	426186	600	750	47
S-1103	426185	600	750	39
S-1117	426162	450	900	5
S-1118	426164	750	900	162
S-1273	426159	750	900	68
S-1274	426160	750	900	13
S-1275	426057	750	900	70
S-1295	426124	450	900	122
S-1296	426122	450	900	113
S-1104	426192	750	1200	15
S-1106	426193	750	1200	15
S-1108	426199	750	1200	5
S-1109	426200	750	1200	5
S-1111	426197	750	1200	34
S-1113	426196	750	1200	34
S-1115	426179	750	1200	117
S-1116	426183	750	1200	84
MN-10				
S-1187	425936	600	900	111
S-1188	425935	600	900	80
S-1189	425934	600	900	82

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1191	425942	900	1200	46
S-1192	425941	900	1200	3
S-1195	425956	900	1200	46
S-1196	425946	900	1200	76
S-1197	425947	900	1200	75
S-1198	425943	900	1200	15

Table E-2
Major System Upgrades

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
MA-1				
3rd_Outfall	434266	750	1500	49
City of Delta ID		**Upgrades**		
Pumps at 3rd Avenue Pump Station		Triple capacity of all pumps		
MA-2				
C-1364	*435180*	*1050 x 1050*	*2400*	*13*
C-1365	*434761*	*1200*	*Two 2400 Culverts*	*49*
C-1366	*426617 / 426618*	*1200*	*Two 2400 Culverts*	*11*
D-1378	437289	H: 2200 W: 3000 S: 1:1.5	H: 2200 W: 4000 S: 1:2	151
D-1377	437289	H: 1700 W: 3000 S: 1:1.5	H: 2200 W: 4000 S: 1:2	201
D-1376	437289	H: 1800 W: 3000 S: 1:1.5	H: 2200 W: 4000 S: 1:2	132
D-1375	437289	H: 1800 W: 3000 S: 1:1.5	H: 2200 W: 4000 S: 1:2	52

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
D-1374	437289	H: 1800 W: 3000 S: 1:1.5	H: 2200 W: 4000 S: 1:2	62
City of Delta ID		**Upgrades**		
Pumps at 12th Avenue Pump Station		Double capacity of all pumps		
MA-3				
C-1251	*Culvert below Highway 17 from 16th Avenue to Eagle Way*	*1200*	*1800*	*63*
C-1250	*Culvert below Highway 17 from 16th Avenue to Eagle Way*	*1800*	*2750*	*64*
C-1361	*Culvert below Highway 17 from 16th Avenue to Eagle Way*	*1050*	*1500*	*70*
C-1201	*Culvert Along 16th Avenue*	*1500*	*2400*	*13*
C-1344	*Culvert parallel to Highway 17*	*1800*	*2750*	*28*
C-1248	*Culvert parallel to Salish Sea Drive*	*1500*	*2400*	*38*
C-1249	*Culvert below Blue Heron Drive*	*1500*	*2400*	*53*
D-1435_2	Ditch along Eagle Way from Tsawwassen Drive to Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	428
D-1263	Ditch Along 16 Avenue	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	75

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
D-1437	Ditch parallel to 52 Street	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	354
D-1254	Ditch along Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	59
D-1345	Ditch along Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	57
D-1346_1	Ditch along Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	881
D-1357	Ditch parallel to Salish Sea Drive	H: 1050 W: 1500 S: 1:2	H: 1050 W: 3000 S: 1:2	284
D-1356	Ditch parallel to Salish Sea Drive	H: 1050 W: 1500 S: 1:2	H: 1050 W: 3000 S: 1:2	220
D-1430	Ditch parallel to Salish Sea Drive	H: 1050 W: 1500 S: 1:2	H: 1050 W: 3000 S: 1:2	265

City of Delta ID	Upgrades
Pumps at Brandrith Pump Station	Double capacity of all pumps

**Culvert upgrades are indicated with italics.*

Table E-3
Minor System Upgrades: MN-1
Reference Figure E-1

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$32,000	$32,000
1.2	Erosion & Sediment Control Plan		1	LS	$16,000	$16,000
1.3	Traffic Planning		1	LS	$16,000	$16,000
1.4	Utility Relocation		1	LS	$10,000	$10,000
					Sub-Total - Section 1	**$74,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 1200mm Concrete Pipe	S-1297	15	LM	$2,137	$32,055
2.2	Supply & Install 1200mm Concrete Pipe	S-1298	20	LM	$2,137	$42,740
2.3	Supply & Install 1200mm Concrete Pipe	S-1299	106	LM	$2,137	$226,522
2.4	Supply & Install 1200mm Concrete Pipe	S-1300	96	LM	$2,137	$205,152
2.5	Supply & Install 1200mm Concrete Pipe	S-1301	9	LM	$2,137	$19,233
2.6	Supply & Install 1200mm Concrete Pipe	S-1314	117	LM	$2,137	$250,029
2.7	Supply & Install 1200mm Concrete Pipe	S-1316	20	LM	$2,137	$42,740
2.8	Supply & Install 1350mm Concrete Pipe	S-1302	16	LM	$2,658	$42,528
2.9	Supply & Install 1350mm Concrete Pipe	S-1303	2	LM	$2,658	$5,316
2.10	Supply & Install 1350mm Concrete Pipe	S-1304	16	LM	$2,658	$42,528
2.11	Supply & Install 1350mm Concrete Pipe	S-1305	13	LM	$2,658	$34,554
2.12	Supply & Install 1350mm Concrete Pipe	S-1306	16	LM	$2,658	$42,528
2.13	Supply & Install 1350mm Concrete Pipe	S-1307	13	LM	$2,658	$34,554
2.14	Supply & Install 1350mm Concrete Pipe	S-1308	23	LM	$2,658	$61,134
2.15	Supply & Install 1350mm Concrete Pipe	S-1309	16	LM	$2,658	$42,528
2.16	Supply & Install 1350mm Concrete Pipe	S-1310	3	LM	$2,658	$7,974
2.17	Supply & Install 1350mm Concrete Pipe	S-1311	23	LM	$2,658	$61,134
2.18	Supply & Install 1350mm Concrete Pipe	S-1312	16	LM	$2,658	$42,528
2.19	Supply & Install 1350mm Concrete Pipe	S-1313	55	LM	$2,658	$146,190
2.20	Supply & Install 1350mm Concrete Pipe	S-1315	95	LM	$2,658	$252,510
2.21	Supply & Install 1350mm Concrete Pipe	S-1317	90	LM	$2,658	$239,220
2.22	Supply & Install 1350mm Concrete Pipe	S-1318	92	LM	$2,658	$244,536
2.23	Supply & Install 1350mm Concrete Pipe	S-1319	125	LM	$2,658	$332,250
2.24	Supply & Install 1350mm Concrete Pipe	S-1320	56	LM	$2,658	$148,848
2.25	Supply & Install 1500mm Concrete Pipe	S-1321	9	LM	$3,151	$28,359
2.26	Supply & Install Manholes *					$525,538
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$3,153,228**
					Sub Total	**$3,227,228**
					Engineering (10%)	$323,000
					Contingency (40%)	$1,291,000
					Total	**$4,841,228**

Table E-4
Minor System Upgrades: MN-2
Reference Figure E-2

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$100,000	$100,000
1.2	Erosion & Sediment Control Plan		1	LS	$50,000	$50,000
1.3	Traffic Planning		1	LS	$50,000	$50,000
1.4	Utility Relocation		1	LS	$31,000	$31,000
					Sub-Total - Section 1	**$231,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 750mm Concrete Pipe	S-1006	37	LM	$1,318	$48,766
2.2	Supply & Install 750mm Concrete Pipe	S-1007	64	LM	$1,318	$84,352
2.3	Supply & Install 1050mm Concrete Pipe	S-1005	104	LM	$1,870	$194,480
2.4	Supply & Install 1200 x 1800mm Concrete Pipe	S-1000	117	LM	$5,698	$666,666
2.5	Supply & Install 1200 x 1800mm Concrete Pipe	S-1001	47	LM	$5,698	$267,806
2.6	Supply & Install 1200 x 1800mm Concrete Pipe	S-1002	113	LM	$5,698	$643,874
2.7	Supply & Install 1200 x 1800mm Concrete Pipe	S-1003	53	LM	$5,698	$301,994
2.8	Supply & Install 1200 x 1800mm Concrete Pipe	S-1009	60	LM	$5,698	$341,880
2.9	Supply & Install 1200 x 1800mm Concrete Pipe	S-1010	81	LM	$5,698	$461,538
2.10	Supply & Install 1200 x 1800mm Concrete Pipe	S-1011	18	LM	$5,698	$102,564
2.11	Supply & Install 1200 x 1800mm Concrete Pipe	S-1012	49	LM	$5,698	$279,202
2.12	Supply & Install 1200 x 1800mm Concrete Pipe	S-1013	69	LM	$5,698	$393,162
2.13	Supply & Install 1200 x 1800mm Concrete Pipe	S-1014	65	LM	$5,698	$370,370
2.14	Supply & Install 1200 x 1800mm Concrete Pipe	S-1015	68	LM	$5,698	$387,464
2.15	Supply & Install 1800mm Concrete Pipe	S-1018	89	LM	$3,394	$302,066
2.16	Supply & Install 1200 x 1800mm Concrete Pipe	S-1020	36	LM	$5,698	$205,128
2.17	Supply & Install 1200 x 1800mm Concrete Pipe	S-1021	18	LM	$5,698	$102,564
2.18	Supply & Install 1200 x 1800mm Concrete Pipe	S-1022	47	LM	$5,698	$267,806
2.19	Supply & Install 1200 x 1800mm Concrete Pipe	S-1023	124	LM	$5,698	$706,552
2.20	Supply & Install 1200 x 1800mm Concrete Pipe	S-1024	32	LM	$5,698	$182,336
2.21	Supply & Install 1200 x 1800mm Concrete Pipe	S-1025	81	LM	$5,698	$461,538
2.22	Supply & Install 1200 x 1800mm Concrete Pipe	S-1026	34	LM	$5,698	$193,732
2.23	Supply & Install 1200 x 1800mm Concrete Pipe	S-1027	95	LM	$5,698	$541,310
2.24	Supply & Install 1208 x 1800mm Concrete Pipe	S-1028	36	LM	$5,698	$205,128
2.25	Supply & Install 1200 x 2400mm Concrete Pipe	C-1354	70	LM	$7,467	$522,690
2.26	Supply & Install 1800 x 2100mm Concrete Pipe	S-1247	20	LM	$7,353	$147,060
2.27	Supply & Install Manholes *					$1,676,405.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$10,058,434**
					Sub Total	**$10,289,434**
					Engineering (10%)	$1,029,000
					Contingency (40%)	$4,116,000
					Total	**$15,434,434**

