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Final Report

Fleetwood Greenway North Creek Integrated Stormwater Management Plan

KWL Project No. 471.288
June 2016

Submitted by:

KERR WOOD LEIDAL
consulting engineers

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Executive Summary

Overview of the Study Areas

The Fleetwood Greenway North Creek Integrated Stormwater Management Plan (ISMP) study looks at the current management and planning issues for the study watersheds and future issues for the health of the watersheds. This ISMP is comprised of two separate study areas containing several smaller creeks in the City of Surrey. All of the upland creeks in the study area drain to the lowlands and into the Serpentine River and then the Ocean at Mud Bay. *Figure 1-1* shows the study area for the ISMP.

While there are only four named creeks within the study areas, there are also several un-named creeks included in the ISMP which have been designated by nearby road names according to their location. The creeks included in this ISMP are Fleetwood Creek and its tributaries, 161A Street Creek, 162 Street Creek, 166 Street Creek, and Drinkwater Creek.

The 999 ha study area is largely urbanized with single family residential, high density residential, commercial and industrial land uses. The study area watersheds have experienced substantial urban development over the past 50 years. Plans for the future of the areas include revision of the Fleetwood Town Centre Plan in the Fleetwood-Greenway study area. In addition, the watershed is expected to experience infilling and redevelopment of the single family residential neighbourhoods.

The Fleetwood Greenway North Creek ISMP sets out how the resources within the watershed can be managed to balance land development and stormwater management with environmental protection, watershed health preservation and enhancement of social and environmental values. Green spaces, riparian corridors, and economic considerations are integrated into the study to provide a holistic and integrated outlook for the long term health of this watershed.

Table i: Details of Fleetwood ISMP Study Areas

Description	Fleetwood Greenway North Creek Study Area
Drainage Area	• 999 ha total, including: • 512 ha in Fleetwood • 445.5 ha in North Creek • 41 ha in extra catchment southwest of and adjacent to North Creek catchment not included in previous ISMPs
Stream Structure	• 2.1 km Fleetwood Creek and tributaries • 0.7 km 161A Street Creek • 1.4 km 162 Street Creek • 1.0 km 166 Street Creek • 2.5 km Drinkwater Creek --- • 4.6 km North Creek and tributary • 1.9 km South Creek • 2.4 km St. Gelais Brook *Figure 1-1 shows the creeks and tributaries*
Topography	• Fleetwood topography ranges from El. 1 m (on 168 St. at the Surrey Golf Club) to El. 97 m (Fraser Hwy and 154 St). • North Creek topography ranges from El. 1 m (Fraser Hwy and Hwy 15) to El. 84 m (west of 72 Ave and 192 St).

Description	Fleetwood Greenway North Creek Study Area
Drainage and Hydraulic Structures	• Fleetwood Creek, 161A St. Creek, 162 St. Creek and 166 St. Creek drain generally south to the lowland areas, where they discharge into the Serpentine River via floodboxes and the Fleetwood pump station. • Drinkwater Creek drains generally east to the lowland areas, where it discharges into the Serpentine River via floodboxes and the Fry's Corner North pump station. • North Creek, South Creek and St. Gelais drain generally north-west to the boundary of the lowland areas, where they discharge into the Serpentine River via floodboxes and the Fry's Corner pump station. • Existing storm sewers and culverts range in size from 100 mm circular pipes to a 3000 mm x 1500 mm box culvert (the largest pipes are structures for stream conveyance or culverts). • System includes 115 km of conduits. • Stream crossings include culverts and bridges.
Erosion	• 253 erosion sites were identified and ranked during the engineering field inventory: o 17 High Risk o 61 Medium Risk o 175 Low Risk
Soils	• Based on Provincial Soils mapping: o 1% Sand and Silt o 4% Peat o 7% Sand o 10% Till o 78% Silt and Clay *Figure 2-7 shows the soil distribution in the watershed based on available mapping*

ISMP Goals

The goals of the Fleetwood Greenway North Creek ISMP include:

- Protect and enhance the overall health and natural resources of the watershed;
- Protect and enhance human health through improved environmental quality;
- Promote participation from all stakeholders to achieve a common understanding of the importance, and future vision, of the watershed;
- Minimize risk of life and property damages associated with flooding and provide strategies to attenuate peak flows;
- Protect and enhance watercourses and aquatic life;
- Prevent pollution and maintain/improve water quality;
- Prepare an inventory of watercourses, wildlife, and benthos for the watershed;
- Protect and enhance the environment, wildlife, and habitat corridors;
- Identify areas of existing and future agricultural, residential, commercial, and recreational land uses;
- Develop a cost effective and enforceable implementation plan; and
- Establish a monitoring and assessment strategy to ensure goals are achieved, maintained, and enforced.

ISMP Key Issues

The key issues for the ISMP are:

Key Issues
Flood Management • Undersized storm sewers and culverts
Erosion Management • Erosion in the stream channels
Mitigation of Future Development/Redevelopment Impacts • Increasing TIA and EIA in the watershed with new development and re-development
Environmental Protection and Enhancement • Threats to riparian and stream integrity

Vision for the Future

The Vision for the ISMP was developed through a workshop with City staff. The Vision for the watersheds is made up of three pillars, in line with the City's OCP and the ISMP framework:

Greener: The net health of the watersheds is protected and maintained or enhanced over the long-term as the watersheds are developed and re-developed.

Safer: The stormwater infrastructure continues to protect life and property from erosion and flooding as development continues and the climate changes.

Inclusive: The watersheds include programs and places that foster getting outdoors, community-building, and connection to nature. The watersheds provide access to nature in a manner that promotes appreciation of the natural environment without intrusion.

Recommendations

Stormwater Criteria

The following stormwater criteria are proposed for all future development and redevelopment. Each item below must be addressed in the site stormwater design. Some items may overlap, for example, capture of 32 mm rainfall may reduce the volume of detention required and may or may not provide treatment of 80% of runoff from vehicle-accessible impervious areas.

Table ii: Proposed Stormwater Criteria for Fleetwood Greenway North Creek ISMP

Application		Criteria/Methodology		Checklist
		All Development		
Hydrotechnical Component (Flood and Erosion Protection)	Minor Drainage System	• 5-year return period design event.[1]		✓
	Major Drainage System	• 100-year return period design event[1]		✓
	Agricultural Drainage	• Maintenance of a flood control and drainage system in the lowlands for agriculture in floodplains to ARDSA criteria[1,2]		✓
	Watercourse Erosion Prevention/ Rate Control	*See environmental criteria below.*		
		All Development (except Single Family Residential)	Single Family Residential	
Environmental Component (Environmental Protection)	Volume Reduction Source Controls	• Source controls on single-family subdivisions, multi-family residential, commercial, institutional, and industrial development and roads to mitigate the target volume for all impervious area. • On-site rainfall capture (runoff volume reduction) target of 32 mm in 24 hours.	• For single-family residential development, 450 mm of absorbent topsoil on all landscaping areas, disconnected roof leaders discharge to landscape areas, and grading hard surfaces to landscape or pervious areas. • Regional facilities to make up for any on-site capture shortfalls.	✓
	Water Quality Treatment	• Collect and treat 80% of annual runoff from ground surface impervious areas with BMPs. • Design BMPs and water treatment facilities to remove sediments, metals and hydrocarbons and meet the maximum allowable total suspended solids (TSS) of 75 mg/L [3]	N/A	✓
	Watercourse Erosion Prevention/ Rate Control	• Control 5-year, 2-year and 6-month event post-development flows from development site to corresponding 5-year, 2-year, and 6-month pre-development flow rates.[4,5,6]	N/A	✓
	Riparian	• Establish riparian setbacks to comply with *Riparian Area Bylaw (proposed, 2016)* and the City of Surrey's Ecological Management Study and the recommendations from the Biodiversity Plan.		✓

1. City of Surrey Design Criteria Manual, January 2016.
2. Agricultural Land Commission Website, 2012.
3. City of Surrey Erosion and Sediment Control Bylaw 2006 No.16138.
4. DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat, 2001.
5. City of Surrey Design Criteria Manual, January 2016, requires control of 5-year post-development flow to more stringent of 50% of 2-year post-development flow or 5-year pre-development flow.
6. Pre-development flow rates for design are summarized in Table iii.

Predevelopment release rates for the study area watersheds were developed to streamline design of detention to the new standard for rate control.

Table iii: Pre-development 24-hour release rates for detention

Return Period	Peak Unit Release Rate (L/s/ha)
6-month	6.04
2-year	10.43
5-year	15.81
Peak release rates are for detention design using the 24-hour duration event	

Capital Upgrade Plan

Notwithstanding the measures proposed above, there is a need for the following capital projects to address existing capacity issues, creek erosion, and environmental concerns. *Figures 7-1 to 7-3* show the recommended capital projects and *Table iv* summarizes the project costs. See Section 7 in the main text for a full list of recommendations for the capital upgrade plan.

Flood management upgrades: A capital upgrade plan was developed to address the existing and future conveyance system capacity issues. Pipes flagged for upgrade are listed in *Table 7-6* and shown in *Figure 7-1.*

Erosion management recommendations: No high risk erosion sites were identified for immediate action, though 17 sites were recommended for further monitoring (see Appendix B). The potential for further creek erosion due to increases in peak flows is to be addressed through a combination of volumetric reduction source controls and detention to be applied to all future development and redevelopment. The Fleetwood Creek catchment may not have opportunity for application of source controls as it is expected that increases in total impervious area will primarily be realized through single-family redevelopment. In this case, a diversion structure and storm system upgrade has been previously recommended and is supported by the ISMP. In addition, it is recommended that the diversion on 162 St. Creek be completed.

Fish passage improvements: A number of fish passage improvement projects are proposed on creeks in the Fleetwood-Greenway and North Creek watersheds, including one private culvert upgrade.

In-stream enhancement projects: A number of in-stream habitat complexing projects (bank stabilization; planting of native species; addition of large woody debris, boulders, spawning gravels, and channel meanders) have been identified to mitigate existing impacts.

Off-channel enhancement projects: One off-channel habitat creation project was identified for the low-middle reaches of North Creek to provide shelter and rearing habitat for juvenile salmon.

Riparian protection, restoration and planting: Riparian areas should be conveyed to the City during redevelopment, particularly adjacent to Fleetwood and Drinkwater Creeks, and St. Gelais Brook. A number of sites have been identified for riparian restoration through reforestation and invasive species management.

Wildlife/Biodiversity enhancement projects: Four non-riparian areas were identified for wildlife habitat enhancement. Particularly in the North Creek catchment where overall forest cover is low, these projects are identified both as a means to increase ecological value and to restore hydrological functions provided by tree vegetation and forest soils over the long term.

Neighbourhood-scale water quality treatment: Several opportunities for water quality facilities such as oil and grit separators have been identified, though water quality treatment for future development should primarily be accomplished through the application of the on-site treatment source controls. Monitoring of water temperature at the detention pond in the headwaters of North Creek is also recommended.

Table iv: Cost estimate for recommended capital projects

Project	Funding Source	Cost ($)
Flood Management		
Priority 1 Pipe Upgrades (NONE)	City	-
Priority 2 Pipe Upgrades	City	$1,570,000
Priority 3 Pipe Upgrades (NONE)	City	-
Priority 4 Pipe Upgrades	City	$5,068,000
Priority 5 Pipe Upgrades	City & DCCs	$3,532,000
Erosion Management		
162 St. Creek Diversion	City & DCCs	$2,535,000
Fleetwood Creek Diversion	City & DCCs	$8,735,000
Environmental Protection and Enhancement		
Water Quality Treatment	Drainage	$1,000,000
Riparian Protection, Restoration, Planting	Drainage	$770,000
Wildlife Habitat Creation (Not costed)	BCS	-
In-Stream Habitat Complexing	Drainage	$250,000
Off-Channel Habitat Creation	Drainage	$50,000
Fish Passage Improvements	Drainage	$2,470,000
Total Capital Costs		**$25,980,000**

DCCs = Development Cost Charges
BCS = Biodiversity Conservation Strategy

Bylaw and Policy Changes

A number of Bylaw and Standards changes are proposed to avoid conflicts with the requirements proposed in this ISMP and with the latest stormwater management methodologies. The recommended changes include:

Design Criteria Manual

These changes to the Design Criteria Manual are recommended to incorporate and consolidate design requirements, both to make the design and review process simpler for designers, and to make the review process easier and more streamlined for the City staff that review stormwater management plans.

1) Emphasize wording to require modifying culverts where needed to allow fish and wildlife passage.
2) Add recommended stormwater criteria so that they are in the same place as the servicing design criteria. A map and table of stormwater criteria by watershed could be included in the Manual.
3) Expand the water quality criteria in the manual to include treatment targets for roads, in addition to the requirement for treatment of runoff from parking lots.
4) Revise the storage and rate control requirements to the 5-year, 2-year, and 6-month flows to pre-development levels.

Building By-law, No. 17850, 2012

5) Revise to allow disconnection of roof leaders on all land uses, with proper consideration in the stormwater management plan for the site and lot grading plan.
6) Add the need for inspections of source controls, proper piping connections, overflows, etc.

Riparian Area By-law (*new* in process at time of this work)

7) Revise zoning bylaws to incorporate wider (30m) riparian setbacks.

Property Maintenance and Unsightly Premises Bylaw, 2007, No. 16393

8) Clarify that boulevard maintenance activities required under the bylaw include the maintenance of source controls such as rain garden weeding, watering, debris removal, etc. within the boulevard and on lot.

Monitoring and Adaptive Management

Monitoring of key parameters in the watershed is proposed to comply with the Metro Vancouver Adaptive Management Framework and to assess the long term effectiveness of the ISMP. The monitoring recommendations are found in Section 8.

1. Introduction and Framework for ISMP

1.1 Introduction

The Fleetwood Greenway North Creek Integrated Stormwater Management Plan (ISMP) study looks at the management and planning issues that are current issues for the study watersheds and future issues for the health of the watersheds. This ISMP is comprised of two separate study areas containing several smaller creeks in the City of Surrey. As such, this ISMP departs from standard ISMPs by incorporating:

- Multiple creeks and their watersheds,
- Different issues and solutions that are considered and proposed for different watersheds, and
- Overall policies for approaching multiple watersheds, as well as recommendations for individual watersheds.

All of the upland creeks in the study area drain to the lowlands and into the Serpentine River and then the Ocean at Mud Bay. Figure 1-1 shows the study area for the ISMP. While there are only four named creeks within the study areas, there are also several un-named creeks that are included in the ISMP. The 999 ha study area is largely urbanized with single family residential, high density residential, commercial and industrial land uses.

The study area watersheds have experienced substantial urban development over the past 50 years. Plans for the future of the areas include revision of the Fleetwood Town Centre Plan in the Fleetwood-Greenway study area. In addition, the watershed is expected to experience infilling and some redevelopment of the single family residential neighbourhoods.

The Fleetwood Greenway North Creek ISMP sets out how the resources within the watershed can be managed to balance land development and stormwater management with environmental protection, watershed health preservation and enhancement of social and environmental values. Green spaces, riparian corridors, and economic considerations are integrated into the study to provide a holistic and integrated outlook for the long term health of this watershed.

Fleetwood Greenway North Creek ISMP Purpose and Objectives

This report fulfills the goals of the ISMP including:

- Document the existing condition of the drainage system and the ecological health of the watershed;
- Identify enhancement opportunities for aquatic and wildlife habitats;
- Determine 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 for long-term “Net Gain” in watershed health.

1.2 LWMP Stormwater Commitments

The 2001 Metro Vancouver *Liquid Waste Management Plan* (LWMP) included commitments for stormwater management that incorporated:

- Sharing of information and knowledge through the Stormwater Interagency Liaison Group (SILG);
- Stakeholder participation;
- Updating and adopting policies and bylaws; and
- Undertaking watershed-scale Integrated Stormwater Management Plans (ISMPs).

In 2002, Metro Vancouver, SILG members and KWL developed the Terms of Reference Template for ISMPs to provide guidance and a flexible framework to the ISMP planning process. The Template document was updated in 2005 based on feedback from member municipalities on its application.

Metro Vancouver updated the LWMP in 2010 to create the *Integrated Liquid Waste and Resource Management Plan (ILWRMP), May 2010*. The key stormwater points are summarized as follows:

- Continue requirement for ISMP planning and implementation;
- Place emphasis on managing rainwater runoff at the site level which reduces negative quality and quantity effects;
- Integrate land use planning and stormwater management;
- Improve stormwater bylaws and development of design standards and guidelines;
- Promote the collection and use of rainwater for non-potable water uses; and
- Develop watershed health indicators.

The Ministry of Environment's accompanying letter requires the development of a coordinated program to monitor stormwater, and assess and report the implementation and effectiveness of ISMPs using a weight-of-evidence performance measurement approach. The ISMP completion deadline may be extended from 2014 to 2016.

Metro Vancouver and its members provide progress reports to the province every two years and will review and update the ILWRMP on an eight-year cycle.

1.3 Existing Bylaws

City bylaws form part of the context for the ISMP study. Existing bylaws related to stormwater management include:

Stormwater Drainage Regulation and Charges (By-Law #16610) - to regulate extensions, connections, and use of the stormwater drainage system, to impose connection charges to the stormwater drainage system, and to prohibit the fouling, obstructing, or impeding the flow of any stream, creek waterway, watercourse, ditch, or stormwater drainage system.

Erosion and Sedimentation Control (By-Law #16138) - All applications for proposed construction on land areas of 2000 m^2 or larger, shall be submitted with a complete ESC Permit application to the City. All construction on land areas of less than 2000 m^2 shall utilize the best management practices for erosion and sediment control as outlined in Schedule "B" of the By-Law.

Zoning (By-law #12000) – Part 8.D – requires a minimum setback requirement of 15 m from any watercourse.

Subdivision and Land Development (By-Law #8830) - to regulate the subdivision and development of land. It sets out servicing requirements, including drainage works, for new developments and the circumstances under which alternative servicing systems can be implemented. The bylaw also describes the expectations of developers to provide land and facilities for drainage control.

1.4 Existing Stormwater Criteria

City of Surrey Stormwater Criteria

Table 1-1 summarizes the existing City of Surrey stormwater criteria applicable in the Fleetwood Greenway and North Creek watersheds.

Table 1-1: Summary of Existing Stormwater Criteria

Application		Criteria/Methodology
Hydrotechnical Component (Flood and Erosion Protection)	Minor Drainage System	• 5-year return period design event
	Major Drainage System	• 100-year return period design event
	Agricultural Lowland Flooding – ARDSA[1]	• Maintenance of a flood control and drainage system in the lowlands that meets provincial guidelines for agriculture in floodplains
Environmental Component (Environmental Protection)	Watercourse Erosion Prevention	The more stringent of: • Control the 5-year post-development flow to 50% of the 2-year post development rate; or • Control the 5-year post-development flow to 5-year pre-development flow rate

1. ARDSA = Agriculture and Rural Development Subsidiary Agreement. Not applied during this study.

1.5 Scope of Work

The work program is summarized in Table 1-2.

Table 1-2: Engineering Work Program

Major Tasks		
Stage 1 Review Existing Information & Data Collection	1.1	Gather and Review Available Information
	1.2	Project Initiation Meeting
	1.3	Base Map Preparation (GIS database)
	1.4	Engineering Inventory
	1.5	Environmental Inventory and Assessment
	1.6	Optional Task: Update of North Creek Analyses (2010-2014)
	1.7	Hydrologic/Hydraulic Modelling and Existing Land Use Assessment
	1.8	Stakeholder Consultation and City Meeting #1.

Major Tasks		
Stage 2 Vision for Future Development	2.1	Estimated Future Land Use
	2.2	City Meeting #2 to Establish Watershed Goals and Vision for Future Development
	2.3	External Stakeholder Consultation
	2.4	Revised Future Land Use, Vision, and Goals
Stage 3 ISMP Implementation Plan, Funding Strategies, & Enforcement	3.1	Evaluate and Recommend Cost Effective Solutions
	3.2	Future Land Use Modelling and Hydrotechnical Assessment
	3.3	Erosion Mitigation Works
	3.4	Environmental Compensation and Enhancement Works
	3.5	Capital Cost Estimates and Funding Strategies
	3.6	Approval Procedure and Enforcement Strategy
	3.7	City Meeting #3 to Present ISMP
Stage 4 Monitoring & Assessment Plan	4.1	Develop a Monitoring Strategy
	4.2	Adaptive Management
	4.3	Optional Task: Assess SFR in Surrey vs. MV Baseline
	4.3	Reporting

1.6 Project Team

This project was undertaken by an inter-disciplinary team of professionals. The members and companies involved are outlined in the following table.

Table 1-3: Project Team

Firm	Team Members
City of Surrey	David Hislop, P.Eng., Project Manager, Drainage Planning Carrie Baron, Drainage and Engineering Helen Chan, Community Planning Amanda Silvers, Communications Don Wright, Operations Matt Brown, Lowland Drainage Stephen Godwin, Environmental Ted Uhrich, Parks Jeannie Lee, Drainage Harbinder Bains, Development Services Liana Ayach, Environmental Andrew Dyck, Drainage and Engineering Lauren Peterson, Engineering
Kerr Wood Leidal Associates Ltd.	Laurel Morgan, M.Sc., P.Eng., Project Manager David Zabil, M.A.Sc., P.Eng., Technical Review Sara Pour, P.Eng., Project Engineer Shayna Scott, EIT, Junior Engineer and Modeller Jack Lau, GIS Specialist Patrick Lilley, R.P.Bio., Biologist Peter deKoning, R.P.Bio., Junior Biologist

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

FLEETWOOD GREEN WAY STUDY AREA

NORTH CREEK STUDY AREA

Drinkwater Creek

162 St. Creek

166 St. Creek

North Creek

Fleetwood Creek

161A St. Creek

South Creek

St. Gelais Brook

Fleetwood Way
E Crk
Austin Brk
88 Ave
Swanson Brk
Lokiotis Crk
Harvie Crk
90 Ave
Old Sawmill Crk
Fruso Crk
Latimer Crk
Harvie Rd
192 St
159 St
160 St
84 Ave
158 St
82 Ave
Drinkwater Crk
152 St
162 St Crk
166 St Crk
161A St Crk
Fleetwood Crk
80 Ave
Glayton Crk
South Latimer Crk
Fraser Hwy
Highway 15
76 Ave
Bear Crk
168 St
Serpentine River
72 Ave
North Crk
South Crk
St Gelais Brk
184 St
186 St
189 St
192 St Diversion
68 Ave
66 Ave
188 St
Serpentine Channel
Hyland Crk
64 Ave
166 St
63 Ave
172 St
180 St
164 St
Hook Brk
60 Ave

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	May 2015

Study Area Watersheds

Figure 1-1

Path: O:\0400-0499\471-288\430-GisMXD-Rpt\471288_Fig1-1_StudyArea.mxd Date Saved: 14/05/2015 9:18:21 AM
Author: SScott

2. Overview of Study Areas

2.1 Watershed Overview

Location and Description

The 999 ha study area and catchment for the Fleetwood Greenway North Creek ISMP is located in the north-east quadrant of the City of Surrey. The study area is made of up two separate upland land areas, both located along the Fraser Highway on opposite sides of the Serpentine River. The Fleetwood-Greenway study area (512 ha) includes the upland portions of Fleetwood, Walnut and Drinkwater Creeks, and portions of the Middle Serpentine, East Fleetwood, and Greenway drainage catchments. The North Creek study area (445.5 ha) includes the upland portions of North Creek and St. Gelais Brook, and the upland portion of the North West Clayton drainage catchment. Also included in the study area is an extra catchment (41 ha) directly southwest of the North Creek catchment. This catchment does not drain into the North Creek catchment, but it was included in the study as it had not been included in any previous ISMPs. Figure 1-1 shows the study area for the ISMP.

All of the upland creeks in the study area drain to the lowlands and into the Serpentine River and then the Ocean at Mud Bay.

The ISMP study areas are developed urban watersheds with total impervious area coverage of approximately 65%. The current land use within the study areas is mostly residential, comprehensive development, and agricultural. Despite the high level of urbanization of the watersheds, the prevalence of single family residential land use and disconnected roof leaders on single family lots means that these watersheds have an overall high level of disconnection of impervious area.

Creek Names

The study areas for this ISMP include multiple small creeks that do not have official names, in either the City of Surrey's GIS or in provincial databases. In general, the ISMP uses the names that are in the City of Surrey's GIS database, supplemented with names based on the streets near creek locations that are consistent with previous reports developed for the City of Surrey. The names of creeks used in the ISMP are shown on Figure 1-1.

Note that the creek labeled as 162 Street Creek in this and other work is also called Fleetwood Creek in at least one provincial database. That same creek has also been called Walnut Creek in at least one report, as it runs through Walnut Park.

Watershed and Creek Characteristics

A number of background reports and GIS layers were available for the study. This data was supplemented by engineering and environmental field inventories. Background information reviewed for the project is listed and described in Appendix A. Appendix B provides detailed findings of the engineering inventory while Appendix C provides detailed findings of the environmental inventory. The following table and Figures 2-1 to 2-7 summarize the key study area characteristics.

Table 2-1: Drainage Overview

Description	Fleetwood Greenway North Creek Study Area
Drainage Area	• 999 ha total, including: • 512 ha in Fleetwood • 445.5 ha in North Creek • 41 ha in extra catchment not included in previous projects
Stream Structure	• 2.1 km Fleetwood Creek and tributaries • 0.7 km 161A Street Creek • 1.4 km 162 Street Creek • 1.0 km 166 Street Creek • 2.5 km Drinkwater Creek --- • 4.6 km North Creek and tributary • 1.9 km South Creek • 2.4 km St. Gelais Brook Figure 1-1 shows the creeks and tributaries
Topography	• Fleetwood topography ranges from El. 1 m (on 168 St. at the Surrey Golf Club) to El. 97 m (Fraser Hwy and 154 St). • North Creek topography ranges from El. 1 m (Fraser Hwy and Hwy 15) to El. 84 m (west of 72 Ave and 192 St).
Land Use	Existing: • Total: 56% residential, 3% industrial, 1% commercial, 1% institutional, 11 % comprehensive development, 1% park and open space, 12% Agricultural, 15% ROW. • Fleetwood: 57% residential, 1% industrial, 2% commercial, 2% institutional, 7% comprehensive development, 1% park and open space, 15% Agricultural, 15% ROW. • North Creek: 56% residential, 3% industrial, 1% commercial, 1% institutional, 16% comprehensive development, 10% Agricultural, 13% ROW. • Extra Catchment: 41% residential, 29% industrial, 12% comprehensive development, 18% ROW. Figures 2-1 and 2-2 show existing zoning. Future (based on current OCP and land use plans): • Total: 43% residential, 8% suburban, 1% industrial, 7% commercial, 3% institutional, 16% park and open space, 3% agricultural, 18% ROW. • Fleetwood: 41% residential, 12% suburban, 1% industrial, 6% commercial, 3% institutional, 15% park and open space, 5% agricultural, 17% ROW. • North Creek: 45% residential, 4% suburban, 4% industrial, 6% commercial, 4% institutional, 18% park and open space, 2% agricultural, 20% ROW. • Extra Catchment: 26% residential, 44% industrial/commercial, 9% park and open space, 18% ROW. Figures 2-3 and 2-4 show future zoning.

Description	Fleetwood Greenway North Creek Study Area
Drainage and Hydraulic Structures	• Fleetwood Creek, 161A St. Creek, 162 St. Creek and 166 St. Creek drain generally south to the lowland areas, where they discharge into the Serpentine River via floodboxes and the Fleetwood pump station. • Drinkwater Creek drains generally east to the lowland areas, where it discharges into the Serpentine River via floodboxes and the Fry's Corner North pump station. • North Creek, South Creek and St. Gelais drain generally north-west to the boundary of the lowland areas, where they discharge into the Serpentine River via floodboxes and the Fry's Corner pump station. • Existing storm sewers and culverts range in size from 100 mm circular pipes to a 3000 mm x 1500 mm box culvert (the largest pipes are structures for stream conveyance or culverts). • System includes 115 km of conduits. • 2286 conduits and 2288 manholes were modelled in the drainage system for Fleetwood/North Creek watersheds. • Stream crossings include culverts and bridges. Figures 2-5 and 2-6 show an overview of the drainage system.
Erosion	• 253 erosion sites were identified and ranked during the engineering field inventory: o 17 High Risk o 61 Medium Risk o 175 Low Risk Section 3 provides additional details.
Soils	Based on provincial soils mapping: • 1% Sand and Silt • 4% Peat • 7% Sand • 10% Till • 78% Silt and Clay Figure 2-7 shows the soil distribution in the watershed based on available mapping.

2.2 Land Use

Existing Land Use

Existing land use in the study area is shown in Table 2-2 below and on Figures 2-1 and 2-2.

Table 2-2: Existing Land Use

Land Use	Area (hectares)*	Percentage of Total Area*
Residential	558	56%
Industrial	32	3%
Commercial	13	1%
Institutional	12	1%
Comprehensive Development	110	11%
Park and Open Space	5	1%
Agricultural	118	12%
ROW	151	15%
TOTAL	999	100%
* Values based on City of Surrey GIS Zoning layer, 2014		

Future Land Use

Future projected land use was developed for this project based on an amalgamation of the City's OCP, Neighbourhood Plans, and Town Centre Plans, collectively referred to in this report as Future OCP land use. Future OCP land use in the study area is shown in Table 2-3 below and on Figures 2-3 and 2-4.

Table 2-3: Future Land Use

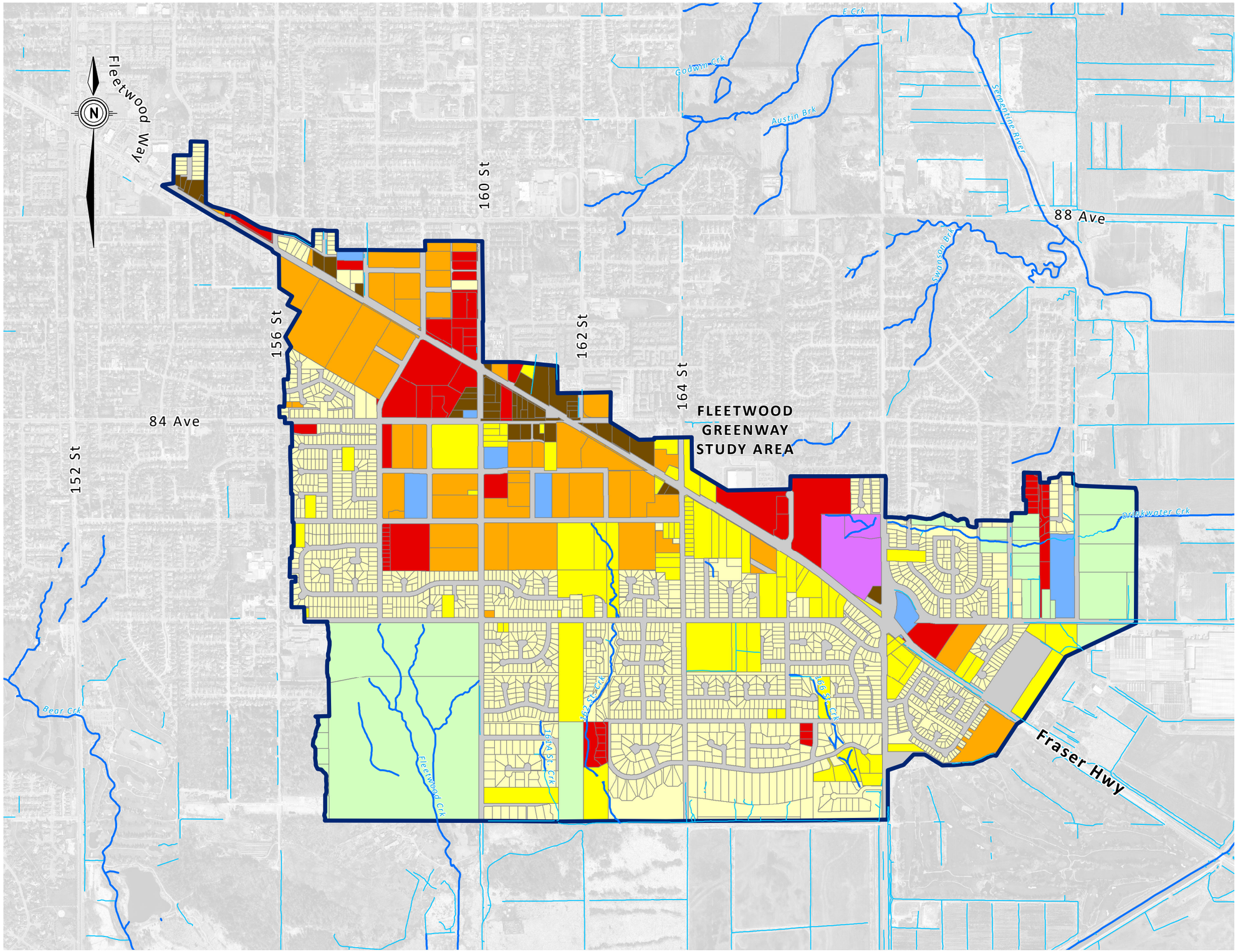
Land Use	Area (hectares)*	Percentage of Total Area*
Residential	426	43%
Industrial	6	1%
Commercial	72	7%
Institutional	33	3%
Suburban	79	8%
Park and Open Space	164	16%
Agricultural	31	3%
ROW	183	18%
TOTAL	999	100%
* Values based on City of Surrey GIS Future OCP land use layers, 2015		

2.3 Surficial Geology

To determine the characteristics of the surficial geology, information from Natural Resources Canada and the Geological Survey of Canada was reviewed. These sources suggest that the Fleetwood Greenway study area is underlain principally by silt and clay. The North Creek study area appears to be underlain by silt/clay with lenses of peat, till, and sand.

Refer to Figure 2-7 for soils mapping, which shows the approximate boundaries of the different soil types.

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan



Legend

- Study Area
- Creek
- Ditch

Zoning

- Agricultural
- Commercial
- Industrial
- Institutional
- Comprehensive Development
- Single Family Residential
- Multi-Family Residential
- One Acre Residential
- Park and Natural Areas
- ROW

Reference: 2013 Orthophoto, 2014 Existing Zoning, and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Fleetwood Greenway
Existing Zoning

Figure 2-1

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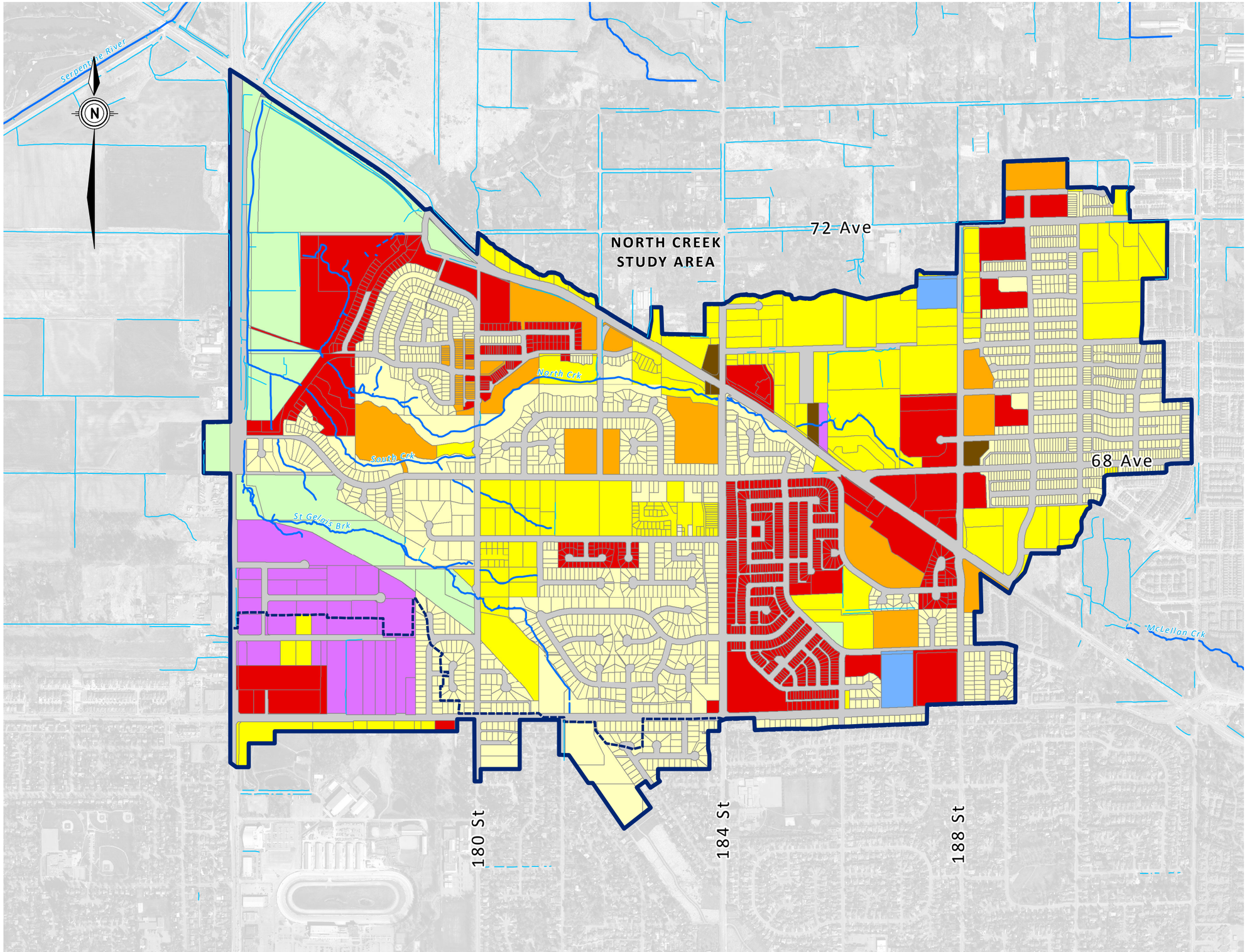

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

Zoning

- Agricultural
- Commercial
- Industrial
- Institutional
- Comprehensive Development
- Single Family Residential
- Multi-Family Residential
- One Acre Residential
- Park and Natural Areas
- ROW

Reference: 2013 Orthophoto, 2014 Existing Zoning, and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

North Creek Existing Zoning

Figure 2-2

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

FLEETWOOD GREENWAY STUDY AREA

88 Ave
84 Ave
82 Ave
80 Ave
156 St
158 St
159 St
160 St
162 St
164 St
168 St
Venture Way
Fraser Hwy
E Crk
Austin Brk
Serpentine River
Swanson Brk
Drinkwater Crk
162 St Crk
166 St Crk
Fleetwood Crk

Legend

- Study Area
- Creek
- Ditch

OCP Future Land Use

- Agricultural
- Commercial
- Half Acre Residential
- Industrial
- Institutional
- Single Family Residential
- Multi-Family Residential
- Parks and Open Space
- SF Residential - East Clayton
- Suburban
- ROW

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.
OCP Land Use Zoning provided by the City of Surrey, 2015
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Project No.	Date
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Fleetwood Greenway
OCP Future Land Use

Figure 2-3

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

NORTH CREEK
STUDY AREA

Serpentine River
Fraser Hwy
72 Ave
68A Ave
68 Ave
64 Ave
66 Ave
North Crk
South Crk
St Gelais Brk
McLellan Crk
184 St
186 St
188 St
189 St
192 St
192 St Div
180 St

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

OCP Future Land Use

- Agricultural
- Commercial
- Half Acre Residential
- Industrial
- Institutional
- Single Family Residential
- Multi-Family Residential
- Parks and Open Space
- SF Residential - East Clayton
- Suburban
- ROW

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.
OCP Land Use Zoning provided by the City of Surrey, 2015
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Project No.	Date
471-288	June 2016

North Creek
OCP Future Land Use

Figure 2-4

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Detention Facility
- Culvert
- Creek
- Ditch

Storm Main Diameter

- < 251 mm
- 251mm - 450mm
- 451mm - 600mm
- > 600mm

FLEETWOOD GREENWAY STUDY AREA

Fleetwood Way
88 Ave
84 Ave
82 Ave
80 Ave
76 Ave
152 St
156 St
158 St
159 St
160 St
162 St
164 St
168 St
Venture Way
Fraser Hwy
Godwin Crk
E Crk
Austin Brk
Swanson Brk
Serpentine River
Drinkwater Crk
162 St Crk
161A St Crk
166 St Crk
Fleetwood Crk
Bear Crk

Reference: 2013 GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
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Fleetwood Greenway Modeled Network

Figure 2-5

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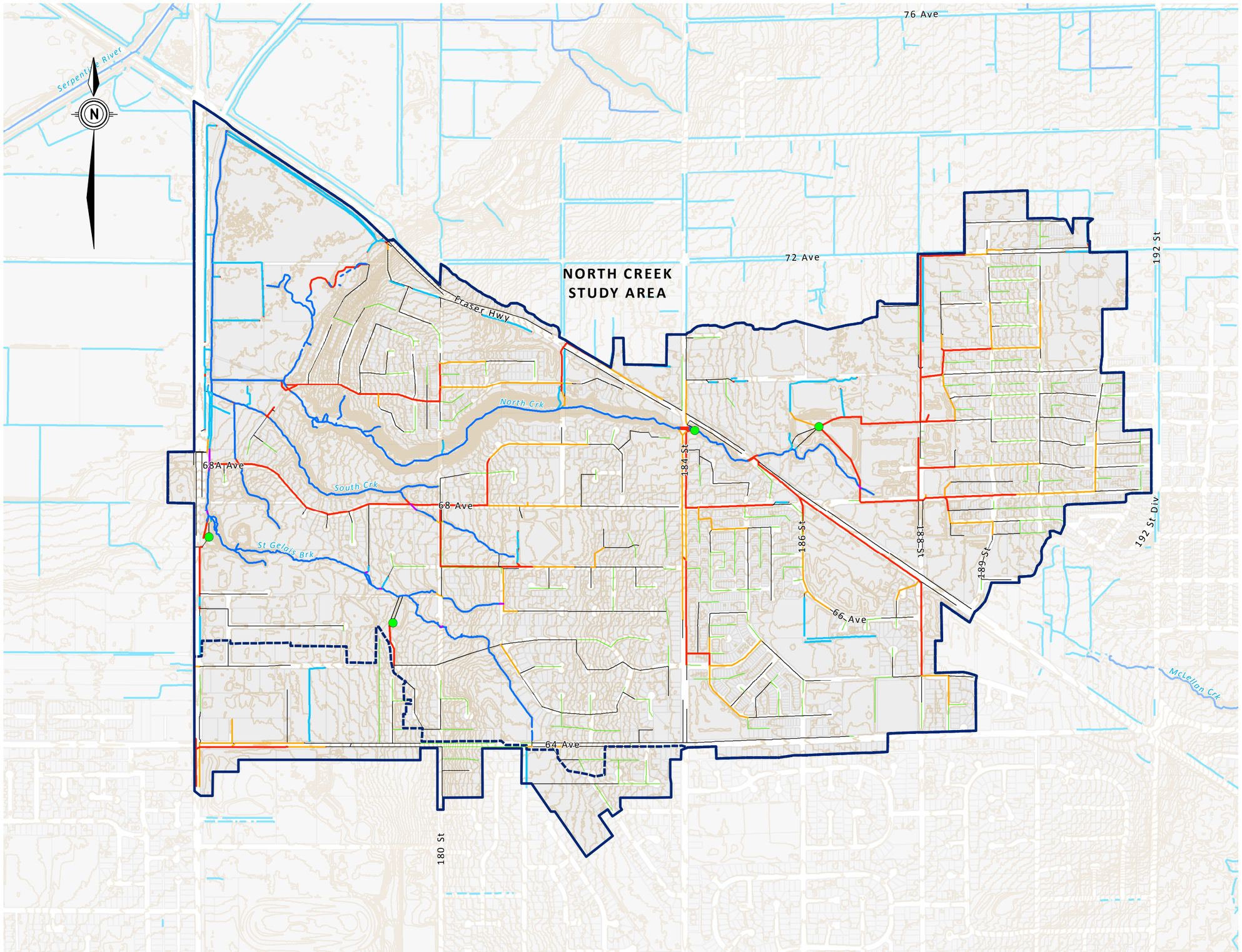

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Detention Facility
- Culvert
- Creek
- Ditch

Storm Main Diameter

- < 251 mm
- 251mm - 450mm
- 451mm - 600mm
- > 600mm

Reference: 2013 GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	April 2015

North Creek Modeled Network

Figure 2-6

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

Soil Material

- Peat
- Sand
- Sand and Silt
- Silt and Clay
- Till

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.
Surficial Geology Information: Natural Resource Canada and the Geological Survey of Canada, 2012
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Project No.	Date
471-288	April 2015

Soils Map

Figure 2-7

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3. Engineering Field Inventory

KWL undertook an engineering field inventory in February and March 2015. The scope of work for the Fleetwood Greenway watersheds included:

- Fleetwood Creek and its tributaries;
- 161A Street Creek;
- 162 Street Creek;
- 166 Street Creek; and
- Drinkwater Creek.