Table E-5
Minor System Upgrades: MN-3
Reference Figure E-3 & E-4

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$80,000	$80,000
1.2	Erosion & Sediment Control Plan		1	LS	$40,000	$40,000
1.3	Traffic Planning		1	LS	$40,000	$40,000
1.4	Utility Relocation		1	LS	$24,000	$24,000
					Sub-Total - Section 1	**$184,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 675mm Concrete Pipe	S-1062	43	LM	$1,204	$51,772
2.2	Supply & Install 675mm Concrete Pipe	S-1063	107	LM	$1,204	$128,828
2.3	Supply & Install 750mm Concrete Pipe	S-1060	16	LM	$1,318	$21,088
2.4	Supply & Install 900mm Concrete Pipe	S-1051	69	LM	$1,562	$107,778
2.5	Supply & Install 900mm Concrete Pipe	S-1052	80	LM	$1,562	$124,960
2.6	Supply & Install 900mm Concrete Pipe	S-1053	14	LM	$1,562	$21,868
2.7	Supply & Install 900mm Concrete Pipe	S-1054	38	LM	$1,562	$59,356
2.8	Supply & Install 900mm Concrete Pipe	S-1055	46	LM	$1,562	$71,852
2.9	Supply & Install 900mm Concrete Pipe	S-1056	87	LM	$1,562	$135,894
2.10	Supply & Install 900mm Concrete Pipe	S-1059	69	LM	$1,562	$107,778
2.11	Supply & Install 900mm Concrete Pipe	S-1061	22	LM	$1,562	$34,364
2.12	Supply & Install 900mm Concrete Pipe	S-1064	81	LM	$1,562	$126,522
2.13	Supply & Install 900mm Concrete Pipe	S-1065	27	LM	$1,562	$42,174
2.14	Supply & Install 900mm Concrete Pipe	S-1075	73	LM	$1,562	$114,026
2.15	Supply & Install 900mm Concrete Pipe	S-1078	15	LM	$1,562	$23,430
2.16	Supply & Install 900mm Concrete Pipe	S-1079	78	LM	$1,562	$121,836
2.17	Supply & Install 900mm Concrete Pipe	S-1138	102	LM	$1,562	$159,324
2.18	Supply & Install 900mm Concrete Pipe	S-1139	18	LM	$1,562	$28,116
2.19	Supply & Install 1200mm Concrete Pipe	S-1076	4	LM	$2,137	$8,548
2.20	Supply & Install 1200mm Concrete Pipe	S-1077	74	LM	$2,137	$158,138
2.21	Supply & Install 1200mm Concrete Pipe	S-1080	72	LM	$2,137	$153,864
2.22	Supply & Install 1200mm Concrete Pipe	S-1081	12	LM	$2,137	$25,644
2.23	Supply & Install 1200mm Concrete Pipe	S-1082	80	LM	$2,137	$170,960
2.24	Supply & Install 1200mm Concrete Pipe	S-1119	59	LM	$2,137	$126,083
2.25	Supply & Install 1200mm Concrete Pipe	S-1122	97	LM	$2,137	$207,289
2.26	Supply & Install 1200mm Concrete Pipe	S-1123	6	LM	$2,137	$12,822
2.27	Supply & Install 1200mm Concrete Pipe	S-1125	82	LM	$2,137	$175,234
2.28	Supply & Install 1200mm Concrete Pipe	S-1126	55	LM	$2,137	$117,535
2.29	Supply & Install 1200mm Concrete Pipe	S-1136	57	LM	$2,137	$121,809
2.30	Supply & Install 1200mm Concrete Pipe	S-1137	52	LM	$2,137	$111,124
2.31	Supply & Install 1200mm Concrete Pipe	S-1140	15	LM	$2,137	$32,055
2.32	Supply & Install 1200mm Concrete Pipe	S-1141	15	LM	$2,137	$32,055
2.33	Supply & Install 1200mm Concrete Pipe	S-1144	27	LM	$2,137	$57,699
2.34	Supply & Install 1200mm Concrete Pipe	S-1145	3	LM	$2,137	$6,411
2.35	Supply & Install 1200mm Concrete Pipe	S-1146	39	LM	$2,137	$83,343
2.36	Supply & Install 1200mm Concrete Pipe	S-1162	94	LM	$2,137	$200,878
2.37	Supply & Install 1200mm Concrete Pipe	S-1164	99	LM	$2,137	$211,563
2.38	Supply & Install 1200mm Concrete Pipe	S-1166	103	LM	$2,137	$220,111
2.39	Supply & Install 1200mm Concrete Pipe	S-1244	47	LM	$2,137	$100,439
2.40	Supply & Install 1200mm Concrete Pipe	SS-1245	114	LM	$2,137	$243,618
2.41	Supply & Install 1500mm Concrete Pipe	C-1200	8	LM	$3,151	$25,208
2.42	Supply & Install 1500mm Concrete Pipe	S-1143	9	LM	$3,151	$28,359
2.43	Supply & Install 1500mm Concrete Pipe	S-1147	93	LM	$3,151	$293,043
2.44	Supply & Install 1500mm Concrete Pipe	S-1148	49	LM	$3,151	$154,399
2.45	Supply & Install 1800mm Concrete Pipe	SS-1142	4	LM	$3,394	$13,576
2.46	Supply & Install 2100mm Concrete Pipe	SS-1161	130	LM	$4,205	$546,650
2.47	Supply & Install 2100mm Concrete Pipe	SS-1165	125	LM	$4,205	$525,625
2.48	Supply & Install 2100mm Concrete Pipe	SS-1167	113	LM	$4,205	$475,165
2.49	Supply & Install 2100mm Concrete Pipe	SS-1174	99	LM	$4,205	$416,295
2.50	Supply & Install 2400mm Concrete Pipe	SS-1168	17	LM	$4,769	$81,073
2.51	Supply & Install Manholes *					$1,323,516.20
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$7,941,097**
					Sub Total	**$8,125,097**
					Engineering (10%)	$813,000
					Contingency (40%)	$3,251,000
					Total	**$12,189,097**

Table E-6
Minor System Upgrades: MN-4
Reference Figure E-3

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$10,000	$10,000
1.2	Erosion & Sediment Control Plan		1	LS	$5,000	$5,000
1.3	Traffic Planning		1	LS	$5,000	$5,000
1.4	Utility Relocation		1	LS	$3,000	$3,000
					Sub-Total - Section 1	**$23,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 750mm Concrete Pipe	S-1043	71	LM	$1,318	$93,578
2.2	Supply & Install 750mm Concrete Pipe	S-1044	21	LM	$1,318	$27,678
2.3	Supply & Install 750mm Concrete Pipe	S-1045	22	LM	$1,318	$28,996
2.4	Supply & Install 750mm Concrete Pipe	S-1046	15	LM	$1,318	$19,770
2.5	Supply & Install 750mm Concrete Pipe	S-1048	21	LM	$1,318	$27,678
2.6	Supply & Install 750mm Concrete Pipe	S-1049	58	LM	$1,318	$76,444
2.7	Supply & Install 750mm Concrete Pipe	S-1057	97	LM	$1,318	$127,846
2.8	Supply & Install 750mm Concrete Pipe	S-1058	73	LM	$1,318	$96,214
2.9	Supply & Install 750mm Concrete Pipe	S-1325	93	LM	$1,318	$122,574
2.10	Supply & Install 750mm Concrete Pipe	S-1326	102	LM	$1,318	$134,436
2.11	Supply & Install 750mm Concrete Pipe	S-1343	13	LM	$1,318	$17,134
2.12	Supply & Install Manholes *					$154,469.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$926,818**
					Sub Total	**$949,818**
					Engineering (10%)	$95,000
					Contingency (40%)	$380,000
					Total	**$1,424,818**

Table E-7
Minor System Upgrades: MN-5
Reference Figure E-3

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$49,000	$49,000
1.2	Erosion & Sediment Control Plan		1	LS	$25,000	$25,000
1.3	Traffic Planning		1	LS	$25,000	$25,000
1.4	Utility Relocation		1	LS	$15,000	$15,000
					Sub-Total - Section 1	**$114,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 1200mm Concrete Pipe	S-1041	66	LM	$2,137	$141,042
2.2	Supply & Install 1200mm Concrete Pipe	S-1042	31	LM	$2,137	$66,247
2.3	Supply & Install 1200mm Concrete Pipe	S-1083	41	LM	$2,137	$87,617
2.4	Supply & Install 1200mm Concrete Pipe	S-1084	36	LM	$2,137	$76,932
2.5	Supply & Install 1200mm Concrete Pipe	S-1085	4	LM	$2,137	$8,548
2.6	Supply & Install 1200mm Concrete Pipe	S-1086	13	LM	$2,137	$27,781
2.7	Supply & Install 1200mm Concrete Pipe	S-1087	69	LM	$2,137	$147,453
2.8	Supply & Install 1200mm Concrete Pipe	S-1088	88	LM	$2,137	$188,056
2.9	Supply & Install 1200mm Concrete Pipe	S-1093	37	LM	$2,137	$79,069
2.10	Supply & Install 1200mm Concrete Pipe	S-1094	33	LM	$2,137	$70,521
2.11	Supply & Install 1350mm Concrete Pipe	D-1222	70	LM	$2,658	$186,060
2.12	Supply & Install 1350mm Concrete Pipe	S-1120	23	LM	$2,658	$61,134
2.13	Supply & Install 1350mm Concrete Pipe	S-1133	44	LM	$2,658	$116,952
2.14	Supply & Install 1350mm Concrete Pipe	S-1134	15	LM	$2,658	$39,870
2.15	Supply & Install 1350mm Concrete Pipe	S-1135	32	LM	$2,658	$85,056
2.16	Supply & Install 1350mm Concrete Pipe	S-1149	12	LM	$2,658	$31,896
2.17	Supply & Install 1350mm Concrete Pipe	S-1150	24	LM	$2,658	$63,792
2.18	Supply & Install 1350mm Concrete Pipe	S-1151	3	LM	$2,658	$7,974
2.19	Supply & Install 1350mm Concrete Pipe	S-1152	8	LM	$2,658	$21,264
2.20	Supply & Install 1350mm Concrete Pipe	S-1153	33	LM	$2,658	$87,714
2.21	Supply & Install 1350mm Concrete Pipe	S-1154	63	LM	$2,658	$167,454
2.22	Supply & Install 1350mm Concrete Pipe	S-1155	74	LM	$2,658	$196,692
2.23	Supply & Install 1350mm Concrete Pipe	S-1156	14	LM	$2,658	$37,212
2.24	Supply & Install 1350mm Concrete Pipe	S-1157	109	LM	$2,658	$289,722
2.25	Supply & Install 1350mm Concrete Pipe	S-1158	4	LM	$2,658	$10,632
2.26	Supply & Install 1500mm Concrete Pipe	S-1089	104	LM	$3,151	$327,704
2.27	Supply & Install 1500mm Concrete Pipe	S-1090	111	LM	$3,151	$349,761
2.28	Supply & Install 1500mm Concrete Pipe	S-1091	79	LM	$3,151	$248,929
2.29	Supply & Install 1500mm Concrete Pipe	S-1092	88	LM	$3,151	$277,288
2.30	Supply & Install 1500mm Concrete Pipe	S-1124	31	LM	$3,151	$97,681
2.31	Supply & Install 1500mm Concrete Pipe	S-1132	138	LM	$3,151	$434,838
2.32	Supply & Install Manholes *					$806,578.20
	Cost estimate for manholes is based on 20% of total pipe cost					
					Sub-Total - Section 2	**$4,839,469**
					Sub Total	**$4,953,469**
					Engineering (10%)	$496,000
					Contingency (40%)	$1,982,000
					Total	**$7,431,469**

Table E-8
Minor System Upgrades: MN-6
Reference Figure E-4

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$24,000	$24,000
1.2	Erosion & Sediment Control Plan		1	LS	$12,000	$12,000
1.3	Traffic Planning		1	LS	$12,000	$12,000
1.4	Utility Relocation		1	LS	$8,000	$8,000
					Sub-Total - Section 1	**$56,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 900mm Concrete Pipe	S-1163	60	LM	$1,562	$93,720
2.2	Supply & Install 900mm Concrete Pipe	S-1160	74	LM	$1,562	$115,588
2.3	Supply & Install 900mm Concrete Pipe	S-1184	103	LM	$1,562	$160,886
2.4	Supply & Install 900mm Concrete Pipe	S-1173	31	LM	$1,562	$48,422
2.5	Supply & Install 900mm Concrete Pipe	S-1171	7	LM	$1,562	$10,934
2.6	Supply & Install 900mm Concrete Pipe	S-1169	23	LM	$1,562	$35,926
2.7	Supply & Install 1200mm Concrete Pipe	S-1417	98	LM	$2,137	$209,426
2.8	Supply & Install 1200mm Concrete Pipe	S-1418	216	LM	$2,137	$461,592
2.9	Supply & Install 1200mm Concrete Pipe	S-1419	141	LM	$2,137	$301,317
2.10	Supply & Install 1200mm Concrete Pipe	S-1420	114	LM	$2,137	$243,618
2.11	Supply & Install 1200mm Concrete Pipe	S-1421	147	LM	$2,137	$314,139
2.12	Supply & Install Manholes *					$399,113.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$2,394,682**
					Sub Total	**$2,450,682**
					Engineering (10%)	$246,000
					Contingency (40%)	$981,000
					Total	**$3,677,682**

Table E-9
Minor System Upgrades: MN-7
Reference Figure E-5

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$3,000	$3,000
1.2	Erosion & Sediment Control Plan		1	LS	$2,000	$2,000
1.3	Traffic Planning		1	LS	$2,000	$2,000
1.4	Utility Relocation		1	LS	$1,000	$1,000
					Sub-Total - Section 1	**$8,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 1200mm Concrete Pipe	S-1038	95	LM	$2,137	$203,015
2.2	Supply & Install Manholes *					$40,603.00
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$243,618**
					Sub Total	**$251,618**
					Engineering (10%)	$26,000
					Contingency (40%)	$101,000
					Total	**$378,618**

Table E-10
Minor System Upgrades: MN-8
Reference Figure E-6

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$37,000	$37,000
1.2	Erosion & Sediment Control Plan		1	LS	$19,000	$19,000
1.3	Traffic Planning		1	LS	$19,000	$19,000
1.4	Utility Relocation		1	LS	$11,000	$11,000
					Sub-Total - Section 1	**$86,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 900mm Concrete Pipe	S-1071	99	LM	$1,562	$154,638
2.2	Supply & Install 900mm Concrete Pipe	S-1277	99	LM	$1,562	$154,638
2.3	Supply & Install 900mm Concrete Pipe	S-1278	99	LM	$1,562	$154,638
2.4	Supply & Install 900mm Concrete Pipe	S-1279	90	LM	$1,562	$140,580
2.5	Supply & Install 900mm Concrete Pipe	S-1280	3	LM	$1,562	$4,686
2.6	Supply & Install 900mm Concrete Pipe	S-1281	14	LM	$1,562	$21,868
2.7	Supply & Install 900mm Concrete Pipe	S-1282	42	LM	$1,562	$65,604
2.8	Supply & Install 900mm Concrete Pipe	S-1283	112	LM	$1,562	$174,944
2.9	Supply & Install 900mm Concrete Pipe	S-1284	33	LM	$1,562	$51,546
2.10	Supply & Install 900mm Concrete Pipe	S-1285	14	LM	$1,562	$21,868
2.11	Supply & Install 900mm Concrete Pipe	S-1286	112	LM	$1,562	$174,944
2.12	Supply & Install 900mm Concrete Pipe	S-1287	93	LM	$1,562	$145,266
2.13	Supply & Install 900mm Concrete Pipe	S-1288	95	LM	$1,562	$148,390
2.14	Supply & Install 900mm Concrete Pipe	S-1290	149	LM	$1,562	$232,738
2.15	Supply & Install 900mm Concrete Pipe	S-1291	93	LM	$1,562	$145,266
2.16	Supply & Install 900mm Concrete Pipe	S-1292	100	LM	$1,562	$156,200
2.17	Supply & Install 900mm Concrete Pipe	S-1293	84	LM	$1,562	$131,208
2.18	Supply & Install 1050mm Concrete Pipe	S-1096	89	LM	$1,870	$166,430
2.19	Supply & Install 1050mm Concrete Pipe	S-1097	15	LM	$1,870	$28,050
2.20	Supply & Install 1050mm Concrete Pipe	S-1098	148	LM	$1,870	$276,760
2.21	Supply & Install 1050mm Concrete Pipe	S-1099	155	LM	$1,870	$289,850
2.22	Supply & Install 1050mm Concrete Pipe	S-1100	106	LM	$1,870	$198,220
2.23	Supply & Install Manholes *					$607,666.40
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$3,645,998**
					Sub Total	**$3,731,998**
					Engineering (10%)	$374,000
					Contingency (40%)	$1,493,000
					Total	**$5,598,998**

Table E-11
Minor System Upgrades: MN-9
Reference Figure E-7

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$41,000	$41,000
1.2	Erosion & Sediment Control Plan		1	LS	$21,000	$21,000
1.3	Traffic Planning		1	LS	$21,000	$21,000
1.4	Utility Relocation		1	LS	$13,000	$13,000
					Sub-Total - Section 1	**$96,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 600mm Concrete Pipe	S-1030	84	LM	$1,104	$92,736
2.2	Supply & Install 600mm Concrete Pipe	S-1031	69	LM	$1,104	$76,176
2.3	Supply & Install 600mm Concrete Pipe	S-1032	8	LM	$1,104	$8,832
2.4	Supply & Install 600mm Concrete Pipe	S-1033	81	LM	$1,104	$89,424
2.5	Supply & Install 600mm Concrete Pipe	S-1034	55	LM	$1,104	$60,720
2.6	Supply & Install 600mm Concrete Pipe	S-1035	85	LM	$1,104	$93,840
2.7	Supply & Install 600mm Concrete Pipe	S-1067	102	LM	$1,104	$112,608
2.8	Supply & Install 600mm Concrete Pipe	S-1069	82	LM	$1,104	$90,528
2.9	Supply & Install 600mm Concrete Pipe	S-1070	93	LM	$1,104	$102,672
2.10	Supply & Install 600mm Concrete Pipe	S-1072	42	LM	$1,104	$46,368
2.11	Supply & Install 600mm Concrete Pipe	S-1073	23	LM	$1,104	$25,392
2.12	Supply & Install 600mm Concrete Pipe	S-1074	117	LM	$1,104	$129,168
2.13	Supply & Install 600mm Concrete Pipe	S-1294	50	LM	$1,104	$55,200
2.14	Supply & Install 600mm Concrete Pipe	S-1322	30	LM	$1,104	$33,120
2.15	Supply & Install 750mm Concrete Pipe	S-1264	66	LM	$1,318	$86,988
2.16	Supply & Install 750mm Concrete Pipe	S-1265	74	LM	$1,318	$97,532
2.17	Supply & Install 750mm Concrete Pipe	S-1267	38	LM	$1,318	$50,084
2.18	Supply & Install 750mm Concrete Pipe	S-1268	85	LM	$1,318	$112,030
2.19	Supply & Install 750mm Concrete Pipe	S-1269	19	LM	$1,318	$25,042
2.20	Supply & Install 750mm Concrete Pipe	S-1270	18	LM	$1,318	$23,724
2.21	Supply & Install 750mm Concrete Pipe	S-1271	9	LM	$1,318	$11,862
2.22	Supply & Install 750mm Concrete Pipe	S-1276	106	LM	$1,318	$139,708
2.23	Supply & Install 750mm Concrete Pipe	S-1427	14	LM	$1,318	$18,452
2.24	Supply & Install 750mm Concrete Pipe	S-1428	16	LM	$1,318	$21,088
2.25	Supply & Install 750mm Concrete Pipe	S-1272	106	LM	$1,318	$139,708
2.26	Supply & Install 750mm Concrete Pipe	S-1110	7	LM	$1,318	$9,226
2.27	Supply & Install 750mm Concrete Pipe	S-1102	47	LM	$1,318	$61,946
2.28	Supply & Install 750mm Concrete Pipe	S-1103	39	LM	$1,318	$51,402
2.29	Supply & Install 900mm Concrete Pipe	S-1117	5	LM	$1,562	$7,810
2.30	Supply & Install 900mm Concrete Pipe	S-1118	162	LM	$1,562	$253,044
2.31	Supply & Install 900mm Concrete Pipe	S-1273	68	LM	$1,562	$106,216
2.32	Supply & Install 900mm Concrete Pipe	S-1274	13	LM	$1,562	$20,306
2.33	Supply & Install 900mm Concrete Pipe	S-1275	70	LM	$1,562	$109,340
2.34	Supply & Install 900mm Concrete Pipe	S-1295	122	LM	$1,562	$190,564
2.35	Supply & Install 900mm Concrete Pipe	S-1296	113	LM	$1,562	$176,506
2.36	Supply & Install 1200mm Concrete Pipe	S-1104	15	LM	$2,137	$32,055
2.37	Supply & Install 1200mm Concrete Pipe	S-1106	15	LM	$2,137	$32,055
2.38	Supply & Install 1200mm Concrete Pipe	S-1108	5	LM	$2,137	$10,685
2.39	Supply & Install 1200mm Concrete Pipe	S-1109	5	LM	$2,137	$10,685
2.40	Supply & Install 1200mm Concrete Pipe	S-1111	34	LM	$2,137	$72,658
2.41	Supply & Install 1200mm Concrete Pipe	S-1113	34	LM	$2,137	$72,658
2.42	Supply & Install 1200mm Concrete Pipe	S-1115	117	LM	$2,137	$250,029
2.43	Supply & Install 1200mm Concrete Pipe	S-1116	84	LM	$2,137	$179,508
2.44	Supply & Install Manholes *					$677,939.00
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$4,067,634**
					Sub Total	**$4,163,634**
					Engineering (10%)	$417,000
					Contingency (40%)	$1,666,000
					Total	**$6,246,634**

Table E-12
Minor System Upgrades: MN-10
Reference Figure E-8

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$12,000	$12,000
1.2	Erosion & Sediment Control Plan		1	LS	$6,000	$6,000
1.3	Traffic Planning		1	LS	$6,000	$6,000
1.4	Utility Relocation		1	LS	$4,000	$4,000
					Sub-Total - Section 1	**$28,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 900mm Concrete Pipe	S-1187	111	LM	$1,562	$173,382
2.2	Supply & Install 900mm Concrete Pipe	S-1188	80	LM	$1,562	$124,960
2.3	Supply & Install 900mm Concrete Pipe	S-1189	82	LM	$1,562	$128,084
2.4	Supply & Install 1200mm Concrete Pipe	S-1191	46	LM	$2,137	$98,302
2.5	Supply & Install 1200mm Concrete Pipe	S-1192	3	LM	$2,137	$6,411
2.6	Supply & Install 1200mm Concrete Pipe	S-1195	46	LM	$2,137	$98,302
2.7	Supply & Install 1200mm Concrete Pipe	S-1196	76	LM	$2,137	$162,412
2.8	Supply & Install 1200mm Concrete Pipe	S-1197	75	LM	$2,137	$160,275
2.9	Supply & Install 1200mm Concrete Pipe	S-1198	15	LM	$2,137	$32,055
2.10	Supply & Install Manholes *					$196,836.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$1,181,020**
					Sub Total	**$1,209,020**
					Engineering (10%)	$121,000
					Contingency (40%)	$484,000
					Total	**$1,814,020**

Table E-13
Major System Upgrades: MA-1
Reference Figure E-9

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$38,000	$38,000
1.2	Erosion & Sediment Control Plan		1	LS	$19,000	$19,000
1.3	Traffic Planning		1	LS	$19,000	$19,000
1.4	Utility Relocation		1	LS	$12,000	$12,000
					Sub-Total - Section 1	**$88,000**
2.0	**Section 2 - Pump Station Upgrades**					
2.1	Increase Pump Capacity		2.4	m^3	$1,200,000	$2,880,000
					Sub-Total - Section 2	**$2,880,000**
3.0	**Section 3 - Stormwater Infrastructure**					
3.1	Supply & Install 1500mm Concrete Pipe	3rd_Outfall	49	LM	$18,000	$882,000
					Sub-Total - Section 3	**$882,000**
					Sub Total	**$3,850,000**
					Engineering (10%)	$385,000
					Contingency (40%)	$1,540,000
					Total	**$5,775,000**

Table E-14
Major System Upgrades: MA-2
Reference Figure E-10

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$100,000	$100,000
1.2	Erosion & Sediment Control Plan		1	LS	$50,000	$50,000
1.3	Traffic Planning		1	LS	$50,000	$50,000
1.4	Utility Relocation		1	LS	$63,000	$63,000
					Sub-Total - Section 1	**$263,000**
2.0	**Section 2 - Pump Station Upgrades**					
2.1	Increase Pump Capacity		13.5	m^3	$1,200,000	$16,200,000
					Sub-Total - Section 2	**$16,200,000**
3.0	**Section 3 - Stormwater Infrastructure**					
3.1	Widen Ditch along Boundary Bay Road	D-1378	695	m^3	$60	$41,700
3.2	Widen Ditch along Boundary Bay Road	D-1377	1813	m^3	$60	$108,780
3.3	Widen Ditch along Boundary Bay Road	D-1376	1086	m^3	$60	$65,160
3.4	Widen Ditch along Boundary Bay Road	D-1375	422	m^3	$60	$25,320
3.5	Widen Ditch along Boundary Bay Road	D-1374	509	m^3	$60	$30,540
3.6	Supply & Install 2400 mm Culvert	C-1364	13	LM	$33,000	$429,000
3.7	Supply & Install Two 2400 mm Culverts	C-1365	98	LM	$33,000	$3,234,000
3.8	Supply & Install Two 2400 mm Culverts	C-1366	22	LM	$33,000	$726,000
					Sub-Total - Section 3	**$4,660,500**
					Sub Total	**$21,123,500**
					Engineering (10%)	$2,113,000
					Contingency (40%)	$8,450,000
					Total	**$31,686,500**