The scope of work for the North Creek watersheds included:

- North Creek and its tributaries;
- South Creek; and
- St. Gelais Brook.

The purpose of the inventory was to supplement the City of Surrey's existing geographic information system (GIS) database by locating, photographing and assessing the following features along the creeks and each major tributary:

- Significant bank or channel erosion sites;
- Channel obstructions; and
- Hydraulic structures and stormwater outfalls.

The City provided orthophotos and GIS data showing the storm sewer collection system, the streams and their tributaries, outfalls, and road crossings. This data served as background information and was used to plan the field inventory. The findings of the field inventory are summarized in GIS layers (shown in Figures 3-1 to 3-8) and summary tables (included in Appendix B) for each of the following categories: erosion sites, obstructions, bridges, culverts and outfalls.

The terms left and right in this report refer to the left and right side of the creek channel when looking downstream. The detailed observations and findings are described in Appendix B.

3.1 Erosion

As part of the engineering field inventory, KWL carried out an assessment of bank instability sites in each stream. The bank instability assessment consisted of the following components:

- Review of previous ravine stability assessment studies (completed by other consultants in 2009 and 2011) to identify sites of active erosion and instability along Fleetwood Creek, 161A Street Creek, 162 Street Creek, 166 Street. Creek, Drinkwater Creek, North Creek, South Creek, and St. Gelais Brook.
- A field survey to assess the condition of previously identified erosion sites and to identify new incidents of erosion, bank instability and debris accumulations in stream channels.
- Comparison of photos and data assessment sheets from the 2015 field inventory to those included in the 2011 ravine stability assessment prepared by Web Engineering.
- Evaluation of the progression of ongoing erosion or bank instabilities and of the effectiveness of remediation works conducted as a result of the previous studies.

The erosion GIS layer contains the locations of observed erosion sites, the severity of the erosion, the length, width, and height of the erosion, and comments or observations of the erosion and causes. See Figures 3-1 to 3-2 and Table B-1 in Appendix B.

Erosion Risk Criteria

The relative risk assessment completed as part of this field inventory was based on the observations of the site made during fieldwork. Erosion sites were identified and assigned a relative severity level based on a visual assessment that took into account the following parameters, where they could be observed:

Hazard: based on the measured height of visible scour or slippage.

- Low: height of erosion < 0.3 m;
- Moderate: height of erosion from 0.3 to 1.2 m; and
- High: height of erosion > 1.2 m.

Consequence: based on the proximity of manmade features (sheds, fences, buildings, retaining structures, etc.) to the eroding bank

- Low: setback > 10 m;
- Moderate: setback between 5 m and 10 m; and
- High: setback < 5 m.

Note that these evaluation criteria are not the same as the criteria used in the City's bi-annual ravine assessments.

Hazard and consequence were evaluated independently of one another at each site. Consequently, an area of minor erosion with structures in close proximity could receive a low hazard, but a high consequence rating. Conversely, major erosion sites in undeveloped areas with no apparent risk to habitat, property or public safety may receive a high hazard but low consequence rating.

A matrix was developed to evaluate erosion risk based on the hazard and consequence ratings. This is presented in Table 3-1 below.

Table 3-1: Erosion Risk Ratings

	Hazard		
Consequence	**High (> 1.2 m)**	**Moderate (0.3 m to 1.2 m)**	**Low (< 0.3 m)**
High (>10 m)	High	High	Medium
Moderate (5m to 10 m)	High	Medium	Medium
Low (> 10 m)	Medium	Low	Low

The 2015 KWL field inventory identified a total of 253 erosion sites in the Fleetwood Greenway and North Creek streams and tributaries. Based on the information collected during the fieldwork, 17 high risk sites were identified, 61 medium risk, and 175 low risk. See Appendix B for a full list of erosion sites.

3.2 Channel Obstructions

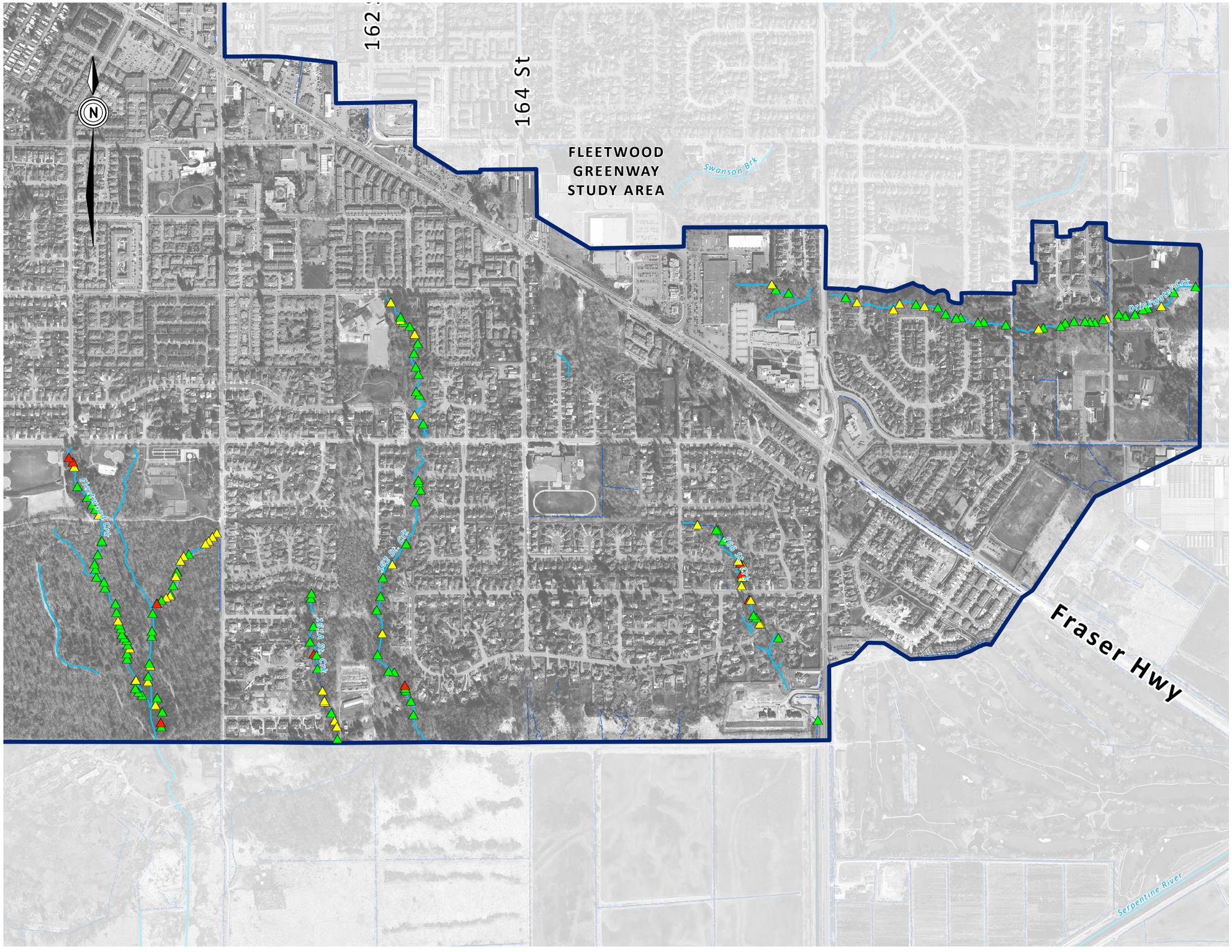
The obstructions GIS layer contains the type of obstruction, the location of the obstruction, whether the obstruction is a hydraulic barrier in the stream and comments or observations for each obstruction. See Figures 3-3 and 3-4 and Table B-3 in Appendix B for more details.

The 2015 field inventory identified a total of 136 obstructions within the creek and tributary channels. The obstructions mostly consisted of large woody debris. On a few occasions, build-up of debris was restricting flow to culverts, but posed no apparent major risk.

3.3 Drainage Structures

The culverts and bridges GIS layer contains the location, material, and comments on the condition of the structures. See Figures 3-5 and 3-6 and Tables B-4 and B-5 in Appendix B.

The outfalls GIS layer contains the location, material, condition and comments on the condition of the structures. See Figures 3-7 and 3-8 and Table B-6 in Appendix B.



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Watercourse
- Ditch

Erosion (Severity)

2015 Risk

- Low
- Medium
- High

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	May 2015

Fleetwood Greenway Observed Erosion Sites

Figure 3-1

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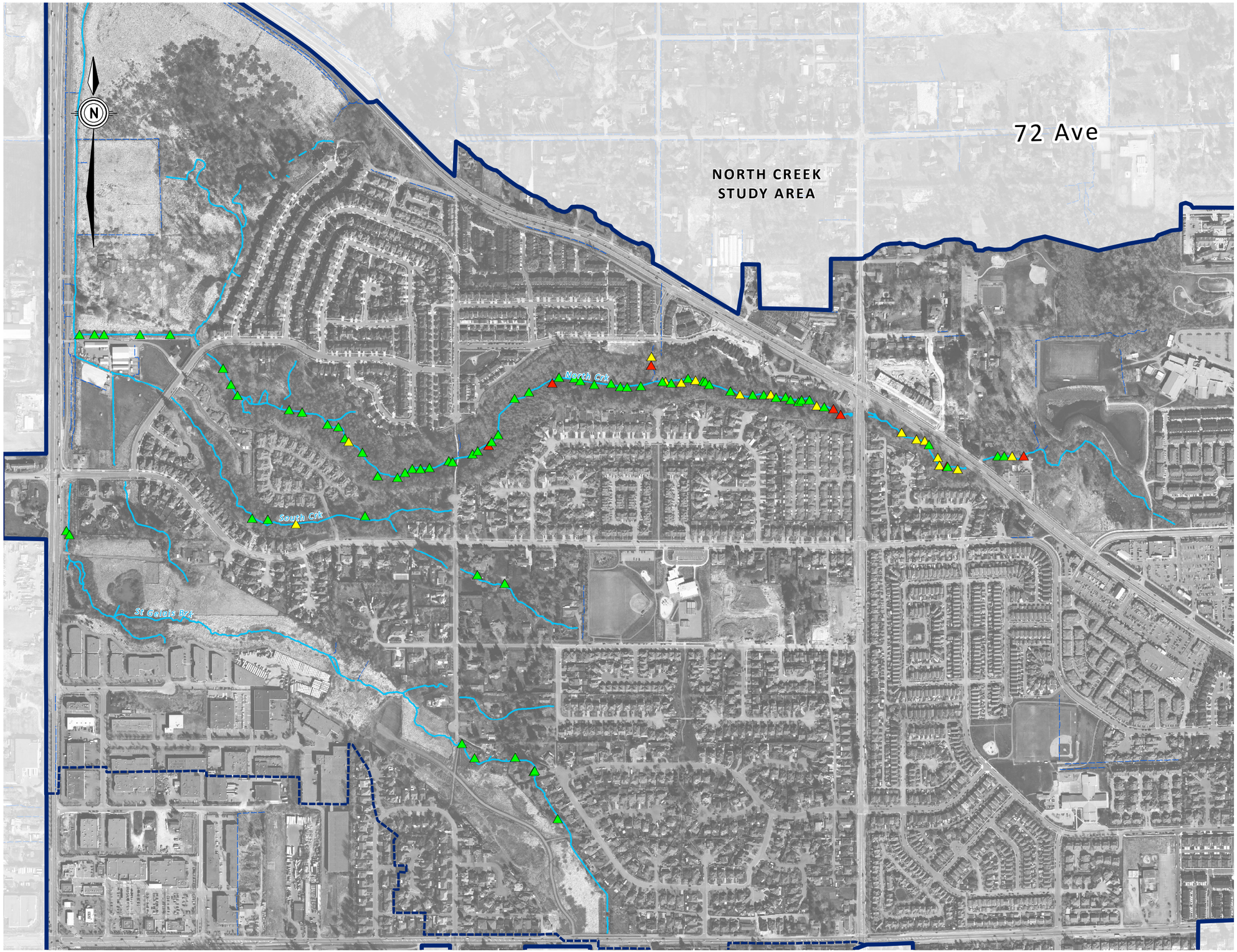

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Ditch

Erosion (Severity)

2015 Risk

- Low
- Medium
- High

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	May 2015

North Creek
Observed Erosion Sites

Figure 3-2

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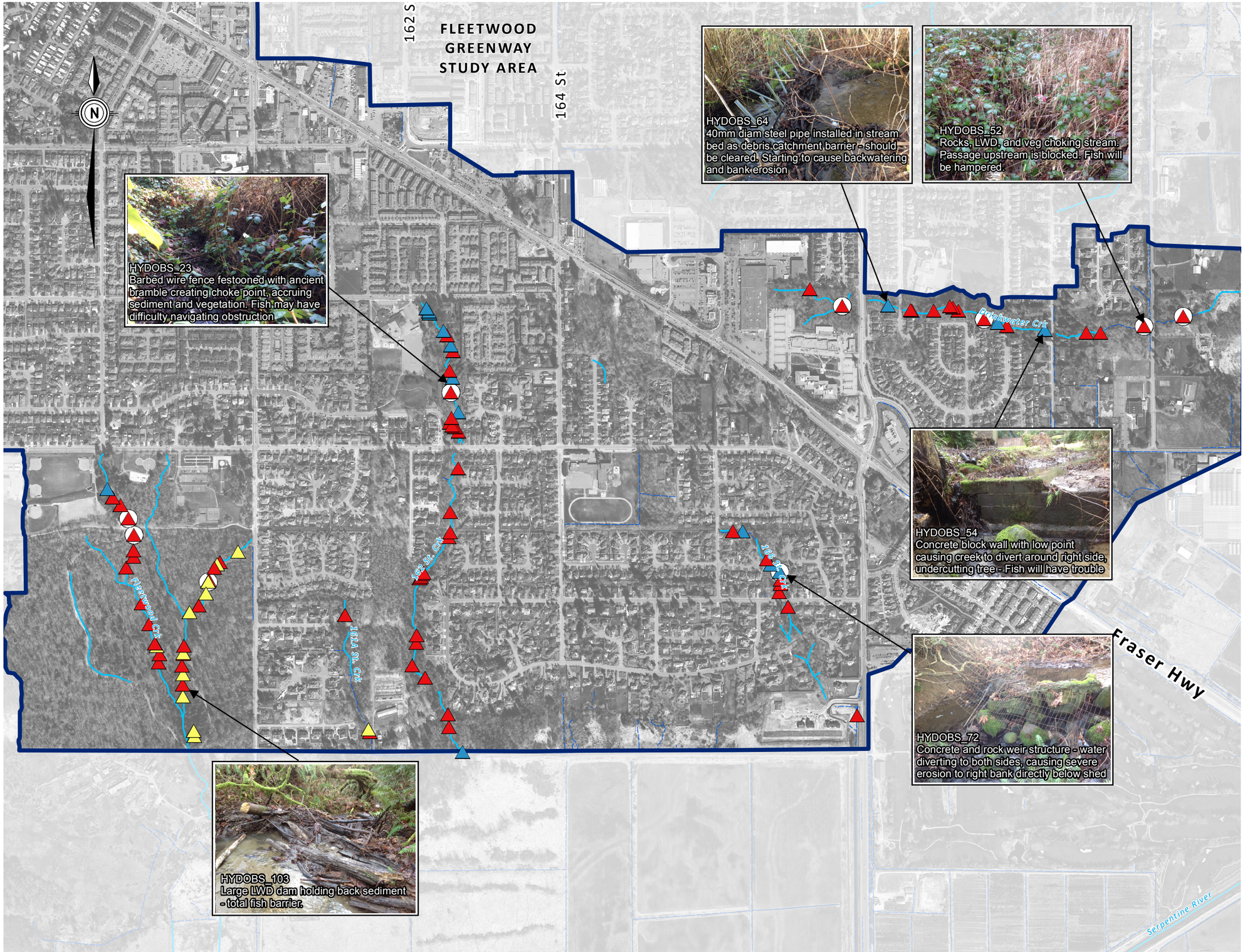
Author: SScott



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Watercourse
- Ditch
- Obstruction Sites Identified in 2011 Field Visit that Remained Stable in 2015 Field Visit

Obstructions

- ANTHROPOGENIC
- BOULDER
- LWD

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
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Fleetwood Greenway Obstruction Sites

Figure 3-3

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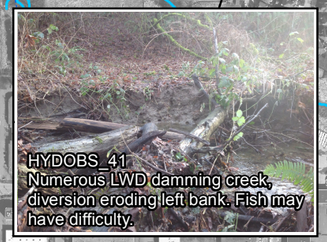
Author: BWhitehouse

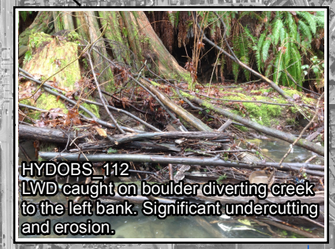
NORTH CREEK
STUDY AREA

North Crk

South Crk


HYDOBS_41
Numerous LWD damming creek, diversion eroding left bank. Fish may have difficulty.

HYDOBS_124
Steel box in creek, looks like garbage


HYDOBS_112
LWD caught on boulder diverting creek to the left bank. Significant undercutting and erosion.

180 St

184 St

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Ditch
- Obstruction Sites Identified in 2011 Field Visit that Remained Stable in 2015 Field Visit

Obstructions

- ANTHROPOGENIC
- BOULDER
- LWD

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

North Creek Obstruction Sites

Figure 3-4

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Author: BWhitehouse

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Watercourse
- Ditch
- Bridge

Stream Culverts

Condition

- Poor
- Fair
- Good

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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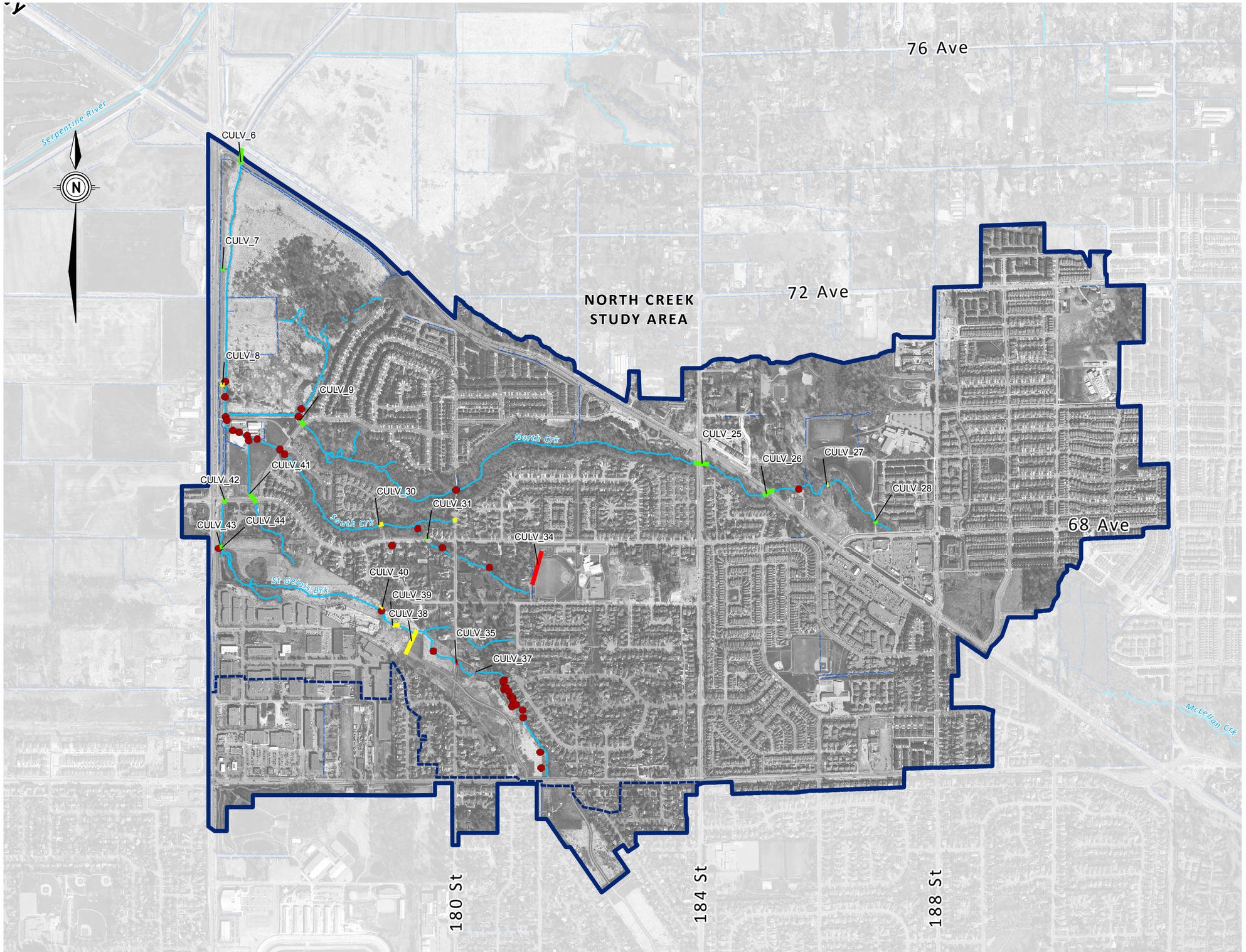
Project No.	Date
471-288	June 2016

Fleetwood Greenway Inspected Culverts and Bridges

Figure 3-5

Path: \\libra25.burnaby.kerrwoodleidal.org\0000-0999\0400-0499\471-288\430-GIS\MXD-Rpt\471288_Fig3-5_CulvBridges_Fleetwood.mxd Date Saved: 13/06/2016 1:56:52 PM
Author: BWhitehouse



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Ditch
- Bridge

Stream Culverts

Condition

- Poor
- Fair
- Good

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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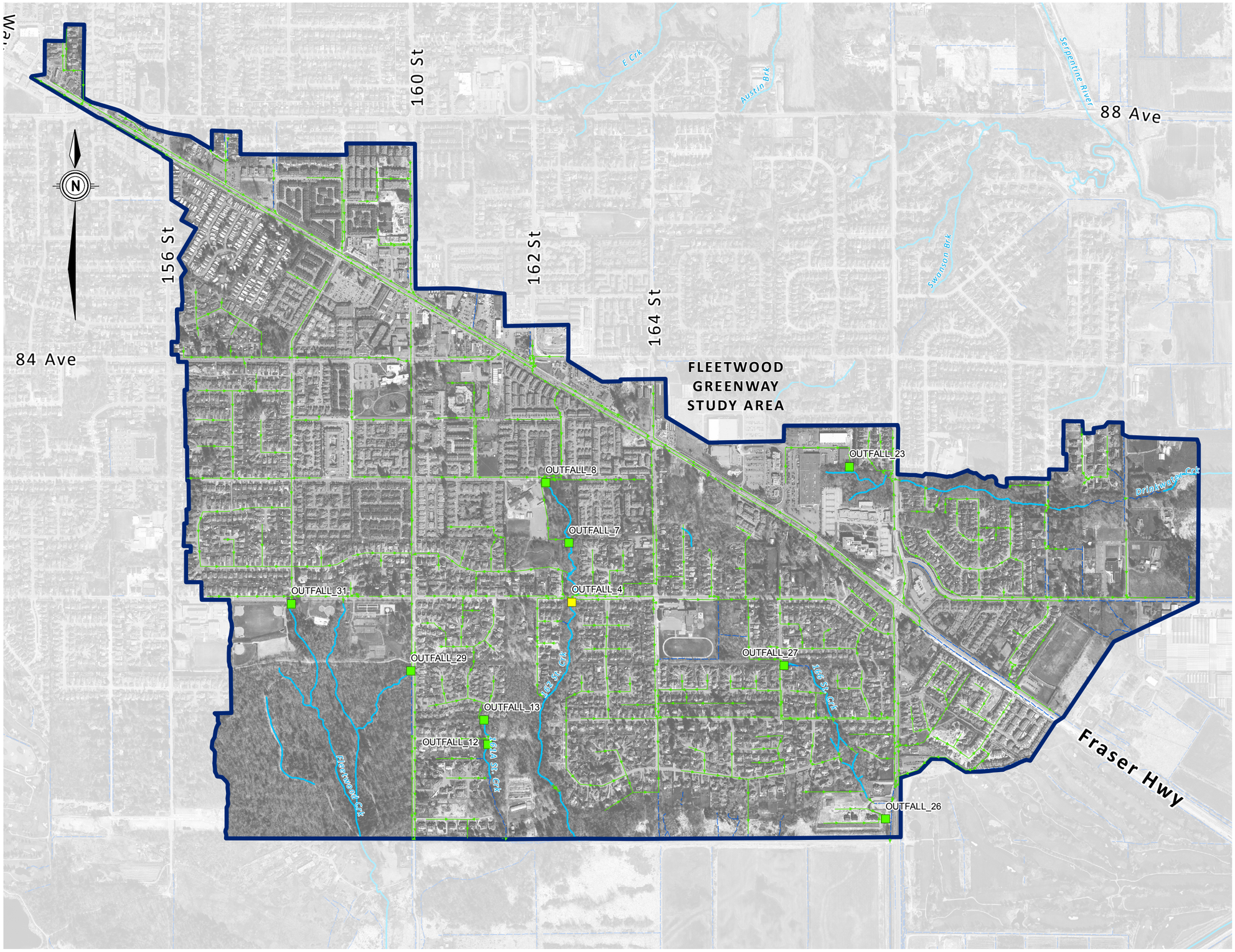
Project No.	Date
471-288	June 2016

North Creek Inspected Culverts and Bridges

Figure 3-6

Path: \\libra25.burnaby.kerrwoodleidal.org\0000-0999\0400-0499\471-288\430-GIS\MXD-Rpt\471288_Fig3-6_CulvBridges_NorthCrk.mxd Date Saved: 13/06/2016 2:30:44 PM
Author: BWhitehouse



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Watercourse
- Ditch
- Storm Main

Major Storm Outfalls (>600mm)

Condition

- Poor (None)
- Fair
- Good

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Fleetwood Greenway Inspected Storm Outfalls

Figure 3-7

Path: \\lbra25.burnaby.kerrwoodleidal.org\0000-0999\0400-0499\471-288\430-GIS\MXD-Rp\471288_Fig3-7_MajOutfalls_Fleetwood.mxd Date Saved: 13/06/2016 2:31:20 PM
Author: BWhitehouse

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

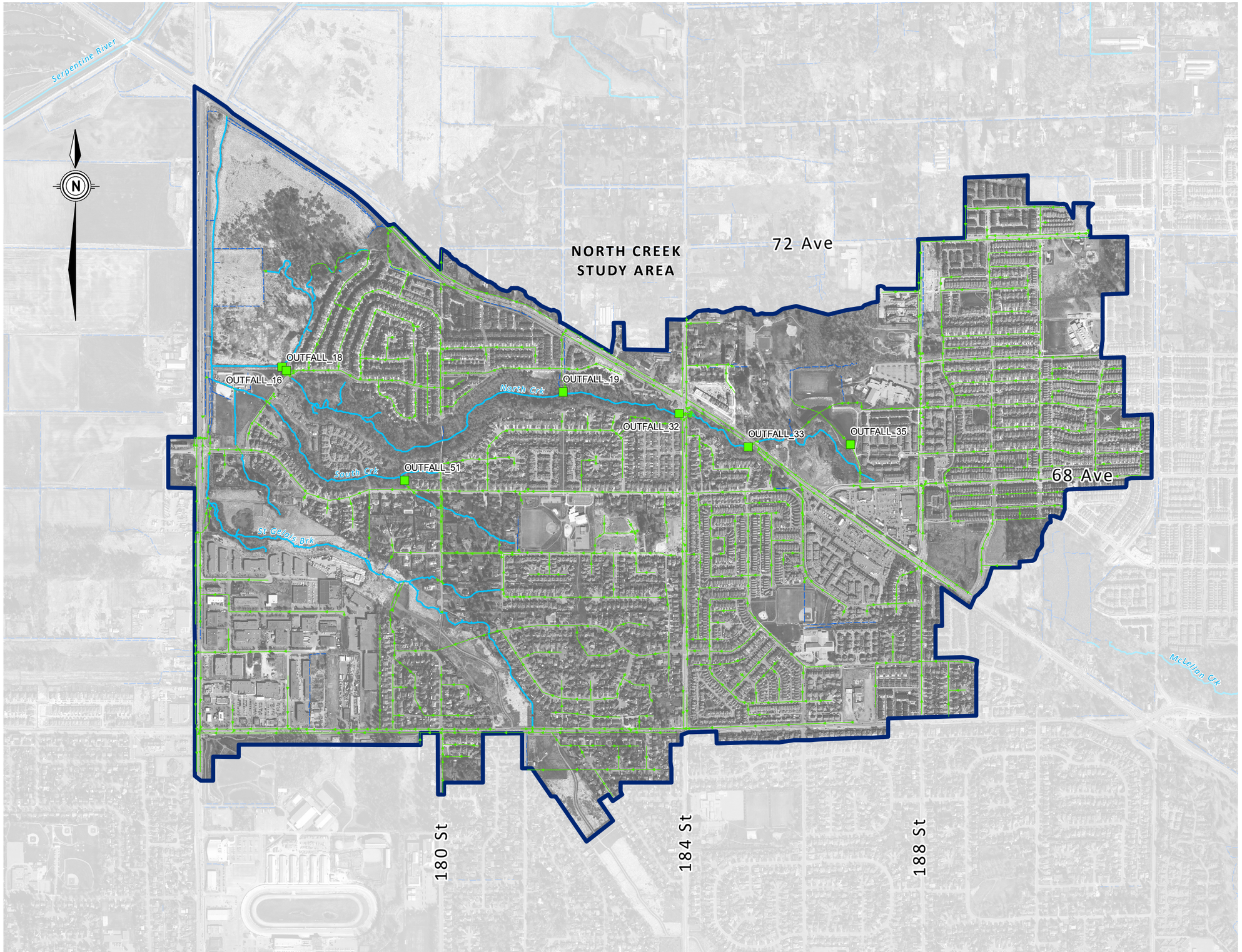
Legend

- Study Area
- Watercourse
- Ditch
- Storm Main

Major Storm Outfalls (>600mm)

Condition

- Poor (None)
- Fair (None)
- Good



Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

North Creek Inspected Storm Outfalls

Figure 3-8

Path: \\llbra25.burnaby.kerrwoodleidal.org\0000-0999\0400-0499\471-288\430-GIs\MXD-Rp\471288_Fig3-8_MajOutfalls_NorthCrk.mxd Date Saved: 13/06/2016 2:33:54 PM
Author: BWhitehouse

4. Environmental Inventory and Assessment

4.1 Key Findings

- Watershed health indicators in the Fleetwood Greenway and North Creek catchments were generally indicative of high levels of urbanization and development within the catchment areas. Innovative stormwater management techniques have mitigated some of the impacts of development to stream flows in North Creek.
- Water quality parameters: elevated conductivity levels and temperatures, and low levels of dissolved oxygen. Conductivity levels indicate likely impacts from non-point source pollution. Elevated temperatures and low dissolved oxygen levels are below optimum levels for rearing salmonids.
- Benthic invertebrate data, summarized using B-IBI (Benthic Index of Biotic Integrity), was used as indicator of stream and watershed health. Mean B-IBI in the 162 Street Creek was 14.0 in 2013. Mean B-IBI in North Creek was 19.7 in the spring of 2015. These values are consistent with high levels of urbanization in these catchments.
- A total of 17.3% (88.4 ha) of the Fleetwood catchment is forested. Overall forest cover in the North Creek catchment is low, covering only 10.1% (45.1 ha) of the catchment.
- Riparian forest integrity (RFI) in the Fleetwood catchment remains high at 75.5%. Four of the five creeks in the catchment have greater than 70% riparian forest cover. Fleetwood Creek has over 90% riparian forest cover, while 166 Street Creek is the most urbanized catchment with only 36.8% riparian forest cover remaining. RFI in the North Creek catchment is 40.6% overall, and ranged from 13.6% (St. Gelais Brook) to 52.8% (North Creek). Young deciduous forest (<80 years) is the dominant forest type.
- Coho salmon and cutthroat trout are present throughout both catchments, with a number of other native species present, including rainbow trout, threespine stickleback, brassy minnow and redside shiner.
- The amount of large woody debris (LWD) and deep pool habitat was generally below what would be found in natural streams. Stream enhancements increasing the complexity of stream habitat, as well as increasing riparian forest cover, could be beneficial to fish populations.
- Addressing fish passage concerns on lower 162 Street Creek could improve access to fish habitat upstream for coho salmon and cutthroat trout.

4.2 Water Quality

Maintaining adequate water and sediment quality in watersheds is important to protecting aquatic life and downstream water uses. Water quality is influenced by several factors: inputs from point and non-point pollutant sources, instream disturbances (anthropogenic or otherwise), or both, and by the conditions in the broader watershed such as levels of imperviousness. Water quality parameters include chemical, physical and biological measurements including water temperature, dissolved oxygen, specific conductivity, pH, turbidity as well as fecal coliforms and *E. coli*. For this study, two different assessments of water quality were conducted: a rapid in-situ assessment of physical water quality parameters at 31 sites and an analysis of long-term monitoring data in North Creek.

Rapid In-situ Water Quality Assessment

In-situ measurements of general water quality parameters (temperature, specific conductivity, dissolved oxygen, pH, oxygen reduction potential (ORP), and turbidity) were taken at 31 sites in early September 2015 during low flow conditions (Figure 4-1). Sites were assessed according to Metro Vancouver's Monitoring and Adaptive Management Framework (2012) using the categories "good", "satisfactory", and "needs attention". Table 4-1 summarizes the results for the Fleetwood and North Creek catchments. Key findings from the sampling include:

- Mean conductivity levels fell into the MAMF's "needs attention" category in both catchments. Four of six subcatchments were in the "needs attention" category, while two were in the "satisfactory" category. This indicates there is likely some impact from non-point source pollution in both catchments.
- Dissolved oxygen in both catchments was satisfactory, suggesting dissolved oxygen levels are approaching a level of concern. Both catchments had one site in the "needs attention" category.
- Temperatures in North Creek, especially in the headwater areas, exceed guidelines in the MAMF ("needs attention" category). Temperatures in the North Creek catchment overall are consistently approaching levels of concern ("satisfactory" category). Temperatures above 16 ºC are above optimum rearing temperatures for salmonids.
- Turbidity and pH consistently are in the MAMF's "good" category, with few exceptions. Only three of 31 sites indicated levels approaching concern ("satisfactory" category).

Table 4-1: In-situ Water Quality Sampling Results

Sites	Mean Dissolved Oxygen (mg/L)	Mean pH	Mean Water Temperature (ºC)	Mean Conductivity (mS/cm)	Mean Turbidity (NTU)
161A / 162 / 166 St. Creek (n=9)	8.35	7.54	15.08	0.206	1.0
Drinkwater Creek (n=3)	9.48	8.04	16.17	0.256	0.5
Fleetwood Creek (n=3)	7.37	7.59	17.46	0.157	0.2
Fleetwood Catchment (n=15)	**8.38**	**7.65**	**15.77**	**0.206**	**0.7**
North Creek (n=6)	9.73	7.99	18.24	0.222	5.2
North Creek Lowlands (n=7)	8.66	7.73	17.07	0.234	1.8
South Creek (n=3)	10.04	7.95	17.54	0.145	1.1
North Creek Catchment (n=16)	**9.32**	**7.87**	**17.60**	**0.213**	**2.9**

* No colour = Good, Yellow = Satisfactory, Red = Needs Attention

North Creek Long-term Water Quality Monitoring

The City of Surrey has been monitoring benthic invertebrate communities and physical water quality parameters in North Creek in east-central Surrey, BC since 1999 and 2002, respectively. The purpose of the monitoring was to assess the impacts on the creek from development of the East Clayton Neighbourhood. More specifically, the monitoring was intended to assess whether the variety of innovative stormwater management practices that were incorporated into development of the area have mitigated the impacts of that development on the health of the North Creek watershed. A recent analysis of the data resulted in the following key findings (KWL 2016):

- There was a non-significant increasing trend in water temperature from 2002 to 2009. The largest increases in temperature appear to have occurred from 2003 to 2005. Higher temperatures observed after 2005 may reflect the influence of the large stormwater detention pond in the catchment as well as the larger amount of runoff originating from hard surfaces and the lack of shading of these surfaces. Water temperature has exceeded 17 °C for over 40 cumulative days each year since 2003 (except 2013).
- Specific conductivity increased from 2002 to 2009, and has remained at elevated levels since development has occurred in the upper watershed. Recent observed specific conductivity values are typical of highly urbanized catchments and suggest higher levels of dissolved contaminants are entering the creek in runoff.
- pH was outside of the recommended window of 6.5 to 9.0 only for brief periods in 2003 (below pH 6.5), 2005, 2011, and 2012 (above pH 9.0). The pH values below 6.5 in 2003 may be associated with the amount of exposed soil in the catchment during the initial clearing phase of development. The high pH values above 9.0 in 2005, 2011, and 2012 are likely attributable to spills of concrete or concrete wash water from construction sites.
- Turbidity decreased from 2002 to 2009 and has remained relatively low. Annual average turbidity was noticeably higher in 2003 and 2004 and these years also recorded the highest number of larger severity (moderate severity-of-ill-effects category) turbidity events. It is unclear if declines in turbidity in the latter part of the development period reflect the success of the City's Erosion and Sediment Control bylaw, the innovative stormwater management practices used in East Clayton or a combination of both.