Table E-15
Major System Upgrades: MA-3
Reference Figure E-11

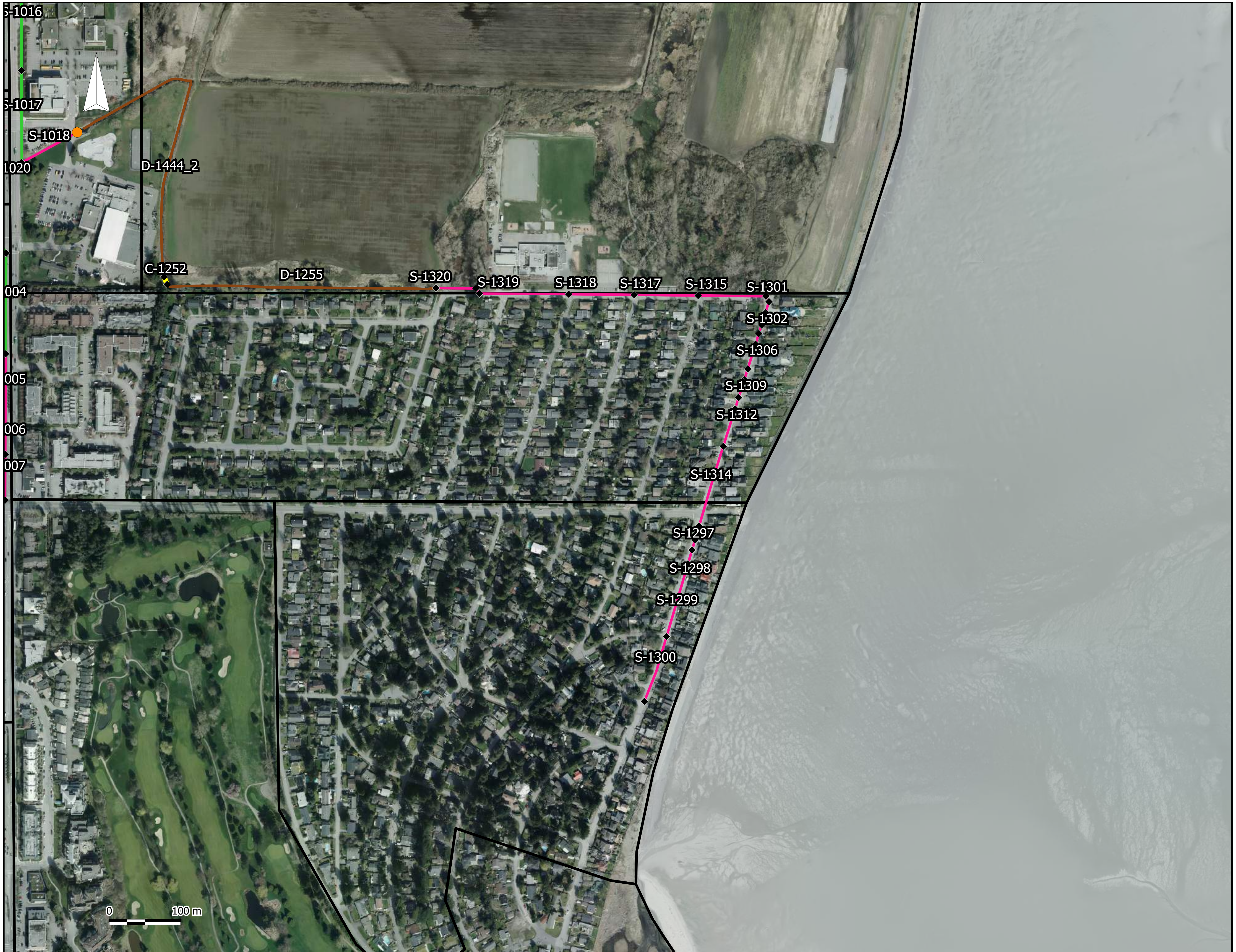
	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$100,000	$100,000
1.2	Erosion & Sediment Control Plan		1	LS	$50,000	$50,000
1.3	Traffic Planning		1	LS	$50,000	$50,000
1.4	Utility Relocation		1	LS	$71,000	$71,000
					Sub-Total - Section 1	**$271,000**
2.0	**Section 2 - Pump Station Upgrades**					
2.1	Increase Pump Capacity		11	m³	$1,200,000	$13,200,000
					Sub-Total - Section 2	**$13,200,000**
3.0	**Section 3 - Stormwater Infrastructure**					
3.1	Widen Ditch along Eagle Way	D-1435_2	1709	m³	$60	$102,540
3.2	Widen Ditch along 16 Avenue	D-1263	300	m³	$60	$18,000
3.3	Widen Ditch along 52 Street	D-1437	1414	m³	$60	$84,840
3.4	Widen Ditch along Highway 17	D-1254	235	m³	$60	$14,100
3.5	Widen Ditch along Highway 17	D-1345	227	m³	$60	$13,620
3.6	Widen Ditch along Highway 17	D-1346_1	3522	m³	$60	$211,320
3.7	Widen Ditch along Salish Sea Drive	D-1357	447	m³	$60	$26,820
3.8	Widen Ditch along Salish Sea Drive	D-1356	346	m³	$60	$20,760
3.9	Widen Ditch along Salish Sea Drive	D-1430	418	m³	$60	$25,080
3.10	Supply & Install 1800mm Culvert	C-1251	63	LM	$23,000	$1,449,000
3.11	Supply & Install 2750mm Culvert	C-1250	64	LM	$39,000	$2,496,000
3.12	Supply & Install 1500mm Culvert	C-1361	70	LM	$18,000	$1,260,000
3.13	Supply & Install 2400mm Culvert	C-1201	13	LM	$33,000	$429,000
3.14	Supply & Install 2750mm Culvert	C-1344	28	LM	$39,000	$1,092,000
3.15	Supply & Install 2400mm Culvert	C-1248	38	LM	$33,000	$1,254,000
3.16	Supply & Install 2400mm Culvert	C-1249	53	LM	$33,000	$1,749,000
					Sub-Total - Section 3	**$10,246,080**
					Sub Total	**$23,717,080**
					Engineering (10%)	$2,372,000
					Contingency (40%)	$9,487,000
					Total	**$35,576,080**

Table E-16
Environmental Enhancement Opportunity: EV-1

	Item	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**				
1.1	Mobilization & Demobilization	1	LS	$2,000	$2,000
1.2	Erosion & Sediment Control Plan	1	LS	$1,000	$1,000
1.3	Traffic Planning	1	LS	$1,000	$1,000
1.4	Utility Relocation	1	LS	$1,000	$1,000
				Sub-Total - Section 1	**$5,000**
2.0	**Section 2 - Wetlands**				
2.1	Construct/Expand Wetlands	1	LS	$200,000	$200,000
				Sub-Total - Section 2	**$200,000**
				Sub Total	**$205,000**
				Engineering (10%)	$21,000
				Contingency (40%)	$82,000
				Total	**$308,000**

Table E-17
Environmental Enhancement Opportunity : EV-2

	Item	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**				
1.1	Mobilization & Demobilization	1	LS	$2,000	$2,000
1.2	Erosion & Sediment Control Plan	1	LS	$1,000	$1,000
1.3	Traffic Planning	1	LS	$1,000	$1,000
1.4	Utility Relocation	1	LS	$1,000	$1,000
				Sub-Total - Section 1	**$5,000**
2.0	**Section 2 - Wetlands**				
2.1	Construct Wetlands	1	LS	$200,000	$200,000
				Sub-Total - Section 2	**$200,000**
				Sub Total	**$205,000**
				Engineering (10%)	$21,000
				Contingency (40%)	$82,000
				Total	**$308,000**



LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-1

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-1 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-1		

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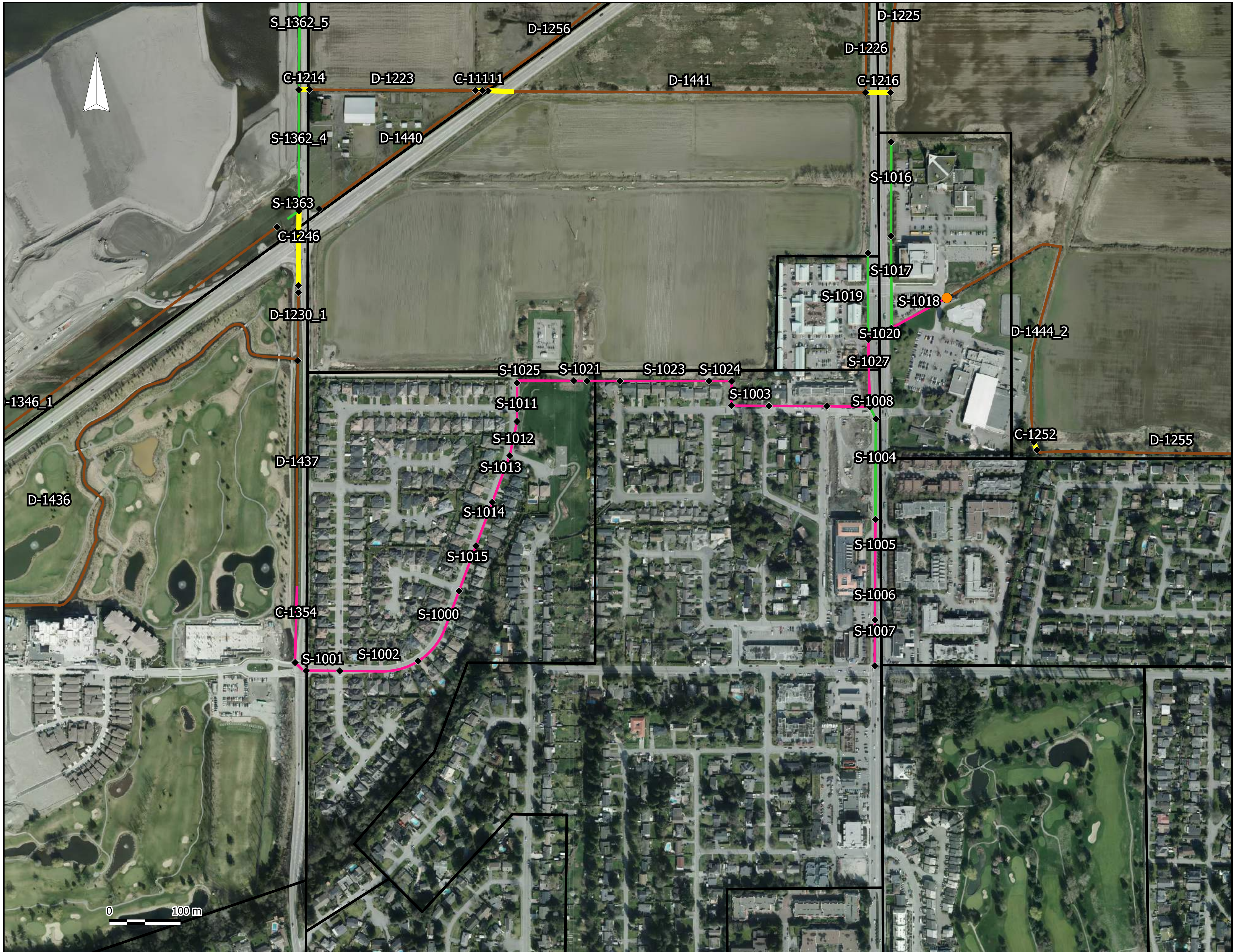

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-2

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MN-2 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-2		

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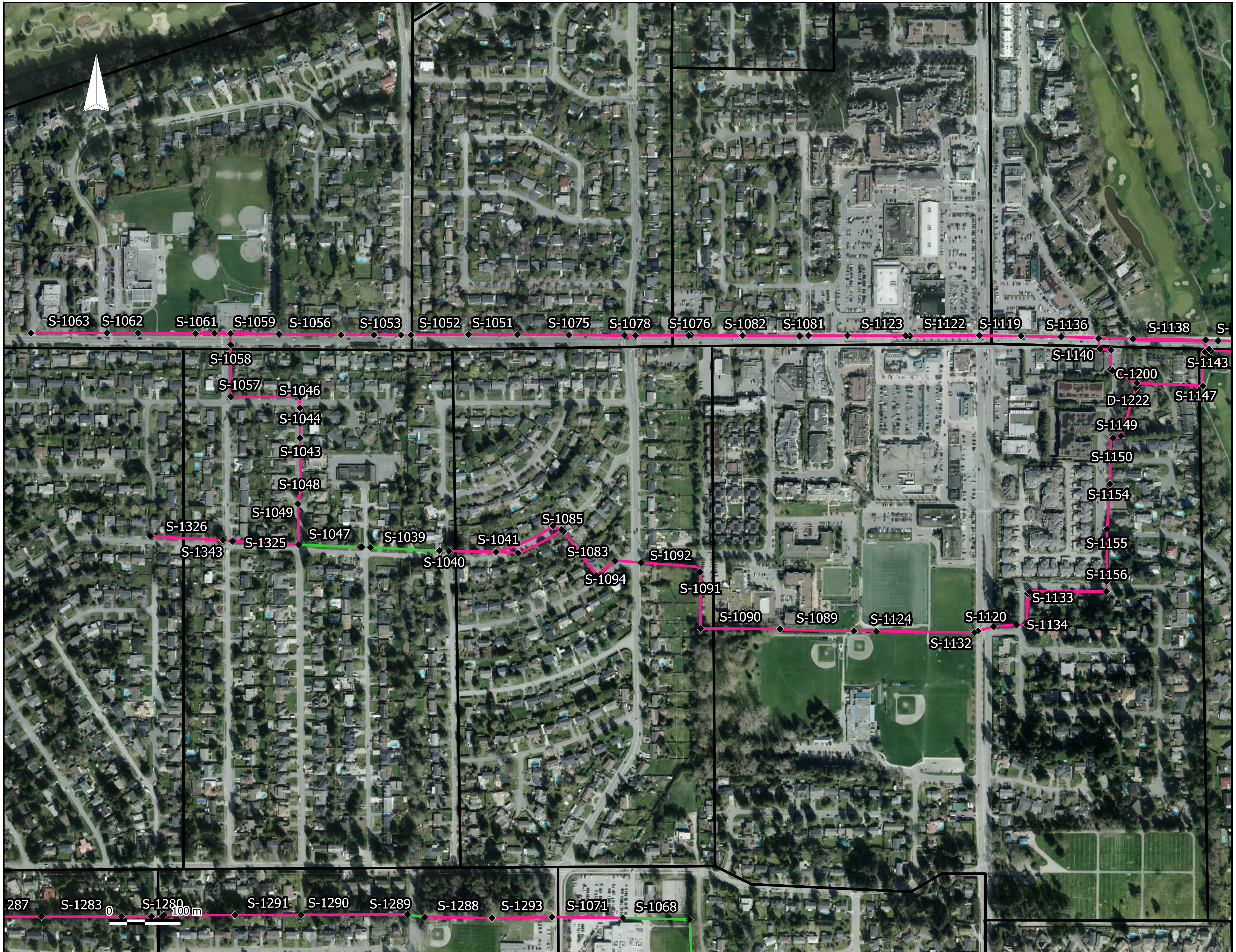

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES MINOR SYSTEM UPGRADES: MN-3, MN-4, MN-5

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MN-3 & MN-4 & MN-5 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-3		

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LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES MINOR SYSTEM UPGRADES: MN-3, MN-6

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MN-3 & MN-6 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-4		

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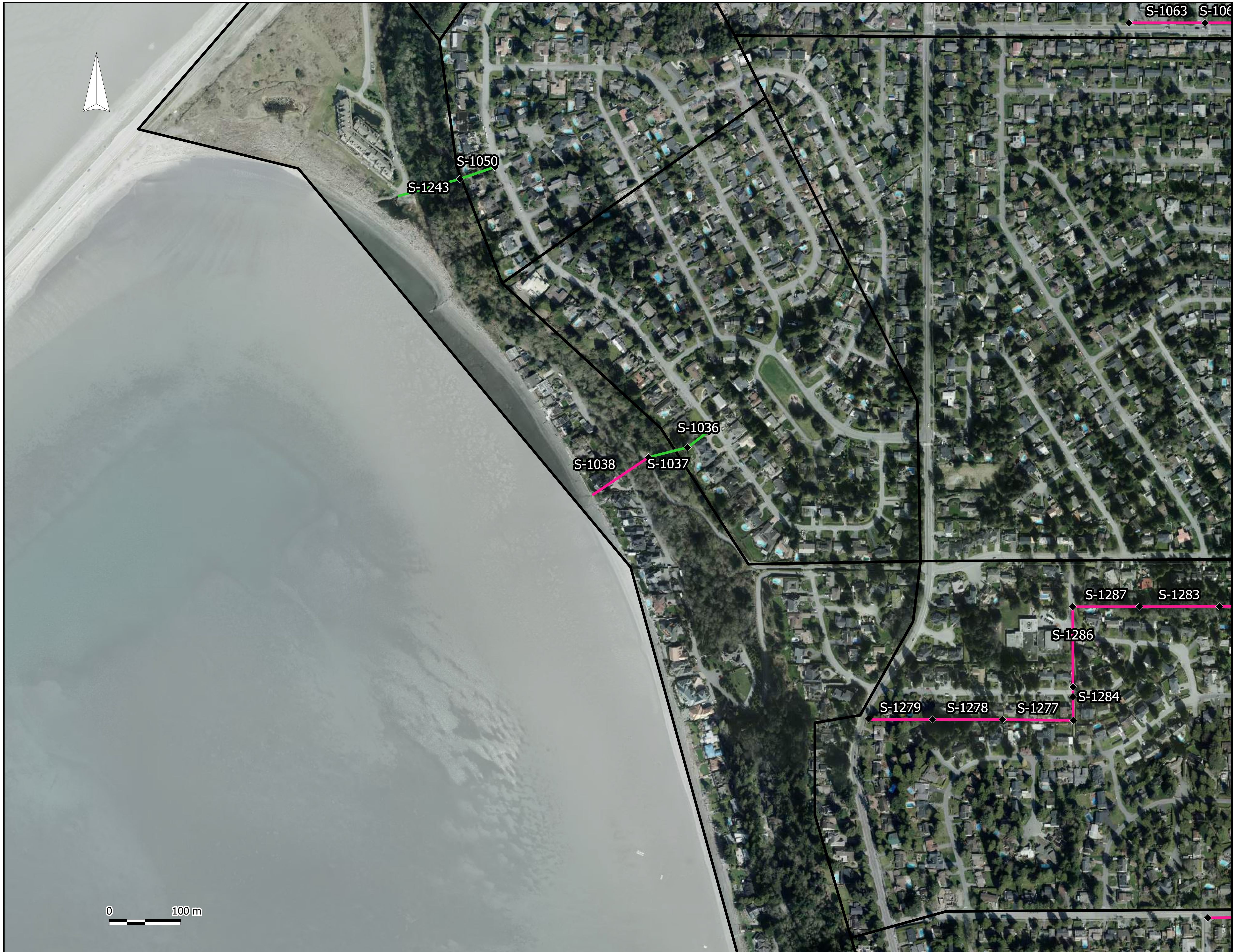

LEGEND

XXXX MODEL ID
PUMP STATION
CULVERT
DITCH
GRAVITY MAIN
UPGRADED PIPE
SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-7

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MN-7 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-5		

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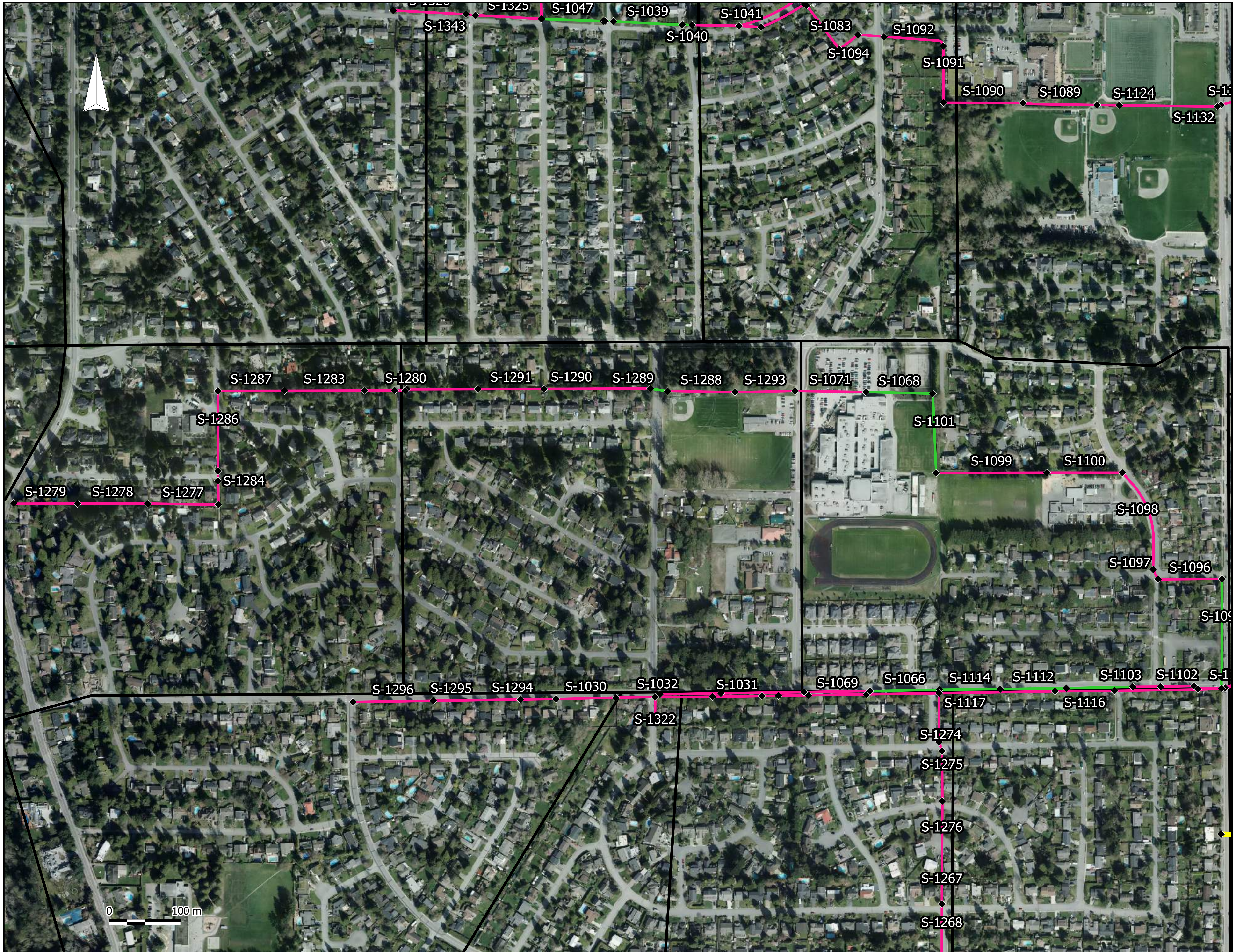

LEGEND

XXXX	MODEL ID
●	PUMP STATION
yellow line	CULVERT
brown line	DITCH
green line	GRAVITY MAIN
pink line	UPGRADED PIPE
outline	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-8