4.3 Benthic Invertebrates

Benthic invertebrates are a commonly-used indicator of stream health and can be used to track changes in watershed health. Changes in both the species richness and composition of invertebrate communities indicate changes in watershed conditions. B-IBI (Benthic Index of Biotic Integrity) is a 10-metric index characterizing the composition of the benthic invertebrate community (Karr, 1998). B-IBI scores can range from 10 and 50, with 10 being a degraded watershed and 50 being in excellent condition. Undeveloped watersheds in Metro Vancouver have scored up to a maximum of 40, which is considered good condition.

Three benthic invertebrate monitoring sites are located within the study area. One site is located on 162 Street Creek and has been monitored since 2012. Monitoring at two sites on North Creek has been conducted since 1999. Figure 4-1 shows the location of benthic sampling and summarizes key values. Refer to Table C-1, C-2, and C-3 in Appendix C for a full list of B-IBI values.

Mean B-IBI scores and total taxa richness for the sampling site located on 162 Street Creek in the Fleetwood catchment were 14 and 10 for 2012 and 2013, respectively (Table C-1). These scores are typical of high levels of urbanization and development in these catchments.

A complete analysis of the North Creek benthic invertebrate monitoring data is detailed in the report described in the previous section (KWL, 2016). Key findings include:

- Mean B-IBI values at Station N1 increased significantly from 1999 to 2015 (Figure 4-1). In contrast, mean B-IBI value at North Creek Station N2 has declined slightly since 1999 although the change is not statistically significant (Figure 4-1).
- At both stations, taxa richness was lower before 2001, peaked between 2002 and 2004, and then declined (Figure 4-1). This peak in taxa richness was statistically significant at Station N1, but not at Station N2. Observed patterns were likely due to the rapid establishment of new tolerant taxa concurrent with a somewhat slower loss of sensitive taxa, which is typical in urbanizing streams.
- Changes to mean B-IBI values at both stations were driven by changes to only some of the ten component metrics. The percent of tolerant organisms has increased since 2004. The increase in predator organisms was primarily caused by the increase in abundance of Turbellaria flatworms which thrive in fine sediments common in urban streams. Although it is not the general pattern observed in urbanizing streams, percent dominance has declined in North Creek during the study period.
- The two most abundant taxa, Oligochaete worms and Chironomid larva, have declined since 1999. Turbellaria flatworms, Caecitodea isopods, and Ceratopogonidae (biting midges) established or increased substantially in abundance from 2006 to 2013, and then recently declined.

4.4 Watershed and Riparian Forest Cover

Watershed and riparian forest cover are indicators of stream and watershed health and relate to the effect of changing land use can have on hydrology, water quality, and other components of stream ecosystems.

Watershed forest cover is strongly tied to the ability of a landscape to support biodiversity. There is evidence that protecting between 30-50% forest cover and at least one, and preferably several, large patches (>200 ha) is necessary to maintain even marginal levels of biodiversity and aquatic ecosystem health. Protection of 50% of watershed forest cover is recommended.

Riparian forest integrity (RFI) is the amount of intact riparian forest corridor along a stream, expressed as a percentage of area within a 30 m setback on both sides of a watercourse over its entire length. Riparian (streamside) vegetation provides a source of large organic debris for fish habitat, stabilizes streambanks to reduce erosion, shades the channel to moderate water temperatures, and introduces food for aquatic life. Maintaining a 70-75% RFI is a recommended guideline for urban watersheds.

Key findings for the Fleetwood catchment (Figure 4-2; Table 4-2):

- A total of 17.3% (88.4 ha) of the Fleetwood catchment is forested. The largest patch of forest, 38 ha or 43% of total forest cover in the catchment, is found in Fleetwood Urban Park.
- Riparian forest cover in the watershed remains high at 75.5%, in line with the recommended guidelines. Four of the five creeks in the catchment have greater than 70% riparian forest cover (Photo 4-1)

Key findings for the North Creek catchment (Figure 4-2; Table 4-2):

- The North Creek catchment is highly urbanized and developed, with low levels of watershed and riparian forest.
- Overall forest cover in the North Creek catchment is low, covering only 10.1% (45.1 ha) of the catchment. Forest cover is generally concentrated around North Creek.
- Only 40.6% of riparian areas remain forested (Photo 4-2). Riparian forest cover along St. Gelais Brook is particularly lacking.

Table 4-2: Watershed Health Indicators – Watershed and Riparian Forest Cover

Catchment	Total Area (ha)	Forested Area (ha)	% of Area Forested	Total Riparian Area (ha)	Total Riparian Forest (ha)	Riparian Forest Integrity (%)
Fleetwood	512.0	88.4	17.3	37.8	28.5	75.5
North Creek	445.6	45.1	10.1	55.4	22.5	40.6
Extra Catchment	41.2	1.5	3.7	-	-	-

Photo 4-1: Example of More Healthy and Diverse Riparian Forests on Fleetwood Creek

Photo 4-2: Example of Encroachment from Residential Development and Impacts of Invasive Species on Riparian Areas on North Creek

4.5 Fish and Aquatic Habitat

Fish and aquatic habitat in the catchments were assessed through a combination of existing information and field investigations. As part of this assessment, all major creeks and tributaries in the catchments were walked and important habitat features mapped and characterized, including channel characteristics, large wood, deep pools, and fish passage concerns.

Fish Community

The Fleetwood and North Creek catchments contains three salmonid species: cutthroat trout (*Oncorhynchus clarki clarki*), coho salmon (*Oncorhynchus kisutch)*, and rainbow trout (*Oncorhynchus mykiss*) (Table 4-3). Other native species include threespine stickleback *(Gasterosteus aculeatus),* the brassy minnow (*Hybognathus hankinsoni*), and redside shiner (*Richardsonius balteatus*). Bass/sunfish (*Lepomis gibbosus*), an aggressive invasive species, are present in lowland ditches of the North Creek catchment as well. Several spawned out coho salmon were observed in the lower reaches of North Creek, upstream of 177 St, during field visits in December 2014.

Table 4-3 summarizes the fish species present in the Fleetwood and North Creek catchments.

Table 4-3: Fish Species Present or Likely Present in Catchment Areas.

Fish Species	Fish Presence							
	Fleet-wood Creek	Lower 161A Avenue Creek	162 Street Creek	166 Street Creek	Drink water Creek	North Creek	South Creek	Lower St. Gelais Brook
Coho salmon		X,Y	Z			i	i	i
Cutthroat trout	W	X,Y	Z	Z	V	i	i	i
Rainbow trout		X				i	i	
Threespine stickleback		X,Y		Z		i	i	i
Redside shiner						i		i
Lamprey sp.			i					
Brassy minnow		Y						
Bass/sunfish								i

X -Data from Scientific Fish Collection Permit VISU04-1301 Sampling of Numerous Streams in the Lower Mainland
Y - Fish Collection Permit SU06-21421 Serpentine River, Cougar Creek, East Hoy Creek, Eugene Creek, Morgan Creek, Archibald Creek, Hunt Brook, Bolivar Creek, Fleetwood Creek, Southward Creek, Dingwall Creek, Scott Creek, Robson Creek, and trib. to Little Campbell River
Z – Envirowest 1994b.
W- Envirowest 1994a.
V - Envirowest 1994c
i – iMapBC

Instream Fish Habitat

Instream habitat characteristics were assessed during field visits in December 2014 (Figures 4-3 and 4-4). Bankfull width, wetted width, % boulder, % cobble, % large gravel, % small gravel and % fines, the degree of embeddedness of the substrate were all recorded.

Large woody debris (LWD) and deep pool habitat were also mapped and quantified during the field visits. LWD consisted of pieces of wood larger than 10cm in diameter and 2 meters in length. Deep pools consisted of pools greater than 40 cm depth. LWD and deep pools provide and facilitate the development of habitat complexity in streams, and increase the habitat value for fish by providing important cover from predators, particularly for juvenile salmonids. LWD is often measured as an indicator of stream health and condition, and low quantities of LWD are indicative of urbanized watersheds and streams with little mature forest remaining in riparian areas.

Key findings:

- The highest quality fish habitat was located in North Creek, particularly in the middle reaches upstream of 77 Avenue (Photo 4-3).
- Creeks generally have high proportions of large and small gravel, with lower levels of cobble and fines. The lower reaches of North Creek catchment streams exhibited high levels of sedimentation, indicated by significant proportions of fines in the substrate and high level of embeddedness of substrates.
- Low quantities of large woody debris (LWD) were mapped, typical of urbanized streams. The number of pieces of LWD per 100 m of channel ranged from 0 to 7.5 (except 14.4 in South Creek), whereas natural streams typically have between 10 and 20, indicating higher levels of development and younger forests.
- Deep pools (>40 cm deep) were located predominantly in the lower reaches of Fleetwood Creek and 162 Street Creek, and the middle reaches of North Creek. Pools typically were associated with LWD and boulders in the stream, as well anthropogenic features such as culverts or weirs.

Fish Access/Passage Concerns

Fish access and passage concerns were also assessed during field visits in December 2014 (Figures 4-3 and 4-4). Barriers to fish passage were identified in all creeks within the Fleetwood catchment area except 166 Street Creek. No significant barriers were identified in the North Creek catchment area, though a number of partial and seasonal barriers were mapped.

Key findings:

- The most significant barrier is in lower 162 Street Creek, where a partial barrier to passage exists in the lower reach of the stream, restricting fish access to red-coded (Class A) habitat (Photo 4-4).
- Complete barriers exist in the upper reaches of Fleetwood and Drinkwater Creeks, but do not block access to large amounts of fish habitat.
- No complete barriers to fish passage were identified in the North Creek catchment.

Photo 4-3: Gravel Spawning Reach in North Creek

Photo 4-4: Obstruction on Lower 162 Street Creek

4.6 Terrestrial Habitat, Wildlife and Species at Risk

Terrestrial Habitat

The Fleetwood and North Creek catchments are predominantly urban with high levels of residential development. Both catchments border agricultural lands of the Serpentine-Nicomekl lowlands, a primarily agricultural area within the City. Agricultural areas generally support a more diverse assemblage of mammal, amphibian, and bird species than urban areas.

Key Findings:

- The Fleetwood catchment contains 139 ha of natural areas. Young deciduous forest is the dominant habitat type (44% of natural areas), followed by young mixed forest (18%), agricultural herb and grass habitat (7%) and unmanaged shrub habitat (6%) (City of Surrey 2014). A small patch of mature forest (>80 years) exists in the southern portion of Fleetwood Park.
- The Fleetwood catchment is located in the Fleetwood Management Area identified in the Biodiversity Conservation Strategy. Fleetwood Park has been identified as a high-value hub in the Green Infrastructure Network, with local corridors connecting to Surrey Lake (high value corridor) and along the ALR lands along the 76 Avenue alignment on the southern border of the study area (moderate value corridor) (Figure 4-5).
- The North Creek catchment contains approximately 150 ha of natural areas. Agricultural herb and grass habitat is the dominant habitat type in the North Creek catchment, comprising 31% of the natural areas. Four other habitat types make up the majority of the remaining natural area: unmanaged shrub, young deciduous forest, young mixed forest, and turf grass (City of Surrey 2014).
- The North Creek catchment is predominantly located within the urban Cloverdale Management Area, with a small area within the agricultural Serpentine Nicomekl Management Area. A number of local corridors have been identified as part of the Green Infrastructure Network. These follow riparian corridors within the catchment providing linkages to hubs to the south and northwest of North Creek, as well as connecting to the ALR lands along the Serpentine River (Figure 4-5).

Wildlife

Common wildlife in the Fleetwood and North Creek catchments are generally species which are tolerant of human impacts on the landscape, or have been able to adapt to the presence of humans. Species representative of urban environments are summarized in Table 4-4.

Table 4-4: Representative Species of Urban Environments in Surrey (from City 2014)

Mammals	Amphibians/Reptile	Birds	
Common Shrew	Common Garter Snake	American Robin	Northwestern Crow
Creeping Vole	Long-toed Salamander	Black-capped Chickadee	Song Sparrow
Mouse/Shrew/Vole sp.	Pacific Tree Frog	Bushtit	Spotted Towhee
Raccoon		Canada Goose	Mallard
Shrew Mole		Dark-eyed Junco	
Vagrant Shrew		Downy Woodpecker	
Virginia Opossum		House Finch	

Species at Risk

The Fleetwood and North Creek catchments contain a number of confirmed or potential species at risk that should be taken into consideration in land use planning. Species are listed in Table 4-5. For more details on species, see Appendix C.

Table 4-5: Confirmed and Potential Species at Risk

Taxa	Species
Birds	Great Blue Heron
Mammals	Pacific Water Shrew
Amphibians	Northern Red-legged Frog
Plants	Vancouver Island Beggarticks Chaffweed
Fish	Coastal Cutthroat Trout, Brassy Minnow

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

FLEETWOOD GREENWAY STUDY AREA

NORTH CREEK STUDY AREA

WA1	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
2012	14.0	10	-	-
2013	14.0	10	-	-

N1	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
1999	14.0	12	14.0	8
2000	14.0	16	-	-
2001	14.0	17	17.3	24
2002	16.0	24	15.3	19
2003	16.7	21	18.0	20
2004	19.3	21	18.0	26
2005	17.3	27	14.7	22
2006	16.0	24	14.0	16
2007	14.7	19	18.7	17
2008	16.0	22	18.7	17
2009	17.3	17	19.3	16
2010	20.7	17	18.0	16
2011	16.7	18	18.7	12
2012	15.3	16	18.0	11
2013	17.3	13	18.7	8
2014	17.3	14	17.3	13
2015	22.7	23	-	-

N2	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
1999	15.3	26	15.3	13
2000	14.0	13	NS	NS
2001	14.7	19	NS	NS
2002	15.3	27	18.7	32
2003	19.3	33	18.7	20
2004	18.7	30	16.7	24
2005	15.3	21	18.0	26
2006	14.0	17	17.3	24
2007	14.0	18	16.7	32
2008	14.7	22	14.0	19
2009	14.7	23	15.3	25
2010	15.3	28	16.7	15
2011	14.0	12	20.0	23
2012	14.0	17	16.7	22
2013	14.7	20	17.3	16
2014	14.0	18	17.3	20
2015	16.7	21	-	-

Legend

- Study Area
- Extra Catchment
- Watercourse
- Culvert
- Continuous Water Quality Monitoring Station
- Flow Monitoring Station
- Benthic Invertebrate Sites (with Site Code)

In-situ Water Quality Monitoring Sites

Subcatchment

- 161A/162/166 Street Creek
- Drinkwater Creek
- Fleetwood Creek
- North Creek
- North Creek Lowlands
- South Creek
- Dry Sites

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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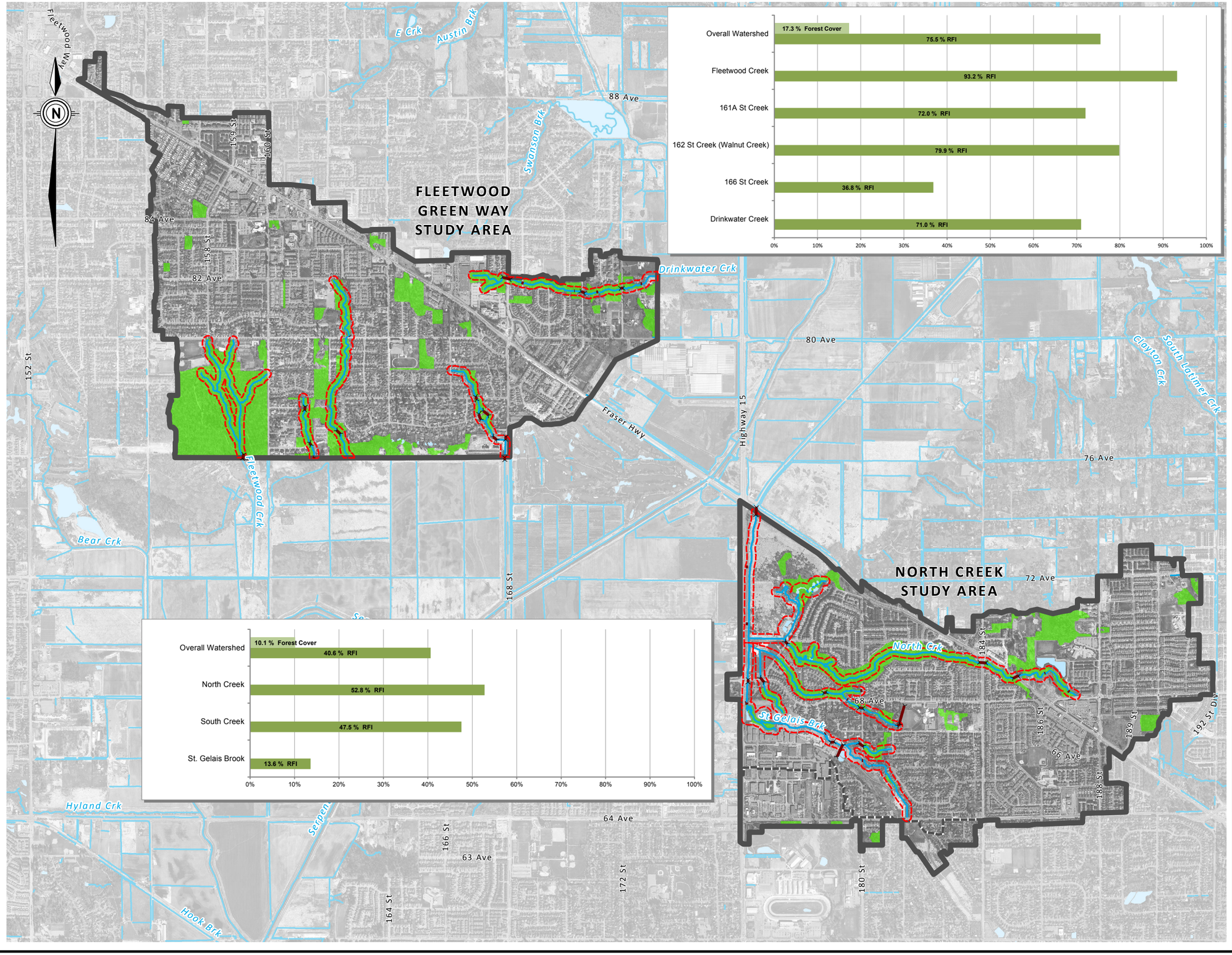
Project No.	Date
471-288	April 2016

Environmental Sampling Sites

Figure 4-1

Path: O:\0400-0499\471-288\430-GisMXD-Rp\471288_Fig4-1_EnvironmentalSampling_V2.mxd Date Saved: 29/03/2016 2:30:53 PM
Author: PdeKoning



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Culvert
- 30m Riparian Buffer
- Watershed Forest Cover

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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Project No.	Date
471-288	May 2015

Riparian and Watershed Forest Cover

Figure 4-2

Path: O:\0400-0499\471-288\430-GIS\MXD-Rp\471288_Fig4-2_Riparian.mxd Date Saved: 14/05/2015 3:52:30 PM
Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Watercourse Classification

Class A (RED):	*Inhabited by salmonids year round or potentially inhabited year round.*
Class A(O) (RED dashed):	*Inhabited by salmonids primarily during the over-wintering period or potentially inhabited during the over-wintering period with access enhancement.*
Class B (YELLOW):	*Significant food/nutrient value. No fish present.*
Unknown	

FLEETWOOD GREENWAY STUDY AREA

88 Ave
84 Ave
82 Ave
80 Ave
156 St
158 St
159 St
160 St
162 St
164 St
168 St
Venture Way
Fraser Hwy
E Crk
Austin Brk
Swanson Brk
Drinkwater Crk
Fleetwood Crk
164A St Crk
166 St Crk

Legend

- Study Area
- Extra Catchment
- Culvert
- Large Wood Debris
- Deep Pools
- Fish Observation

Fish Passage Barrier

- Full
- Partial
- Seasonal

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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Project No.	Date
471-288	May 2015

Fleetwood Greenway Fish and Aquatic Habitat Inventory

Figure 4-3

Path: O:\0400-0499\471-288\430-GIs\MXD-Rp\471288_Fig4-3_FishAquaticHabitat_Fleetwood.mxd Date Saved: 14/05/2015 3:44:40 PM
Author: SScott

Watercourse Classification

Class A (RED):	*Inhabited by salmonids year round or potentially inhabited year round.*
Class A(O) (RED dashed):	*Inhabited by salmonids primarily during the over-wintering period or potentially inhabited during the over-wintering period with access enhancement.*
Class B (YELLOW):	*Significant food/nutrient value. No fish present.*
Unknown	

NORTH CREEK STUDY AREA

Serpentine River
Fraser Hwy
72 Ave
192 St
Highway 15
68A Ave
North Crk
South Crk
184 St
68 Ave
St George's Brk
186 St
188 St
189 St
192 St Div
66 Ave
McLellan Crk
64 Ave
180 St

City of Surrey
Fleetwood Greenway North Creek Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Culvert
- Large Wood Debris
- Deep Pools
- Fish Observation

Fish Passage Barrier

- Full
- Partial
- Seasonal

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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Project No.	Date
471-288	May 2015

North Creek Fish and Aquatic Habitat Inventory

Figure 4-4

Path: O:\0400-0499\471-288\430-Gis\MXD-Rpt\471288_Fig4-4_FishAquaticHabitat_NorthCrk.mxd Date Saved: 14/05/2015 3:46:46 PM
Author: SScott

Figure 4-5: Excerpt of Green Infrastructure Network Map for Study Area from Biodiversity Conservation Strategy (from City of Surrey 2014)

5. Modelling and Engineering Assessments

5.1 Introduction

This section outlines the development of the hydrologic and hydraulic model and drainage system capacity assessments. The model was built using the City's GIS database to assess the existing drainage system under different design event conditions. The results of the analyses are presented in the following subsections.

5.2 Hydrologic and Hydraulic Modelling

Hydrologic and hydraulic modelling using the PC-SWMM software was undertaken for the entire Fleetwood Greenway and North Creek catchments and drainage systems. An extra catchment southwest of and adjacent to the North Creek catchment was also included in the study area at the request of the City, as it had not been included in any of the drainage models previously developed. See Figure 1-1 for an overview of the study area.

The model includes 5,441 urban catchments, 1,983 road catchments, 115 km of storm sewers, 2,286 conduits, 2,288 manholes, 8 detention facilities, and all the creek channels within the study area (Fleetwood Creek, 161A St. Creek, 162 St. Creek, 166 St. Creek, Drinkwater Creek, North Creek, South Creek, St. Gelais Brook). See Figures 2-5 and 2-6 for the modelled network.

Models were created for both existing and future (unmitigated) land use conditions. The existing conditions model was calibrated and validated using flow monitoring data collected at North Creek at Fraser Highway. The flow monitoring station has been in operation and continuously recording data since 1996. Recorded storm events at two nearby rain gauges (71A Avenue at 190 Street, 68 Avenue at 176 Street) from 2012 to 2014 were used to calibrate the model. Detailed information on the building of the model and results of calibration can be found in Appendix D.

The impervious coverage for the existing and future land use scenarios are shown in Table 5-1. Effective Impervious Area (EIA) is the impervious cover in the watershed that effectively contributed runoff directly to the storm drainage system as determined during calibration of the existing conditions model. EIA for the future unmitigated conditions scenario must be based on engineering judgement of the predicted increase in total impervious area (TIA) combined with the expected level of hydrologic disconnection in the future conditions scenario.

Overall, TIA is expected to increase an average of 6.5%, while EIA is expected to increase by 8.8%. The largest increase in TIA from existing to future unmitigated conditions is in the extra catchment southwest of and adjacent to the North Creek catchment; however, the largest increase in expected EIA is in North Creek (26% increase). The increase in EIA in North Creek is primarily due to the zoning conversion of some hydrologically disconnected single family lots, to multi-family or commercial lots.

Table 5-1: Existing and Future Land Use Impervious Coverage

Scenario	Study Area	Total Impervious Area (TIA)	Effective Impervious Area (EIA)
Existing Conditions	Total	56%	46%
	Fleetwood Catchment	56%	49%
	North Creek Catchment	53%	28%
	Extra Catchment	66%	52%
Future Unmitigated Conditions	Total	63%	55%
	Fleetwood Catchment	62%	55%
	North Creek Catchment	62%	54%
	Extra Catchment	77%	69%

5.3 Hydrotechnical Assessment

This subsection outlines the assessment of the drainage system under different design storm events for the existing and future land use conditions. The unmitigated future conditions were modelled and assessed to provide an indication of the worst case scenario under expected future development; however, the application of best management practices (BMPs) including volume reduction source controls, explained later in Section 7, are expected to reduce the effective impervious area of the watersheds under future land use to pre-development (existing) conditions. The pipe capacity assessment and recommended upgrades, therefore, are based on an assessment of the drainage system under "future mitigated" conditions.

Peak Flow Estimates

The peak flow estimates for all major creeks in the study area are summarized in the following table for existing and future unmitigated land use conditions. Peak flows in 162 Street Creek and North Creek are not expected to increase dramatically with future development (<20%), while peak flows in Fleetwood Creek, 161A St. Creek, 166 St. Creek, and Drinkwater Creek are expected to increase by roughly 30 to 90%.

Table 5-2: Peak Flow Estimates

Location	5-yr Peak Instantaneous Flow Estimate (m^3/s)		100-yr Peak Instantaneous Flow Estimate (m^3/s)		Expected Increase in Peak Flows (%)	
	Existing Land Use	Unmitigated Future Development	Existing Land Use	Unmitigated Future Development	5-yr	100-yr
Fleetwood Creek	3.0	5.0	6.1	10.6	67%	74%
161A Street Creek	0.7	1.2	1.5	2.3	71%	53%
162 Street Creek	2.0	2.1	3.9	3.45	5%	-12%
166 Street Creek	2.3	4.3	5.2	8.4	87%	62%
Drinkwater Creek	0.8	1.3	1.7	2.2	63%	29%
North Creek*	6.4	7.6	12.6	13.4	19%	6%
*Downstream of confluence with South Creek and St. Gelais Brook						

Note that the magnitude of increase in peak flows is greater than expected for the predicted land use changes. This is partly due to the difference in rainfall depths between the older IDFs (*Surrey Design Criteria Manual,* 2004) used for the existing land use assessment, and the updated IDFs (*Surrey Design Criteria Manual*, 2016) used for the future land use assessment. The rainfall depths have increased by 4% to 8% for the 5-year return period, and by -1 to 12% for the 100-year return period. The newer IDFs were used for the future conditions modelling (both mitigated and unmitigated) in order to provide future flows and associated pipe sizing consistent with the City's revised Design Criteria Manual once the study is completed.

5.4 Pipe Capacity Assessment

The entire drainage system was assessed under the 5-year and 100-year return period design storm events to flag pipes with capacity issues and provide a basis for prioritization of upgrades. Additional details are found in Appendix E.

Minor Drainage System

The drainage system was assessed to determine its ability to convey the minor design storm event (5-year return period). The assessments did not include a review of storm sewer condition or age. The following three criteria were used to determine whether each pipe is undersized:

- Modelled instantaneous peak flow is larger than pipe capacity under free-flowing conditions;
- Pipe surcharged for longer than 15 minutes; and
- Water surcharged higher than 0.3 m above the crown of the pipe.

Incorporating an allowance for surcharging eliminates flagging pipes for upgrade simply because of minor surcharging that may happen during the design storm, but that likely will not cause drainage issues.

The storm sewers that exceed the criteria under existing land use conditions are shown schematically on Figures 5-1 and 5-2. Pipes that have sufficient capacity for existing flows but will need to be upgraded to meet the capacity requirements of the mitigated future 5-year flows are shown on Figures 5-3 and 5-4. Proposed upgrades have been sized for the future mitigated flow for each pipe that failed the criteria (see Section 7 or Appendix H for existing and proposed pipe sizes).

Pipes requiring a one standard pipe size upgrade and pipes at the top end of the system may not need to be upgraded immediately. They can operate under a surcharged condition and as they deteriorate near the end of their design life, they should be replaced with the recommended sizes.

Major Drainage System

The culverts were assessed on their ability to pass the required 100-year peak flow without flooding the land upstream. No culverts were found to exceed the criteria for existing conditions; however, one culvert (Pipe ID 1001195671) floods the land upstream under mitigated future land use conditions. Figures 5-5 and 5-6 show the results from the 100-year mitigated future land use modelling. Refer to Appendix H for prioritized upgrades.

Climate Change Impacts

It is generally accepted that climate change will increase the intensity of storms of all return periods, particularly for shorter duration events. As the actual increases can only be projected, generic percentage increases of 10%, 20%, and 30% were applied to the 5-year and 100-year IDF curve rainfall volumes. The climate change scenarios were modelled with future unmitigated land use and assessed using the same criteria as above. The results are a useful indication of the potential magnitude increase in pipes requiring upgrade under climate change conditions, though they were not incorporated into the capital plan. The results of the climate change scenarios are compared to the existing land use and future land use scenarios in Table 5-5 below. The climate change scenarios are for information only at this time; they have not been used in sizing for future pipe upgrades as the City has not yet determined a comprehensive approach to account for and address climate change impacts on stormwater infrastructure.

Table 5-3: Count of Minor and Major Conduits Failing Criteria Under Climate Change Conditions

	Existing Land Use	Mitigated Future Land Use	Unmitigated Future Land Use	Unmitigated Future Land Use with Climate Change		
				10%	20%	30%
Minor System - Surcharged	33	52	113	124	215	282
Minor System - Flooding	10	10	21	58	82	108
Major System - Flooding	0	1	1	1	1	1

Note: The existing land use conditions were modelled with the IDF curves in the 2004 Surrey Design Criteria Manual, while the future land use conditions were modelled with the updated IDF curves in the 2016 Surrey Design Criteria Manual; peak flows under mitigated future land use are larger for this reason.

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Culvert
- Storm Main
- Ditch
- Surcharged > 0.3 m for > 15 min
- Flooded above ground

FLEETWOOD GREENWAY STUDY AREA

88 Ave
84 Ave
82 Ave
80 Ave
156 St
158 St
159 St
160 St
162 St
164 St
168 St
Fraser Hwy
Venture Way
E Crk
Austin Brk
Serpentine River
Swenson Brk
Drinkwater Crk
162A St Crk
166 St Crk
161A St Crk
Fleetwood Crk

1000751128
1000750678
1000750698
1000750701
1000750702
1000751065
1000751067
1000751069
1000816847
1000816859
1000816861
1000816864
1000742079
1000741909
1000852018
1000736800
1000736935
1000736938
1000736745
1000765868
1000736746
1000761399
1000736747
1000736940
1000736946

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

5-Year Minor System Existing Land Use Model Results Fleetwood Study Area

Figure 5-1

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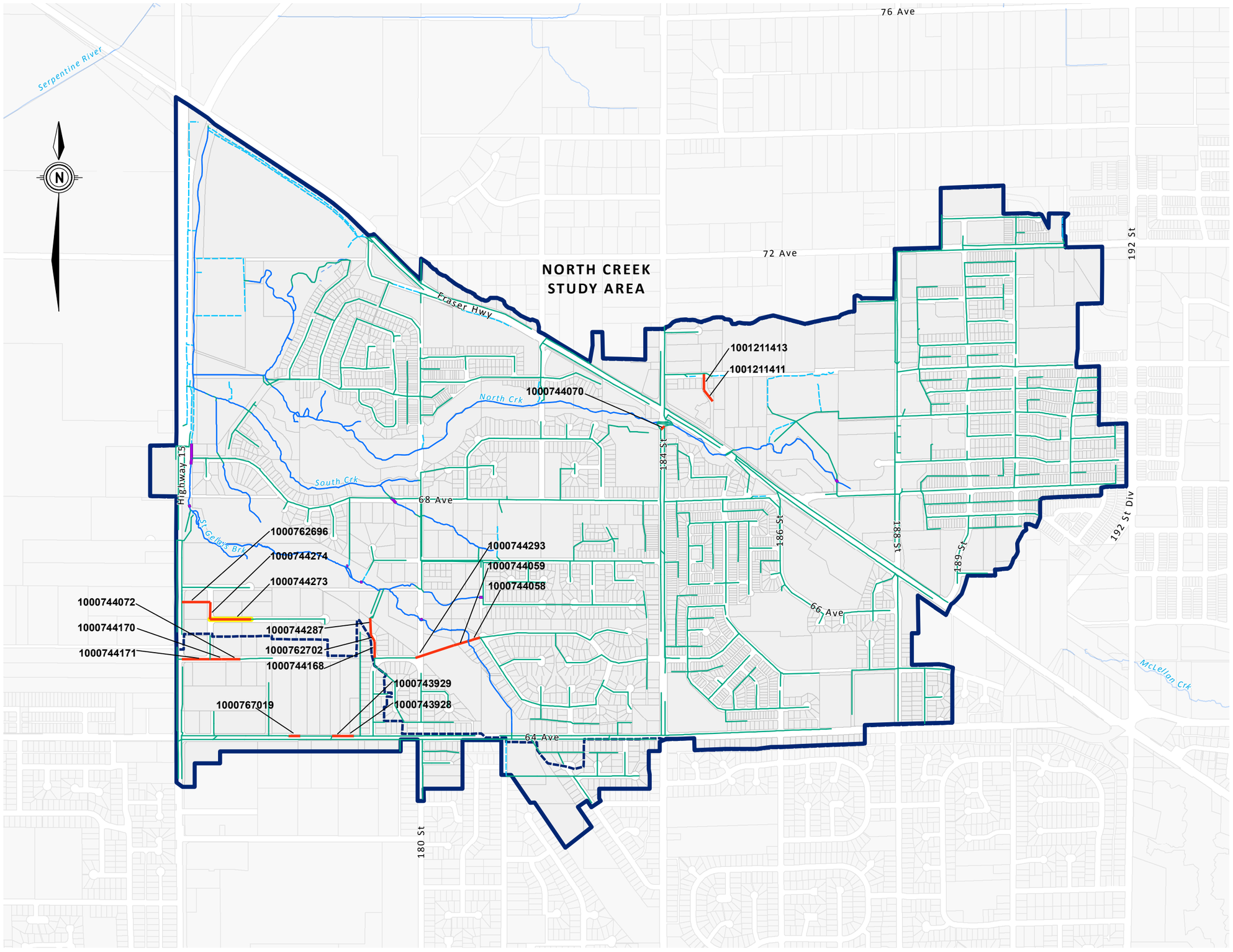

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Culvert
- Storm Main
- Ditch
- Surcharged > 0.3 m for > 15 min
- Flooded above ground

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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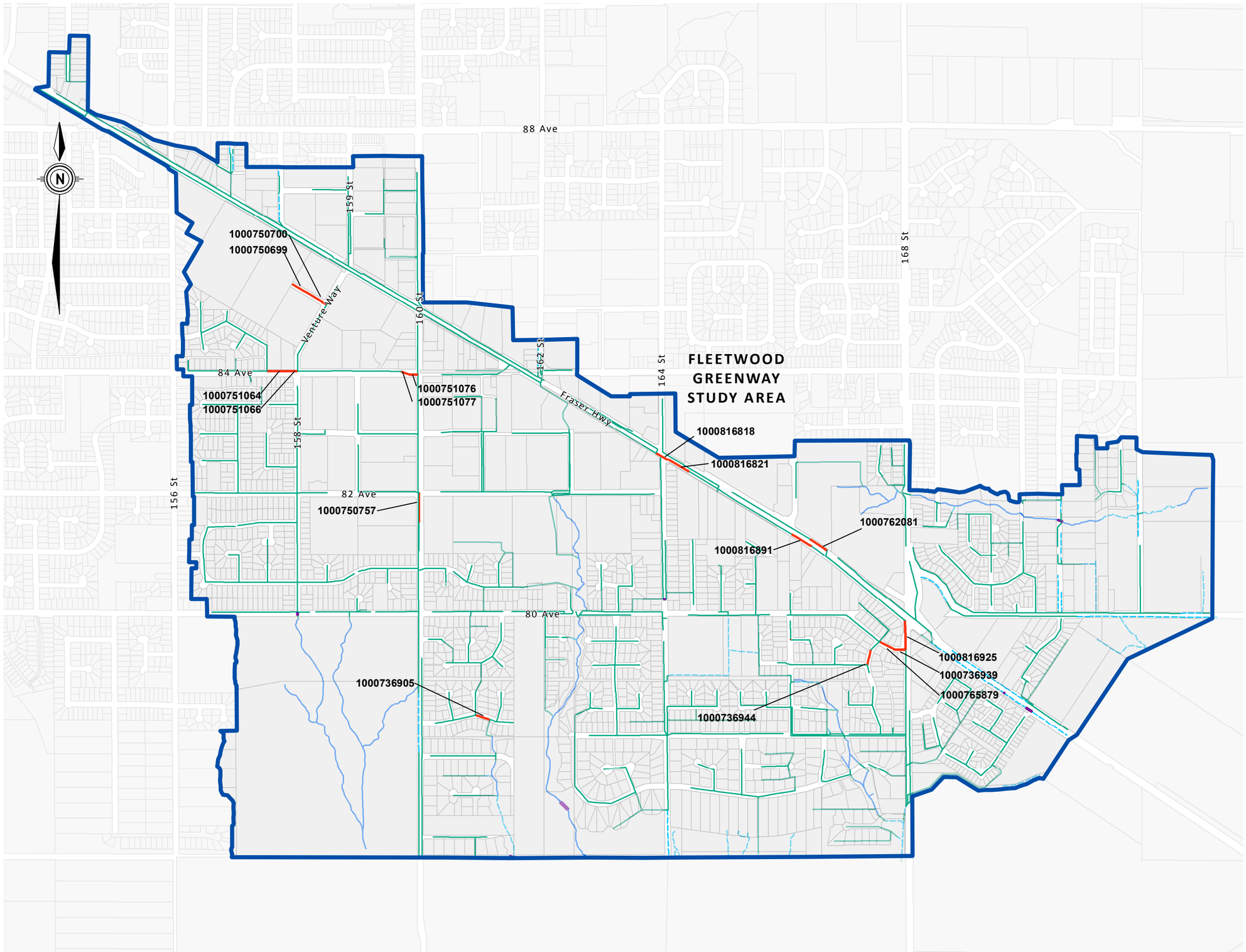
Project No.	Date
471-288	June 2016

5-Year Minor System Existing Land Use Model Results North Creek Study Area

Figure 5-2



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- StudyArea
- Creek
- Culvert
- Storm Main
- Ditch
- Surcharged > 0.3 m for > 15 min

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

5-Year Minor System Mitigated Future Land Use Model Results Fleetwood Study Area

Figure 5-3

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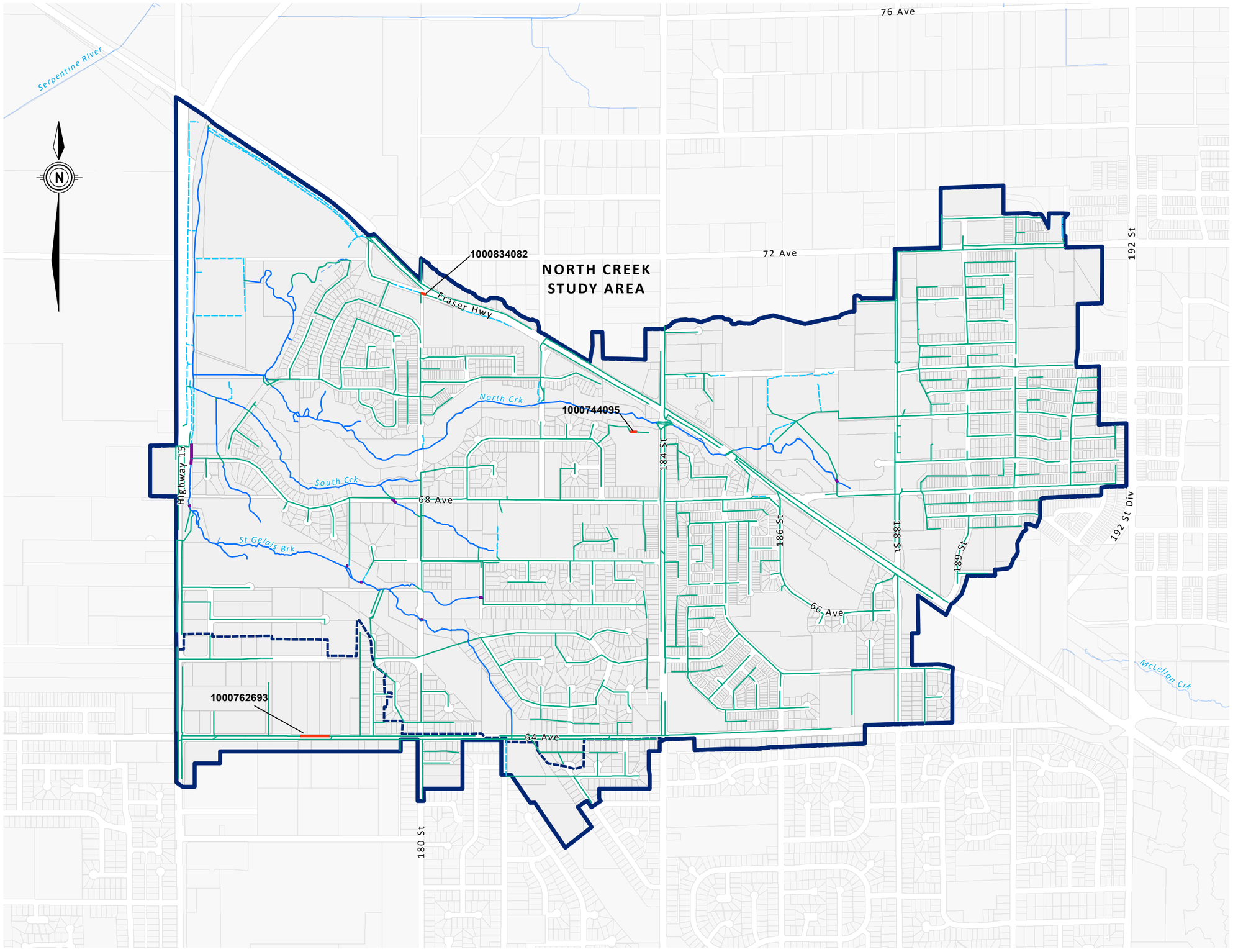