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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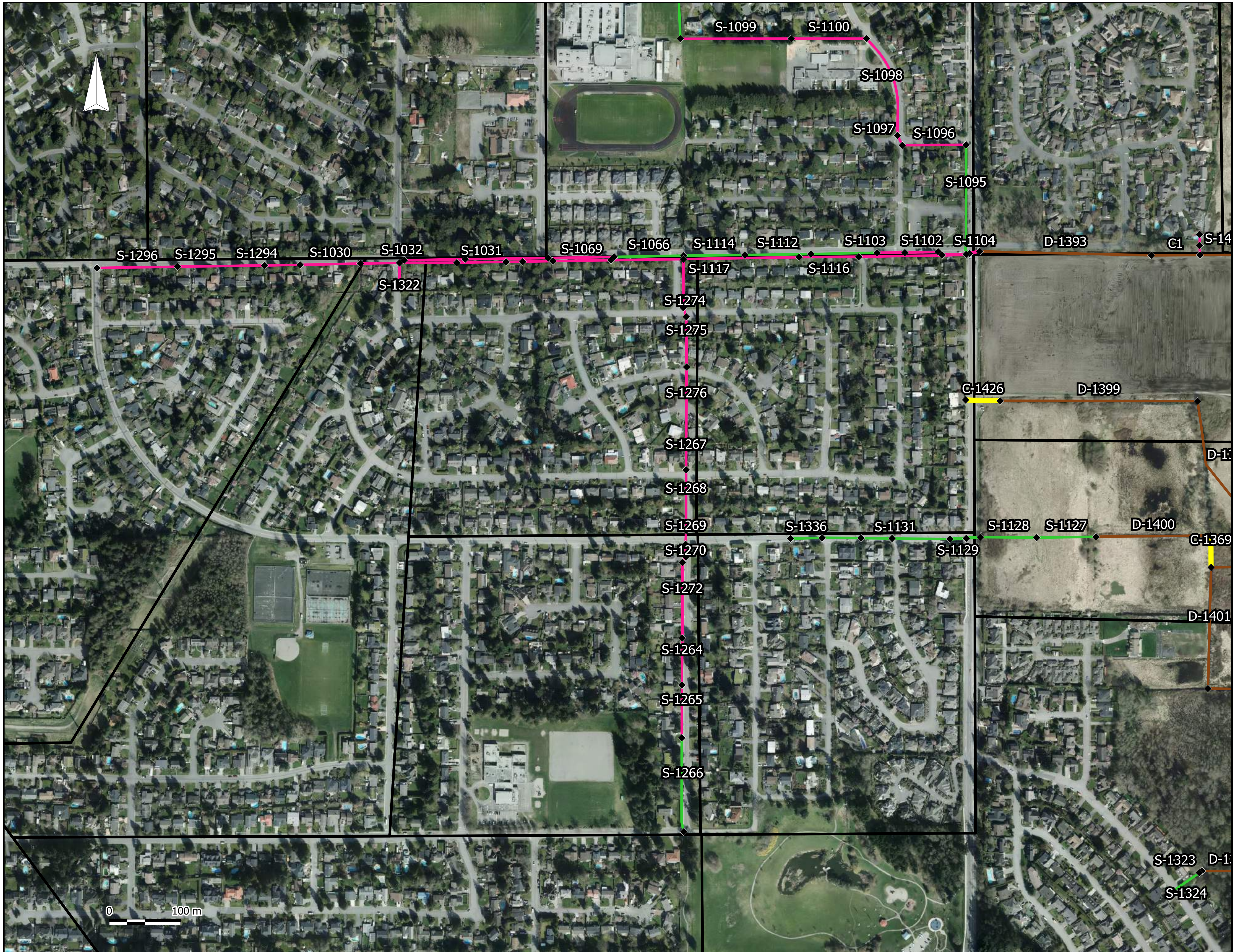
MANAGEMENT PLAN

MN-8 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-6		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map



LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-9

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MN-9 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-7		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-10

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MN-10 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-8		

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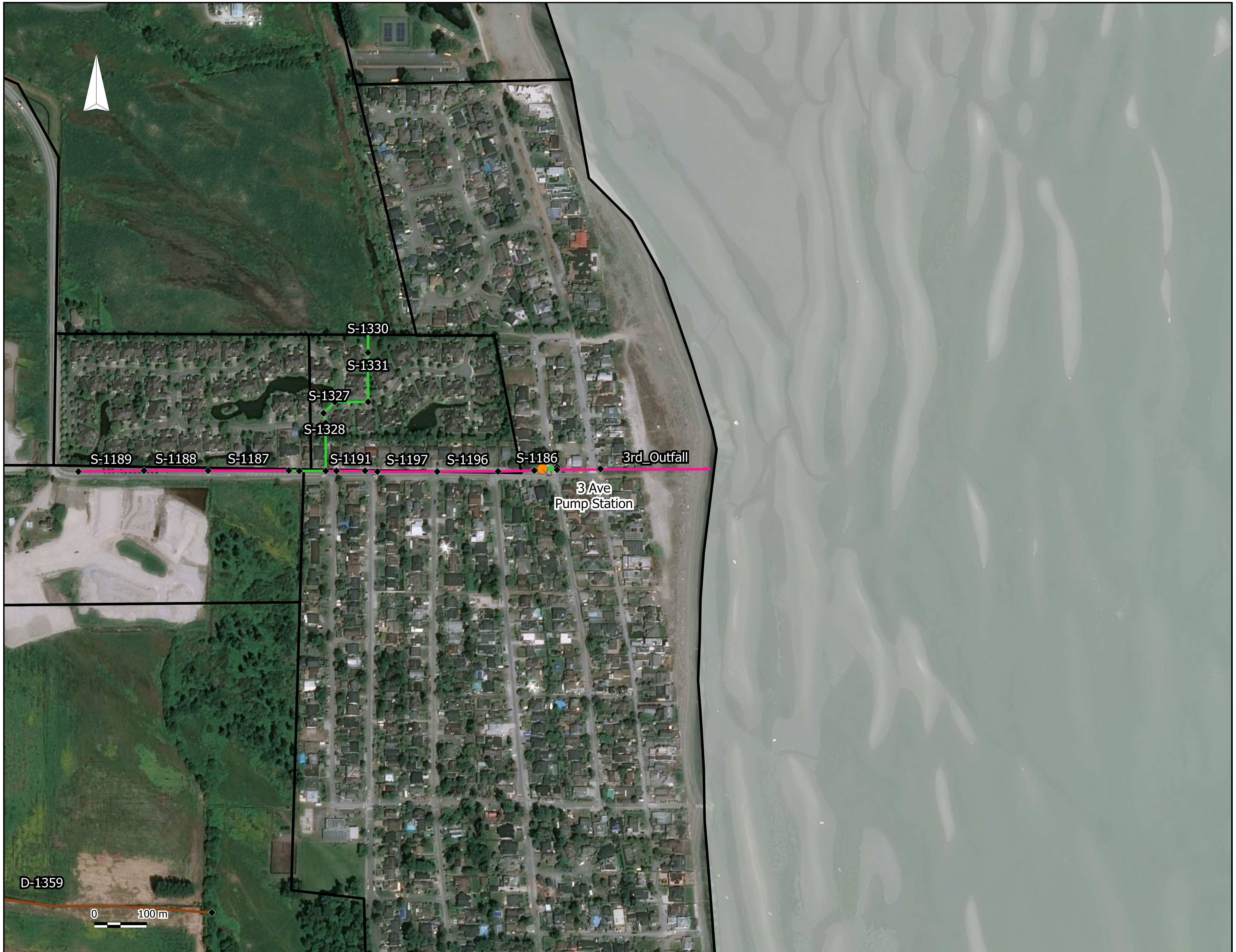

LEGEND

XXXX MODEL ID
ABCD PUMP STATION NAME
PUMP STATION
CULVERT
DITCH
GRAVITY MAIN
UPGRADED PIPE
UPGRADED DITCH
SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MAJOR SYSTEM UPGRADES: MA-1

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	20-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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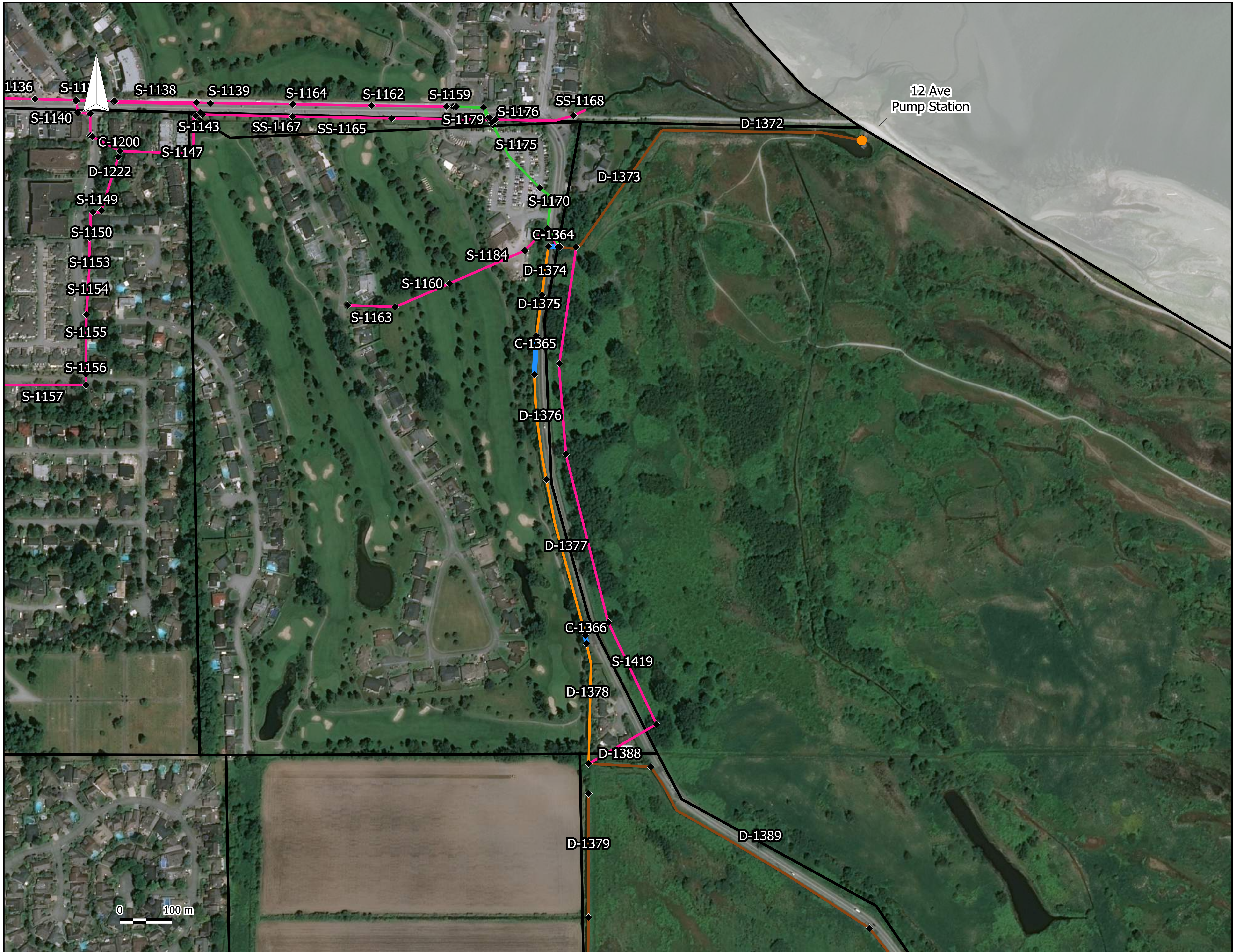
MA-1 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-9		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map



LEGEND

XXXX	MODEL ID
ABCD	PUMP STATION NAME
	PUMP STATION
	CULVERT
	UPGRADED CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	UPGRADED DITCH
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MAJOR SYSTEM UPGRADES: MA-2

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	20-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MA-2 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-10		