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Culvert
- Storm Main
- Ditch
- Surcharged > 0.3 m for > 15 min

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

5-Year Minor System Mitigated Future Land Use Model Results North Creek Study Area Figure 5-4

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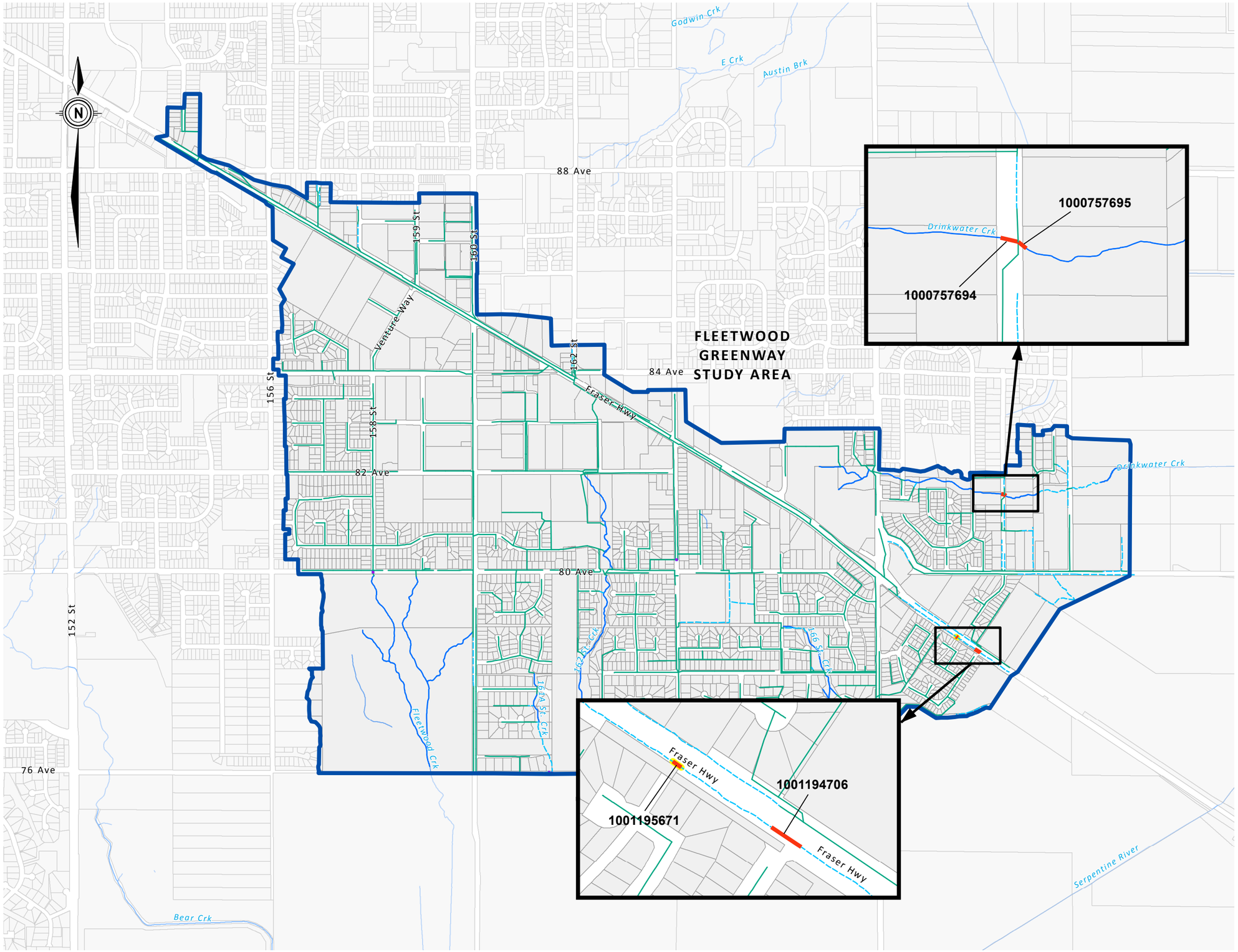

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Culvert
- Storm Main
- Ditch
- Surcharged >.3m for >15min
- Floods Land Upstream

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

100-Year Major System Mitigated Future Land Use Model Results Fleetwood Study Area

Figure 5-5

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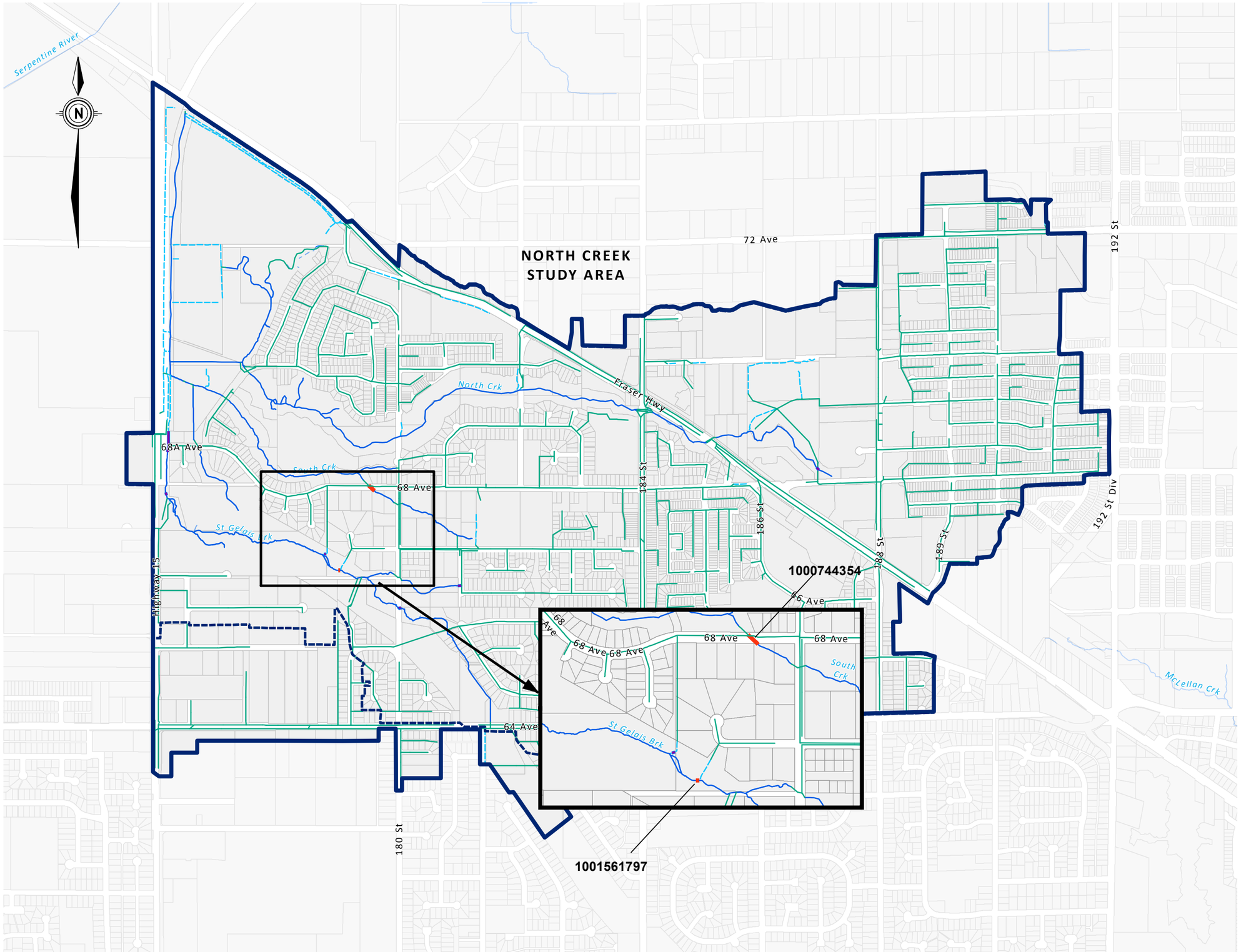

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Culvert
- Storm Main
- Ditch
- Surcharged > 0.3 m for > 15 min

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

100-Year Major System Mitigated Future Land Use Model Results North Creek Study Area Figure 5-6

6. Vision for Future Development

A key part of the ISMP process is to establish the vision, goals and criteria for the watershed. During this process the stakeholders begin to take ownership of the ISMP and it becomes a shared mission. To achieve this, external stakeholders were engaged via City Speaks and telephone interviews, and a visioning workshop was held with City staff.

6.1 Stakeholder Outreach

Public Stakeholder Outreach with City Speaks

The City of Surrey's City Speaks public information and consultation platform was used to reach out to residents and business that are registered with the City Speaks program and that are located within the study areas for this ISMP. A series of questions was developed to engage the public to think about and provide feedback on:

- the importance of the creeks in their neighbourhoods,
- what values the creeks provide to the public and neighbourhoods,
- any issues the public may be aware of related to flooding or creek health, and
- what values and watershed assets need to be preserved and enhanced for the future.

The City Speaks survey included reference maps as well as drop-downs and 'cards' for multiple-choice answers, and a few open questions with space for write-in answers. The survey was open to City Speaks participants for three weeks. The results of the City Speaks outreach may be found in the tables in Appendix F.

There were 23 complete responses to the City Speaks survey, and only 39% of respondents said they were aware of and had any sort of interactions with the creeks in these study areas. This is not a very large percentage of the respondents, given how many small, accessible creeks are located within these study areas, however, this appears to be in line with the expectations and experience of City staff.

Of the 7 write-in responses regarding the future of the watersheds and the values that should be preserved or enhanced, all of them concern the integrity and preservation of riparian areas around the creeks. It is quite clear that the public that is aware of and concerned about the creeks are very interested in seeing improvements in riparian management and protection.

Government Agency Outreach

Both the Department of Fisheries and Oceans Canada (DFO) and the British Columbia Ministry of Environment (MOE) were contacted regarding this ISMP to identify any additional agency concerns for the priorities and solutions for the ISMP. Emails and phone calls to DFO found that there is currently no DFO effort allocated to ISMPs. DFO no longer gets involved in planning processes early, but waits until there is a project that may cause Harmful Alteration, Disruption or Destruction to fish or fish habitat occurring.

MOE was also contacted directly regarding this ISMP. The head of the Environmental Impact Assessment Section indicated that there was no one on staff currently tasked with urban stormwater concerns and that, at this time, MOE would not be involved in ISMPs unless there were significant environmental threats. This ISMP does not include such concerns and MOE declined to participate in it.

6.2 Visioning Workshop

The objective of the vision workshop was to establish a vision for the watershed and to establish goals for mitigating the impacts of future development on watershed health.

Fleetwood and North Creek are both highly developed watersheds. There are a number of studies concerning the future of the area that have already been conducted including the Cloverdale and Fleetwood Town Centre Plans. These studies along with the City of Surrey Sustainability Charter and the Surrey Drainage Policy lay the foundation for the Fleetwood Greenway North Creek Watershed Vision. The Vision Workshop was structured to build on the pre-existing goals and objectives.

Multiple stakeholders from the City were invited to participate in a 1-hour workshop. Nine representatives from parks, engineering, and planning departments attended the meeting. The attendees were asked to participate in a questionnaire and to give their thoughts on the vision for the watershed. Meeting minutes as well as the workshop agenda, and supplementary material are included in Appendix F.

Vision Workshop Questionnaire

Three questions were asked:

What does 'Project Vision' mean to you?

Responses to this question were fairly consistent. City stakeholders responded that 'Project Vision' is a big picture idea for a desired future state. The 'Project Vision' sets high-level goals and objectives for end-of-project outcomes.

Why do you think a vision is important?

Vision is important to you because it puts all stakeholders on the same page and sets the direction for the project. By setting goals for the future it may guide future decisions and implementation.

What are 3 priorities for the vision for Fleetwood Greenway North Creek ISMP?

Responses to this question were much more varied, but generally fit the following three themes. City stakeholders would like the vision to be:

- Green – improve water quality and fish habitat, and preserve or enhance tree coverage;
- Inclusive – all members of the community should benefit from the goals of the ISMP; and
- Safe – allowing for protection of people and property.

Vision Statement

The City of Surrey Official Community Plan (OCP) strives for healthy sustainable communities. The OCP has nine building blocks that describe the vision for Surrey: greener, complete, compact, connected, resilient, safer, inclusive, healthier, and beautiful. In line with the City's OCP, the Fleetwood Greenway North Creek ISMP provides a road map for healthy, sustainable communities in its watersheds. Three words were chosen, Greener, Safer, and Inclusive, to express key ISMP vision elements but the ISMP uses all 9 building blocks as guiding principles:

Greener: The net health of the watersheds is protected and maintained or enhanced over the long-term as the watersheds are developed and re-developed.

Safer: The stormwater infrastructure continues to protect life and property from erosion and flooding as development continues and the climate changes.

Inclusive: The watersheds include programs and places that foster getting outdoors, community-building, and connection to nature. The watersheds provide access to nature in a manner that promotes appreciation of the natural environment without intrusion.

Achieving the vison will require managing stormwater runoff generated by development, protecting and enhancing the natural environment, and improving the interaction of the urban and natural spheres in the watersheds. ISMP goals for each of the three core concepts are described below. To achieve the vision and goals, a mixture of traditional and progressive stormwater management practices will be employed to manage excess runoff from development. Traditional -tried and tested- methods include upgrading pipes for safe conveyance of flow and using central detention facilities for peak flow attenuation. More green and progressive approaches include use of Low Impact Development design and Stormwater Source Controls to promote retention, infiltration, and treatment of runoff at the source (at the site of development). Beyond stormwater management, the realization of the vision requires protecting and, where possible, enhancing watercourses, riparian areas, and wildlife habitats to support and enhance the environmental values of the watershed. To this end, one of the core concepts of the ISMP is re-defining access to nature and watercourses. The plan strives to connect residents to nature in a manner that builds community and promotes healthy living but limits encroachment and impairment of riparian areas.

Goals

Greener: The net health of the watersheds are protected and maintained or enhanced over the long-term as the watersheds are developed and re-developed.

- Protect and enhance watercourses and aquatic habitat:
  - Reduce flood impacts on the stream channel and strive to restore a more natural flow regime.
  - Return stream baseflows towards their natural pre-development levels.
  - Remove fish barriers and enhance in-stream habitat.
  - Prevent pollution and maintain/improve stream water quality.
- Protect and enhance riparian areas. No development should encroach on the riparian area.
- Protect and enhance key wildlife habitat. Protect existing hubs and corridors and maintain and improve connectivity.

Safer: The stormwater infrastructure continues to protect life and property from flooding and erosion.

- Upgrade failing or undersized stormwater infrastructure and prevent flooding due to increased peak flows from developed impervious area.
- Provide adequate detention on site to maintain post-development flows at pre-development levels.
- Reduce stream erosion and downstream sedimentation to levels approaching a more natural system.

Inclusive: The watersheds include programs and places that foster getting outdoors, community-building, and connection to nature. The watersheds provide access to nature in a manner that promotes appreciation of the natural environment without intrusion.

- Protect and enhance human health through improved environmental quality.
- The watersheds will provide access to nature in a manner that promotes appreciation of the natural environment without destruction.
  - Re-claim and preserve riparian areas to preserve stream health.
  - Improve recreational access to creek and riparian area with managed access points and promote appreciation without intrusion.
  - Build-in opportunities (including programs and places) that foster neighbourhood connections. For example, stormwater features such as detention ponds can help protect life and property (preventing flooding and erosion), prevent degradation of creeks (reduce peak flow), and provide community amenities (park).

The ISMP provides the tools to achieve the vision through a cost effective, practical, *Implementation Plan* as well as a *Monitoring & Assessment Strategy* to ensure the goals are achieved, maintained, and enforced.

- Focus on solutions for areas where development is causing issues – where modelling is showing increased flow, pipes failing, etc.;
- Focus on areas where there is evidence of erosion in creeks downstream; and
- Build on existing initiatives, policies, and plans – these include Surrey's existing roof leader disconnection bylaw for single family land use, standard 450 mm of absorbent soil, existing sustainability and biodiversity guidance documents, riparian area bylaws, and Metro Vancouver's Region-Wide Baseline for On-site Rainwater Management.

7. Integrated Stormwater Management Plan

7.1 Introduction

The key issues for this ISMP include the following:

Table 7-1: Key Issues in Fleetwood Greenway North Creek ISMP

Key Issues
Flood Management • Undersized storm sewers
Erosion Management • Erosion in the stream channels
Mitigation of Future Development/Redevelopment Impacts • Increasing imperviousness in the watershed with new development and re-development
Environmental Protection and Enhancement • Threats to Riparian and Stream integrity

This section discusses the elements necessary to address the key issues of flood management, erosion management, mitigation of the impacts of development and re-development and environmental protection and enhancement.

The solutions are developed in line with the City's Sustainability Charter to minimize environmental impacts of development. The Charter cites that the City will demonstrate best practices in sustainable civil engineering by:

1. Reviewing current practices and regulations and removing any unnecessary barriers to the provision of green infrastructure;
2. Implementing sustainable green infrastructure on public land, in public rights-of-way and in private developments;
3. Minimizing environmental impacts of development by re-creating the natural environment to the extent possible in drainage, landscaping, sewer and water projects, and
4. Implementing demonstration projects, including monitoring, refining of future best practices and distributing lessons learned.

The Charter also enters into details with respect to enhancing and protecting natural areas, fish habitat and wildlife habitat; which are also key components of the Fleetwood Greenway North Creek ISMP.

7.2 Proposed Watershed Criteria

The purpose of this section is to review existing criteria applicable to the Fleetwood Greenway North Creek ISMP study areas and clarify them as required, and to summarize the criteria proposed for the watersheds in this ISMP.

Fleetwood Greenway North Creek ISMP Criteria

The proposed criteria for the Fleetwood ISMP are summarized below in Table 7-2. Subsequently, additional details outlining the steps to meet the proposed criteria, including sample calculations are provided.

Table 7-2: Proposed Stormwater Criteria for Fleetwood Greenway North Creek ISMP

Application		Criteria/Methodology		Checklist
		All Development		
Hydrotechnical Component (Flood and Erosion Protection)	Minor Drainage System	• 5-year return period design event.[1]		✓
	Major Drainage System	• 100-year return period design event[1]		✓
	Agricultural Drainage	• Maintenance of a flood control and drainage system in the lowlands for agriculture in floodplains to ARDSA criteria[1,2]		✓
	Watercourse Erosion Prevention/ Rate Control	*See environmental criteria below.*		
		All Development (except Single Family Residential)	**Single Family Residential**	
Environmental Component (Environmental Protection)	Volume Reduction Source Controls	• Source controls on single-family subdivisions, multi-family residential, commercial, institutional, and industrial development and roads to mitigate the target volume for all impervious area. • On-site rainfall capture (runoff volume reduction) target of 32 mm in 24 hours.	• For single-family residential development, 450 mm of absorbent topsoil on all landscaping areas, disconnected roof leaders discharge to landscape areas, and grading hard surfaces to landscape or pervious areas. • Regional facilities to make up for any on-site capture shortfalls.	✓
	Water Quality Treatment	• Collect and treat 80% of annual runoff from ground surface impervious areas with BMPs. • Design BMPs and water treatment facilities to remove sediments, metals and hydrocarbons and meet the maximum allowable total suspended solids (TSS) of 75 mg/L [3]	N/A	✓
	Watercourse Erosion Prevention/ Rate Control	• Control 5-year, 2-year and 6-month event post-development flows from development site to corresponding 5-year, 2-year, and 6-month pre-development flow rates.[4,5,6]	N/A	✓
	Riparian	• Establish riparian setbacks to comply with *Riparian Area Bylaw (proposed, 2016)* and the City of Surrey's Ecological Management Study and the recommendations from the Biodiversity Plan.		✓

1. City of Surrey Design Criteria Manual, January 2016.
2. Agricultural Land Commission Website, 2012.
3. City of Surrey Erosion and Sediment Control Bylaw 2006 No.16138.
4. DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat, 2001.
5. City of Surrey Design Criteria Manual, January 2016, requires control of 5-year post-development flow to more stringent of 50% of 2-year post-development flow or 5-year pre-development flow.
6. Pre-development flow rates for design are summarized in Table 7-3.

Calculations for Volume Reduction[1]

Three priorities have been previously identified (AECOM, 2010) for volume reduction and each one has a simple calculation linking the amount of infiltration material or storage volume required. The following prioritized approach for addressing volume capture is intended to approximately meet the 32 mm capture criterion. Independent calculations using capture volumes have been performed to verify that when applied correctly, this prioritized approach should meet the intent of mitigating future impacts to flows as they relate to volume reduction.

Priority 1 – Infiltration

In order to meet the volume capture criteria, infiltration is the preferred method especially in areas with good soils. The following recommendation is for a required volume of infiltration material based on total site area.

Required Volume of Infiltration Material (m^3) = (site area in m^2) x 0.5 metres

Priority 2 – Evapotranspiration

If runoff from areas cannot be infiltrated into ground, for example, where there are site constraints such as underground parking, there should be a minimum 75 mm of growing medium designed to meet the volume capture criteria. If the vegetated areas are in poor soils, there must be a storage volume to detain flows to meet the rate control criteria as the growing medium alone may not fully achieve the capture criteria.

Required stormwater storage (m^3) = (landscaped area with no infiltration in m^2) x 0.02 metres

Priority 3 – Detention

For areas where runoff cannot be captured via infiltration or evapotranspiration, storage should be provided to detain post-development flows and release at an equivalent rate to pre-development flows.

Required stormwater storage (m^3) = (impervious area in m^2) x 0.05 metres

Assumptions and Conditions for Criteria

The following section provides further clarification for the criteria determined in the *Surrey Centre General Land Use Plan Update* (AECOM 2010) report. The prioritized criteria is to be applied on all development to meet the capture criteria overall in the watershed.

Priority 1 - Infiltration

The strategy proposed above will be used to meet the rainfall capture target. The first priority prescribes a volume of infiltration material equal to a 0.5 m depth multiplied by the total site area. This infiltration material can come in the form of low impact development techniques such as pervious pavement, absorbent topsoil, and landscaping growing medium.

Using this equation would result in large infiltration material volumes and excessive depths of infiltration material. For example, a site that is 50% impervious would require that the pervious half of the site

[1] Based on calculations developed for the City Centre criteria determined in the *Surrey Centre General Land Use Plan Update* (AECOM 2010) report.

accommodate a one meter thick layer of infiltration material. Furthermore, for catchments that are mostly impervious, the footprint area available to place this material would be very small. A limitation on how deep the layer of soil can be placed is necessary to avoid unfavourable capture and infiltration conditions. A deep layer of soil over a small area is not equal to a shallow layer of soil over a larger area given the same soil volume due to difference in the infiltration footprint.

It is reasonable to assume that the 0.5 metre layer of infiltration material (topsoil) is placed only on the pervious areas and the impervious surfaces are graded to drain into these areas. To avoid overwhelming the topsoil on the pervious areas, the impervious to pervious ratio should not exceed 2:1. If the impervious area is less than twice the size of the pervious area, then no other action is required as the capture criterion is met. If the impervious are is larger, Priority 2 mitigation should be added.

Priority 2 – Evapotranspiration

Similarly with the Priority 2 calculated water storage volume for evapotranspiration, adequate footprint has to be provided for plantings to be able to use the stored water. Using a large depth of topsoil with a small footprint could mean that the water stored in the lower depth will not be accessible for uptake by the plants. Furthermore, the small footprint could mean that there simply are not enough plants to evapotranspirate the volume required to meet the capture criterion. Again, additional sizing information is needed.

For roof top planters the maximum soil depth is 1 m and the impervious to pervious ratio should not exceed 10:1. For green roofs, the maximum soil depth is 0.3 m and the impervious to pervious ratio should not exceed 2:1. If the Priority 2 capture source controls are not large enough to deal with the remaining impervious area, Priority 3 detention should be added.

Priority 3 – Detention

It is important to attempt to capture the rainfall using infiltration and evapotranspiration measures but if proven inadequate to capture the entire volume, the remaining volume of runoff will determine the size of the detention facility. Example 1 below shows how a detention facility can be sized for the remaining unmitigated impervious surfaces. The release rate should be limited to the 6-month predevelopment rate listed in Table 7-3 and the detention facility should be able to drain within three days.

The equation provided in the previous section is for impervious areas that are not directed to pervious areas, or covered by planters or a green roof to calculate the required stormwater storage volume. Essentially, this equation provides 50 mm of storage depth for all unmitigated impervious areas.

The following two examples illustrate how the criteria can be achieved in two distinct land uses within the study areas. The example calculations approximate the 32 mm capture recommended for the Fleetwood Greenway North Creek watersheds.

Example 1: Commercial/Institutional Calculation

Consider a typical commercial lot in the Fleetwood Greenway North Creek Watersheds assuming:
Area = 0.2 hectares (2,000 m^2) Impervious percentage = 90%
Impervious area = 90% x 2,000 m^2 = 1,800 m^2 Pervious area = 200 m^2
(1,000 m^2 is building roof area and 800 m^2 is pavement)

Priority 1 – Apply infiltration material:
Place 0.5 m layer of infiltration material (topsoil) on the 200 m^2 pervious area and drain a maximum of 400 m^2 of impervious pavement to it.

Priority 1 takes care of the 200 m^2 pervious area and 400 m^2 of impervious pavement. This leaves 1,000 m^2 of roof and 400 m^2 of pavement to be addressed with the next priorities.

Priority 2 – Apply evapotranspiration storage:
Install rooftop planters or a green roof with 75 mm minimum growing medium thickness. For the 1,000 m^2 roof area, provide the storage volume as per the Priority 2 equation:
Stormwater volume = Roof area x 0.02m = 1,000 m^2 x 0.02m = 20 m^3 of water holding capacity in planters or green roof in addition to the growing medium water holding capacity.

Priority 2 takes care of the entire 1,000 m^2 roof. This leaves the remaining 400 m^2 of pavement to be addressed with Priority 3.

Priority 3 – Add detention storage:
Calculate the volume required for the runoff from the remaining 400 m^2 of pavement as per the Priority 3 equation:
Stormwater storage volume = 400 m^2 x 0.05m = 20 m^3 of water storage in a detention tank.

The outlet orifice for the detention tank should be sized to release flow at a rate equivalent to the pre-development runoff rate and be able to drain down within three days.

Priority 3 takes care of the 400 m^2 of pavement meaning that now the entire site is accounted for with the three priorities.

Example 2: Single Family Residential Calculation

Consider a typical residential lot in the Fleetwood Greenway North Creek Watersheds assuming:
Area = 0.04 hectares (400 m^2) Impervious percentage = 65%
Impervious area = 65% x 400 m^2 = 260 m^2 Pervious area = 140 m^2

Priority 1 – Apply infiltration material:
Place 0.5 m layer of infiltration material (topsoil) on pervious area.

Check that the impervious area is less than twice the pervious area:
260/140 = 1.86 and therefore confirmed.

Draining the entire 260 m^2 area onto the 140 m^2 pervious area with 0.5m of infiltration material meets the volume reduction criterion. No other action is required.

Control Release Rates

The 5-year, 2-year, and 6-month event post-development flows should be controlled to the corresponding pre-development flow rates. The pre-development flows were modelled using PCSWMM software, assuming a roughly 20% impervious agricultural catchment as representative of the pre-development condition. These flows are summarized in the following table. The modelled flow hydrographs are included in Appendix J.

Table 7-3: 5-year, 2-year, and 6-month Event Control Release Rates

Return Period	Peak Unit Release Rate (L/s/ha)
6-month	6.04
2-year	10.43
5-year	15.81
Peak release rates are for detention design using the 24-hour duration event	

7.3 Flood Management

Historically, flooding records within the study areas do not indicate any widespread problem of major flooding. Potential localized flooding within the study areas would most likely be attributed to heavy rainfall and clogged catch basins or undersized storm sewers. Two areas of concern were identified during this study by City staff: 162 St South of 80 Ave. and on South Creek.

Undersized storm sewers and culverts were identified in Section 5. Pipe upgrades were evaluated and prioritized according to the following criteria:

Priority 1. Based on the existing land use model results, major storm pipes (culverts) that have inadequate capacity to convey the 100-year design flow and result in flooding on the surface, are sized to meet the 100-year flow as calculated in the mitigated future land use model.

Priority 2. Based on the existing land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow, result in flooding on the surface, and require two or more incremental pipe diameter increases, are sized to meet the 5-year flow as calculated in the mitigated future land use model.

Priority 3. Based on the existing land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow, result in flooding on the surface, and require one incremental pipe diameter increase, are sized to meet the 5-year flow as calculated in the mitigated future land use model.

Priority 4. Based on the existing land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow and result in surcharging higher than 0.3 m above the pipe crown for over 15 minutes, are sized to meet the 5-year flow as calculated in the mitigated future land use model. These are recommended as end of service life upgrades only.

Priority 5. Based on the mitigated future land use model results, major storm pipes (culverts) that have inadequate capacity to convey the 100-year design flow (regardless of whether or not surface flooding occurs) are sized to meet the 100-year flow as calculated in the mitigated future land use model.

Based on the mitigated future land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow (regardless of amount of surcharge) are sized to meet the 5-year flow as calculated in the mitigated future land use model. Both of these (major and minor) system upgrades are recommended as end of service life upgrades only.

The design flow and pipe size should be checked during the detailed design where more site specific information is known and refined, if needed.

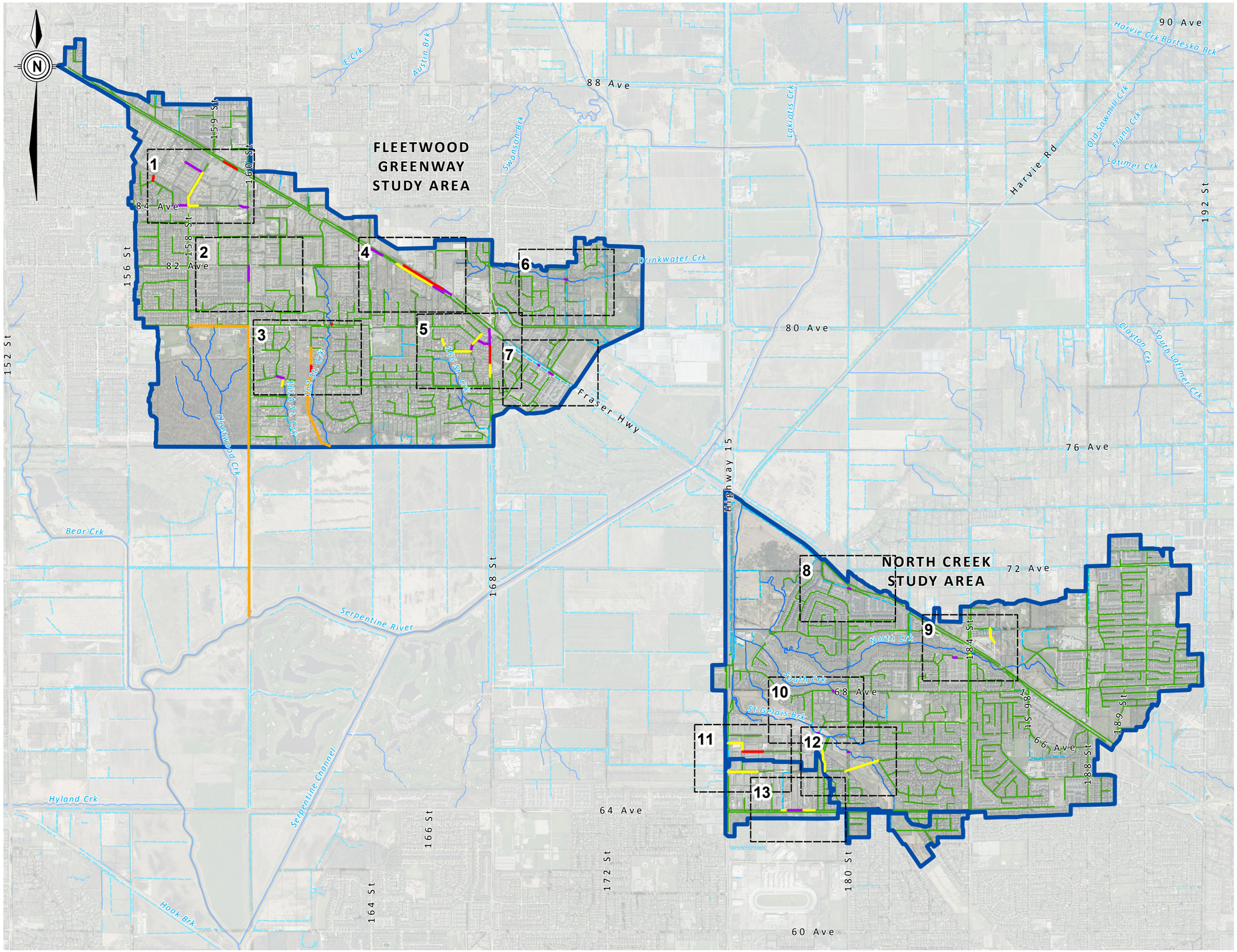
Pipe upgrades identified for each priority are shown in Figure 7-1 and listed in Table 7-4. Detailed tables and location figures are found in Appendix H.

Table 7-4: Flood Management Upgrades

Priority	Conduit ID	Existing Diameter (mm)	Future Mitigated Peak Flow (m^3/s)	Recommended Diameter (mm)	Key Plan Area[1]
2	1000751128	200	0.249	375	1
2	1000750678	375	0.306	525	1
2	1000852018	300	0.515	600	3
2	1000741909	250	0.708	750	3
2	1000816847	375	0.206	525	4
2	1000742079	250	0.23	375	4
2	1000736746	450	1.511	900	5
2	1000736745	450	1.46	675	5
2	1000765868	450	1.498	750	5
2	1000744273	450	0.467	675	11
4	1000750702	375	0.539	600	1
4	1000750701	375	0.411	525	1
4	1000751067	600	1.411	900	1
4	1000750698	300	0.294	450	1
4	1000751069	600	1.424	1050	1
4	1000751065	450	0.577	675	1
4	1000736800	600	0.793	750	3
4	1000816864	450	0.562	600	4
4	1000816861	450	0.549	600	4
4	1000816859	450	0.529	600	4
4	1000736747	450	1.55	600	5
4	1000736938	375	0.361	525	5
4	1000736935	250	0.115	375	5
4	1000761399	450	1.523	900	5
4	1000736940	250	0.103	300	5
4	1000736946	300	0.272	450	5
4	1000744070	600	0.721	900	9
4	1001211413	250	0.16	450	9
4	1001211411	200	0.1	300	9
4	1000744274	450	0.519	900	11
4	1000744072	375	0.268	525	11
4	1000762696	450	0.586	900	11
4	1000744170	375	0.325	600	11
4	1000744171	450	0.453	900	11
4	1000762702	675	1.074	900	12
4	1000744168	675	1.05	900	12
4	1000744059	450	0.769	525	12
4	1000744058	450	0.756	750	12
4	1000744287	675	1.085	1050	12

Priority	Conduit ID	Existing Diameter (mm)	Future Mitigated Peak Flow (m^3/s)	Recommended Diameter (mm)	Key Plan Area[1]
4	1000744293	450	0.769	600	12
4	1000743928	300	0.271	375	13
4	1000767019	300	0.176	375	13
4	1000743929	300	0.379	450	13
5	1000751077	600	1.67	900	1
5	1000751064	600	0.803	900	1
5	1000751066	600	0.826	750	1
5	1000750699	300	0.167	375	1
5	1000750700	300	0.267	375	1
5	1000751076	600	1.676	900	1
5	1000750757	600	0.816	675	2
5	1000736905	525	0.702	600	3
5	1000762081	300	0.241	375	4
5	1000816891	525	0.596	600	4
5	1000816818	450	0.397	525	4
5	1000816821	450	0.417	525	4
5	1000736944	375	0.33	525	5
5	1000816925	600	0.933	675	5
5	1000765879	450	0.69	675	5
5	1000736939	450	0.72	675	5
5	1000834082	300	0.251	375	8
5	1000744095	300	0.19	450	9
5	1000762693	300	0.169	375	13
5	1000757695 1000757694	600	1.31	1050	6
5	1001195671	375	0.346	600	7
5	1001194706	375	0.323	600	7
5	1000744354	600	0.601	750	10
5	1001561797	450	2.022	1350	12
5	1001561761	675	1.118	1050	12

1. Refer to Appendix H for key plan area maps.
2. Light grey shading represents culverts that are undersized for 100-yr mitigated future peak flows, but do not flood the land upstream.
3. Dark grey shading represents culverts that flood the land upstream under 100-yr mitigated future conditions.



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main / Culvert
- Creek
- Ditch
- Key Plan Area - *Figures in Appendix H*

Flood Management Upgrades

- (Priority 2): Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4): Fail Existing - 5 Year, Surcharge > 15 min and > 0.3 m
- (Priority 5): Fail Future Mitigated

Erosion Management Projects

- Proposed Diversion

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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consulting engineers

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects Key Plan

Figure 7-1

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7.4 Erosion Management

The engineering inventory noted a number of areas of erosion and channel obstructions in the creek system. Erosion is a naturally occurring process and may not be a serious issue for every instance. No high risk sites were identified as needing immediate repair. Nevertheless, these sites should be monitored for maintenance efforts and any potential downstream effects.

Erosion Monitoring

A number of sites were identified as being high risk, but as their locations are away from property or infrastructure, they may not warrant repair. Additional high risk sites are encroaching on infrastructure, but do not require immediate restorative action. Most of these sites, identified in Appendix B, were either newly identified or were given higher risk ratings than previous years and should be monitored regularly to ensure they do not threaten infrastructure.

Future Erosion Potential

The future conditions modelling results were compared to existing land use to determine the potential changes in creek flows. The 5-year increases in peak flow, summarized in the table below, were used to identify locations that may be at risk of increased erosion in the future.

Table 7-5: 5-Year Instantaneous Peak Flows for Existing and Unmitigated Future Land Use

Location	Instantaneous Peak Flow (m^3/s)			Expected Increase in 5-Yr Peak Flow (%)	
	Existing Land Use	Mitigated Future Development	Unmitigated Future Development	Mitigated	Unmitigated
Fleetwood Creek	3.0	3.1	5	3%	67%
161A Street Creek	0.7	0.8	1.2	14%	71%
162 Street Creek	2.0	2.0	2.1	0%	5%
166 Street Creek	2.3	2.4	4.3	4%	87%
Drinkwater Creek	0.8	0.9	1.3	13%	63%
North Creek*	6.4	6.1	7.6	-5%	19%

*Downstream of the confluence with South Creek and St. Gelais Brook

Peak flow increases in 162 St. Creek and North Creek are minimal for the 5-year event and may be maintained at pre-development levels through the incorporation of detention during redevelopment, and the completion of the 162 St. Creek diversion (see Figure 7-1). Increases in peak flows (3% to 14%) are predicted for Fleetwood, 161A Street, 166 Street, and Drinkwater Creeks even with the proposed stormwater criteria. Additional mitigation measures to prevent erosion in these four creeks are discussed in the following paragraphs.

Fleetwood Creek

The largest contributor to peak flow increases in Fleetwood Creek is densification of single family lots. Detention should be introduced during redevelopment, though it may not be required under the City's current bylaws. An alternative to detention would be a flow diversion at 80 Ave. from 158 St. to 160 St. as proposed in the recent *10-Year Servicing Plan*. This diversion is recommended as it would act to limit peak flows in the creek and thereby limit the erosion potential of flows up to the 5-year design event. In conjunction with this flow diversion, the City should consider upgrading the existing storm system along 160 St. from 80 Ave. to 76 Ave. and installing a new sewer that continues from 76 Ave. to the Fleetwood pump station. The location of this proposed diversion is shown in Figure 7-1.

161A St. Creek and 166 St. Creek

Peak flow increases in 161A St. Creek and 166 St. Creek are caused both by densification of single family lots and by a zoning change from one acre residential lots to higher density single family residential, suburban, and multi-family residential lots. Detention should be provided for re-development if areas are re-developed as part of neighbourhood development plans and detention can be incorporated into the re-development plan. However, infill re-development generally does not incorporate detention on single or subdivided lots and other rate control mechanisms would be required to mitigate the increases in flows from redevelopment of single family lots. The ditch along the southern Fleetwood Greenway catchment boundary from 164 St. to 168 St. may provide detention for runoff from any future development north of the ditch to 80 Ave. between 162 St. Creek and 166 St. Creek. This may help to protect 166 St. Creek south of the catchment boundary.

Drinkwater Creek

Redevelopment of single family residential lots is primarily responsible for the peak flow increases in Drinkwater Creek. As this creek's contributing catchment area is relatively small, an increase in the impervious percentage of a few lots can make a large difference to the peak flows in the creek. A 0.8 ha lot at 168 St. and 81A Ave. is set to change from one acre residential zoning to single family residential under future land use. Detention should be provided for re-development to control runoff entering Drinkwater Creek.

7.5 Mitigating the Impacts of Future Development

To meet the goal of the ISMP and maintain and improve the ecological health of the Fleetwood Greenway North Creek ISMP watersheds over the long-term, the ISMP includes mitigation for the hydrologic and environment impacts of anticipated development and redevelopment.

Recommended Source Controls

Based on the outcome of the visioning process, the primary tool for mitigating the impacts of future development is the use of source controls for all developments and re-developments within the Fleetwood Greenway North Creek study areas. Appendix G provides background and an overview of low impact development and source control technologies.

To arrive at the recommendations, the project team generated and mapped possible opportunities for source control implementation throughout the watersheds. Development is mostly expected to occur in large part through conversion of single family to multifamily and other higher impervious land uses, and through infilling of single family residential areas. Based on aerial photos provided by the City and future land use mapping from the OCP, the team evaluated the suitability of each BMP type for different types of development.

Source control recommendations are developed for different land uses. The recommendations are summarized in Table 7-5. Appendix G shows details of roadside bump out rain gardens that are primarily recommended for Collector Roads but could also be used for other road classes.

Source controls need to be sized not only for the capture target, but also to handle the pollutants that come with impervious runoff. Minimum source control sizes relative to the impervious tributary area are often recommended to account for pollutants and long term viability of the source controls. These minimum sizes are documented in the 2012 Metro Vancouver *Stormwater Source Control Design Guidelines* (SSCDG). http://www.metrovancouver.org/services/wastewater/sources/Pages/StormwaterManagement.aspx

Table 7-6: Suggested BMPs for Fleetwood Greenway North Creek Land Uses

Land Use		Projected Future Unmitigated TIA[1]	Suggested BMPs	Timeline for Implementation
A	Single Family Residential	65-80%	• Provide 450 mm absorbent soils depth on all grassed and landscaped areas • Disconnect roof leaders and direct to absorbent landscape • Grade driveways and parking areas to drain to absorbent landscape or pervious driveways	Ongoing
	Half Acre/One Acre Residential	50%	• Provide 450 mm absorbent soils depth on all grassed and landscaped areas • Disconnect roof leaders and direct to absorbent landscape • Grade driveways and parking areas to drain to absorbent landscape or pervious driveways	Ongoing
	Suburban	55%	• Provide 450 mm absorbent soils depth on all grassed and landscaped areas • Disconnect roof leaders and direct to absorbent landscape • Grade driveways and parking areas to drain to absorbent landscape or pervious driveways	Ongoing
B	Duplex & Multi-Family Residential	75-85%	• Provide 450 mm absorbent soils depth on all grassed and landscaped areas • Use pervious pavement for walkways, driveways, and surface parking • Direct roof and any other impervious pavement runoff to subsurface infiltration facilities or rain gardens	1 – 10 years
C	Commercial/Industrial	90%	• Provide 450 mm absorbent soils depth on all grassed and landscaped areas • Use pervious pavement for walkways, driveways, and surface parking • Direct roof and any other impervious pavement runoff to subsurface infiltration facilities • Detention tank	1 – 10 years
	Institutional (includes Schools and Churches)	80%	• Provide 450 mm absorbent soils depth on all grassed and landscaped areas • Use pervious pavement for walkways, driveways, and surface parking • Direct roof and any other impervious pavement runoff to subsurface infiltration facilities or rain gardens	1 – 10 years
D	Parks, Playgrounds, Cemeteries	10%	• Direct impervious runoff to pervious areas	Ongoing
	Agricultural	10-20%	• Direct impervious runoff to pervious areas	Ongoing
E	Road	70%	• Use pervious pavement for sidewalks • Direct road runoff to bump out rain gardens (see Appendix G for details), linear rain gardens, or subsurface water quality treatment units and infiltration chambers.	1 – 10 years

7.6 Environmental Compensation and Enhancement Works

Environmental restoration and enhancement projects have been identified throughout the Fleetwood and North Creek catchment areas. Restoration opportunities have been grouped into 6 categories:

1. **Fish Passage Improvements:** Addressing fish passage barriers will allow fish to access more high quality habitat in the catchment areas that is currently difficult to access, or inaccessible. Though there are not many concerns about fish passage barriers in this study, a number of culverts, debris build-ups, and other barriers were identified that may restrict the movement of adult and juvenile fish throughout the stream, and prevent full utilization of habitat.
2. **In-Stream Habitat Complexing:** Fish habitat can often be improved by adding complexity to the stream channel. This can be done in a variety of ways, including physical addition of meanders to streams, or the addition of large wood and boulder complexes. Increasing complexity in stream habitats allows for the formation of deep pools, spawning habitat and cover for fish that are important throughout the life cycle of salmonids.
3. **Off-Channel Habitat Creation**: Off-channel habitat is critical to juvenile salmonids. Rearing fish use off-channel pond habitat both during summer when flows are low and water temperature is high and during high flow conditions through the winter months. Adding off-channel habitat can increase the productive capacity of streams.
4. **Riparian Protection, Restoration and Planting**: These projects focus on increasing the connectivity and health of forested areas adjacent to streams. High levels on development in both catchment areas have reduced the amount of forested riparian area on a number of streams, with impacts on water quality, as well as aquatic and terrestrial habitat. Restoring riparian areas will have large impacts on overall watershed health.
5. **Wildlife/Biodiversity Habitat and Corridors**: Landscape-level planning focuses on how the Fleetwood and North Creek catchment areas support overall ecological health and biodiversity in the broader context of the City of Surrey. These projects focus on the protection and restoration of forested corridors and hubs identified in the Green Infrastructure Network (GIN). Healthy and contiguous corridors provide critical connections between the core habitat areas in the city, allowing for dispersal and migration of wildlife. Hubs provide key refuge areas, and support wildlife with larger home ranges and species that are less tolerant of human activity.
6. **Water Treatment Opportunities:** The health of aquatic ecosystems depends on clean water. Projects to remove pollutants and treat stormwater from urbanized areas can significantly improve water quality in streams. Opportunities include water treatment wetlands and other source controls.

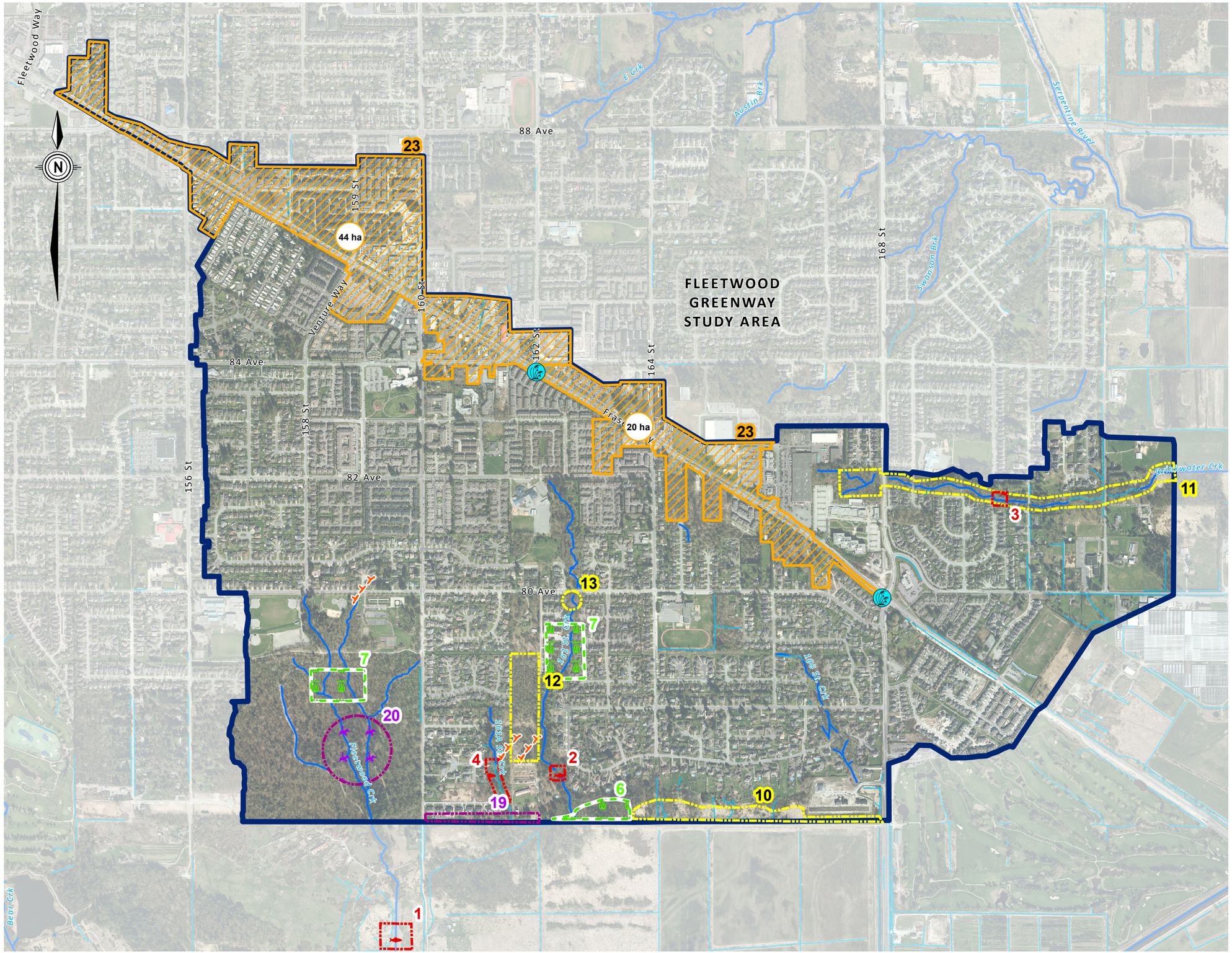
Projects have also been categorized as high, medium and low priority projects based on the importance to overall biodiversity and ecological health of the catchments, land ownership, and ease of implementation. Potential restoration and enhancement sites are listed in Table 7-7 on the next page and can be located on Figure 7-1 and 7-2.

Table 7-7: Environmental Restoration and Enhancement Projects

Project ID[1]	Project Type	Description	Priority
Fish Passage Improvements			
1	*Investigate obstruction to fish passage downstream of Fleetwood Park*	A possible barrier to fish passage has been identified by City staff downstream of Fleetwood Park outside the study area. High value fish habitat in Fleetwood Park cannot be utilized until fish passage downstream is addressed.	High
2	*Work with landowner to upgrade private twin culvert crossing on 162 Street Creek*	A long twin culvert, apron, and 0.5 m drop likely prevents fish movement between the lower and upper watershed approximately 170 m upstream of 76 Ave. 162 Street Creek has high fish habitat value, but reaches of the stream are likely not being well utilized. Upgrading can include replacement with a clear span bridge, open bottom arch culvert, or a box culvert with fish baffles.	High
3	*Remove debris blockage on Drinkwater Creek*	A debris blockage is creating a barrier to fish passage on Drinkwater Creek, restricting access to approximately 650 m of upstream habitat.	High
4	*Remove barriers on 161A Street Creek*	A series of barriers on 161A Street Creek could be removed, but the creek is not classified as fish habitat.	Low
5	*Remove partial barriers on South Creek*	A number of partial barriers due to debris and logs exist on South Creek, but they are not significant issues for fish passage	Low
In-Stream Habitat Complexing			
6	*Increase channel complexity along ALR boundary upland/lowland transition*	Along the southern of edge of the catchment, 162 Street Creek drains along the ALR boundary. Instream habitat value can be enhanced through the addition of channel meanders, wood and boulder structures.	High
7	*Add spawning gravels to creeks*	Spawning gravels and habitat were identified in Fleetwood and 162 Street Creek. Additional sites for gravel placement could be identified to promote the return of adult salmon to the catchment.	Low
8	*Stabilize banks, add meanders and plant native species in the lower reaches of North Creek*	The lower reaches of North Creek can be enhanced by increasing channel complexity by creating channel meanders, planting native shrub and tree species in the riparian area, and stabilizing stream banks using bioengineering techniques. Accumulation of fine sediment remains an on-going issue in this reach; enhancement plans should meet agricultural standards for ditch maintenance.	High
Off-Channel Habitat Creation			
9	*Create off-channel habitat and wetland habitat for over-wintering fry*	Off-channel habitat and wetland habitat is scarce in the North Creek catchment. Construction of off-channel habitat in the low-middle reaches of North Creek would provide shelter and rearing habitat for juvenile salmon.	High
Riparian Protection, Restoration and Planting			
10	*Enhance riparian corridor at south of Fleetwood Catchment*	Identified as a moderate value corridor (Corridor 80) in the Green Infrastructure Network, this corridor provides important habitat linkages for wildlife between Fleetwood Park and the Serpentine River corridor. To enhance the value of corridor, riparian habitat can be enhanced by planting native tree and shrub species, and controlling invasive species including reed canary grass. Steep slopes, saturated soils and private land ownership adjacent to the site may make access to for works difficult.	High
11	*Protect and/or convey riparian areas during re-development along Drinkwater Creek*	In order to better protect the riparian area of Drinkwater Creek and allow future enhancement activities to be undertaken, identify opportunities to convey land as it becomes available.	High
12	*Protect and/or convey riparian areas during re-development along 162nd Street Creek*	Intact forested areas adjacent to 162 Street Creek may be conveyed to the City during re-development. Forested cover in the Fleetwood Catchment is low and remaining opportunities to protect forested areas are a priority.	Medium
13	*Discourage access to 162 Street Creek from 80th Avenue*	Access to 162 Street Creek has degraded the riparian area of the creek. Access to the creek can be discouraged through the planting of native species and the installation of railings to create a visual barrier.	Low
14	*Create a forested riparian corridor adjacent to 176th Street*	Where North Creek, South Creek and St. Gelais Brook join and flow towards Fraser Highway has been identified as an important wildlife corridor in the Green Infrastructure Network (Corridor 140). A corridor on crown land could be enhanced between the Cloverdale Greenway and North Creek, with a possible widening of the buffer east of the creek in conjunction with private landholders. Native trees and shrubs could be established beside the trail to provide cover and shading to the stream, as well as increase the aesthetic value of the stream for trail users.	High
15	*Monitor erosion sites in North Creek ravine*	A number of erosion sites have been identified in the North Creek ravine with the potential to significantly impact North Creek and its associated fish populations. Sites should be monitored over time and when appropriate, erosion controls put in place.	High
16	*Protect and/or convey riparian areas along the lower reaches of St. Gelais Brook when opportunities become available*	Opportunities to protect the lower reaches of St. Gelais Brook should be explored to maintain and enhance a natural riparian corridor. Shrub communities could be established as well. The lower reaches of St. Gelais Brook are part of Corridor 143 in the Biodiversity Conservation Strategy.	Medium
17	*Remove garbage from North Creek*	Significant amount of garbage has accumulated in the middle and upper reaches of North Creek and could be removed.	Medium
18	*Plant coniferous tree species and remove invasive species from North Creek riparian area*	The riparian area of North Creek, centering around the pedestrian walkway at 180th Street, can be enhanced through plantings and invasive plant removals. Much of the forested area in the North Creek catchment is young deciduous forest; planting coniferous species will accelerate forest succession.	Low
Wildlife/Biodiversity Habitat and Corridors			
19	*Work with private landowners to enhance a wildlife corridor along the southern edge of the Fleetwood Catchment adjacent to the ALR lands between 160th Street and 161A Street Creek*	The enhancement of a 50m wide forested corridor along the ALR lands would provide important habitat linkages to the Serpentine River corridor. This corridor is identified as a moderate value in the Green Infrastructure Network (Corridor 80), but is fragmented by housing developments along 76th Avenue between Fleetwood Park and 161A Street. By working with private landowners, the corridor can be expanded and enhanced through plantings of native tree and shrub species.	Medium

Project ID[1]	Project Type	Description	Priority
20	*Enhance wildlife habitat through the creation of a wildlife refuge in Fleetwood Park*	Fleetwood Park is an important hub for wildlife with high ecological value identified in the Biodiversity Conservation Strategy. The creation of a wildlife refuge with restricted access would promote forest health and provide important habitat for wildlife with reduced disturbance. This work could be combined with the control of invasive species and underplanting with coniferous trees to speed up the succession of the young deciduous forest already present.	Low
21	*Establish hedgerow, shrub pockets and native grassland where possible along the right-of-way along St. Gelais Brook*	Although the ability to plant tree species in this area is limited, habitat can still be enhanced by creating shrub communities and hedgerows to improve wildlife usage and migration. Identified as Corridor 143 in the Biodiversity Conservation Strategy), this corridor connects the North Creek catchment to natural areas in the south.	Medium
22 (not shown)	*Increase forest cover throughout the catchment area*	The North Creek catchment has low overall and riparian forest cover. Promote backyard naturalization projects with landowners and identify locations owned by the City of Surrey.	Medium
Water Treatment Opportunities			
23	*Incorporate water quality treatment devices such as oil-grit separators along the Fraser Highway*	Runoff from large portions of the Fraser Highway could be treated with oil-grit separators located on the Fraser Highway at 162a St. and 168 St., 180 St., 182 St., and 185a St.	High
24	*Monitor temperatures at the detention pond in the headwaters of North Creek*	Water temperature can be monitored at the inlet and outlet of the stormwater detention pond in the headwaters of North Creek to better identify the source of high temperature water entering North Creek.	Medium

1. Project ID refers to environmental enhancement and protection sites identified in Figures 7-1 and 7-2.



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Ditch

Project Type

- Fish Passage Improvements
- Instream Habitat Complexing
- Riparian Protection, Restoration and Planting
- Wildlife/Biodiversity Habitat and Corridors
- Water Quality Treatment
- Locations for Water Quality Treatment
- Locations for Bank Stabilization / Erosion Protection

Note: Coloured numbers refer to project IDs in Table 7-7

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.
This information is not warranted as to its accuracy by Kerr Wood Leidal Associates. This information is provided for illustrative purposes only.

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Project No.	Date
471-288	June 2016

Fleetwood Greenway Environmental Enhancement and Protection Projects

Figure 7-2

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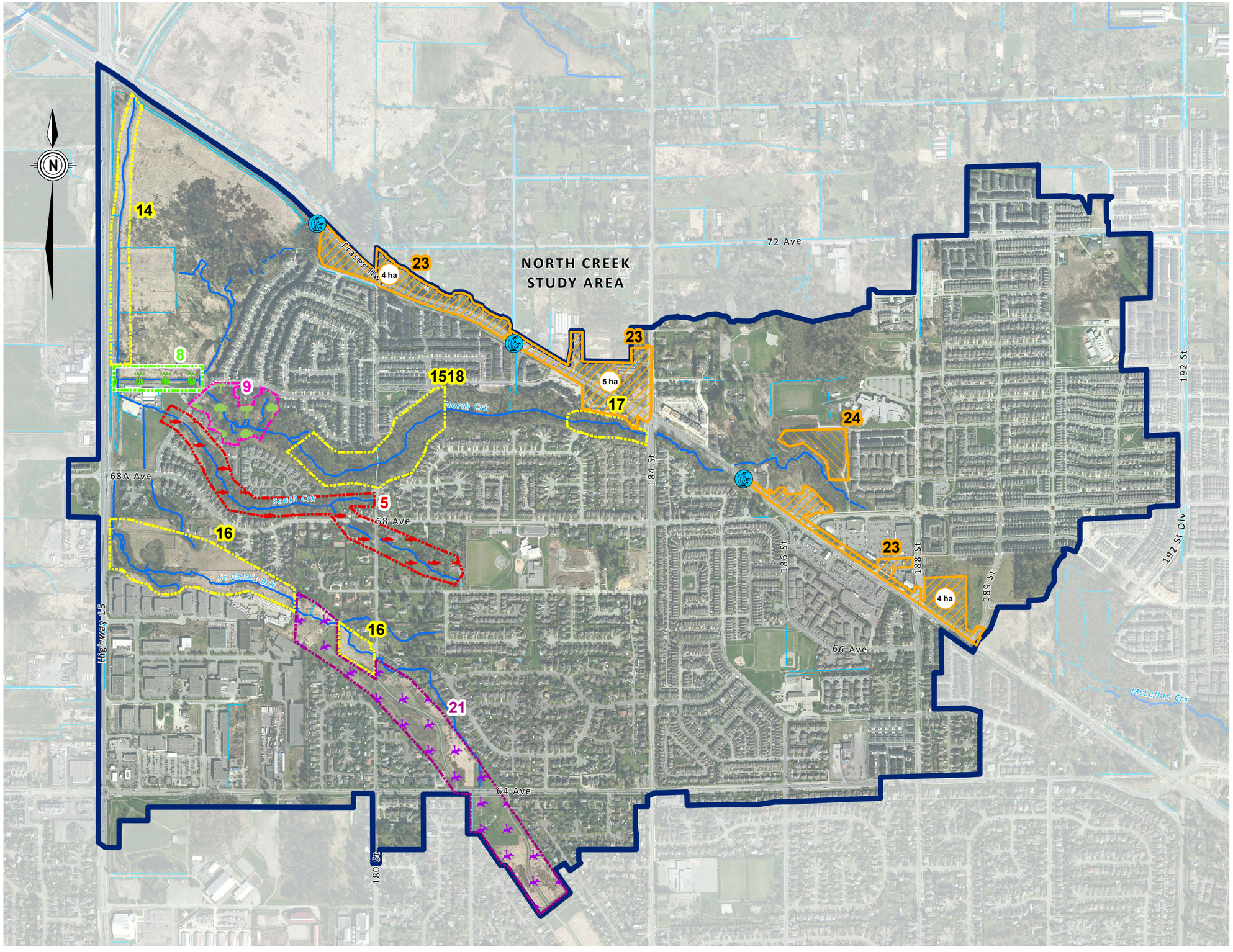

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Ditch

Project Type

- Fish Passage Improvements
- Instream Habitat Complexing
- Off-channel Habitat Creation
- Riparian Protection, Restoration and Planting
- Wildlife/Biodiversity Habitat and Corridors
- Water Quality Treatment
- Water Quality Treatment Locations

Note: Coloured numbers refer to project IDs in Table 7-7

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.
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Project No.	Date
471-288	June 2016

North Creek Environmental Enhancement and Protection Projects

Figure 7-3

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7.7 Potential Regional Water Quality Facilities

For areas that do not have source controls or do not meet the water quality treatment criteria, regional water quality facilities such as oil and grit separators should be considered.

Figure 7-1 and 7-2 show the location of potential regional water quality treatment facilities as part of environmental enhancements as the primary goal is environmental protection. The proposed locations could be structural treatment units (oil/grit separators), but there may also be opportunities to incorporate biofiltration BMPs in the re-development of the Fraser Highway corridor to treat the proposed catchment runoff. The re-development of the road corridor is a unique opportunity to mitigate and improve the environmental impact of the road along with the proposed incorporation of light rail in the corridor. Other cities including Portland, Oregon, and Minneapolis-St. Paul, Minnesota, have taken a similar opportunity to incorporate stormwater BMPs with light rail and road re-development projects.

Conceptual Image of Proposed Central Corridor Project, Minneapolis-St. Paul, Minnesota[2]

[2] By Kimley-Horn and Associates, Inc. http://www.arboretum.umn.edu/UserFiles/File/Water-Climate%20Summit/Mike%20Herman.pdf

7.8 Capital Cost Estimates and Funding Strategies

Cost Estimate Assumptions

The cost estimates for the proposed capital works is 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 that may affect construction:

- Relocation of adjacent services (water, hydro, etc.);
- Special permitting requirements (fisheries windows, contaminated sites, etc.);
- Geotechnical issues requiring special construction such as pile-supported piping, buoyancy problems or rock blasting; and
- Critical market shortages of materials.

Surveys and more detailed assessments of proposed capital works should be conducted prior to construction.

Capital Cost Summary

Flood Management

Costs for each priority are summarized in the table below. Detailed tables and figures are found in Appendix H.

Table 7-8: Storm Sewer Upgrades Capital Costs

Priority	Description of Upgrade	Estimated Timeline	Funding Source	Cost ($)
1	Major System, Flooding on Surface, Existing 100-Year Analysis (NONE)	0 – 5 years	City	$0
2	Minor System, Flooding on Surface, Two Incremental Dia. Or More Upgrade, Existing 5-Year Analysis	6 – 10 years	City	$1,570,000
3	Minor System, Flooding on Surface, One Incremental Dia. Upgrade, Existing 5-Year Analysis (NONE)	6 – 10 years	City	$0
4	Minor System, Surcharge >0.3 m for >15 min, Existing 5-Year Analysis	End-of-Life	City	$5,068,000
5	Major System, Undersized, Future Mitigated 100-Year Analysis **AND** Minor System, Undersized, Future Mitigated 5-Year Analysis	End-of-Life	City & DCCs	$3,532,000
Flood Management Capital Upgrades Program Total				**$10,170,000**

Erosion Management

No erosion sites were found that warranted immediate restorative action. The following projects are to manage potential creek erosion due to increased flows under future land use conditions. The location each project is shown on Figure 7-1. Detailed cost estimates are found in Appendix H.

Table 7-9: Erosion Management Capital Costs

Description of work	Timeline	Funding Source	Cost Allowance ($)
162 St. Creek Diversion	0 – 5 years	City & DCCs	$2,535,000
Fleetwood Creek Diversion	6 – 10 years	City & DCCs	$8,733,000
Erosion Management Capital Costs Total			**$11,268,000**

Environmental Protection and Enhancement

The following table summarizes environmental protection and enhancement projects that included sufficient information for a Class D cost estimate. Where possible, projects should be implemented in conjunction with infrastructure projects, upstream development, and as compensation for habitat loss.

Table 7-10: Environmental Protection and Enhancement Capital Costs

Location	Description of work	Cost ($)
Fish Passage Improvements		
162 Street Creek	Work with landowner to upgrade private twin culvert crossing on 162 Street Creek (~35m)	$2,470,000[a]
Drinkwater Creek	Remove debris blockage on Drinkwater Creek	Staff time
South Creek	Remove partial barriers due to logs/debris	Staff time
In-Stream Habitat Complexing		
162 Street Creek	Increase channel complexity along ALR boundary upland/lowland transition (~600m)	$120,000[b]
North Creek	Stabilize banks, add meanders and plant native species in the lower reaches of North Creek (~650m)	$130,000[b]
Off-Channel Habitat Creation		
North Creek	Create off-channel habitat and wetland habitat for over-wintering salmon fry (~4000 m^2)	$50,000[c]
Riparian Protection, Restoration and Planting		
162 Street Creek	Enhance riparian corridor at south of Fleetwood Catchment (~3.5 ha)	$420,000[d]
Drinkwater Creek	Protect and/or convey riparian areas during re-development.	Market land rates
North Creek	Create a forested riparian corridor adjacent to 176th Street (~3 ha)	$350,000[d]

Location	Description of work	Cost ($)
Water Treatment Opportunities		
Fleetwood and North Creek Catchments	Incorporate water quality treatment devices such as oil-grit separators along the Fraser Highway at five locations	$1,000,000[e]
Environmental Protection and Enhancement Capital Costs[f]		**$4,540,000**

[a] See Appendix H for detailed cost estimate.
[b] Based on unit rate of $200/m, and includes increasing density of large wood by ~2 pieces / 100 m
[c] Based on cost estimates provided in *Fish Habitat Rehabilitation Procedures* (Slaney and Zaldokas, 1996).
[d] Based on unit rate of $120,000/ha for invasive species removal, plant purchase and placement and maintenance.
[e] Based on unit rate of $200,000 per oil-grit separator .
[f] Does not include acquisition of land at market rates and staff time to remove fish passage barriers.

Funding Strategy

The following section discusses potential funding sources for the capital works, operations and maintenance and education strategies as recommended in the ISMP.

Developer/Development Cost Charges

As the watershed redevelops over time, funds can be collected from developers as part of meeting conditions of the ISMP. The engineering and construction costs are paid by the developer in implementing the solutions to meet the criteria.

The City of Surrey has used a system of Development Cost Charges (DCCs) since 1979 and the funds generated by DCCs are used to fund the costs to provide city services such as roads, drainage, water and sewer based on projected growth. These charges are to provide a way for the City to continue to expand without overloading the existing infrastructure. In addition to traditional "grey" infrastructure requirements, recommended improvements such as source controls and other green infrastructure can be considered in determining appropriate rates. Only items classified as an asset, such as storm sewers, culverts, bank stabilization, WQ treatment structures etc. can access DCC funds; general planting or aesthetic upgrades cannot. Recommended infrastructure upgrades include larger sized pipes to accommodate climate change and revised IDF information from the City of Surrey's 2016 Design Criteria Manual. Upgrades required for development may be allocated partially to DCC funding and partially to the City's capital funds for existing infrastructure.

Stormwater Utility

The City currently imposes a drainage parcel tax under *Bylaw No. 14593* for the entire municipality. The funds collected under the drainage parcel tax are used to construct and operate storm drainage systems. The tax is a flat fee and the rates are described in Schedule A of the bylaw; ranging from $216 to $309 per parcel per year (2016). These funds are used for stormwater projects in the City's Capital Plan to repair, replace, and upgrade stormwater infrastructure in accordance with identified priorities.

Some municipalities across Canada are looking into creating a utility for stormwater infrastructure. Currently, the City of Victoria is in the final process of implementing a new stormwater utility to fund the management of stormwater in the City. The first stormwater utility bills are set to be sent out in the fall of 2016. Instead of charging a flat fee, the City of Victoria is using impervious percentage as the main factor in determining the rate per parcel. By basing the fee on impervious percentage, it provides residents and businesses a practical reason to limit the amount of impervious surfaces on the site. It also creates the opportunity for incentives for residents and businesses to implement source controls.

Other Funding Sources

Building Canada Plan – Infrastructure Canada

The new Building Canada Plan will provide federal funds to provinces, territories, and municipalities over the next 10 years. The plan includes the Gas Tax Fund, giving municipalities greater flexibility to spend federal funding on a broader range of infrastructure priorities.

Additional information: http://www.infrastructure.gc.ca/plan/plan-eng.html

Green Municipal Fund – Federation of Canadian Municipalities

This fund provides funds for three types of environmental initiatives: plans, studies and projects. The funding is allocated into five sectors of municipal activity: brownfields, energy, transportation, waste and water. All municipal governments and their partners in eligible projects have access to the funding. Below-market rate loans usually combined with grants are available to implement capital projects.

Additional information: http://www.fcm.ca/home/programs/green-municipal-fund.htm

EcoAction Community Funding Program – Environment Canada

This program encourages completion of projects that will protect, rehabilitate or enhance the natural environment. The program supports projects that address the following:

- Clean air: to reduce emissions that contribute to air pollutants;
- Clean water: to divert and reduce substances that negatively affect water quality or to focus on water conservation and efficiency;
- Climate change: to reduce greenhouse gas emissions that contribute to climate change or to deal with the impacts of climate change; and,
- Nature: to reduce biodiversity loss, protect wildlife and plants, and protect and improve the habitat where they live.

The funding is available for non-government, non-profit groups and organizations.

Additional information: www.ec.gc.ca/ecoaction

Evergreen Foundation (multiple programs)

The RBC-Evergreen Watershed Champions Award

This grant provides funding for school programs designed to teach students in publicly funded schools about their local watershed or about water in the context of their local watershed. Classes that provide participation in other watershed or water based programs through local outdoor education centres, conservation authorities, community groups, non-profit organizations and/or government programs are also eligible to apply.

Additional information: http://info.evergreen.ca/en/watershed-champions/award

Toyota Evergreen Learning Grounds School Ground Greening Grants

The purpose is to help schools create outdoor classrooms to provide students with a healthy place to play, learn and develop respect for nature. This grant is available for publicly funded and accessible schools up to $3,500 for schools and $2,500 for daycares. Eligible expenses include: native plant species, heritage berries, vegetable seeds and plants, tools, materials and professional services.

Additional information: http://www.evergreen.ca/en/funding/grants-available/school-ground-greening-grants/

We Are Cities: Community Innovation Grant

This grant provides funding to support projects that address issues critical to the success of communities, including mobility, the built and natural environment, citizen engagement, multi-sectoral collaboration, policy design, waste management and energy. Grants of $2,000 and $5,000 are available to Canadian community groups and non-profit organizations to be used on publicly accessible lands. Eligible expenses include: native plant species, heritage berries, vegetable seeds and plants, tools, materials and professional services.

Additional information: http://www.evergreen.ca/get-involved/funding-opportunities/community-innovation-grant/

TD Friends of the Environment Foundation

Founded in 1990, the TD Friends of the Environment Foundation is a national charity that funds environmental projects across Canada. The unique organizational structure allows dollars donated in a community to be directly invested in environmental programs in that community. Grants are available for organizations such as:

- registered Canadian charities with a Charitable Registration Number (CRN);
- educational institutions (primary/secondary/post-secondary);
- municipalities; and
- aboriginal groups.

Eligible projects include:

- environmental education;
- tree plantings (native plant species);
- energy conservation;
- schoolyard or urban naturalization projects;
- community gardening programs;
- habitat restoration;
- endangered species/wildlife protection;
- environmental research.

Additional information: https://fef.td.com/funding/

8. Implementation and Adaptation of the ISMP

8.1 Approval Procedure and Enforcement Strategy

This section outlines the approval procedure and enforcement strategy for incorporating the ISMP requirements at time of development and re-development.

Departmental Responsibilities

It is important that all departments dealing with development and land use change permitting be aware of the requirements set forth in this ISMP to protect people, property, and the environment while allowing development to occur. Communication between departments is key. Appointment of an in-house Rainwater Management Champion to lead and facilitate interdepartmental communication, coordination and change would be useful. The following responsibilities have been identified:

Planning and Development

- Provide information for developers.
- Check that development plans and designs meet ISMP requirements.
- Inspect source controls during construction as part of the plumbing and lot grading inspections.
- Revise land use plans and council policies to incorporate wider (30m) riparian setbacks and to convey privately owned riparian areas to the City during re-development.

Engineering

- Implement drainage upgrades and erosion remediation as listed.
- Monitor watershed response to development as per the Adaptive Management Framework.
- Revise ISMP criteria/requirements to adapt to observed changes.
- Complete fish habitat and passage improvement projects as listed.
- Implement water quality treatment devices along Fraser Highway, and monitor water temperatures at the detention pond in the headwaters of North Creek as listed.

Environment and Sustainability

- Coordinate on and pursue habitat enhancement opportunities and integration with other projects.
- Protect and enhance riparian areas.
- Develop an invasive species removal program.

Parks, Recreation, and Culture

- Incorporate awareness, outreach, and education into public spaces.
- Provide examples and exposure for new initiatives.

Proposed Bylaw and Standards Changes

The City's current *Stormwater Drainage Regulation and Charges By-law, 2008, No. 16610*, makes it possible for the recommendations in ISMPs to form a part of the development criteria. The wording in this bylaw largely negates the need for bylaw changes or new bylaws. However, there are clauses in existing bylaws that may conflict with the requirements proposed in this ISMP and with the latest stormwater management methodologies. The following changes are proposed in the long term:

Design Criteria Manual

Many of the recommendations below are approaches that the City is already doing, but through other means such as the engineering drainage review process. These changes to the Design Criteria Manual are recommended to incorporate and consolidate design requirements, both to make the design and review process simpler for designers, and to make the review process easier and more streamlined for the City staff that review stormwater management plans.

1) Emphasize wording to require modifying culverts where needed to allow fish and wildlife passage. We understand this is currently done through the review process and this wording is incorporated in some neighbourhood plans, but it would help designers to have this concern included in the design guidance.

2) Add recommended stormwater criteria so that it is in the same place as the servicing design criteria. It is understood that this varies by watershed subject to the recommendations of individual ISMPs. A map of ISMPs to reference could be included in the Design Criteria Manual, as well as a table of stormwater criteria by watershed.

3) Expand the water quality criteria in the manual to include treatment targets for roads, in addition to the requirement for treatment of runoff from parking lots.

4) Revise the storage and rate control requirements to the 5-year, 2-year, and 6-month flows to pre-development levels. Typical "pre-development" release rates were developed for this ISMP (see Section 7.1) that may be able to be generalized to large sections of the City.

Building By-law, No. 17850, 2012

5) In addition to single family detached house, clarify that disconnection of roof leaders is permitted on all land uses, with proper consideration in the stormwater management plan for the site. Disconnecting roof leaders must take into consideration the downslope impacts and a hydrogeologist should be consulted in steep slope areas or where downslope seepage is a concern.

6) Changes are needed to the inspection procedure during development and construction currently noted in the *Building By-law, 2012, No. 17850*, to include the need for inspections of source controls, proper piping connections, overflows, etc. Specifically, the overflow elevations and pipe grading should be checked to confirm that they will facilitate proper site drainage. These changes must occur alongside training for the municipal inspectors as they may not be aware of the requirements and LID practices.

Riparian Area By-law (*new* in process at time of this work)

7) Revise zoning bylaws to incorporate wider (30m) riparian setbacks. The ISMP recommends 30m riparian setbacks for all creeks within the study area which may be wider than the setbacks required under the current Riparian Areas Regulation (RAR). To accommodate the extra width, zoning bylaws should designate the 30m buffer adjacent to the creeks as "Riparian Protection Area".

Property Maintenance and Unsightly Premises Bylaw, 2007, No. 16393

8) Explore public reception to incorporating wording to clarify that boulevard maintenance activities required under the bylaw include the maintenance of source controls such as rain garden weeding, watering, debris removal, etc. within the boulevard and on lot.

Enforcement Tools

To effectively enforce the ISMP vision, goals, criteria, and plan, the following tools are recommended:

- **Bylaws** – revise bylaws as noted above and enforce current bylaws. Minimize the granting of development variances that seek to reduce or eliminate BMPs.
- **Permits** – continue checking plans submitted by developers for conformance with bylaws and ISMP requirements. Utilize source control design/sizing checks (see Checklists section below).
- **Inspections** – confirm that approved designs are being implemented during construction. Check stormwater facilities, riparian setbacks, sediment and erosion control, etc. City inspectors may require training to inspect stormwater BMPs.
- **Maintenance** – Perform annual inspections of stormwater BMPs for commercial/industrial properties. Alternatively, require owner/tenant to obtain independent annual inspection by a professional to be submitted with business license renewal.
- **Monitoring** – Collect water quality and flow data on an ongoing basis to confirm that the minimum ISMP goal of no-net-loss is being achieved. Follow Metro Vancouver Adaptive Management Framework process (see Section 8.2 for additional information).

Checklists for Design and Maintenance

Checklists for ensuring that source controls are sized to meet the ISMP criteria that can be used by the Planning and Development Department during building permit and development permit applications have been developed and are included in Appendix I. There is a generic checklist and also source control specific checklists included.

A maintenance checklist to be used during and after construction is also included in Appendix I. In addition to this checklist, the following maintenance activities are recommended.

Inspection: The Fleetwood Greenway North Creek drainage systems should be inspected every 5 years during low flow conditions, ideally in the winter so that remediation of identified problems can be undertaken during the following summer dry 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 inspection should include all open channels, culverts, ponds, diversions, and flow splitters. An overall drainage system inspection should also be completed after large 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: Sand/silt accumulation in sumps, oil/grit separators, and catch basins is expected and should be removed every two years, ideally at the end of summer before the autumn rainy season.

Debris Control: Debris blockages at hydraulic structures can cause flooding problems. Annual inspection and regular debris removal (as required) from the ditches and culverts is necessary.