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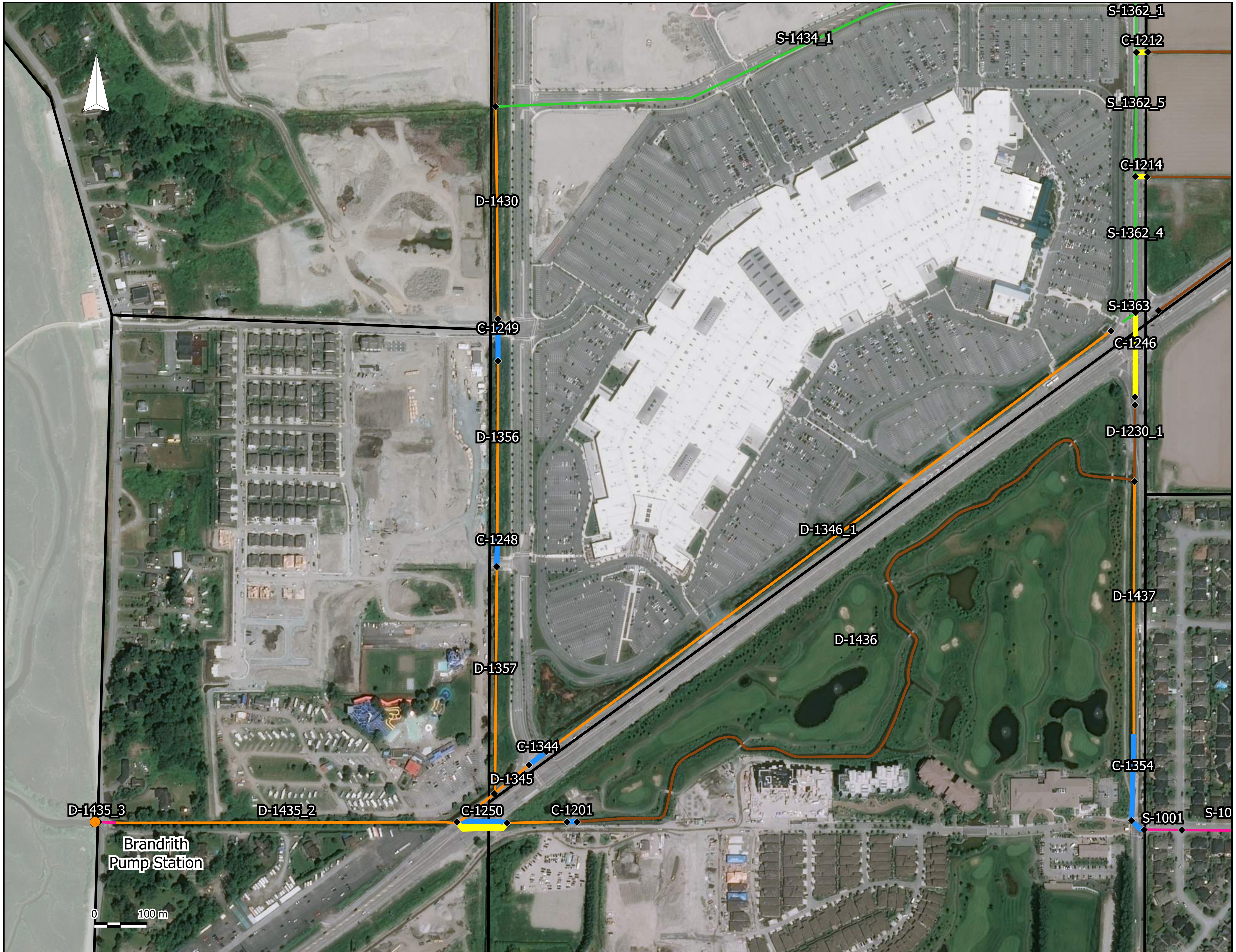

LEGEND

XXXX	MODEL ID
ABCD	PUMP STATION NAME
	PUMP STATION
	CULVERT
	UPGRADED CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	UPGRADED DITCH
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MAJOR SYSTEM UPGRADES: MA-3

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	20-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MANAGEMENT PLAN

MA-3 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-11		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

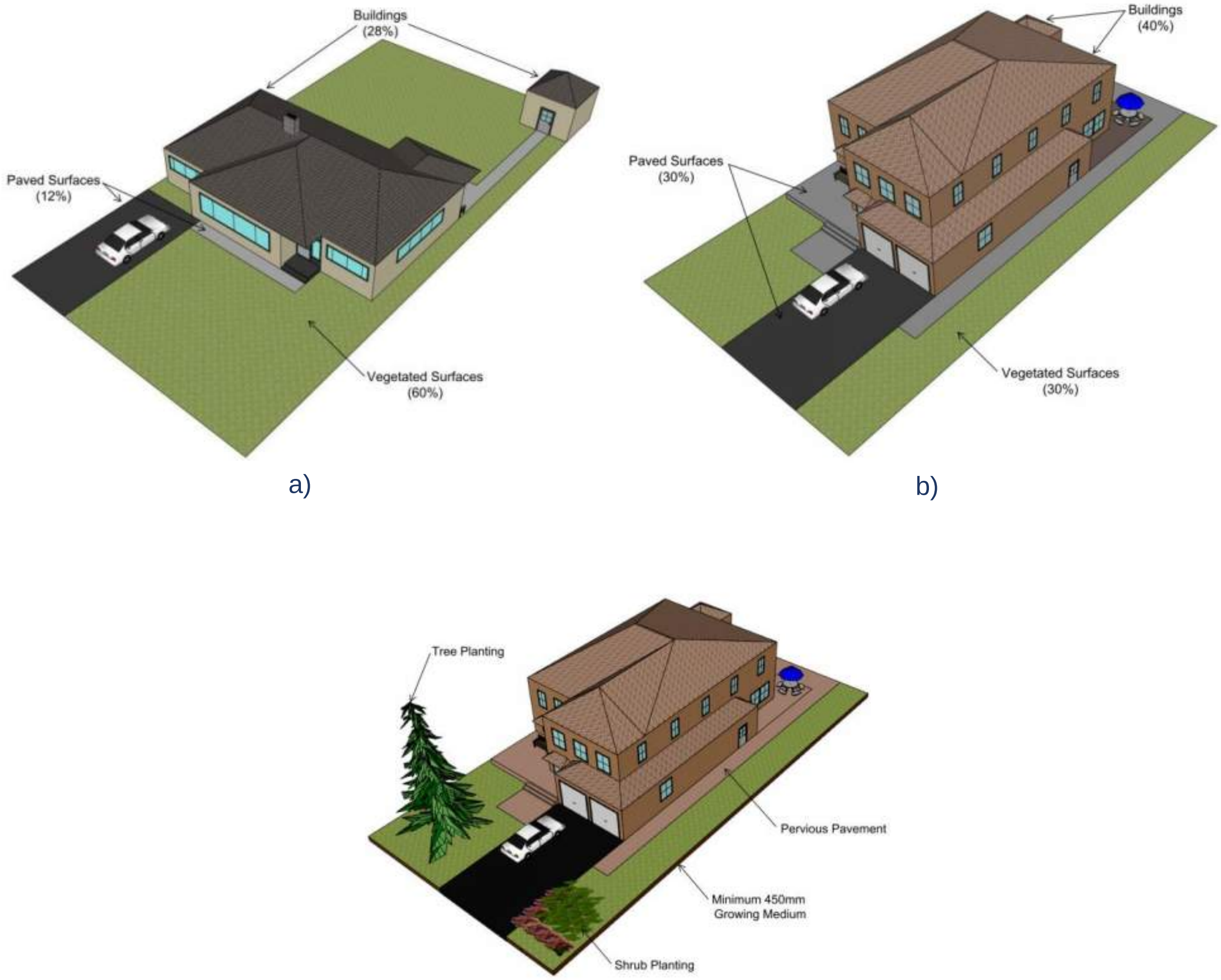
Appendix F - Description of Stormwater BMPs

This appendix outlines practical Best Management Practices (BMPs) with an assessment of their effectiveness in reducing flow and peak runoff for residential lots, industrial/commercial/multi-family lots, and roadways.

In general, BMP measures allow surface runoff to infiltrate back into the groundwater table or slow peak runoff by naturally attenuating flows. However, infiltration is only suitable in areas with underlying pervious soils such as sands or gravels, and in areas where the ground is not already saturated. The majority of the land use in Tsawwassen consists of residential areas, parks space, agricultural areas, with a small proportion of commercial/industrial/multi-family development.

F1 RESIDENTIAL LOTS

In Tsawwassen, residential areas contribute significantly to the net impervious area of the overall watershed. Older residential lots tend to have a relatively small building footprint, and a substantial proportion of pervious surface. In contrast, newly developed lots typically maximize building coverage, and include additional impervious features such as garages, sheds, concrete slab patios and larger driveways. Figure F-1 illustrates the general difference in lot configuration between old and new residential developments.



a) b)

c)

a) Older residential lot; b) Newly constructed / redeveloped residential lot;

c) Newly constructed / redeveloped residential lot with mitigative source controls / BMPs

Figure F-1
Residential Lot Layouts

As discussed above, our model calibration resulted in assigning an Effective Impervious Area (EIA) of 40% to single family residential areas to accurately represent downstream flow responses for the existing condition. An EIA of 40% should be achievable in future development scenarios even as impervious area increases as a result of densification through the implementation of BMPs. As such, all residential lots undergoing development or redevelopment should meet an EIA of 40% through the use of source controls. Further, vegetation should be planted and / or preserved.

The source controls that are most applicable to residential developments are described below.

F1.1 Disconnect Impervious Areas

In conventional drainage systems, impervious surfaces such as roads, driveways, parking lots, and roofs are connected directly into a conveyance system or receiving watercourse. Runoff from these impervious surfaces moves very rapidly and mobilizes and transports sediment and other pollutants. The result is very flashy flows with low times of concentration, high peak flow rates, large runoff volumes, and high pollutant mobility. These negative hydrologic impacts can be mitigated by disconnecting impervious areas from each other and the downstream pipe networks.

In some cases, residential roof leaders may be connected directly to the storm drainage system. Runoff originating from the roofs of these buildings is therefore unattenuated. During redevelopment of these lots, roof drains should be disconnected from the storm system, and instead discharged to pervious surfaces, such as lawns or gardens.

Disconnection can also include parking lots, roads, and other impervious surfaces; runoff can be directed to vegetated/pervious surfaces prior to arriving at a conventional drainage system. This approach will promote infiltration (subject to local soil conditions), evapotranspiration, and overland filtering. Even where runoff volumes are not significantly reduced, slowing of runoff provides downstream benefits in receiving streams, and is closer to a natural hydrologic regime.

The location, capacity, and soil conditions of each receiving vegetated area should be given careful consideration to ensure that directing impervious area runoff to pervious surfaces does not result in potential flooding or erosion.

Disconnecting impervious areas has good potential in medium and low density residential developments since there are generally green spaces available to receive runoff.

F1.2 Absorbent Landscaping and Growing Media

Absorbent landscaping acts like a sponge that retains rainfall, stores it temporarily, and then slowly releases it. Its primary purpose is to mimic the hydrologic function of undeveloped land on a developed site. It tends to have only a limited capacity, and will saturate and lose functionality during large rainfall events. Regardless, it is an appropriate measure to manage stormwater at the source, and is particularly effective for small, frequent rainfall events. Additionally, the filtration mechanism of the soil layer provides water quality benefits.

Absorbent landscapes typically consist of a layer of absorbent soil with vegetation such as shrubs and trees. The vegetation provides an additional function of supporting interception and evapotranspiration. Absorbent landscapes receive direct rainfall and runoff from small impervious surfaces (such as driveways, paths and patios). Additionally, roof downspouts can be directed such that they discharge to the absorbent landscape, rather than directly to other impervious surfaces or the storm drainage network.

Absorbent landscapes are easily applied (relative to other source controls) to existing residential lots, and provide aesthetic benefits for the community and individual homeowners. Vegetation can be selected such that it also supports backyard biodiversity and the increased presence of native plants. Required maintenance includes typical gardening activities such as weeding and replacing dead plants, as well as watering during extended dry periods. As well, an overflow should be considered, and should be inspected monthly and debris removed.

For the purpose of effective stormwater management, the depth of absorbent soils should be a minimum of 450 mm, and be comprised of soils with high organic content, such as sandy loam.

F1.3 Pervious Pavement

Pervious pavement provides an alternative to otherwise impermeable surfaces, such as driveways, walkways and patios. It consists of a paving system that allows rainfall to percolate into an underlying subgrade reservoir. If sufficient infiltration capacity exists in the subgrade or underlying soils, the water will be infiltrated. Otherwise, it can be discharged to the storm network through an underdrain.