Wet Ponds: 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 excessive over growth that may reduce the flow capacity.

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 autumn, inspect overflow, hydraulic and structural facilities annually.

Education Strategy

The City of Surrey already engages in several educational programs that increase public awareness of environmental and habitat issues. The Salmon Habitat Restoration Program (SHaRP) and Surrey Natural Areas Partnership (SNAP) both employ post-secondary and high school students to continue habitat restoration, natural area preservation, water quality assessment, environmental education and outreach in the City. The programs are an excellent venue to educate business and community members about the possible negative environmental effects of stormwater and why integrated stormwater management is so important. The City should also continue to work with schools to encourage student involvement in stream clean-up, riparian planting, and other activities.

There are several other initiatives that the City of Surrey can start to educate the public and businesses on the importance of integrated stormwater management. These include:

- Continuing to hold workshops and forums that engage designers, architects and other professionals;
- Holding internal workshops to educate City Staff, coordinating with upcoming Metro Vancouver workshops if timing allows;
- Holding workshops for builders and developers;
- Creating a brochure to be handed out with building permits and development permit applications to explain the on-lot requirements for development in the watershed; and
- Setting up small booths at every public open house or other such event to help raise awareness about stormwater and environmental issues with the public. Generally the public is aware that stormwater can be damaging to a watershed, but are unaware of what they can do to help.

Further outreach could be achieved by creating a newsletter about restoration, environmental outreach or other management activities happening within the Fleetwood Greenway North Creek watersheds. This document could be posted on the City web-site or mailed to residents and businesses. The newsletter could highlight exemplary stormwater or environmental projects that are happening within the watersheds and could provide simple examples of measures that could be done by individual home owners or businesses to improve the stormwater quality or reduce the runoff volume leaving their properties. This could include items such as rain-barrels for water re-use, absorbent landscaping to reduce the quantity of runoff, and treatment options to improve water quality.

8.2 Monitoring Strategy

Condition 7 of the BC Minister of Environment's approval of Metro Vancouver's 2011 Integrated Liquid Waste Resource Management Plan (ILWRMP) requires that all municipalities, with coordination from Metro Vancouver, monitor stormwater to assess and report on the effectiveness of ISMP implementation. To fulfill this provincial requirement, Metro Vancouver and its member municipalities have developed a *Monitoring and Adaptive Management Framework for Stormwater* (MAMF) (Metro Vancouver, 2014). The MAMF takes a weight of evidence approach, using several types of monitoring and indicators to develop an overall assessment of watershed conditions. Through repeated sampling, watershed health and the response to specific watershed protection measures and management actions can be tracked over time.

The MAMF provides direction on the general types of monitoring for higher gradient, lower gradient, and piped systems (Table 8-1), the methods and parameters to be used for monitoring and the reporting required.

Table 8-1: Standard MAMF Monitoring Program Elements Based on Stream Type

Stream Type	Water Quality	Hydrometric	Benthic Invertebrates
Lower Gradient	Yes	Yes (natural channels only)	Yes
Higher Gradient	Yes	Yes	Yes
Piped Systems	Yes	No	No

Based on the MAMF, most of the creeks within the study area are classified as higher gradient streams (average channel slope >1%), although many have significant piped systems as headwater areas. For higher gradient streams, water quality, hydrometric, and benthic invertebrate monitoring is recommended with at a minimum frequency every five years.

Monitoring Framework

Table 8-2 provides a recommended monitoring framework for the ISMP to track the impact of development and redevelopment, as well as the influence of stormwater management activities on creek health in the Fleetwood and North Creek catchments. The core monitoring parameters, based on MAMF requirements, can be grouped into three categories:

- Water quality monitoring indicators;
- Flow monitoring indicators; and
- Benthic invertebrate biomonitoring indicators.

Several additional performance indicators have been included in a fourth category to provide a more comprehensive assessment of watershed health and ISMP implementation over time. The table also contains methods of data collection and analysis, indicates priority for measurement (primary or secondary parameter classification), identifies baseline data availability and sets short- and long-term targets for trends in water quality parameters.

Table 8-2: Monitoring Framework for Fleetwood Greenway North Creek ISMP

Parameter	Method of Data Collection/Analysis	Indicator Type	Baseline Data Available?	Short-term Trend/Target	Long-term Target
WATER QUALITY MONITORING INDICATORS					
General Water Quality Parameters					
Water Temperature	Continuous water quality monitoring or grab sampling following MAMF protocols	Primary	Y	Stable or decreasing	<16 °C (low flow summer) 7–12 °C (wet weather fall/winter)
Dissolved Oxygen		Primary	Y	Stable or increasing	≥6.5 mg/L
Turbidity		Primary	Y	Decrease	≤ 25 NTU
Conductivity		Secondary	Y	No increase	≤ 200 µS/cm
pH		Secondary	Y	Neutral pH	6.5–9.0
Nutrients					
Nitrate (as Nitrogen)	Grab sampling following MAMF protocols	Primary	N	Decrease	See MAMF
Microbiological Parameters					
Escherichia coli	Grab sampling following MAMF protocols	Primary	N	Decrease	See MAMF
Fecal Coliforms		Primary	N	Decrease	See MAMF
Metals					
Total Iron	Grab sampling following MAMF protocols	Primary	N	Stable or decreasing	See MAMF
Total Copper		Primary	N	Stable or decreasing	See MAMF
Total Lead		Primary	N	Stable or decreasing	See MAMF
Total Zinc		Primary	N	Stable or decreasing	See MAMF

Parameter	Method of Data Collection/Analysis	Indicator Type	Baseline Data Available?	Short-term Trend/Target	Long-term Target
Total Cadmium		Primary	N	Stable or decreasing	See MAMF
FLOW MONITORING INDICATORS					
MAD (L/s)	Flow monitoring and analysis following MAMF protocols		Y	-	-
TQ_{mean}			Y	Stable or increasing	Same as short-term
Low Pulse Count			Y	Stable or decreasing	Same as short-term
Low Pulse Duration (days)			Y	Stable or increasing	Same as short-term
Summer Baseflow (L/s)			Y	Stable	Same as short-term
Winter Baseflow (L/s)			Y	Stable or increasing	Same as short-term
High Pulse Count			Y	Stable or decreasing	Same as short-term
High Pulse Duration (days)			Y	Stable or increasing	Same as short-term
BENTHIC INVERTEBRATE BIOMONITORING INDICATORS					
B-IBI Score	Benthic invertebrate sampling following MAMF protocols	Primary	Y	Stable or increasing	
Total Taxa Richness		Primary	Y	Stable or increasing	
ADDITIONAL PERFORMANCE INDICATORS					
No. of Erosion Sites	Air photo interpretation and GIS-based analysis	Secondary	Y	Stable or decreasing	
TIA (% of Watershed Area)	Air photo interpretation and GIS-based analysis	Secondary	Y	-	
EIA (% of Watershed Area)	GIS-based analysis and hydrologic/hydraulic modelling	Secondary	Y	Stable or decreasing	

Parameter	Method of Data Collection/Analysis	Indicator Type	Baseline Data Available?	Short-term Trend/Target	Long-term Target
RFI (% of Riparian Area)	Air photo interpretation and GIS-based analysis	Secondary	Y	Stable or increasing	
Fish Populations	Spawner counts from creek walks	Secondary	N	Stable or increasing	
Fish Passage Barriers	Updates to inventory when restoration projects completed	Secondary	Y	Decreasing	No human-made fish passage barriers
MAMF = *Monitoring and Adaptive Management Framework for Stormwater* (Metro Vancouver, 2014).					

Proposed Monitoring Program

The proposed monitoring program focuses on answering two essential questions:

1. Is development/redevelopment negatively impacting the ecological health of creeks?
2. Are stormwater management activities resulting in no-net-loss of the overall health of the creeks?

Monitoring Program Components

Based on the above monitoring framework, the proposed monitoring program includes a mix of existing and new monitoring program components. Existing continuous flow, water quality, and benthic invertebrate monitoring already occurring at sites in the ISMP area should be continued. In addition to their ongoing usefulness in adaptive management during ISMP implementation, the significant baseline of data from these sites can be used to more clearly identify long-term trends and changes in stream health.

In addition to the existing monitoring, the following additions to the overall monitoring program are also recommended:

- Add continuous temperature monitoring in the North Creek catchment to monitor impacts of stormwater detention pond and the status of water temperatures in the primary coho rearing habitat reach of the creek. Temperature monitoring stations should be established at each inlet to the detention pond as well as upstream of 177 St. This recommendation was included in the findings of the North Creek water quality data analysis conducted as part of the ISMP.
- Implement water quality grab sampling following MAMF protocols at three sites as per City's existing plans. First sampling is scheduled for summer/fall 2018 and every four years thereafter.
- Add fourth MAMF water quality grab sampling site at the stormwater outfall on the west side of 168 St, south of 76 Ave. for 166 St. Creek. This site captures most of the Fraser Highway corridor in the Fleetwood catchment, an area expected to be re-developed when light rapid transit is added along Fraser Highway to Langley. As significant stormwater management improvements have been recommended for this area, this monitoring will provide useful data on the performance of these improvements. It also complements other existing stream monitoring sites, which are more representative of the watersheds as a whole. As this is a piped system, only water quality sampling is recommended for this site.
- Conduct annual erosion monitoring for high priority unstable ravine sites, such as the North Creek ravine. Slope instability and existing failures observed during the ISMP suggest that regular checks and re-assessment of risks are required.
- Conduct desktop monitoring of changes in total impervious area, effective impervious area (EIA), and riparian forest integrity (RFI) from aerial photos and GIS-based analysis. This could be implemented on a City-wide basis for all of the City's ISMPs.
- Conduct salmon spawner counts for salmon in 162nd Street Creek and North Creek annually.

Table 8-3 summarizes the proposed monitoring program for the Fleetwood and North Creek catchments, including both the existing and newly proposed components.

Table 8-3: Proposed Monitoring Program for Fleetwood Greenway North Creek ISMP

Program Component	Parameters	Site(s)	Minimum Sampling Frequency	Recommended Implementation Approach
Continuous Flow Monitoring	Level Discharge	North Creek downstream of Fraser Highway	Ongoing – 15 minute intervals	Continue as part of existing City-wide program
Continuous Water Quality Monitoring	Water temperature Dissolved oxygen Turbidity Conductivity pH	North Creek downstream of Fraser Highway	Ongoing – 15 minute intervals	Continue as part of existing City-wide program
Continuous Temperature Monitoring	Water temperature	2 sites: (1) Major inlets to large stormwater detention pond (2) North Creek upstream of 177 St	Ongoing – 15 minute intervals	New
Water Quality Grab Sampling	Nutrients Microbiological parameters Metals	4 sites: (1) 162 Street Creek downstream of 80 Ave (2) North Creek at Fraser Highway (3) Drinkwater Creek at 172nd Street (4) 168 Street outfall north of 76 Ave	Once every 4 years – 5 times in 30 days in dry and wet seasons as per MAMF protocols	New, sampling planned to begin in 2018 as part of newly initiated City-wide program Add additional monitoring site (168 St outfall) for Fraser Highway corridor re-development area (piped system)
Benthic Invertebrate Monitoring	Taxa richness B-IBI scores	3 sites: (1) 162 Street Creek downstream of 80 Ave (WA1) (2) North Creek upstream of Fraser Highway (N1) (3) North Creek downstream of 180 St footbridge (N2)	North Creek sites: Biannually – spring and fall 162 Street Creek site: Annually – spring only	Continue as part of existing City-wide program
Ravine Stability Assessments	Erosion locations Hazard-consequence ratings	High priority: North Creek Lower priority: other creeks	Ongoing	Continue as part of existing City-wide program
GIS Land Use / Change Analysis	Total Impervious Area (TIA) Effective Impervious Area (EIA) Riparian Forest Integrity (RFI)	Whole watershed	Every 5 years	New, consider undertaking as part of regular City-wide analyses for all ISMPs
Salmon Spawner Surveys	No., species, and locations of spawners	2 reaches: 162 Street Creek North Creek	Annually	New

8.3 Adaptive Management

Maintaining and enhancing the ecological health of a watershed is best achieved through adaptive management. Using an adaptive management approach for ISMP implementation allows for regular feedback on the effectiveness of measures recommended in the ISMP such that informed decisions can be made about future measures based on whether watershed goals are being achieved. In cases where existing measures are not achieving results, changes can be made to improve their effectiveness, or new measures can be taken. Monitoring also allows assessment of progress towards the plan's goals and reporting to decision-makers, stakeholders, and the public. Adaptive management is also recommended to ensure improvements in watershed health are achieved in the most cost-effective manner.

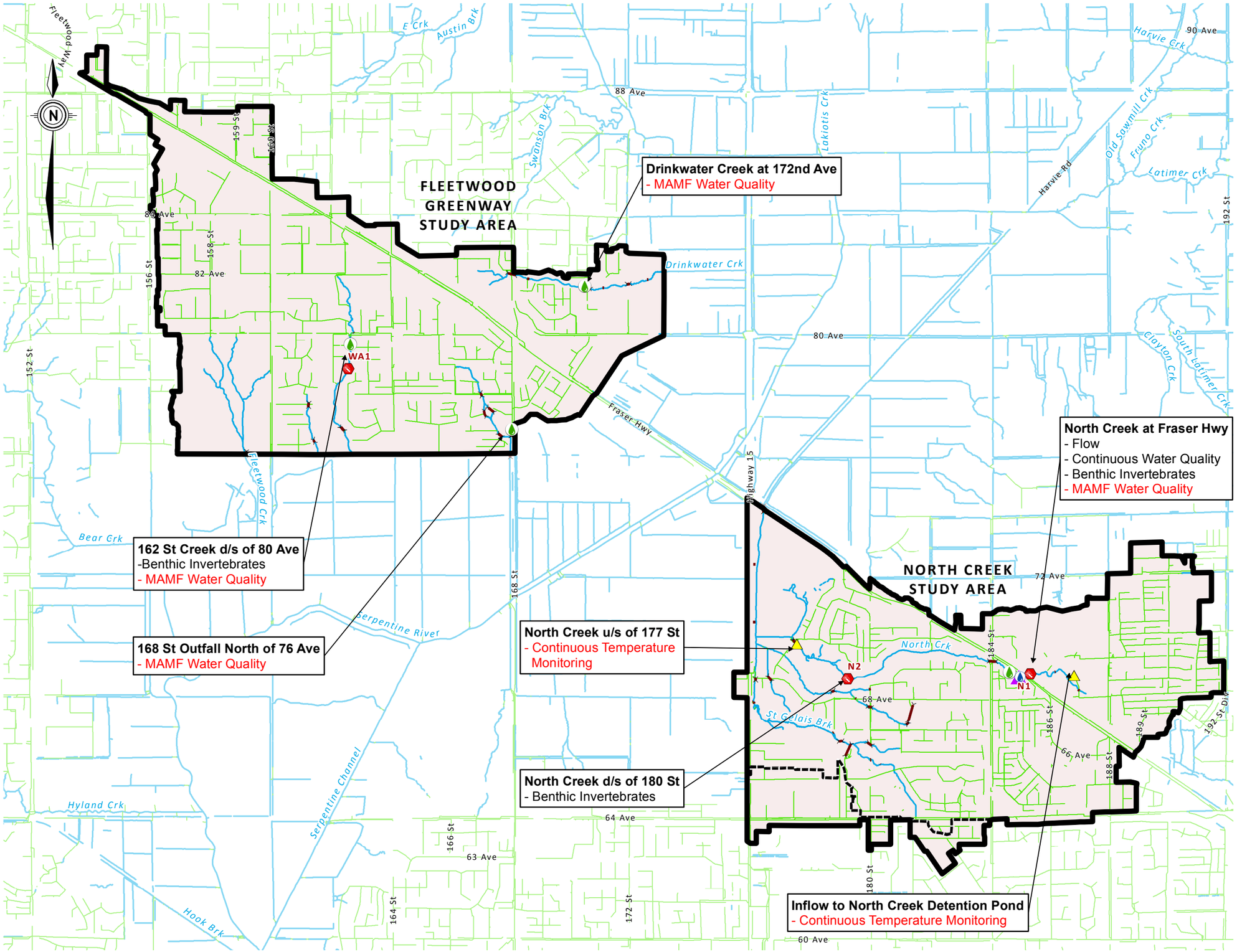
Within the MAMF, measures taken to mitigate the impacts of land development on watershed health are defined as Adaptive Management Practices (AMPs). These include measures under a variety of functional categories such as source controls, runoff detention and infiltration facilities, runoff pollution control, runoff treatment, outreach and education, and mitigation of construction impacts. The iterative process of carefully collecting, analyzing, and interpreting data will allow for the effectiveness of these AMPs to be assessed, and if not achieving the desired results, to change measures or to target different priority areas. The process requires both proper planning but also flexibility as stormwater management practices and knowledge evolve over time and new technologies are introduced.

The basis for adaptive management is long-term monitoring of the indicators listed in the proposed monitoring plan described above. If the monitoring results indicate issues in aquatic health, previously implemented AMPs should be re-evaluated or new, more appropriate AMPs should be implemented to mitigate the problem. Analysis of monitoring data should occur on a regular basis. The indicators selected in the monitoring program do not all have to move in a particular direction to show improvement or degradation in watershed health. The full suite of indicators should be reviewed in regular cycles to:

- Note changes or trends in particular indicators;
- Evaluate possible causes of those changes;
- Determine if changes in the indicators represent an impact;
- Evaluate if observed changes are expected or unforeseen; and
- Review the goals, elements, and implementation plan of the ISMP to assess if changes should be made to the plan to remain on track and achieve the overall stormwater goals over the implementation timeline for the ISMP.

The collection of data and its full review (listed above) for the watershed health indicators should be conducted once every five years (four full reviews during the 20-year expected implementation timeline). After the implementation period is complete, monitoring should continue once every five years.

As recommended in the MAMF, rather than preparing an adaptive management plans for each ISMP, it is recommended that municipalities prepare a single Adaptive Management Plan on a municipal-wide basis. As City of Surrey will have soon completed ISMPs for all of its watersheds and has several City-wide monitoring programs and datasets, the City is an excellent position to develop such as a plan. This City-wide Adaptive Management Plan can be used to prioritize among both watersheds and issues, identify and address the highest priority issues first, and ensure the efficient utilization of City resources.



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Existing Storm Main
- Culvert

Monitoring Sites

- MAMF Water Quality
- Continuous Temperature Monitoring
- Continuous Water Quality Monitoring Station
- Flow Monitoring Station
- Benthic Invertebrates (with Site Code)
- ABC New Monitoring Highlighted in Red

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

KERR WOOD LEIDAL
consulting engineers

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Project No.	Date
471-288	April 2016

Monitoring and Adaptive Management Plan

Figure 8-1

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9. Recommendations from the ISMP

Based on the above report, it is recommended that the City:

a. Adopt proposed stormwater criteria for Fleetwood Greenway North Creek watersheds and educate developers on bylaws, policies and procedures;

b. Require 450 mm of absorbent topsoil on all pervious areas and grading of impervious areas to pervious areas for single family residential lots;

c. Require source controls on multi-family residential, commercial, institutional and industrial development and roads;

d. Install regional water quality facilities such as oil and grit separators at outfalls for areas where water quality criteria are not met on site via source controls in upstream catchment;

e. Develop schedule to construct Priority 2 upgrades within the next 6 to 10 years, lower priority upgrades can be upgraded at end of design life or during redevelopment;

f. Develop schedule to construct recommended diversion projects within the next 10 years;

g. Continue monitoring erosion sites on an annual basis;

h. Initiate environmental restoration and enhancement projects, including fish passage improvements as shown on Figure 7-2 and Figure 7-3.

i. Monitor watershed health and adapt stormwater approaches as necessary to maintain watershed health over long term.

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the CITY OF SURREY for Fleetwood Greenway North Creek Integrated Stormwater Management Plan. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

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Revision History

Revision #	Date	Status	Revision	Author
1	June 2016	Final	Final Report	SS

Appendix A – Background Information

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Table A-1: Background Reports 1

Appendix A – Background Information

A Background Information

A.1 Background Information

The available background reports are summarized in the following table.

Table A-1: Background Reports

Year	Report Title	Author
2016	Design Criteria Manual	City of Surrey Engineering Department
2015	Upper Serpentine Integrated Stormwater Management Plan	Urban Systems
2015	Lower Bear Creek Integrated Stormwater Management Plan	Parsons
2014	2014 - 2023 Ten year Servicing Plan	City of Surrey Engineering Department
2014	Fleetwood Functional Plan Update - Memo 1	Kerr Wood Leidal
2014	Fleetwood Functional Plan Update - Memo 2	Kerr Wood Leidal
2014	Updated IDF Statistics for the City of Surrey	Dillon
2014	Official Community Plan	City of Surrey
2014	Biodiversity Conservation Strategy	Diamond Head Consulting
2013	Rainfall IDF Data	Dillon
2013	2013 City of Surrey Benthic Invertebrate Sampling Program	Raincoast Applied Ecology
2012	Clayton ISMP	AECOM
2012	2012 City of Surrey Benthic Invertebrate Sampling Program	Raincoast Applied Ecology
2011	2011 Ravine Stability Assessment	Web Engineering
2011	Cloverdale McLellan Integrated Stormwater Management Plan	Delcan
2010	Analysis of Streamflow, Water Quality, and Benthic Community Changes in North Creek (1999-2009)	Raincoast Applied Ecology
2009	Fleetwood Master Drainage Plan Review	Delcan
2009	2009 Ravine Stability Assessments	Web Engineering
2008	Upland Cloverdale Drainage Review	Stantec
2006	East Clayton Sustainable Development Stormwater Strategy Evaluation Monitoring Report	Kerr Wood Leidal
2005	Fleetwood Groundwater Development	Piteau Associates
2005	Fleetwood Groundwater Supply Control Model Development of Operating Strategy	Kerr Wood Leidal

Appendix A – Background Information

Year	Report Title	Author
2005	Fleetwood Well Water Quality	Dayton & Knight
2005	Exploratory Drilling, Fleetwood Booster Station, Surrey	Piteau Associates
2005	East Clayton Sustainable Development Stormwater Strategy Evaluation Annual Report No. 2	Kerr Wood Leidal
2004	Drainage Assessment of 56B Avenue and 188 Street	McElhanney
2004	Design Criteria Manual	City of Surrey Engineering Department
2003	Benthic Invertebrate Data - East Clayton Watercourses (2001 - 2002) and Surrey Lake (2002)	Dillon
2002	Surrey Ravine Stability Assessment	Urban Systems
2000	Fleetwood Pump Station Performance Review	UMA
2000	Fleetwood Town Centre Land Use Plan and Urban Design Concept Plan	City of Surrey Planning and Development
2000	North Cloverdale Community Detention Pond O&M Manual	New East Consulting
2000	Cloverdale Top-of-Bank Survey and Fish Habitat Assessment	Dillon
1999	North Cloverdale Pump Station Functional Plan - Final Report and Photo Inventory	Stantec
1999	Proposed Fish Habitat Compensation Package: Greenway Wetland Stormwater Detention Facility	Dillon
1999	Clayton MDP	Dillon
1998	Fleetwood Drainage Service Plan	Reid Crowther
1998	Fleetwood Drainage Service Plan 1998 Report on Opportunities and Constraints	Reid Crowther
1997	North Cloverdale Community Detention Facility Drainage Design Post Construction Flow Monitoring	New East Consulting
1997	Hydrogeological Assessment for the Clayton Neighbourhood Concept Plan	Dillon
1997	Clayton Area Neighbourhood Concept Plan	Environmental Report
1996	Greenway Feasibility - Functional Plan Technical Appendix	Reid Crowther
1996	Greenway Wetland Project Preliminary Design Report	Dillon
1996	Upper Serpentine, Fleetwood and Greenway Basin Master Drainage Plan	IDG / Duncan & Associates
1996	North and West Cloverdale Master Drainage Plan	UMA
1995	Cloverdale Canal Hydraulic Analysis	Associated Engineering

Appendix A – Background Information

Year	Report Title	Author
1994	Biophysical Assessment of Fleetwood Creek, Surrey, B.C.	ECL Envirowest Consultants
1994	Biophysical Assessment of Three Unnamed Streams in the East Fleetwood Area of Surrey, B.C.	ECL Envirowest Consultants
1994	Biophysical Assessment of Two Unnamed Tributaries to the Serpentine River	ECL Envirowest Consultants
1993	Fleetwood Park Drainage Pump Station	Associated Engineering
1993	Advance Design Fleetwood Park Drainage Catchment	Associated Engineering
1985	The Serpentine River Watershed Salmonid Resource Studies	D.C. Backman and T.L Simonson
1981	Fleetwood-Guildford Phase II Drainage Study	Aplin & Martin
1978	Fleetwood-Guildford Development Area Stormwater Control System Preliminary Design Report	Sigma Resource Consultants

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Appendix B – Engineering Field Inventory

B.1 Engineering Field Inventory

KWL undertook drainage inventory survey activities in February and March of 2015. The scope of work covered all major streams in the Fleetwood Greenway and North Creek study areas (Fleetwood Creek, 161A Street Creek, 162 Street Creek, 166 Street Creek, Drinkwater Creek, North Creek, South Creek, Street Gelais Brook).

The purpose of the survey was to supplement the City of Surrey's existing geographic information system (GIS) database by locating, photographing and assessing the following features along each stream:

- Hydraulic structures and stormwater outfalls;
- Significant bank or channel erosion sites; and
- Channel obstructions.

The terms left and right in this report refer to the left and right side of the creek channel when looking downstream.

Equipment

Features and observations were positioned and recorded using an Apple iPad with mapping grade GPS receiver and ArcGIS Online field data collection software.

All inventory features were photographed with the iPad's digital camera. Photographs were cross referenced to the GPS position and other observations within the field data collection software.

Coordinate System

The coordinate system used for this survey is Universal Transverse Mercator (UTM) Zone 10 North, North American Datum of 1983.

Data Structure

The photographs and GPS positions associated with each feature were combined with additional field observations and measurements to produce a fully cross referenced database. The data collection structure used for this project is summarized below:

Culvert

Material	(CMP, concrete, PVC, etc.)
Diameter	(mm)
Shape	(round, box, etc.)
Headwall	(type)
Headwall Condition	(good, fair, damaged)
Barrier/Trash Rack	(yes/no)
Debris Present	(yes/no)
Maintenance Required	(yes/no)
Maintenance	(type)
Condition	(good, fair, damaged)
Comment	(additional notes or comments)

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Outfall

Location	(left bank, mid-channel, right bank)
Diameter	(mm)
Material	(CMP, concrete, PVC, etc.)
Condition	(good, fair, damaged)
Energy Dissipation	(type)
Headwall	(type)
Headwall Condition	(good, fair, damaged)
Outlet Drop	(from invert of culvert down to creek bed)
Sediment Depth	(from invert of culvert up to creek bed)
Comment	(additional notes or comments)

Bridge

Type	(road, footbridge, etc.)
Length	(along direction of flow)
Thickness	(from bottom chord of bridge up to deck)
Comment	(additional notes or comments)

Erosion

Location	(left bank, mid-channel, right bank)
Hazard	(low, moderate, high)
Consequence	(low, moderate, high)
Length	(along direction of flow)
Depth	(height of eroding bank, or depth of eroded channel)
Comment	(additional notes or comments)

Deposition

Location	(left bank, mid-channel, right bank)
Length	(along direction of flow)
Width	(across channel)
Vegetated	(yes/no)
Comment	(additional notes or comments)

Bank Protection

Location	(left bank, mid-channel, right bank)
Type	(riprap, wall, gabions, etc.)
Length	(along direction of flow)
Height	(vertically from creek bed to top of bank protection)
Condition	(good, fair, poor)
Comment	(additional notes or comments)

Channel Obstruction

Type	(natural, anthropogenic)
Drop	(change in creek bed elevation from upstrm. to dnstrm. side of obstruction)
Sedimentation	(yes/no)
Stability	(low, moderate, high)
Fish Passage Obstacle	(weir, waterfall, etc.)
Comment	(additional notes or comments)

Confluence

Bank	(bank on mainstem stream from which tributary stream enters)
Comment	(additional notes or comments)

Appendix B – Engineering Field Inventory

Observed Sites

Orthophotos and GIS data showing storm water collection systems, outfalls, streams and road crossing locations were provided by the City and used as background information to plan and carry out field investigations.

GIS layers were created for obstructions, erosion, bridges, culverts and outfalls observed during the field inspection.

The erosion GIS layer contains the locations of observed erosion sites, the severity of the erosion, the length, width, and height of the erosion, and comments or observations of the erosion and causes. See Table B-1 and Figure 3-1 and 3-2 in the main body of the report.

The obstructions GIS layer contains the type of obstruction, the location of the obstruction, whether the obstruction is a hydraulic barrier in the stream and comments or observations for each obstruction. See Table B-2 and Figure 3-3 and 3-4.

The culverts, bridges, and outfalls GIS layers contain the location, material, condition and comments on the condition of the structures. These are summarized in Tables B-3 to B-5 and Figures 3-5 to 3-8.

Erosion Risk Assessment

The relative risk assessment completed as part of this field inventory was based on the observations of the site made during fieldwork. Erosion sites were identified and assigned a relative severity level based on a visual assessment that took into account the following parameters, where they could be observed:

Hazard: based on the measured height of visible scour or slippage.

- Low: height of erosion < 0.3 m;
- Moderate: height of erosion from 0.3 to 1.2 m; and
- High: height of erosion > 1.2 m.

Consequence: based on the proximity of manmade features (sheds, fences, buildings, retaining structures, etc.) to the eroding bank

- Low: setback > 10 m;
- Moderate: setback between 5 m and 10 m; and
- High: setback < 5 m.

Note that these criteria are not the same as the criteria used in the City's bi-annual ravine assessments.

Hazard and consequence were evaluated independently of one another at each site. Consequently, an area of minor erosion with structures in close proximity could receive a low hazard, but a high consequence rating. Conversely, major erosion sites in undeveloped areas with no apparent risk to habitat, property or public safety may receive a high hazard but low consequence rating.

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A matrix was developed to evaluate erosion risk based on the hazard and consequence ratings. This is presented in Table B-1 below.

Table B-1: Erosion Risk Ratings

	Hazard		
Consequence	**High (> 1.2 m)**	**Moderate (0.3 m to 1.2 m)**	**Low (< 0.3 m)**
High (>10 m)	High	High	Medium
Moderate (5m to 10 m)	High	Medium	Medium
Low (> 10 m)	Medium	Low	Low

The 2015 KWL field inventory identified a total of 253 erosion sites in the Fleetwood Greenway and North Creek streams and tributaries. Based on the information collected during the fieldwork, 17 high risk sites were identified, 61 medium risk, and 175 low risk. Risk ratings for each erosion site are included in Table B-2.

Sites Requiring Further Monitoring

A number of erosion sites were identified as being high risk, but as their locations are away from property or infrastructure, they may not warrant repair. Additional high risk sites are encroaching on infrastructure, but do not require immediate restorative action. Most of these sites, shown in Figure B-1 and B-2 below, were either newly identified or were given higher risk ratings than previous years and should be monitored regularly to ensure they do not threaten infrastructure.

Table B-2: Field Inventory - Observed Erosion Sites

Erosion Observations											
Object ID	Site ID	Location	Hazard	Consequence	2015 Risk	2011 Risk	2009 Risk	Length	Height	2009/2011 Site ID	Comments
1	EROS_1	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	1m	New	
2	EROS_2	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	0.8m	New	Erosion undercutting bank and exposing fines/cobble
3	EROS_3	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1m	New	
4	EROS_4	LEFT BANK	HIGH (>1.2m)	MODERATE (5-10m)	HIGH	NEW 2015	NEW 2015	7m	3m	New	Erosion occurring almost to top of bank
5	EROS_5	RIGHT BANK				NEW 2015	NEW 2015			New	
6	EROS_6	LEFT BANK	HIGH (>1.2m)	MODERATE (5-10m)	HIGH	NEW 2015	NEW 2015	8m	2m	New	
7	EROS_7	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3	New	Bank undercut and failing
8	EROS_8	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1.2	New	Not increasing currently, high water will affect this erosion
9	EROS_9	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	1.5	New	LWD blockage DS
10	EROS_10	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	8m	4m	New	
11	EROS_11	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	1m	New	Eroding side slope and undercut
12	EROS_12	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	7m	.4	New	Undercutting of bank
13	EROS_13	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	8m	.5m	New	Scouring and undercutting of the left bank
14	EROS_14	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	7 m	2.5m	37-18	Doesn't appear too much more severe, erosion is approaching a shed on Pvt ppty
15	EROS_15	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10	.3m	New	New erosion, undercut bank of minor concern, houses back onto creek >10 m away
16	EROS_16	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1m	New	Erosion from water going over/around obstruction
17	EROS_17	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4m	1.5m	New	Erosion heading for the back of pvt lots
18	EROS_18	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1m	New	
19	EROS_19	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	10m	1m	37-10	Erosion has moved past rock armoured section some rock failing and falling out of place
20	EROS_20	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.2m	New	Low risk but worth monitoring
21	EROS_21	RIGHT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	3m	1.8m	New	Erosion due to adjacent obstruction
22	EROS_22	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15 m	.3 - .4 m	New	Extensive undercut of both banks, incised up to .3 m in some spots
23	EROS_23	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10+m	.3m	New	Undercut both sides
24	EROS_24	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4m	1m	New	Due to location of outfall. Erosion undercutting tree rootball.
25	EROS_25	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	.5m	New	Undercut banks
26	EROS_26	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	1m	New	
27	EROS_27	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	1m	New	Undercutting several large trees
28	EROS_28	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	10m	1m	37-4	Ref 37-4. Banks eroding vertically underneath footbridge on trail in walnut park
29	EROS_29	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.4m	New	
30	EROS_30	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	5m	.5m	37-5	Doesn't appear to be progressing refer to 2011 report item 37-5
31	EROS_31	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	3m	1m	37-5	Refer to 37-5. Tree in photo may fall as a result of continued erosion
32	EROS_32	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	30m	1m	New	May begin to undermine nearby trees if erosion continues
33	EROS_33	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	MEDIUM	LOW		1m +	37-6	Continuous erosion along right bank from previous erosion point. Failing bank is approaching and undermining root wads along the entire length of the feature
34	EROS_34	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	7m	1m	New	Bank protection failing as bank erodes almost no remaining protection
35	EROS_35	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10m	0.6m	New	Nearby driveway on L bank
36	EROS_36	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	6m	1.5m	New	Erosion is adjacent to a driveway
37	EROS_37	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	7m	0.3m	New	Toe erosion along bank
38	EROS_38	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	15m	1.5m	38-3	Significant undercut including large portions of root ball refer to 38-3
39	EROS_39	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	See next erosion point (40)		New	
40	EROS_40	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015		1m	New	End of particularly bad erosion both banks
41	EROS_41	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4 m	1.5m	New	
42	EROS_42	RIGHT BANK	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	MEDIUM	LOW	8m	0.6m	38-4	Same as 38-4
43	EROS_43	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	.5	New	
44	EROS_44	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	25m	.6m	New	Erosion continues along both banks up and down stream
45	EROS_45	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4m	1.5m	New	Major undercut Impacting Doug fir root
46	EROS_46	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	1m	New	
47	EROS_47	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	0.8m	New	Immediately downstream of outfall
48	EROS_48	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015		0.5m	New	Ditch down cutting into muddy clay substrate and over steepening banks
49	EROS_49	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m+	.5m	New	Erosion continues through soft substrate along both banks, in places trees have been undercut and fallen into creek
50	EROS_50	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015		.75m	New	Continued erosion in soft banks partly due to channel obstructions
51	EROS_51	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015		.5	New	Continuing undercut banks and Incised creek bed along both banks
52	EROS_52	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015		.3m	New	Erosion less pronounced, trees in creek will eventually be undercut and fall.
53	EROS_53	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6 m	.3m	New	LWD is causing erosion/undercut to occur on right bank. Erosion will continue until LWD is removed
54	EROS_54	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015			New	Large tree root ball exposed and bank erosion, May impact tree in future
55	EROS_55	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3m	New	High flows have deposited debris and gravels in the creek and eroded sections of both banks
56	EROS_56	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m +	.3m	New	Erosion of soft bank, not approaching trees or buildings
57	EROS_57	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3	New	Bank undermined, may impact trees along bank edge in time
58	EROS_58	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	1m	New	Erosion of bank and clay slope, trees will be undermined as the clay slope fails

Table B-2: Field Inventory - Observed Erosion Sites

Erosion Observations											
Object ID	Site ID	Location	Hazard	Consequence	2015 Risk	2011 Risk	2009 Risk	Length	Height	2009/2011 Site ID	Comments
59	EROS_59	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	10m	2m	34-18	Ref. 34-18. No pictures for comparison in 2011 report. Bank continues to erode.
60	EROS_60	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	.5m	New	Bank failing and releasing cobble/gravel into creek
61	EROS_61	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	6m	Up to 1.5m	New	A tree has been undermined and fallen into the creek causing deposition and further erosion
62	EROS_62	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	2m	New	Creek eroding and undermining r bank May impact trees and fell them in time
63	EROS_63	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m		New	Erosion along left bank
64	EROS_64	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	12m	2m in some spots	New	Bank failure may cause trees to fall into stream over time. Beyond the top of the slope are housing developments
65	EROS_65	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	.3m	New	Erosion will fall tree
66	EROS_66	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	8 m	1m	New	Hard to see in photo right bank erodes away from stream in the bend
67	EROS_67	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20 m	1m	New	Long strip of erosion due to sediment and LWD buildup on right bank diverting flow
68	EROS_68	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10 m	.5	New	Creek eroding bank arounfcorner
69	EROS_69	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015		.5	New	Minor erosion nasties persist. Along both banks no infrastructure is in immediate risk, bridge abutments are more than 10 m away
70	EROS_70	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	6m	2m	34-16	Ref. 34-16 erosion continuing slowly from 2011 report
71	EROS_71	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	NEW 2011	10m	.5m	34-26	Erosion continues along both banks, undercut banks in some areas.ref.34-26 fallen tree now across creek but not obstructing low flow
72	EROS_72	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15 m	1m	New	R bank receiving worst erosion, some present along L bank
73	EROS_73	LEFT BANK	HIGH (>1.2m)	HIGH (<5m)	HIGH	HIGH	HIGH	10 m	2m	34-15	Top of bank eroding, trees undermined, it also appears more material has sloughed since the 2011 photos
74	EROS_74	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	NEW 2011	10	1m	34-25	Ref. 34-25 erosion continuing along left bank
75	EROS_75	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1m	New	Erosion from drainage channelizing down slope to creek has released a boulder into creek
76	EROS_76	RIGHT BANK			LOW	NEW 2015	NEW 2015			New	Stream diverting around boulder and grav is eroding bank no trees or structures threatened
77	EROS_77	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	1m	New	Large tree felled by eroding banks
78	EROS_78	LEFT BANK	HIGH (>1.2m)	HIGH (<5m)	HIGH	NEW 2015	NEW 2015	10m	To top of bank	New	A large fir has recently fallen and the slope failed, more recently there has been channelized down the failing slope further reducing stability, some erosion exists down stream as well pointing to possible further areas of weakened slope
79	EROS_79	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	.5m	New	Eroding bank is undercutting brush and several boulders
80	EROS_80	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	10m	1.5m	34-13	Downstream of site 34-13 clay bank is eroding and has dropped several boulders into the stream
81	EROS_81	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	10m	2m	34-13	Ref 34-13 bank has failed further and a tree and boulder have fallen into the creek
82	EROS_82	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	1m	New	
83	EROS_83	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4m	2.5m	New	Bank has subsided into creek
84	EROS_84	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	.5m	New	Soft clay bank is eroding and undermining the top
85	EROS_85	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	5m	2m	34-12	34-12 bank continues to erode, refer to 2011 report
86	EROS_86	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	10m	1.8m	34-11	Clay banks eroding several trees threatened or have already fallen. This may be site 34-11 from 2011 after significant erosion
87	EROS_87	RIGHT BANK	HIGH (>1.2m)	HIGH (<5m)	HIGH	NEW 2015	NEW 2015	10 m	3-4m	New	Significant slope failure to top of slope, a water course is running down through the failure
88	EROS_88	BOTH BANKS	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015			New	Eroding outfall channel
89	EROS_89	BOTH BANKS	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	5m	1.5	New	At the outlet of a culvert (unknown purpose) culvert has failed, overland flow has eroded the culvert outlet and will continue to erode. Culvert will continue to fall apart, last length has already fallen off. Erosion is continuous and mild downstrea
90	EROS_90	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continues through ditch	.4m	New	Creek eroding soft banks down to gravel bed, some trees undercut
91	EROS_91	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continuous	.4	New	Erosion continues both banks cut down through soft substrate to grav bottom, no major impacts from erosion
92	EROS_92	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continuous	.2m	New	Continuous mild erosion through soft substrate, some undercut banks present
93	EROS_93	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.5m	New	Left bank eroding some deposition to right bank due to blockage upstream
94	EROS_94	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	.3m	New	Bank undercut which may impact 1000 diam. Cedar on r bank
95	EROS_95	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	MEDIUM	10 m	.4m	75-6	Refer to 75-6 erosion is continuing slowly
96	EROS_96	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	To culvert	.3m	75-5	Ref 35-5, erosion continuing stream eroding some vegetation, which is falling and blocking channel
97	EROS_97	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	15m	.8m	75-4	Refer to. 75-4 blockage still present erosion occurring. 172 road not far
98	EROS_98	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	NEW 2011	3m	2m	75-15	Refer to 75-15, erosion continuing flow coming down slope and damaging channel
99	EROS_99	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.4m	New	Bank erosion on outside corner undercutting small trees
100	EROS_100	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	NEW 2011	8m	.5m	75-16	Ref 75-16 debris still in place erosion worsening
101	EROS_101	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1.5m	New	Bank eroding and may drop small trees/veg into channel
102	EROS_102	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4m	1m	New	
103	EROS_103	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Erosion caused by LWD diverting creek
104	EROS_104	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.8m	New	Erosion encroaching on park (?) land due to channel obstruction
105	EROS_105	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Erosion past bank protection
106	EROS_106	RIGHT BANK	LOW (<0.3m)	HIGH (<5m)	MEDIUM	LOW	NEW 2011	10m	.4m	75-18	Continued erosion may destroy path and stairs, ref 75-18 erosion does not appear much worse than 2011
107	EROS_107	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	6m	.3m	75-1	Ref 75-1. Some erosion continuing

Table B-2: Field Inventory - Observed Erosion Sites

Erosion Observations											
Object ID	Site ID	Location	Hazard	Consequence	2015 Risk	2011 Risk	2009 Risk	Length	Height	2009/2011 Site ID	Comments
108	EROS_108	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	.3m	New	Tree undercut, may impact local back lawns , far from structures
109	EROS_109	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3m	New	Conc pipe section in stream causing erosion
110	EROS_110	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	.3m	New	Boulder causing diversion and erosion
111	EROS_111	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	.3m	New	Obstruction downstream likely causing erosion, both banks impacted right bank undercut, left bank has fallen trees
112	EROS_112	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	.2m	New	Minor erosion both sides, severity increases upstream
113	EROS_113	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.2m	New	Downstream blockage contributing to erosion. Trees impacted on rb
114	EROS_114	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	5m	.3m	New	Erosion ds of bridge may cause poplar(?) to fall on bridge. Tree also falling us of bridge
115	EROS_115	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3m	New	Debris in creek causing erosion
116	EROS_116	BOTH BANKS	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10m	.2m	New	Erosion and undermining of banks with less windbreak due to new subdivision knocking down trees
117	EROS_117	BOTH BANKS	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10	.2	New	Erosion due to blockage, trees at risk
118	EROS_118	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	8m	.3m	New	Large cedar is being undermined and may fall near houses, school
119	EROS_119	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	NEW 2011	10m	.3m	75-14	Old blockage has been blown through, blockage had caused erosion and back watering downstream
120	EROS_120	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	.2m	New	Minor erosion to both banks that is. Starting not onions ermine several trees
121	EROS_121	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	NEW 2011	15m	.3m	75-13	Tree uprooted previously, but it doesn't appear that the erosion is worsening any further as the old blockage has been cleared
122	EROS_122	LEFT BANK	LOW (<0.3m)	HIGH (<5m)	MEDIUM	NEW 2015	NEW 2015	20m	.5m	New	Ongoing erosion to the left bank old stump may be undermined. Bank is soft and not far from an old crumbling retaining wall below a house
123	EROS_123	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015		.3m	New	Due to overgrowth length is indeterminate, creek eroding through soft substrates to gravel below
124	EROS_124	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	3m	1.5m	36-6	Appears erosion has stopped, last autumns leaves on top of erosion site
125	EROS_125	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	3m	1m	New	Some old erosion on left bank
126	EROS_126	RIGHT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	5m	2m	New	Erosion moving up the right bank May fell trees at the top
127	EROS_127	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.5m	New	Erosion of left bank may not be worsen un any further should be monitored
128	EROS_128	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	1m	New	Erosion and undercutting of rb may bring more small trees down across creek
129	EROS_129	RIGHT BANK	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	NEW 2015	NEW 2015	5m	1m	New	Eroding banks undercut and toppled trees, trees caused damage to roof of house on left bank. Erosion likely caused by upstream obstruction
130	EROS_130	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015			New	Erosion may undercut and topple more trees. Likely due to upstream blockage
131	EROS_131	RIGHT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	5m	.3m	New	Some erosion undercutting boulders which may bring them down to plug up the creek. Driveway not more than 10m west
132	EROS_132		LOW (<0.3m)	HIGH (<5m)	MEDIUM	NEW 2015	NEW 2015			New	Tree growing mid channel is being eroded and will topple, may damage a house on the left bank
133	EROS_133	LEFT BANK	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	LOW	LOW	8m	.5m	36-5	Nearby houses may be hit by falling trees. Back watering is still eroding the bank and May fell trees
134	EROS_134	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	3m	1m	New	Both banks are failing into stream, there's no immediate danger to houses but there is a shed right on the top of the RB
135	EROS_135	BOTH BANKS	HIGH (>1.2m)	HIGH (<5m)	HIGH	LOW	LOW	5m	1.5m	36-4	Most severe on rb directly below a shed
136	EROS_136	BOTH BANKS	LOW (<0.3m)	HIGH (<5m)	MEDIUM	NEW 2015	NEW 2015	8m	.5m	New	Erosion on both banks is minor but there is a nearby shed on the RB
137	EROS_137	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6 m	.3m	New	Mine continuing erosion, may topple small trees into stream and create blockage
138	EROS_138	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Minor erosion undermining bank
139	EROS_139	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	2m	.5m	New	bank erosion that may impact trees in time
140	EROS_140	RIGHT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10 m	.5m	New	Erosion heading up to the bottom of the fence at the back of yards
141	EROS_141	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Erosion caused by obstruction is beginning on RB
142	EROS_142	RIGHT BANK	HIGH (>1.2m)	MODERATE (5-10m)	HIGH	LOW	LOW	20m	Up to 1.5 m	39-8	Major erosion, undercut banks/trees caused by upstream blockage, likely to worsen at higher flows
143	EROS_143	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m +	.5m	New	Continuing erosion into soft sandstone banks, not a major threat to bank stability in most locations
144	EROS_144	RIGHT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10m	.5m	New	Erosion undercutting rootmass on RB will jeopardize upper bank stability and tree stability
145	EROS_145	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10 m	.2m	New	Minor erosion on LB undercutting bank and destabilizing bank veg.
146	EROS_146	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.2m	New	Undercutting of bank around boulder jeopardizing a nearby cedar
147	EROS_147	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1m	New	Erosion of soft bank material jeopardizing trees farther up the bank
148	EROS_148	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.5m	New	Erosion of upper bank material over sandstone shelf, may compromise vegetation
149	EROS_149	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	10m	2m	New	Significant bank failure, sloughing into creek, threatening trees on the top of bank
150	EROS_150	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	7m	.3m	New	Minor bank undercut will jeopardize bank stability
151	EROS_151	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Bank being undercut will jeopardize bank stability in time
152	EROS_152	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	5m	2m	39-7	Erosion does not appear to be continuing
153	EROS_153	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	2m	.2m	New	Creek constriction is causing undermining, jeopardizing nearby trees
154	EROS_154	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	8m	.3m	New	Minor bank erosion undermining bank veg
155	EROS_155	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.6m	New	Channel constriction is causing erosion, threatening bank veg and dropping large cobble
156	EROS_156	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m +	.5m	New	Constriction of channel causing erosion of clay / till banks threatening stability and veg
157	EROS_157	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3m	New	Bank side being eroded
158	EROS_158	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	4m	1.5m	39-6	Erosion appears to be continuing slowly
159	EROS_159	BOTH BANKS	LOW (<0.3m)	HIGH (<5m)	MEDIUM	LOW	LOW	10m	.5m	39-5	Erosion of sandstone banks partly due to upstream blockage. If it continues significantly the bridge abutments may be in jeopardy LB is 1.3m from abut
160	EROS_160	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	8m	.4m	New	Slow erosion into sandstone bank exposing large boulder, may fall and divert stream
161	EROS_161	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10	.5m	New	Some erosion to RB as well, LB is undercut jeopardizing ve/trees

Table B-2: Field Inventory - Observed Erosion Sites

Erosion Observations											
Object ID	Site ID	Location	Hazard	Consequence	2015 Risk	2011 Risk	2009 Risk	Length	Height	2009/2011 Site ID	Comments
162	EROS_162	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.4m	New	Soft upper bank material being eroded over sandstone lower materials jeopardizing bank stability
163	EROS_163				LOW	LOW	LOW			39-4	Unable to visit due to heavy blackberry growth
164	EROS_164	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	LOW	LOW	10m	.5m	39-3	Erosion appears to have stopped or continued slowly
165	EROS_165	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10	.3m	New	Minor erosion both banks, soft upper layers being stripped from sandstone below
166	EROS_166	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3m	New	Minor erosion on both banks heading upstream undercutting banks
167	EROS_167	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.5m	New	Soft lower soils being stripped from harder sandstone. May jeopardize bank stability and veg
168	EROS_168	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	.2m	New	Minor undercutting is threatening a large poplar (?) due to LWD in stream diverting flow
169	EROS_169	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.4m	New	Fairly deep undercut to bank threatening bank stability
170	EROS_170	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	5m	.3m	New	Some undercutting of LB jeopardizing 1 tree, unlikely to fall towards bridge.
171	EROS_171	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	1m	New	Significant bank failure jeopardizing bank veg
172	EROS_172	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	15m	1m	39-17	Soft bank materials scoured away from lower sandstone, jeopardizing veg on the upper bank, erosion is continuing along toe
173	EROS_173	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	8m	.5m	New	Erosion undercutting rootmass jeopardizing a tree and bank top veg
174	EROS_174	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.5m	New	Banks being undercut due to fast flowing stream on bedrock
175	EROS_175	RIGHT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	5m	.3m	New	Erosion and undercut, d/s of outfall, jeopardizing bank and tree stability
176	EROS_176	RIGHT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	2m	.3m	New	Undercut tree will fall towards path
177	EROS_177	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10m	.3m	New	Bank being undercut, threatened trees have been removed
178	EROS_178	BOTH BANKS	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	Continuous d/s	.4m	New	Erosion of banks continuing d/s minor but jeopardizing bank veg. Trees have been cut down to mitigate.
179	EROS_179	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continuing	.3m	New	Minor but continuing erosion both banks stripping soft upper layers down to sandy conglomerate bedrock. half hearted rip rap sections are failing and falling into stream. Erosion adjacent to path
180	EROS_180	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	Continues d/s	.5m	39-10	Soft upper layers eroded from sandstone bedrock bank stability is compromised. No further erosion
181	EROS_181	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	LOW	LOW	20	1m	39-11	Both banks scoured to sandstone undercutting soft upper layers. Erosion appears to be continuing slowly
182	EROS_182	LEFT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	5m	.5m	New	Erosion at sharp corner on LB, scouring to sandstone undercutting soft upper layers
183	EROS_183	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Erosion continuing slowly, bank scoured to sandstone, upper softer layers undercut exposing root mass all due to partial obstruction in LB
184	EROS_184	RIGHT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10	.4m	New	Scouring is undermining rootmass jeopardizing trees that could fall onto path
185	EROS_185	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	25m	1m	39-13	log jam cleared, erosion has stopped, to a lower degree moss is growing back down. Scouring will jeopardize root mass and upper bank stability
186	EROS_186	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.2m	New	RB beginning to be undercut threatening bank and veg stability
187	EROS_187	LEFT BANK	LOW (<0.3m)	HIGH (<5m)	MEDIUM	LOW	LOW	10m	.7m	39-15	Erosion scouring and undercutting soft upper soils1m from path edge, not due to old blowdown
188	EROS_188	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	3m	.6m	New	Bank eroding/scouring/undercut from new flow direction due to u/s blockage
189	EROS_189	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	8m	1m	39-14	Erosion has continued up stream of bend. Rootmass exposed, jeopardizing upper bank veg
190	EROS_190	LEFT BANK	LOW (<0.3m)	HIGH (<5m)	MEDIUM	NEW 2015	NEW 2015	10m	.4m	New	Erosion u/s of blockage undercutting bank and veg next to trail, below railing, erosion continuing slowly
191	EROS_191	RIGHT BANK	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	NEW 2015	NEW 2015	10m	.5m	New	D/s of blockage under cutting bank and veg including bank under bridge
192	EROS_192	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continues u/s	.3-.6m	New	Sandstone/conglomerate channel appears to be scoured on both sides advancing up the creek, only pockets of boulders remain. Upper banks slightly undercut but not greatly threatened
193	EROS_193	BOTH BANKS	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	Continuing	Up to 2.5m	New	Creek continues to be deeply incised in sandstone bed, some bank failures pulling soft upper bank material down, no trees observed in jeopardy yet
194	EROS_194	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1.2m	New	Erosion of soft soils undercutting bank and veg
195	EROS_195	RIGHT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	10 m	.3m	New	Undercut in some places .3 m deep jeopardizes the bank stability
196	EROS_196	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continues u/s	.3-.8m	New	Beyond this point creek banks again deeply incised sandstone only a few locations threaten upper banks and soft soil, little undercut
197	EROS_197	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continuing, less severe	.3-.5m	New	Continuing erosion both banks, scoured to sandstone, soft upper layers eroded or under cut, particular damage by obstruction
198	EROS_198	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	2m	1m	New	Particularly bad undercut/bank failure. Rootmass exposed upper bank in jeopardy
199	EROS_199	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3m	1m	New	Particularly undercut area of bank no trees endangered
200	EROS_200	RIGHT BANK	LOW (<0.3m)	HIGH (<5m)	MEDIUM	NEW 2015	NEW 2015	10m	.3m	New	Erosion/undercut of soft upper bank material to clay layer some root structure/trees jeopardized
201	EROS_201	LEFT BANK	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	LOW	LOW	30m	Up to 2m	39-18	Large swath of bank erosion with a 2 m high section undermining cedar. Some riprap was placed under cedar and the worst has stopped. Some riprap has failed suggesting that the erosion is ongoing
202	EROS_202	BOTH BANKS	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	NEW 2015	NEW 2015	To outfall	.5m	New	Creek runs through schoolyard, erosion is undercutting both banks down to clay, should be armoured
203	EROS_203	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	5m	2.5m	New	Bank failure likely due to eroding/undercut banks
204	EROS_204	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m d/s	.3m	New	Erosion / undercut of banks, soft material cut down to clay contributes to bank failure over time
205	EROS_205	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.5m	New	Blockage is causing creek to divert into RB and stripped the soft material down to clay
206	EROS_206	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	8m	Up to 2m	New	Bank in corner being undercut to clay layer, existing slope failure and two cedars threatened
207	EROS_207	RIGHT BANK	MODERATE (0.3-1.2m)		MEDIUM	NEW 2015	NEW 2015	20m	Up to 1m	New	Undercutting to clay layer and a bank failure u/s

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Erosion Observations											
Object ID	Site ID	Location	Hazard	Consequence	2015 Risk	2011 Risk	2009 Risk	Length	Height	2009/2011 Site ID	Comments
208	EROS_208	BOTH BANKS	HIGH (>1.2m)	LOW (>10m)	MEDIUM	LOW	LOW	20m		34-10	LB u/s of blockage RB d/s. Significant undercut and several slope failures. U/s erosion has slowed and vegetated at original loan but worsened d/s threatening bank stability
209	EROS_209	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6m	.5m	New	Erosion of bank face behind boulder, may release boulder
210	EROS_210	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	.5m	New	Face of bank eroding
211	EROS_211	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	Up to 1.2 m	New	Erosion/ undercut at toe of bank 1 failed location likely from undercut and overland drainage coming down slope. Likely caused by partial blockage u/s
212	EROS_212	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	1m	New	Bank failure likely caused by high flow water diverting around u/s obstruction
213	EROS_213	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	10m	>2m	New	Bank failure and undercut d/s of blockage
214	EROS_214	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.3m	New	Minor erosion undercutting RB may threaten some veg on top of bank
215	EROS_215	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	.5m	New	Erosion of soft upper material exposing clay banks
216	EROS_216	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	10m	2m in some locn	New	Undercut trees and a failed bank creating a channel widening
217	EROS_217	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	10m	.5m	New	Both banks only on outside corners removal of soft material exposing clay, threatening the upper bank stability
218	EROS_218	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15 m	.3m	New	Erosion of soft upper layers on both banks exposing clay and releasing large gravel and cobble
219	EROS_219	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	NEW 2011	10m	.5m	34-21	Significant undercut on RB threatening tree and exposing clay layer
220	EROS_220	BOTH BANKS	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	10m	.6m	34-9	Erosion appears to have continued, moth banks are undercut to clay layer in some locations
221	EROS_221	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15m	.8m	New	Erosion of RB, cutting deeply into clay layer
222	EROS_222	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	NEW 2011	20m	1m	34-21	RB erosion continues u/s. Upper bank material sloughing away from roots etc, no blockage seen
223	EROS_223	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	NEW 2015	NEW 2015	10 m	2. M	New	Bank failures u/s of blockage
224	EROS_224	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	NEW 2011	20	.5m	34-19	Erosion and widening due to trees in stream, soft material scoured away to clay layer. Blockage is minimal
225	EROS_225	RIGHT BANK	HIGH (>1.2m)	MODERATE (5-10m)	HIGH	NEW 2015	NEW 2015	10m	Up to 3m	New	Bank eroding and falling down, houses and yards at the top of slope
226	EROS_226	LEFT BANK	HIGH (>1.2m)	MODERATE (5-10m)	HIGH	LOW	LOW	10m	3m	34-8	Erosion appears to be continuing at toe, this may jeopardize the upper slope and trees. These trees may be tall enough to impact yards on the far side of the creek if they fall
227	EROS_227	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	Continuing u/s from this point	Up to 2 m	New	Soft materials eroded from toe. Y creek and from bank from undercuts and overland drainage
228	EROS_228	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	MEDIUM	MEDIUM	Continuing, highly eroded locn	Up to 1 m	34-7	Erosion continuing slowly at toes, exposing clay in some locations
229	EROS_229	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	Continuing	1.5m	New	Bad spot large undercut threatens tree that could fall onto adjacent sidewalk
230	EROS_230	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	LOW	LOW	Continuing	1.3m	34-6	Erosion slowed, continuing to undercut toe
231	EROS_231	RIGHT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	15m	Up to 1m	New	Erosion and undercut of RB jeopardizing at least one tree
232	EROS_232	LEFT BANK	HIGH (>1.2m)	LOW (>10m)	MEDIUM	MEDIUM	NEW 2011	10 m	1.5 m	34-22?	Significant undercut on outside corner, appears to be continuing as no veg has grown on erosion face
233	EROS_233	RIGHT BANK	HIGH (>1.2m)	HIGH (<5m)	HIGH	LOW	LOW	Continues u/s	Up to 3m	34-5(?)	Major bank failure and erosion adjacent to sidewalk. Soft upper materials sloughing off above, scoured away to clay layer below. Stream bed becomes increasingly exposed clay heading u/s
234	EROS_234	LEFT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	Continues u/s	.5m	New	Undercut and soft material scoured down to clay layer, continues to outfall
235	EROS_235	BOTH BANKS	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015			New	Both banks continue to erode as far as outfall
236	EROS_236	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5m	.3m	New	Minor erosion undercutting bank no hazard to trees yet
237	EROS_237	RIGHT BANK	MODERATE (0.3-1.2m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	20m	Up to 1.2m	New	Erosion and bank failure on outside corner
238	EROS_238	LEFT BANK	MODERATE (0.3-1.2m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	15 m	.5m	New	Undercut banks and bank failure appears to be slow erosion continuing at toe
239	EROS_239	LEFT BANK	MODERATE (0.3-1.2m)	HIGH (<5m)	HIGH	NEW 2015	NEW 2015	30m	1m	New	Erosion in back yard of automotive shop
240	EROS_240	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	2.0m	0.5m	New	Opposites storm culvert OF
241	EROS_241	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	7.0m	125cm	New	
242	EROS_242	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4.0m	2.5m	New	
243	EROS_243	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	5.5m	0.7m	New	
244	EROS_244	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	4.0m	0.5m	New	
245	EROS_245	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	2.0m	0.5m	New	On private lot in field
246	EROS_246	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	1.5m	40cm	New	Bank slump, fallen into stream channel
247	EROS_247	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	15.0m	0.7m	New	
248	EROS_248	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	12.0m	0.9m	New	
249	EROS_249	LEFT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3.0m	0.4m	New	
250	EROS_250	BOTH BANKS	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	7.0m	1.0m	New	Risk to wooden bridge only.
251	EROS_251	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	3.0m	0.5m	New	Benthos is glacial clay here except where angular rock has purposely been added.
252	EROS_252	RIGHT BANK	LOW (<0.3m)	LOW (>10m)	LOW	NEW 2015	NEW 2015	6.0m	1.0m	New	Looks like a recent event scoured area, new gravel upslope, GVRD main line beside roadway
253	EROS_253	RIGHT BANK	LOW (<0.3m)	MODERATE (5-10m)	MEDIUM	NEW 2015	NEW 2015	9.0m	0.3m	New	Back of residential lot

Table B-3: Field Inventory - Observed Obstruction Sites

Obstruction Observations								
Object ID	Site ID	Obstruction Type	Drop	Sedimentation	Stability	Fish Passage Obstacle	2009/2011 Site	Comments
1	HYDOBS_1	ANTHROPOGENIC	500 mm	YES	MODERATE			Barbed wire fence catching LWD, including root wad. Still fish passable.
2	HYDOBS_2	LWD	.5m	NO	MODERATE			Fish ok
3	HYDOBS_3	LWD	1	YES	MODERATE			Fish ok. Channel shifting right.
4	HYDOBS_4	LWD	0.25	NO	MODERATE			Cedar fallen across creek including root wad; not a fish barrier currently
5	HYDOBS_5	LWD	0.4m	YES	MODERATE	Weir		
6	HYDOBS_6	LWD	1	YES	MODERATE			Trees across the creek
7	HYDOBS_7	LWD	.4m	NO	MODERATE			
8	HYDOBS_8	LWD	.1	NO	MODERATE			Fish ok currently. Fallen logs
9	HYDOBS_9	LWD	0.5m	YES	MODERATE	Weir		LWD caught on logs
10	HYDOBS_10	LWD	.5m	YES	MODERATE			Fish ok in high water. LWD in with boulders
11	HYDOBS_11	LWD	1	YES	MODERATE	Weir		Fish ok in high water
12	HYDOBS_12	LWD	0.1m	NO	LOW			Fish ok blockage is minor
13	HYDOBS_13	LWD	.2m	NO	LOW			Fish ok minor blockage for now
14	HYDOBS_14	LWD	0.2m	YES	MODERATE			Fish ok at high water. Stump and logs in sediment
15	HYDOBS_15	LWD	0.3m	NO	MODERATE			Fish passage ok
16	HYDOBS_16	LWD	.3m	YES	MODERATE			Fish ok, channel diverts around obstruction. Wall has rock armor
17	HYDOBS_17	LWD	.3m	YES	LOW			Fish ok barrier is low
18	HYDOBS_18	LWD	.1m	YES	MODERATE			Tree across creek picking up debris, fish likely ok at highwater
19	HYDOBS_19	LWD	1	NO	MODERATE			Log across stream picking up debris fish ok
20	HYDOBS_20	ANTHROPOGENIC	1	YES	HIGH			Large slabs of concrete and rock in creek. Does not appear to be fish passage barrier.
21	HYDOBS_21	LWD	.3m	YES	MODERATE			Fish ok. Log in channel picking up debris
22	HYDOBS_22	LWD	.5m approx	YES	MODERATE		37-3	Unable to get very close, thick bramble. 4m2 + pool behind blockage see 2011 report for more photos ref. 37-3 brambles have grown across the obstruction
23	HYDOBS_23	ANTHROPOGENIC	.5m	YES	HIGH			Barbed wire fence festooned with ancient bramble is creating a choke point and accruing sediment and veg. Fish may have difficulty navigating this obstruction
24	HYDOBS_24	LWD	.2m	YES	LOW			Fish ok only partial obstruction
25	HYDOBS_25	LWD	.3m	YES	LOW			Fish ok creek 80% obstructed
26	HYDOBS_26	ANTHROPOGENIC	.4m	YES	MODERATE			Portions of conc culvert hooked on bolder and LWD
27	HYDOBS_27	LWD	.2	YES	LOW			Fish ok in higher water likely. Obstruction is a raft of LWD and SWD.
28	HYDOBS_28	ANTHROPOGENIC	0.3m	YES	MODERATE			Fence crossing creek. Fish passable under high flows.
29	HYDOBS_29	ANTHROPOGENIC	.3m	YES	MODERATE			Concrete garden pieces in creek catching LWD
30	HYDOBS_30	ANTHROPOGENIC	1	YES	HIGH			Fish ok concrete block holding up LWD
31	HYDOBS_31	ANTHROPOGENIC	.3m	YES	MODERATE			Fish ok. Rebar staked into streambed holding LWD in place across total width
32	HYDOBS_32	LWD	0.75m	YES	MODERATE			Not fish passage barrier in higher flows; possible barrier at low flows
33	HYDOBS_33	BOULDER	1.0m	YES	HIGH			Fish passage barrier although part is wood which may decay over time.
34	HYDOBS_34	LWD	1	YES	LOW			
35	HYDOBS_35	LWD	1		HIGH			Fish ok large log on right bank. One end is partially obstructing the bridge culverts.
36	HYDOBS_36	LWD	O	NO	HIGH			Trees in creek causing erosion on r bank, in high flow trees will catch debris and plug creek
37	HYDOBS_37	ANTHROPOGENIC	1	YES	HIGH	Weir		Concrete flow splitting box with trapezoidal outfall structure for majority flow. Fish ok. Some silty sedimentation inside flow splitting box. 2.2base 6.8 m top 1.5 m high. .1m steel plate lip with rrap eng dissipation
38	HYDOBS_38	ANTHROPOGENIC	1	NO	HIGH			Concrete outlet flow splitting structure diverts a potion of north creek to the north into a habitat area. May also act as an inlet from the nearby detention pond. Outlet is .35m x.85m
39	HYDOBS_39	LWD	.4m	YES	MODERATE			Fish ok to jump at high flows. Debris jam including trees across creek.
40	HYDOBS_40	LWD	.1m	YES	MODERATE			Tree catching debris across creek. Fish ok at high flow
41	HYDOBS_41	LWD	1	YES	MODERATE			Numerous LWD damming creek, diversion is eroding left bank. Fish may have difficulty

Table B-3: Field Inventory - Observed Obstruction Sites

Obstruction Observations								
Object ID	Site ID	Obstruction Type	Drop	Sedimentation	Stability	Fish Passage Obstacle	2009/2011 Site	Comments
42	HYDOBS_42	BOULDER	.2m	YES				Boulder catching LWD and diverting around obstruction and sediment. Fish will be unobstructed
43	HYDOBS_43	LWD	.2	YES	MODERATE			Obstruction is widening the creek causing deposition and erosion. Fish will be able to pass
44	HYDOBS_44	LWD	1	YES	MODERATE			Fish will be ok several LWD rafted and blocking streAm, causing erosion along both banks
45	HYDOBS_45	LWD	.2m	YES	MODERATE			Fish ok LWD has fallen across stream widening into left bank
46	HYDOBS_46	LWD	.3m	YES	MODERATE			Fish ok at high water, LWD is diverting flow and eroding the r bank
47	HYDOBS_47	LWD	.2m	YES	MODERATE			Fish ok in high water. LWD forming barrier across creek starting some erosion along right bank
48	HYDOBS_48	LWD	1	YES	MODERATE			Fish ok. Blockage is causing erosion along the left bank up and down stream
49	HYDOBS_49	LWD	1	NO	HIGH			Large maple windthrow across creek. Fish passable at this time.
50	HYDOBS_50	LWD	.4m	YES	MODERATE		75-7	Fish ok at high water likely, obstruction is causing erosion ds. Refer to 75-7 debris still in place
51	HYDOBS_51	LWD	.2m	YES	MODERATE		75-3	Ref 75-3 fish ok tree broken across stream. Obstruction still here from 2011 erosion continues
52	HYDOBS_52	LWD	1					Fish will be hampered. By thick veg in stream and little open water. rocks lwd and veg debris choking stream, passage up stream is blocked
53	HYDOBS_53	LWD	.5m	NO	HIGH			Tree on nurse log diverting stream no major erosion
54	HYDOBS_54	ANTHROPOGENIC	1	YES	HIGH			Fish will have trouble passing. Conc block wall with low point. Creek is diverting around right side and undercutting tree
55	HYDOBS_55	LWD	.3m	YES	MODERATE			Fish ok. Several pieces LWD obstructing flow and generating erosion
56	HYDOBS_56	ANTHROPOGENIC	1	NO	MODERATE			Fish ok. Large PVC culvert caught on LWD diverting flow causing erosion
57	HYDOBS_57	LWD	.75m	YES			75-20	Ref.75-20 blockage remains causing ds erosion and braiding, impassable for fish
58	HYDOBS_58	LWD	.2m	YES	MODERATE			Fish ok at high water, blockage causing erosion
59	HYDOBS_59	LWD	.3m	YES				Fish ok. Several trees in creek obstructing flow, redirecting creek, causing erosion.
60	HYDOBS_60	LWD	.3m	YES	MODERATE			Fish obstructed lots of debris clogging creek. Creek is flooding area and may undermine trees
61	HYDOBS_61	LWD	.3m	YES	MODERATE			Fish ok at high water. Tree and root ball blocking, redirecting creek undermining trees and backup up stream
62	HYDOBS_62	LWD	.3m	NO	MODERATE			Fish ok. Wood on boulders across creek, some erosion
63	HYDOBS_63	LWD	.5m	YES	MODERATE			LWD in creek diverting and eroding banks, trees at risk
64	HYDOBS_64	ANTHROPOGENIC	.2m	YES	MODERATE			40mm diam steel pipe installed in stream bed as debris catchment barrier. Barrier should be cleared as it's starting to cause some back watering and bank erosion
65	HYDOBS_65	LWD	0	YES	HIGH		75-12	Ref 75-12. 400 diam tree across creek causing creek to spread out, backwater and drop sediment
66	HYDOBS_66	LWD	.4m	YES	MODERATE			Dammed debris and wood causing sedimentation upstream and erosion d/s. May be a barrier to fish
67	HYDOBS_67	LWD	0	YES	HIGH			Tree growing in channel is causing creek to spread, no significant erosion yet
68	HYDOBS_68	LWD	.3m	YES	MODERATE			Partial to serious fish barrier. LWD and SWD rafter and blocking flow. Creek is diverting and eroding both banks. Unable to get a meaningful photo
69	HYDOBS_69	LWD	.3m	YES	LOW			Minor obstruction from tree cutting debris is causing eros downstream
70	HYDOBS_70	LWD	.2m	YES	HIGH			Log across stream is generating a backwater and causing erosion u/s. Fish likely ok
71	HYDOBS_71	LWD	.5m	YES	MODERATE			Fallen debris is constricting stream and undermining the lb down stream, back watering may Also fell a tree growing on the rb in time
72	HYDOBS_72	ANTHROPOGENIC	.5m	YES	HIGH		36-4	Conc and rock weir structure. Water is diverting to both sides and causing severe erosion to the RB, directly below a shed. Ref 36-4 erosion appears to be continuing

Table B-3: Field Inventory - Observed Obstruction Sites

Obstruction Observations								
Object ID	Site ID	Obstruction Type	Drop	Sedimentation	Stability	Fish Passage Obstacle	2009/2011 Site	Comments
73	HYDOBS_73	ANTHROPOGENIC	.2m	NO	MODERATE			Fish ok. Concrete block and wooden beams are diverting flow and may cause erosion in time
74	HYDOBS_74	LWD	.3m	YES	MODERATE			Rafter LWD and debris causing back watering and sedimentation in stream. may be a total fish barrier. Ponds weakened soils and toppled a tree
75	HYDOBS_75	ANTHROPOGENIC	0	NO	MODERATE			Fish ok. 2 pieces of trunk were placed in the stream as stepping stones, doesn't appear to bead aging the banks. Likely the cause of the fallen tree up stream
76	HYDOBS_76	LWD	.2	NO	LOW			Fish ok at high water. Sediment and woody debris caused a tree to topple partway, it may land on nearby fences. Also causing u/s ponding
77	HYDOBS_77	BOULDER	.3m	YES	HIGH			Boulder has caught log and diverted flow to the right bank, damming the left. Sediment is backing up on the left. Fish ok
78	HYDOBS_78	BOULDER	.5m	YES	HIGH	Weir		Fish barrier. Boulder has caught debris, at low flow creek seeps through, higher flow causes RB erosion, LB protected by massive boulder. U/s sedimentation is minor
79	HYDOBS_79	LWD	.3m	YES	MODERATE			Trunk embedded in bank causing LB erosion nearby. Fish ok
80	HYDOBS_80	LWD	.2m	YES	MODERATE			Fish ok. LWD and sediment constricting stream to RB CAUSING RB to be undermined
81	HYDOBS_81	BOULDER	.2m	YES	HIGH			Fish ok. Boulder has caught LWD damming the left channel, right channel is eroding bank and pool.
82	HYDOBS_82	LWD	.3m	YES	MODERATE			Fish ok. LWD causing erosion up and down stream due to constriction
83	HYDOBS_83	LWD	.5m	YES	MODERATE			Partial fish barrier. LWD blocking the RB causing erosion of LB up and down stream
84	HYDOBS_84	LWD	.6m in 2 steps	YES	MODERATE			Fish barrier. LWD raft constricting flow eroding pool and banks d/s
85	HYDOBS_85	LWD	0	NO	MODERATE			Fish ok. Tree trunk catching debris worsening erosion d/s
86	HYDOBS_86	LWD	.7m	YES	LOW			Debris raft that has partially blown out., still constricting flow and eroding sandstone bed. Partial fish barrier
87	HYDOBS_87	LWD	.2m	YES	MODERATE			Fish ok at high water. Log in stream bed is forcing flow to RB causing minor erosion
88	HYDOBS_88	LWD	.3m	YES	HIGH		39-2	Fish barrier. Debris have rafted and backed up further creating a shallow pool. Ref 39-2
89	HYDOBS_89	LWD	.4m	YES	MODERATE		39-16	Ref 2011 39-16, tree still damming the creek, partial fish barrier
90	HYDOBS_90	LWD	1m	YES	MODERATE			Fish barrier. Hemlock down in creek, branches snagging/rafting debris creating a large blockage
91	HYDOBS_91	LWD	.3m	YES	MODERATE			LWD hooked on boulders constricting flow and generating sediment u/s. Partial fish barrier
92	HYDOBS_92	ANTHROPOGENIC	.5m	YES	HIGH			Fish barrier. LWD hooked on old conc wall crossing creek. Wall and bedrock are being eroded
93	HYDOBS_93	BOULDER	0	NO	MODERATE			Fish ok, rock has caught SWD and started a barrier, som erosion occurring both banks
94	HYDOBS_94	LWD	.2m	NO	MODERATE			Tree across stream, diverting to l and r bank, widening channel, at low flow not a major obstruction
95	HYDOBS_95	BOULDER	0	NO	MODERATE			Fish ok, boulder caught LWD, causing d/s erosion
96	HYDOBS_96	LWD	.3m	YES	MODERATE			LWD on LB diverting creek causing d/s erosion
97	HYDOBS_97	LWD	0	NO	MODERATE			Fish ok, partial blockage diverting flow and eroding RB,
98	HYDOBS_98	BOULDER	.6m	YES	MODERATE		39-13	39-13. Logs hooked in boulders have dammed up debris, creek flowing through or over well but if released will move ~3m3 grav d/s, has cleared somewhat from 2011
99	HYDOBS_99	BOULDER	.2m	YES	HIGH			Minor sediment and partial fish barrier, large boulder mid channel catching debris and diverting stream to both banks causing erosion
100	HYDOBS_100	LWD	.5m	YES	MODERATE			LWD backing up grav/debris causing LB d/s erosion. Partial or greater fish barrier.
101	HYDOBS_101	BOULDER	1.5m	YES	MODERATE			Boulders catching debris and backing up sediment. Diverting channel to LB causing erosion partial fish barrier
102	HYDOBS_102	BOULDER	0	YES	HIGH			Fish ok. Large boulder holding LWD, appears to have been here a long time, creek has widened, no further erosion

Table B-3: Field Inventory - Observed Obstruction Sites

Obstruction Observations								
Object ID	Site ID	Obstruction Type	Drop	Sedimentation	Stability	Fish Passage Obstacle	2009/2011 Site	Comments
103	HYDOBS_103	LWD	1.5m	YES	MODERATE			Large LWD dam holding back sediment total fish barrier deeply incised sandstone bed channel ends here
104	HYDOBS_104	BOULDER	.4m	YES	MODERATE			2boulders holding sediment and creating a pool not fish barrier
105	HYDOBS_105	LWD	.6m	YES	MODERATE			Partial fish barrier. Broken tree damming up debris and eroding pool
106	HYDOBS_106	LWD	2m	YES	MODERATE			Fish barrier. LWD blocking narrow incised channel with sed bed at top.
107	HYDOBS_107	BOULDER	.5m	YES	MODERATE			Partial fish barrier. LWD across stream creating shallow pool
108	HYDOBS_108	LWD	.5m	YES	MODERATE			Fish barrier several chunks LWD rafter up to block creek and bank sediment. Creek diverting to LB causing some erosion
109	HYDOBS_109	LWD	.5m	YES	HIGH			LWD rafted onto boulder causing erosion to the RB, fish ok.
110	HYDOBS_110	LWD	1m in two .5m drops	YES	HIGH		34-24	Several large trees across creek collecting debris, some smaller debris have blown through but creek still eroding undercutting both banks. RB most heavily d/s LB more heavily u/s, fish can get through. Ref 34-24
111	HYDOBS_111	LWD	0	YES	MODERATE			Fish ok, little sediment left u/s. Old blockage that has partially blown down stream caused channel widening and erosion. Could pick up debris again.
112	HYDOBS_112	LWD	.3m	YES	MODERATE			Partial fish barrier. LWD caught on boulder diverting creek to the LB causing significant undercut bad erosion d/s and u/s
113	HYDOBS_113	LWD	.3m	YES	MODERATE			Tree caught on boulders diverting creek. Eroding LB ds and creating a small backwater pool u/s
114	HYDOBS_114	LWD	0	NO	HIGH			Fish ok, two tree trunks across stream causing erosion d/s on RB
115	HYDOBS_115	LWD	0	NO	MODERATE			Partial obstruction only. Failed bank and root wad diverting creek to rb
116	HYDOBS_116	BOULDER	0	YES	HIGH			Creek has undercut RB and gone around boulder and grav deposit obstruction. No obstruction to fish
117	HYDOBS_117	LWD	.4m	NO	MODERATE		34-20	Ref 34-20, tree and other LWD across stream causing d/s RB erosion. Blockage has not dispersed . Partial fish barrier
118	HYDOBS_118	LWD	.2m	NO	HIGH			No fish blockage, tree root growing across stream is holding debris, both sides of channel show Minor erosion
119	HYDOBS_119	LWD	.4m	YES	MODERATE			Fish ok, LWD backing up shallow pool and sed causing continuing LB erosion d/s
120	HYDOBS_120	ANTHROPOGENIC	.2	YES	MODERATE			Old transmission in creek, holding LWD, minor obstruction only
121	HYDOBS_121	LWD	.2m	YES	LOW			LWD holding back some debris, likely causing d/s erosion
122	HYDOBS_122	LWD	0	NO	MODERATE			Fish ok, tires and LWD fallen in creek obstructing flow somewhat
123	HYDOBS_123	LWD	.2m	NO	LOW			Fish ok. LWD and plywood jammed up minor obstruction only
124	HYDOBS_124	ANTHROPOGENIC	0	NO	HIGH			Steel box in creek, looks like garbage
125	HYDOBS_125	ANTHROPOGENIC	1		MODERATE			Weir of concrete blocks
126	HYDOBS_126	ANTHROPOGENIC	1					Weir of bricks - same as D/S see that one for photo this one obscured by recent SWD debris accumulation
127	HYDOBS_127	ANTHROPOGENIC	0.5m		MODERATE	Waterfall		
128	HYDOBS_128	LWD	1		HIGH	Weir		Wood placed perpendicular to stream on benthos creates passable step pools.
129	HYDOBS_129	ANTHROPOGENIC	1		LOW	Weir		
130	HYDOBS_130	ANTHROPOGENIC	1		MODERATE	Weir		
131	HYDOBS_131	ANTHROPOGENIC	1		MODERATE			For cement block weirs on length of property, this photo representative of all four
132	HYDOBS_132	ANTHROPOGENIC	1		MODERATE	Weir		For photo see bridge in same area
133	HYDOBS_133	ANTHROPOGENIC	1		HIGH			Angular rock weir
134	HYDOBS_134	ANTHROPOGENIC	1		HIGH	Weir		Angular rock step pools here (series of four)
135	HYDOBS_135	ANTHROPOGENIC	1		HIGH	Weir		Angular rock
136	HYDOBS_136	ANTHROPOGENIC	1		HIGH	Weir		Angular rock