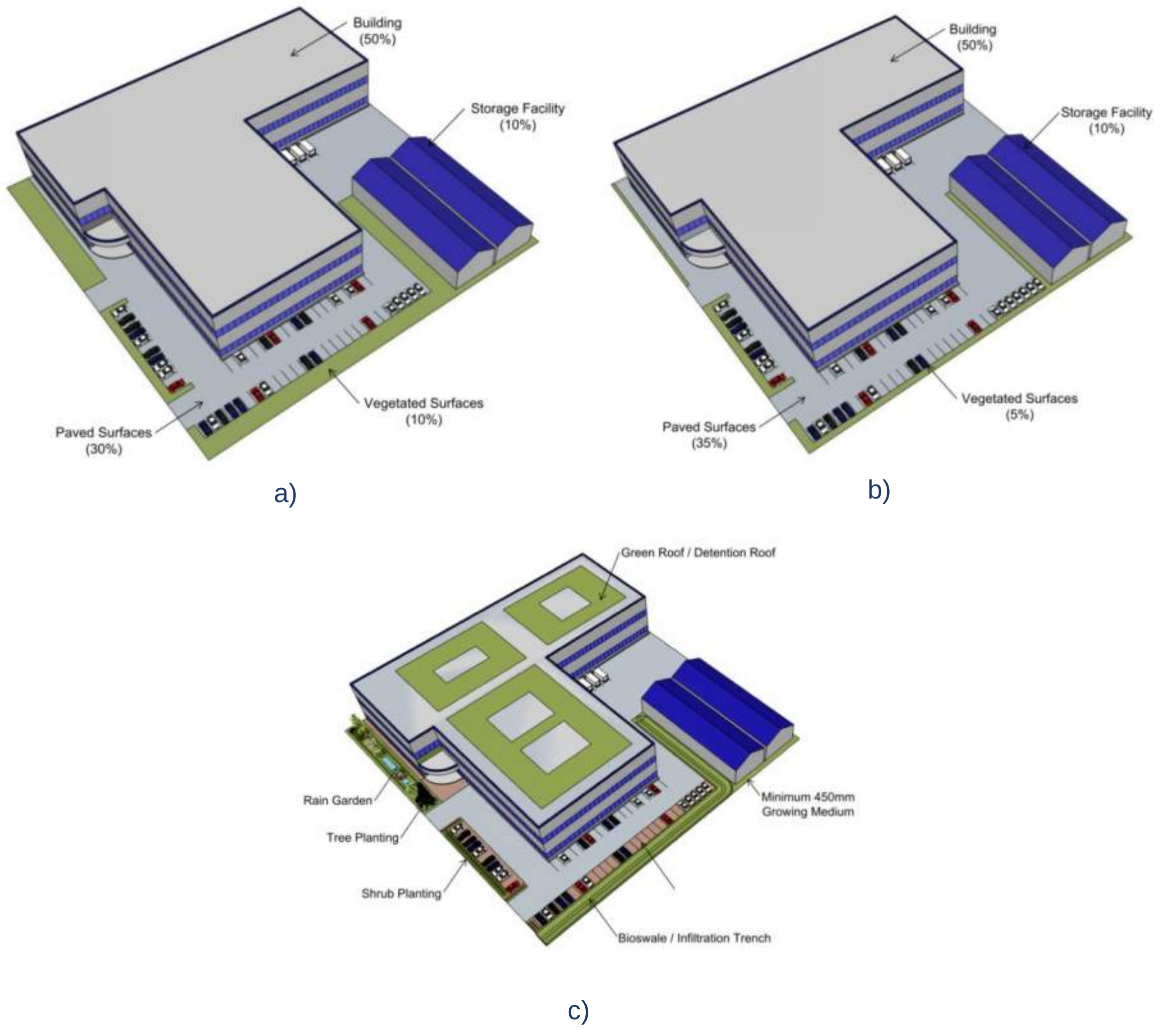
Metro Vancouver’s Stormwater Source Control Guidelines (2012) suggests that pervious pavement can receive runoff from other impermeable areas, provided sediment loads are not excessively high. Pervious pavement can provide a reduction in peak flows and runoff volume, as well as some contaminant removal, and in certain areas assists in rehabilitating baseflows to natural watercourses via groundwater recharge.

Pervious pavement typically consists of five layers including the surface (porous asphalt / concrete, concrete / plastic grid pavers, concrete pavers installed with gapped joints), an aggregate bedding, open graded base, open graded sub base, and subsoil. Additionally, the use of a geotextile to prevent migration of fines into the base drainage courses is recommended. With relatively impermeable soils, a partial-infiltration configuration that includes an underdrain may be required.

On residential lots, pervious pavement provides excellent mitigation to the effects of driveway expansions, new walkways, porches and patios. Due to the relatively complicated nature of construction, however, individual home owners may be hesitant to install pervious pavement for these types of projects. Supplemental support and encouragement from the City may be necessary to maximize the implementation of pervious pavements in Tsawwassen.

F2 COMMERCIAL LOTS

Commercial lots (and multi-family/industrial developments) occupy a small percentage of the total land area but have a high proportion of impervious to pervious areas. As with residential lots, recently constructed commercial lots tend to have greater impervious coverage than older ones, as illustrated in Figure F-2. Bioswales, rain gardens and green roofs could feasibly be applied to 30% of total lot coverage if planned appropriately.



a) Older industrial lot; b) Recently constructed / redeveloped industrial lot

c) Recently constructed / redeveloped industrial lot with mitigative source controls / BMPs

Figure F-2
Commercial Lot Layouts

The most applicable source controls for commercial lots are described below.

F2.1 Absorbent Soils

Absorbent soils are described in Section 6.1.2, and may be applied to landscape areas on industrial / commercial lots to achieve attenuation of runoff.

F2.2 Bioswales

Bioswales are shallow open channels that capture and convey stormwater runoff. They are typically comprised of a vegetated topsoil layer, a drain rock layer and a subgrade drain. In locations where stormwater treatment is a concern, as with industrial developments, bioswales provide stormwater treatment by assisting in the removal of Total Suspended Solids (TSS), heavy metals and some hydrocarbons.

Compared to a traditional piped drainage network, bioswales can significantly attenuate runoff received from impervious surfaces due to the relatively high roughness of the surface layer, the effect of temporary subsurface storage in the drain rock layer, and the promotion of shallow infiltration.

Bioswales can be implemented along the edges of parking lots and provide benefits to stormwater quality while lessening the strain on the City's piped drainage network.

F2.3 Green Roof

A green roof is a modified conventional roof that incorporates features such as planter boxes that support living vegetation. For the purposes of stormwater management, soil depth is typically 300 mm or less. Green roofs operate similar to absorbent landscaping by soaking up and temporarily retaining direct rainfall.

Buildings located on industrial lots tend to occupy a significant fraction of the total lot area and typically have flat roofs. This makes the implementation of green roofs practical and very effective for these areas.

Various studies have highlighted that green roofs provide extra insulation reducing heat transfer as well as improve the longevity of the roof structure by helping to protect the membrane from extreme temperature fluctuations (Metro Vancouver, 2012). With proper communication of these benefits, industrial property managers may be more inclined to support the inclusion of green roofs on their lots.

F2.4 Rain Gardens

Rain gardens are aesthetically pleasing landscape features designed to capture, detain, treat and infiltrate stormwater runoff. Rain gardens typically consist of 450 mm of absorbent topsoil supporting trees, shrubs and groundcover, overlying a drain rock reservoir. The soil and vegetative layers provide attenuation and treatment of water as it percolates and collects in the drain rock reservoir. If infiltration capacity in the drain rock reservoir is sufficient, the water will infiltrate. Otherwise, the water is directed into the storm drainage network either through an overflow catch basin at the surface or through a subdrain located in the drain rock layer.

Within industrial areas, rain gardens can provide a pleasant aesthetic feature while collecting and treating the majority of runoff generated from impervious surfaces such as parking lots or rooftops.

F2.5 Underground Detention

In commercial, industrial, and high density residential areas, detention storage can be provided as tanks located under parking or working areas and in urban residential areas within lawns or under driveways, preferably at the low point of each site.

These systems could be designed to provide both peak flow attenuation and volume reduction functions. To provide attenuation, storage units should be sized and configured with sufficient volume to retain a significant portion of the runoff for an extended period of time. They would require a flow control feature at the outlet to limit release rates. Water would be temporarily stored, and released at a slower rate, which would better mimic the slow percolation and concentration rates of the organic surficial soils and vegetation present under natural conditions. These units would require a bypass system, either external to the unit or an internal overflow, to ensure large design storms exceeding the unit capacity can be conveyed to the downstream system.

F3 ROADWAYS

The City should maximize the opportunity for implementing source controls by promoting inCity of sustainable stormwater management principles into all types of projects, including road construction / rehabilitation projects. Figure F-3 illustrates the potential configuration of roadway source controls to maximize hydrologic benefits across the study area. These measures should be implemented where possible. These roadside BMPs should only be implemented in areas not prohibited by the Delta Subdivision and Development Standards Bylaw No. 7162.

a)

b)

a) Local and collector roads; b) Arterial roads

Figure F-3
Road Right-of-Way Source Control Configurations

F3.1 Bioswales / Enhanced Ditches

The hydrologic benefits and typical structure of bioswales was discussed in Section 1.2.2.

Runoff from travelled lanes and parking areas can be directed to bioswales, rather than being immediately discharged into the storm drainage network. This provides for treatment of TSS, heavy metals and hydrocarbons, reducing the direct loading on the storm drainage network.

F3.2 Pervious Pavement

The hydrologic benefits and typical structure of pervious pavements were discussed in Section 1.1.3.

While pervious pavement should not be implemented in high-traffic areas due to potential structural concerns and ponding, sidewalks and parking lanes can utilize pervious pavement to attenuate runoff and promote shallow infiltration to the underlying soil.

F3.3 Rain Gardens

The hydrologic benefits and typical structure of rain gardens were discussed in Section 1.2.4.

Runoff from travelled lanes and parking lanes can be directed to rain gardens to provide treatment and runoff attenuation. Rain gardens can be placed at the downstream ends of bioswales to provide maximum treatment efficiency and runoff reduction. Rain gardens may be linear features or incorporated into curb bulges.

F3.4 Absorbent Landscaping and Street Trees

The hydrologic benefits and structure of absorbent landscaping were discussed in Section 1.1.2.

Absorbent landscaping can be employed in combination with street trees to support the City's ultimate tree canopy goals as well as the City's goal to provide aesthetically pleasing communities. Absorbent landscaping in a roadway context is best suited to the inclusion of street trees to maximize the hydrologic benefits. Trees can consist of coniferous or deciduous trees, and are most beneficial if they possess high leaf densities. Coniferous trees are preferred over deciduous trees, as leaf litter can restrict the absorption of the underlying soil, and their retention of foliage through the winter rainy season promotes maximum interception.

For maximum effectiveness, the growing medium should have a minimum depth of 450 mm. Analysis of the feasibility of street trees must consider implications to the surrounding pavement structures, as tree roots can damage concrete sidewalks and paved roads, although this effect can be mitigated by the use of structural soils.

Structural soils are soil media that can be compacted to meet pavement design and installation requirements while permitting adequate root growth. It is generally composed of gap-graded crushed stone, clay loam and a hydrogel stabilizing agent to bind the mixture together. It provides a root-penetrable, high strength pavement system that shifts design away from individual tree pits.

Structural soil can be located under the sidewalks adjacent to most arterial and local roads. By allowing roots to cover a greater area without damaging pavement structure, structural soil can reduce some of the drawbacks of street trees.

F4 CITY PARKS AND GREEN SPACES

F4.1 Stormwater Management Ponds

Stormwater management ponds are facilities designed to provide treatment of stormwater runoff through settling of sediment and pollutants and provide quantity control of peak flow through temporary storage. Stormwater management ponds should be employed to provide extended detention of runoff from urban development during large infrequent storm events. They should also be designed to detain and ensure the controlled release of runoff from all events up to and including the 100-year return period. Stormwater management ponds also control runoff and provide extended detention to runoff from small frequently occurring rainfall events, providing relief to downstream stormwater infrastructure and watercourses.

Stormwater management ponds should be located on City controlled property at the downstream end of the contributing drainage catchment, upstream of the receiving watercourse or drainage infrastructure.

When properly designed and managed, ponds can also function as attractive community amenities that provide recreation benefits and habitat for wildlife.