Table B-4: Field Inventory - Observed Culvert Sites

Culvert Observations

Object ID	Site ID	Material	Diameter	Comments	Shape	Headwall	Debris Rack	Debris Present	Maintenance Required	Maintenance Description	Condition
1	CULV_1	CONCRETE	900	PVC headwall w/ trash rack. Rack should be cleaned as it is half covered			YES	YES	YES	Clear rack	GOOD
2	CULV_2	CONCRETE	450		Round	CONCRETE	NO	NO	YES	Headwall is falling apart and falling into culvert. Culvert enters manhole before reaching outfall	POOR
3	CULV_3	PVC	300	1m above creek	Round	CONCRETE	YES	NO	NO		GOOD
4	CULV_4	CONCRETE	1200	5m long concrete apron on the ds end	Round	SANDBAG	NO	YES	YES	Clear inlet (minor)	
5	CULV_5	CONCRETE	700mm		Round	CONCRETE	YES	NO	NO		
6	CULV_6	CMP	1600	Debris piled on top of culvert, water likely backs up in this location. Culvert appears in good condition some debris across lower 15% of culvert. Head wall is partial height riprap in good condition	Round	RIPRAP	NO	YES	NO		GOOD
7	CULV_7	PVC	400(?)	Culvert mostly submerged in brackish water coveys water under path along 176th ave. small rock stack wall at upstream end. Fairly flat	Round	NONE	NO	YES	NO		GOOD
8	CULV_8	PVC	300	Upstream end vegetation surrounding and partly concluding inlet. Small rock stack hwall. DS little debris, outlet in good condition	Round	RIPRAP	NO	YES	YES	Clearing veg	FAIR
9	CULV_9	CONCRETE	3m x 1.5m	Concrete box culvert, some .3m of sediment at d/s end, some send on right side at	Box	LOK BLOCKS	NO	YES			GOOD
10	CULV_10		Unknown	Completly obscured by debris, water is backed up but still flowing through. D/s culvert has fallen apart				YES	YES	Clearing and debris removal, possibly requires an h wall and trash rack	POOR
11	CULV_11	CONCRETE	600	Fairly old outlet has drop past energy dis into pool which is eroding, more brio rap should be installed	Round	RIPRAP	NO	YES	YES	More rrap at outlet	GOOD
12	CULV_12	CMP	900	Some erosion around inlet, some deformation inside pipe	Round	NONE	NO	NO	YES	Install headwall to preempt erosion	FAIR
13	CULV_13	CONCRETE	600	No debris present 250 diam conc pipes discharge through headwall to north and south, joining main channel	Round	CONCRETE	YES	NO	NO		FAIR
14	CULV_14	CONCRETE	300	Culvert and surrounding wall in poor condition. Appears to have been installed by owner to create a bridge. Appears blocked at u/s end	Round	ROCK & CONCRETE	NO	YES	YES	Remove or rebuild wall	POOR
15	CULV_15	CMP	5m x 0.8m	Culvert nearly entirely full of sediment. Headwall is corrugated steel bridge side. Slope is approx.	Arch		NO	NO	YES	Remove sediment	FAIR
16	CULV_16	CONCRETE	1800x900	Has energy dis, conc in culvert and rock lined outfall area. Slope is approx. lots of soft fine sediment. At upstream end, almost a. Swamp. Likely skunk cabbbage growth In summer. Us hwall is conc block	Box	CONCRETE	YES	YES	YES	Clear ds rack and re-bolt	FAIR
17	CULV_17	CONCRETE	1000	Ds outlet is completely overgrown only part of the head wall is visible. Us inlet is also overgrown but in good condition otherwise. Channel is very overgrown with grasses and Himalayan blackberry							
18	CULV_18	CONCRETE	1000	Appears to be 1m diam con at inlet conc block block headwall. Culvert is submerged and difficult to access. Similar at downstream. Pool at ds end submerged culvert, requires maintenance.	Round	CONCRETE	NO	YES	YES	Clear junk and veg from inlet	FAIR
19	CULV_19			Culvert through dyke. Water is deep and heavily vegetated culverts are unknown size floating debris present in channel		LOK BLOCKS	NO	YES	YES	Debris clearance, nothing major	
20	CULV_20	CONCRETE	1200	Culvert is barred at both ends, no debris downstream. Slope is approx	Round	CONCRETE	YES				GOOD
21	CULV_21	PVC	400	Flow appears minimal. Creek is a trickle through heavy veg. Upstream inlet is 1200 diam conc circ culvert in dry creek bed	Round	CONCRETE	YES	NO	NO		GOOD
22	CULV_22	CONCRETE	1000	Could not access ds end of culvert, appears clear with no hwall, appears 300 diam, up stream end measures 1000. Slope is approx. headwall is surrounded w/ rock armour for 2m u/s	Round	CONCRETE	YES	NO	NO		GOOD
23	CULV_23	CONCRETE	1200 x 2	Down stream end has conc pad as eng dis. 30cm drop and sig. Erosion just downstream of pad. Slope is approx. head walls are old and mossy but in generally good condition	Round	SANDBAG	NO	NO	YES	Outlet is becoming overgrown w/ blackberry	GOOD
24	CULV_24	CONCRETE	Twin 1200s	Twin 1200s left is plugged right half plugged with debris at inlet head wall is falling apart. Culverts and bank could likely be removed. Concrete slab to dissipate energy at outlets, .3m drop, fish barrier(?)	Round	SANDBAG	NO	YES	YES	Clear debris u/s end is a deep bowl that could backup a lot of water	FAIR
25	CULV_25	CMP	Twin 1500	4m stepped drop at outlet w/ energy diss. Large concrete inlet structures but no access past fences, debris etc	Round	CONCRETE	YES	NO	NO		GOOD
26	CULV_26	CONCRETE	900	Rocks and notched concrete wires d/s of outlet for energy dis	Round	CONCRETE					GOOD
27	CULV_27	CONCRETE	900	Old conc pipe w/ failing headwall	Round	ROCK & GRAVEL	NO	YES	YES	Some debris in pipe to remove	FAIR
28	CULV_28	CONCRETE	900	Some debris and overgrowth present, inlet inaccessible	Round	CONCRETE	YES				GOOD
29	CULV_29	PVC	26cm	Stream just a trickle here, origin of South Creek under ground?		LOK BLOCKS	NO	YES	YES		FAIR
30	CULV_30	STEEL	275cm	175cm clearance U/S end, 160cm D/S, under condo complex ro		NONE	NO	YES	NO		FAIR

Table B-4: Field Inventory - Observed Culvert Sites

Culvert Observations											
Object ID	Site ID	Material	Diameter	Comments	Shape	Headwall	Debris Rack	Debris Present	Maintenance Required	Maintenance Description	Condition
31	CULV_31	CONCRETE	60cm	U/S end on 17968 68th	Round	CONCRETE	NO	NO			GOOD
32	CULV_32	CONCRETE	60cm		Round	CONCRETE	NO	YES	YES	Sediment @ outlet reduces opening to half, U/S end clogged with SWD - photo	
33	CULV_33	PVC		Conveyed seepage from school field into man made channel then into pond							
34	CULV_34	CONCRETE	60cm	Outlet fro wetland on school property	Round	CONCRETE	YES	YES	YES	Fine sediments obstruct 3/4 of opening	POOR
35	CULV_35	PVC	60cm	D/S end half filled with sediment		CONCRETE	NO	YES	YES	Sediment removal	POOR
36	CULV_36	PVC	60cm	Culvert opening completely blocked D/S, 1/4 blocked U/S end. Twin culverts here: this data for one one right (North culvert) in photo	Round	NONE	NO	YES	YES	Headwall & sediment removal	POOR
37	CULV_37	PVC	30cm	Twin pipes under earth foot bridge	Round	ROCK & CONCRETE	NO	NO			POOR
38	CULV_38	CONCRETE	60	Sediment wedge down stream	Round	CONCRETE	NO	YES	YES	Sediment removal	FAIR
39	CULV_39	CONCRETE	60cm		Round	CONCRETE	NO	YES			FAIR
40	CULV_40	CONCRETE	60cm		Round	CONCRETE	NO	YES			FAIR
41	CULV_41	CONCRETE	80cm	No water currently, had rain overnight	Round	CONCRETE	YES	YES	NO		GOOD
42	CULV_42	CONCRETE				CONCRETE	YES				GOOD
43	CULV_43	CONCRETE	80cm	No flow today and it rained overnight	Round	CONCRETE	YES	NO			GOOD
44	CULV_44	CONCRETE	1.5m x 1.8m	Fish-friendly concrete baffles	Box	CONCRETE	NO	NO			GOOD
45	CULV_45	CONCRETE	60cm	D/S end 3/4 plugged with fines	Round	CONCRETE	NO	YES	YES	Fines/debris obstructing opening both ends	

Table B-5: Field Inventory - Observed Bridge Sites

Bridge Observations				
Object ID	Site ID	Bridge Type	Thickness	Comments
1	BRIDGE_1	FOOTBRIDGE	0.8m	Metal arch with decaying timber deck; abandoned
2	BRIDGE_2	FOOTBRIDGE	1m	Green rail bridge; situated on eroding R bank
3	BRIDGE_3	DRIVEWAY	1.2m	Bridge is dual box culverts 2.4m wide by 1.2m high. .2m thick walls. Right side is partially blocked by LWD inside the box, this is causing sedimentation downstream bridge. Bridge is 7.4 m wide
4	BRIDGE_4	DRIVEWAY	1.2	Twin box culvert bridge, 2.4m wide by 1.2m tall,20cm walls. Good condition, small amt of sediment in culverts, some erosion at outlet end where there is a 15cm drop. Some pooling at upstream und. Bridge is 7.35m wide
5	BRIDGE_5	DRIVEWAY	1.2m	Twin box culverts, 2.4x1.2m 20cm walls 7.4 m long
6	BRIDGE_6	FOOTBRIDGE	0.27m	Small 2x4 footbridge for trail access across blind channel
7	BRIDGE_7	FOOTBRIDGE	1.1m	5m LoNG 1m wide conk foot bridge across flow splitting structure inlet
8	BRIDGE_8	FOOTBRIDGE	High	Blue pedestrian suspension bridge across ravine
9	BRIDGE_9	FOOTBRIDGE	.6m	Wooden footbridge over creek within property
10	BRIDGE_10	FOOTBRIDGE	.8 to conc	In overflow event only would this be a constriction
11	BRIDGE_11	FOOTBRIDGE	1.35m	Steel arch footbridge connecting subdivisions
12	BRIDGE_12	FOOTBRIDGE	2.06m	Wooden footbridge on lock block abutments 6m between abutments, 3.4m bank to bank
13	BRIDGE_13	FOOTBRIDGE	88cm	Low wooden foot bridge, 4.2m wide. 5m between abut, 2.7 bank to bank
14	BRIDGE_14	FOOTBRIDGE	3.2m	1.2m wide wooden footbridge on conc abutments 6.2m apart banks 4.3 m
15	BRIDGE_15	FOOTBRIDGE	1.1 m	Bank protection has fallen away underneath bridge rests on timber beams
16	BRIDGE_16	FOOTBRIDGE	1.1m	Steel frame footbridge on lock-block abuts 5.5m apart at top of bank
17	BRIDGE_17	FOOTBRIDGE	.8m	Improvised creek crossing plywood structure... Short lifespan
18	BRIDGE_18	DRIVEWAY	170cm	32cm pool under bridge has ~ 30 fish
19	BRIDGE_19	FOOTBRIDGE	110cm	
20	BRIDGE_20	DRIVEWAY	90cm	
21	BRIDGE_21	DRIVEWAY	90cm	Culvert, concrete 90cm D, fair condition
22	BRIDGE_22	DRIVEWAY	90cm	90cm D culvert under driveway condition fair
23	BRIDGE_23	DRIVEWAY	90cm	Concrete culvert 90cm D, head wall stacked brick, fair condition
24	BRIDGE_24	ROAD	65cm	Filled with fine sediments
25	BRIDGE_25	ROAD	75cm	Fine settlements obscure opening, not sure how deep.
26	BRIDGE_26	FOOTBRIDGE		Old wooden, collapsing into stream
27	BRIDGE_27	FOOTBRIDGE		Wooden
28	BRIDGE_28	FOOTBRIDGE	60cm	
29	BRIDGE_29	DRIVEWAY	80cm	
30	BRIDGE_30	OTHER	0.5m	Wooden fence between residents
31	BRIDGE_31	FOOTBRIDGE	0.5m	
32	BRIDGE_32		0.4m	To footbridges in residential yard see adjacent bridge for photo
33	BRIDGE_33	OTHER	0.5m	Fence between residential properties, for photo see retaining wall in same area
34	BRIDGE_34	FOOTBRIDGE	1.5m	

Table B-5: Field Inventory - Observed Bridge Sites

Bridge Observations				
Object ID	Site ID	Bridge Type	Thickness	Comments
35	BRIDGE_35	FOOTBRIDGE	0.5m	
36	BRIDGE_36			
37	BRIDGE_37	FOOTBRIDGE	0.2m	
38	BRIDGE_38	OTHER	0.5m	Fence between two residential properties
39	BRIDGE_39	FOOTBRIDGE	0.3m	
40	BRIDGE_40	OTHER	0.2m	Sediment accumulating behind rocks pinned against fence
41	BRIDGE_41	FOOTBRIDGE	1.3m	Footings being undermined by stream (soil holds bridge)
42	BRIDGE_42	FOOTBRIDGE	0.4m	
43	BRIDGE_43	FOOTBRIDGE	0.6m	
44	BRIDGE_44	FOOTBRIDGE	1.2m	Accesses powerline recreational path, on city property (?)
45	BRIDGE_45	FOOTBRIDGE	0.5m	
46	BRIDGE_46	DRIVEWAY		
47	BRIDGE_47	OTHER		Think there is a culvert under here like ones on rest of farm but it's completely blocked by veg & sediments, 30cm pool D/S though
48	BRIDGE_48	FOOTBRIDGE		Informal
49	BRIDGE_49	DRIVEWAY		Driveway to farm, overtop of fish friendly box culvert

Table B-6: Field Inventory - Observed OutfallSites

Storm Outfalls to Creek													
Object ID	Site ID	Bank	Diameter	Height	Shape	Material	Condition	Energy Dissipation	Energy Dissipation Type	Headwall	Headwall Condition	Outfall Drop	Comment
1	OUTFALL_1	RIGHT BANK	200	0.20	Round	HDEP	GOOD	NO		NONE		0.20	There is a second big O pipe flowing in from the south though no flow was observed
2	OUTFALL_2	LEFT BANK	100	0	Round	HDEP	FAIR	NO	NONE	NONE		0	Possible illegal house storm outlet
3	OUTFALL_3	LEFT BANK	150	2	Round	PVC	GOOD	NO		CONCRETE	GOOD	0	
4	OUTFALL_4	MID CHANNEL	900	0.15	Round	CONCRETE	FAIR	NO	NONE	SANDBAG	FAIR	0.15	
5	OUTFALL_5	RIGHT BANK	250	0.10	Round	CONCRETE	GOOD	NO	NONE	NONE		0	Pipe outlets directly into stream perpendicular to flow
6	OUTFALL_6	RIGHT BANK	350	0.40	Round	CONCRETE	GOOD			CONCRETE	GOOD	0.10	Somewhat overgrown but good condition
7	OUTFALL_7	RIGHT BANK	900	0.10	Round	CONCRETE	GOOD	YES	CONCRETE	CONCRETE	GOOD	0	
8	OUTFALL_8	MID CHANNEL	900	0	Round	CONCRETE	GOOD	YES	RIPRAP	CONCRETE	GOOD	0	Trash rack
9	OUTFALL_9	MID CHANNEL	450	0	Round	CONCRETE	GOOD	YES	CONCRETE	CONCRETE	GOOD	0	External grating has been broken off
10	OUTFALL_10	RIGHT BANK	250	0.20	Round	PVC	GOOD	NO		CONCRETE	FAIR	0	Small conc block hwall
11	OUTFALL_11	RIGHT BANK	250	0	Round	PVC	GOOD	NO	NONE	CONCRETE	GOOD	0	
12	OUTFALL_12	MID CHANNEL	900	0	Round	CONCRETE	GOOD	NO	NONE	CONCRETE	GOOD	0	Some sed in pipe
13	OUTFALL_13	MID CHANNEL	600	0	Round	PVC	GOOD	YES	ROCK & GRAVEL	CONCRETE	GOOD	0	Boulders downstream to dissipate energy
14	OUTFALL_14	RIGHT BANK	200	0	Round	PVC	GOOD	YES	RIPRAP	NONE		0	Catch basin outfall from Fraser Hwy
15	OUTFALL_15	LEFT BANK	300	0.50	Round	PVC	GOOD	NO	NONE	NONE		0.30	Some rock placed over top of pipe. Small amount of flow at time of survey
16	OUTFALL_16	LEFT BANK	1000	0.30	Round	CONCRETE	GOOD	NO		CONCRETE	GOOD	0.10	
17	OUTFALL_17	RIGHT BANK	200	0	Round	PVC	FAIR	NO	NONE	NONE		0	Partially submerged outfall from detention pond
18	OUTFALL_18	RIGHT BANK	700	0.10	Round	CONCRETE	GOOD	YES	CONCRETE	CONCRETE	GOOD	0	
19	OUTFALL_19	RIGHT BANK	600	0.50	Round	CONCRETE	GOOD	YES	CONCRETE	CONCRETE	GOOD	0	Channel leading to creek is riprap lined beyond headwall. Grating to prevent ingress on outfall
20	OUTFALL_20	LEFT BANK	150	0.50	Round	PVC	GOOD	NO		CONCRETE		0.05	Possibly house storm drain
21	OUTFALL_21	RIGHT BANK	300	1	Round	CONCRETE	GOOD	YES	RIPRAP	CONCRETE	GOOD	0.10	Outlet into pseudo detention pond before creek confluence
22	OUTFALL_22	LEFT BANK	200	1	Round	PVC	GOOD	YES	ROCK & GRAVEL	CONCRETE	FAIR	0	Headwall in good condition rock bank armour is falling apart and exposing geotextile
23	OUTFALL_23	MID CHANNEL	750	0.10	Round	CONCRETE	GOOD	YES	CONCRETE	CONCRETE	GOOD	0.10	Riprap in channel is eroding and falling into channel. Silt fence across the bottom of the channel has failed.
24	OUTFALL_24	MID CHANNEL	250	0.30	Round	PVC	GOOD	YES	RIPRAP	RIPRAP	GOOD	0.10	Currently dry
25	OUTFALL_25	RIGHT BANK	100	2	Round	PVC	GOOD	NO		NONE		0.30	2 small drainage outfalls
26	OUTFALL_26	RIGHT BANK	600	0.30	Round	CONCRETE	GOOD	YES		CONCRETE	GOOD	0	Outfall exits through rubber tube bolted to outlet. No channel exists, discharge flows through marshy grass land
27	OUTFALL_27	MID CHANNEL	900	0.00	Round	CONCRETE	GOOD	YES		CONCRETE	GOOD	0	Enrg dis is concrete outfall pad and some rock at the end, minor effect only. Storm outfall
28	OUTFALL_28	RIGHT BANK	250	0.50	Round	STEEL	FAIR	YES	ROCK & CONCRETE	SANDBAG	FAIR	0	
29	OUTFALL_29	MID CHANNEL	800	0	Round	CONCRETE	GOOD	YES	ROCK & CONCRETE	CONCRETE	GOOD	0	
30	OUTFALL_30	LEFT BANK	250	1	Round	PVC	FAIR	YES	RIPRAP	NONE		0	Culvert under path enters here, 5 rocks on bank to protect and dissipate eng
31	OUTFALL_31	MID CHANNEL	900	0.10	Round	CONCRETE	GOOD	YES	ROCK & GRAVEL	LOK BLOCKS	GOOD	0.10	Concrete block hwall
32	OUTFALL_32	MID CHANNEL	1100	0	Round	CONCRETE	GOOD	YES	CONCRETE	CONCRETE	GOOD	0	Low flow outfall below twin high flow pipes
33	OUTFALL_33	MID CHANNEL	900	1	Round	CONCRETE	GOOD	YES	ROCK & CONCRETE	CONCRETE	GOOD	0	Conc weir and rrap d/s of outlet
34	OUTFALL_34	MID CHANNEL	0	0			GOOD	YES	ROCK & CONCRETE	CONCRETE	GOOD	0	Unknown pipe out falls through notched conc weir (notch is .3x.2m) into lined channel. Outlet is 3m wide
35	OUTFALL_35	MID CHANNEL	1200	0	Round	CONCRETE	GOOD	NO		CONCRETE	GOOD	0	
36	OUTFALL_36	LEFT BANK	10	0	Round	PVC	POOR	NO	NONE	NONE	POOR	0	
37	OUTFALL_37	RIGHT BANK	0	0	Round	PVC	POOR	NO	NONE	NONE	POOR	0	
38	OUTFALL_38	RIGHT BANK	5	0	Round	PVC	FAIR	NO	NONE	NONE	FAIR	70	White pipe just inside fence on farm
39	OUTFALL_39		0	0								0	White pipe outfall just inside fence on farm
40	OUTFALL_40	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	FAIR	100	
41	OUTFALL_41	RIGHT BANK	5	0	Round	PVC	GOOD	NO	CONCRETE	NONE	FAIR	50	White outfall pipe beside U/S end of driveway bridge
42	OUTFALL_42	RIGHT BANK	3	0	Round	PVC	GOOD	NO	NONE	NONE	FAIR	30	Black pipe has yellow stick beside it (looks like drain from horse stable)
43	OUTFALL_43	RIGHT BANK	0	0	Round	PVC	POOR	NO	NONE	NONE	FAIR	90	
44	OUTFALL_44	LEFT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	FAIR	60	White outfall beside D/S end of driveway bridge for photo see bridge same location
45	OUTFALL_45	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	FAIR	0	Drain from horse shed
46	OUTFALL_46	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	FAIR	35	
47	OUTFALL_47	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	POOR	60	Occurs with 2nd pipe immediately above, See 15 cm pipe for photo
48	OUTFALL_48	RIGHT BANK	15	0	Round	PVC	GOOD	NO	NONE	NONE	POOR	20	Bentos is clay layer, evidence of it being hydro mined: fragment in stream channel

Table B-6: Field Inventory - Observed OutfallSites

Storm Outfalls to Creek													
Object ID	Site ID	Bank	Diameter	Height	Shape	Material	Condition	Energy Dissipation	Energy Dissipation Type	Headwall	Headwall Condition	Outfall Drop	Comment
49	OUTFALL_49	LEFT BANK	5	0	Round	PVC	FAIR	NO	NONE	NONE	POOR	15	Site of erosion around pipe, occurs in elbow of stream
50	OUTFALL_50	RIGHT BANK	40	0	Round	CONCRETE	GOOD	YES	ROCK & GRAVEL	CONCRETE	GOOD	60	
51	OUTFALL_51	MID CHANNEL	85	0	Round	CONCRETE	GOOD	YES	RIPRAP	CONCRETE	GOOD	0	Flow controls inside culvert (concrete baffles?)
52	OUTFALL_52		0	0								0	
53	OUTFALL_53	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	POOR	0.50	
54	OUTFALL_54		5	0		PVC	GOOD	YES	ROCK & GRAVEL			0	
55	OUTFALL_55	RIGHT BANK	5	0	Round	PVC	FAIR	NO	NONE	NONE	POOR	10	
56	OUTFALL_56	RIGHT BANK	5	0	Round	PVC	POOR	YES	RIPRAP	NONE	POOR	5	
57	OUTFALL_57	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	POOR	10	
58	OUTFALL_58	LEFT BANK	5	0	Round	PVC	POOR	NO	NONE	NONE	POOR	5	
59	OUTFALL_59	RIGHT BANK	5	0	Round	PVC	GOOD	NO	NONE	NONE	FAIR	5	
60	OUTFALL_60	MID CHANNEL	30	0	Round	CONCRETE	GOOD	YES	RIPRAP	CONCRETE	GOOD	0	South Creek originates under ground beyond here?
61	OUTFALL_61	MID CHANNEL	15	0	Round	PVC	GOOD	YES	RIPRAP	ROCK & GRAVEL	GOOD	0	
62	OUTFALL_62		0	0								0	Culvert under greenway path, half blocked by sediment D/S enc
63	OUTFALL_63	RIGHT BANK	0	0								0	
64	OUTFALL_64	RIGHT BANK	7	0		PVC	GOOD	NO	NONE	NONE	POOR	70	
65	OUTFALL_65		30	0				YES	ROCK & GRAVEL	CONCRETE	GOOD	0	
66	OUTFALL_66	LEFT BANK	5	0		PVC	FAIR	NO	NONE	NONE	POOR	0.80	
67	OUTFALL_67		0	0								0	Storms later drainage ditch from condos/road

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

FLEETWOOD GREENWAY STUDY AREA

Swanson Brk

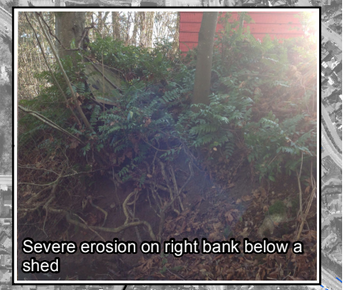
Drinkwater Crk

Fleetwood Crk

163 St. Crk

161A St. Crk

166 St. Crk



EROS_202
EROS_201
EROS_191
EROS_142
EROS_42
EROS_6
EROS_4
EROS_135
EROS_133
EROS_129

Legend

- Study Area
- Watercourse
- Ditch
- Erosion Sites Identified in 2015 Field Visit
- Erosion Sites Identified in Previous Field Visits Deteriorating in 2015 Field Visit

High Risk Erosion Sites

	Hazard	Consequence
▲	High (>1.2m)	*Moderate (5-10m)*
▲	Moderate (0.3-1.2m)	*High (<5m)*
▲	High (>1.2m)	*High (<5m)*

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

KERR WOOD LEIDAL
consulting engineers

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200 0 200 (m)

1:7,500

Project No.	Date
471-288	June 2016

Fleetwood Greenway High Risk Erosion Sites

Figure B-1

Path: O:\0400-0499\471-288\430-GIs\MXD-Rpt\471288_FigB-1_MajErosionFleetwood.mxd Date Saved: 13/06/2016 12:31:53 PM
Author: SScott

NORTH CREEK
STUDY AREA

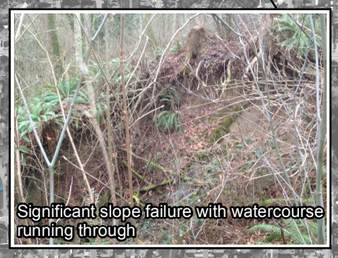
72 Ave

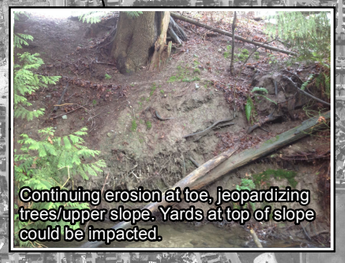
EROS_87
EROS_78
EROS_73
EROS_225
EROS_226
EROS_239
EROS_233

North Crk
South Crk
St Gelais Brk

Bank eroding at toe. Houses at top of slope.

Large fir has fallen and slope failed. Recent channelization down failed slope further reducing stability.


Significant slope failure with watercourse running through


Continuing erosion at toe, jeopardizing trees/upper slope. Yards at top of slope could be impacted.

Major bank failure/erosion adjacent to sidewalk.

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Ditch
- Erosion Sites Identified in 2015 Field Visit
- Erosion Sites Identified in Previous Field Visits Deteriorating in 2015 Field Visit

High Risk Erosion Sites

	Hazard	Consequence
▲	Moderate (0.3-1.2m)	*High (<5m)*
▲	High (>1.2m)	*Moderate (5-10m)*
▲	High (>1.2m)	*High (<5m)*

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

KERR WOOD LEIDAL
consulting engineers

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200 0 200 (m)
1:7,500

Project No.	Date
471-288	June 2016

North Creek
High Risk Erosion Sites

Figure B-2

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Appendix C – Environmental Inventory and Assessment

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Appendix C – Environmental Inventory and Assessment

C Environmental Inventory and Assessment

C.1 Introduction

This Appendix describes the methods and results for the environmental inventory and assessment undertaken in winter 2014/2015 for the Fleetwood Greenway North Creek ISMP. The work program included assessments on the following topics for the study area:

- Water and sediment quality;
- Benthic invertebrates;
- Riparian and watershed forest cover;
- Fish and aquatic habitat; and
- Terrestrial habitat, wildlife and species at risk.

The purpose of the assessments were to: (1) to assess status and trends in watershed health in the Fleetwood and North Creek catchments; (2) to identify priority environmental issues to be addressed in the ISMP; and (3) to identify environmental enhancement opportunities within the study area. Depending on the assessment, the work included collation and review of existing information, field inventories, and data summarization and analysis.

Previous Assessments

A number of previous assessments of streams within the catchment areas have been completed in the past. Three biophysical assessments of creeks within the Fleetwood catchment area were conducted in 1994 by Envirowest as part of a Sub-basin Drainage Plan for the City of Surrey, and included assessments of the riparian area, fish presence, and fish habitat in Fleetwood Creek (Envirowest 1994a), 161A St. Creek, 162 St. Creek, 166 St. Creek (Envirowest 1994b), and Drinkwater Creek (Envirowest 1994c).

A study of North Creek was conducted by Raincoast Applied Ecology (Page and Lilley 2010) to look at changes in streamflow, water quality, and the benthic invertebrate community between 1999 and 2009. The study used existing monitoring data to evaluate the impacts of the East Clayton neighbourhood on North Creek, as developments within the neighbourhood had incorporated a number of innovative stormwater management strategies starting in 2001. The results suggest that management strategies appeared to successfully increase streamflow as a proportion of precipitation and reduce annual stormflows but there were still effects of urbanization on water quality and the benthic invertebrate community.

As part of a latter phase of ISMP development, an updated analysis of the North Creek monitoring data including the last five years of data (2009-2014) will be conducted to further evaluate the success of the stormwater management strategies in North Creek.

Appendix C – Environmental Inventory and Assessment

C.2 Water and Sediment Quality

Maintaining adequate water and sediment quality in watersheds is important to protecting aquatic life and downstream water uses. Water quality is influenced by several factors: inputs from point and non-point pollutant sources, instream disturbances (anthropogenic or otherwise), or both, and by the conditions in the broader watershed such as levels of imperviousness. Water quality parameters include chemical, physical and biological measurements including water temperature, dissolved oxygen, specific conductivity, pH, turbidity, as well as fecal coliforms and *E. coli*.

Heavy metals and other contaminants can accumulate in stream sediments from a variety of sources in developed watersheds. The analysis of sediments provides complimentary data that can be used in concert with water quality data to assess environmental quality in the watershed.

Water and sediment quality assessment for this project consisted of a survey of general water quality parameters and a review of the North Creek monitoring station data. The City of Surrey has conducted water quality grab sampling at select sites within the City since 2009 as part of the Boundary Bay Ambient Monitoring Program (BBAMP). However, none are associated the Fleetwood or North Creek catchments.

Metro Vancouver, with input from its member municipalities, has recently developed a Monitoring and Adaptive Management Framework (MAMF) in order to monitor developing and developed watersheds and assess the implementation of ISMPs. The City is in the process of adding additional sites to its BBAMP sites in order to implement the water quality monitoring component of the MAMF across all of its watersheds. Although future sampling sites for water quality and sediment grab sampling has been identified within the Fleetwood or North Creek catchments, sampling has not been undertaken to date and will be initiated in the next four years.

General Water Quality Survey

Rapid in-situ water quality measurements were taken during low flow conditions on September 10, 2015. A total of 31 sites were visited: 15 sites in the Fleetwood Catchment and 16 in the North Creek Catchment. In-situ water quality parameters (dissolved oxygen, pH, water temperature, conductivity, turbidity, total dissolved solids, salinity, oxygen reduction potential) were measured in the field using a YSI 6920 water quality multiparameter sonde (YSI 6920) rented from Pine Environmental (Burnaby, BC).

Each catchment was further divided into three subcatchments as shown in Figure C-1. Results of the rapid in-situ water quality monitoring are summarized in Table C-1 and C-2. Complete results for each catchment are provided in Table C-3. Results have been assessed according to water quality guidelines in Metro Vancouver's *Monitoring and Adaptive Management Framework Water Quality Evaluation System* (MAMF). Although caution should be taken in comparing one-time sampling results to guidelines based on arithmetic and geometric means, the values are a useful screening tool for assessing the distribution of water quality and potential sources of water quality degradation.

Appendix C – Environmental Inventory and Assessment

The general interpretation of individual categories is the following:

- Good Priority Indicator = suggests that water quality for this parameter, at least at the current monitoring location, is good. Based on this, no further monitoring for this parameter is required in the drainage system for 5 years. No adaptive management is required based on this monitoring.
- Satisfactory Priority Indicator = suggests that water quality is either closely approaching a level of concern for this parameter or is already in non-attainment with provincial water quality guidelines. The level of the parameter result (relative to water quality guidelines and/or objectives) and the incidence of additional priority indicators of concern should be considered in development of the city-wide Adaptive Management Plan. Consideration should be given to supplemental water quality monitoring and/or adaptive management actions.
- Needs Attention Priority Indicator = suggests that water quality is in non-attainment with provincial water quality guidelines. The level of the parameter result and the incidence of additional priority indicators of concern should be considered as part of the city-wide Adaptive Management Plan. Supplemental water quality monitoring and/or adaptive management actions are recommended.

Under the MAMF, water temperature, dissolved oxygen, and turbidity are considered primary indicators. Conductivity and pH are considered secondary indicators, and provide supporting information for interpretation of priority indicators and for identification of the source of an impact. See Metro Vancouver (2014) for more details.

Key findings from the water quality monitoring include:

- Mean conductivity levels fell into the MAMF's "needs attention" category in both catchments. Four of six subcatchments were in the "needs attention" category, while two were in the "satisfactory" category. This indicates there is likely some impact from non-point source pollution in both catchments.
- Dissolved oxygen in both catchments was satisfactory, suggesting dissolved oxygen levels are approaching a level of concern. Both catchments had one site in the "needs attention" category.
- Temperatures in North Creek, especially in the headwater areas, exceed guidelines in the MAMF (needs attention category). Temperatures in the North Creek catchment overall are consistently approaching levels of concern (satisfactory category). Temperatures above 16 ºC are above optimum rearing temperatures for salmonids.
- Turbidity and pH consistently are in the MAMF's "good" category, with few exceptions. Only three of 31 sites indicated levels approaching concern (satisfactory category).

Table C-1: In Situ Water Quality Measurements for the Fleetwood Creek Catchment

Sub-catchment	Water quality parameters														
	Dissolved oxygen (mg/L)			pH			Water Temperature (ºC)			Conductivity (mS/cm)			Turbidity (NTU)		
	Mean	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max
161A / 162 / 166 St. Creek (n=9)	**8.35**	6.33	10.23	**7.54**	7.17	8.03	**15.08**	13.37	18.70	**0.206**	0.143	0.269	**1.0**	0.0	1.8
Drinkwater Creek (n=3)	**9.48**	8.21	10.31	**8.04**	7.86	8.18	**16.17**	15.70	16.76	**0.256**	0.199	0.333	**0.5**	0.0	0.7
Fleetwood Creek (n=3)	**7.37**	5.78	8.93	**7.59**	7.25	7.88	**17.46**	15.02	19.70	**0.157**	0.123	0.193	**0.2**	0.0	1
Catchment Total (n=15)	**8.38**	5.78	10.31	**7.65**	7.17	8.18	**15.77**	13.37	19.70	**0.206**	0.123	0.333	**0.7**	0.0	1.8

* For each sub-catchment , n represents the number of sites where in situ water quality measurements were taken.
** Green = Good, Yellow = Satisfactory, Red = Needs Attention

Table C-2: In Situ Water Quality Measurements for the North Creek Catchment

Sub-catchment	Water quality parameters														
	Dissolved oxygen (mg/L)			pH			Water Temperature (ºC)			Conductivity (mS/cm)			Turbidity (NTU)		
	Mean	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max
North Creek (n=6)	**9.73**	9.34	10.45	**7.99**	7.85	8.13	**18.24**	16.33	19.79	**0.222**	0.138	0.349	**5.2**	0.3	12.7
North Creek Lowlands (n=7)	**8.66**	5.65	9.60	**7.73**	7.54	7.81	**17.07**	14.24	18.12	**0.234**	0.172	0.324	**1.8**	0.7	4.2
South Creek (n=3)	**10.04**	9.93	10.10	**7.95**	7.84	8.01	**17.54**	16.91	18.12	**0.145**	0.139	0.156	**1.1**	0.4	2.1
Catchment Total (n=16)	**9.32**	5.65	10.45	**7.87**	7.54	8.13	**17.60**	14.24	19.79	**0.213**	0.138	0.349	**2.9**	0.3	12.7

* For each sub-catchment , n represents the number of sites where in situ water quality measurements were taken.
** Green = Good, Yellow = Satisfactory, Red = Needs Attention

Table C-3: Fleetwood Greenway - North Creek One-time Water Quality Sampling Results - September 10, 2015

Site	Easting	Northing	Location	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Water Temperature °C	Conductivity (mS/cm)	Conductivity (mS/cm^{C})	Turbidity (NTU)	Total Dissolved Solids (TDS)	Salinity	Oxygen Reduction Potential (ORP)
F-1	517739	5443247	Ditch on 168th st., south of 76th Ave. Sand & gravel bottom	8.41	80.8	7.39	13.48	0.239	0.307	1.3	0.200	0.15	73.3
F-2	517743	5443131	Bottom of 166th St. creek, in ditch where all creeks meet.	6.33	60.9	7.22	13.61	0.193	0.247	1.4	0.160	0.12	72.5
F-3	517736	5443160	Mouth of 166th St. creek	10.23	98.7	7.39	13.72	0.204	0.260	1.8	0.169	0.12	48.3
F-4	517719	5443151	Mouth of Ditch along 76th Ave. alignment	6.47	62.7	7.17	13.94	0.189	0.240	1.6	0.166	0.11	100.2
F-5	517738	5443320	Upstream of 166th St. creek confluence in 168th St. Ditch	7.89	75.6	7.24	13.37	0.269	0.346	-0.2	0.225	0.17	157.7
F-6	516656	5443924	162nd St. creek at 80th Ave, downstream side	9.39	95.0	7.76	15.88	0.164	0.198	0.7	0.129	0.09	202.6
F-7	516124	5443712	Fleetwood Park (160th St.)	8.93	93.7	7.88	17.65	0.156	0.181	1.0	0.118	0.09	217.7
F-8	516369	5443500	162nd St. creek at 77nd A Ave. upstream	8.51	91.2	8.03	18.70	0.257	0.292	0.7	0.190	0.14	225.4
F-9	516685	5443142	76th Ave. alignment	10.01	99.6	7.90	14.98	0.143	0.183	0.0	0.119	0.09	166.4
F-10	515897	5443923	Fleetwood creek at 80th Ave. (East Outfall) 159th St.	5.78	63.4	7.64	19.70	0.193	0.215	-0.2	0.139	0.10	54.5
F-11	515710	5443946	Fleetwood creek at 158th St.	7.40	73.5	7.25	15.02	0.123	0.151	-0.1	0.098	0.07	162.0
F-12	516581	5444346	162nd St. creek at 82nd Ave.	7.89	83.5	7.79	18.02	0.196	0.226	1.3	0.147	0.11	121.2
F-13	517713	5444349	Drinkwater creek @ 168th St. 20m upstream of culvert	8.21	83.4	7.86	16.06	0.333	0.401	0.4	0.261	0.19	236.5
F-14	518132	5444292	Drinkwater at 170th St.	10.31	106.2	8.18	16.76	0.235	0.279	0.7	0.181	0.13	246.0
F-15	518506	5444276	Drinkwater at 172nd St.	9.91	99.8	8.07	15.70	0.199	0.242	0.4	0.157	0.12	241.3
N-1	519434	5442758	North creek at Fraser Highway, 176th St. at culvert	5.65	55.2	7.54	14.24	0.240	0.302	1.8	0.196	0.14	230.5
N-2	521528	5441655	Outlet into storm detention pond	9.56	104.9	7.86	19.79	0.349	0.388	12.7	0.252	0.19	255.5
N-3	521352	5441685	Outlet from detention pond	10.45	113.1	8.13	19.17	0.245	0.276	7.5	0.179	0.13	267.7
N-4	520950	5441753	North creek at 184th St. downstream culvert	9.34	99.6	7.85	18.47	0.138	0.158	1.4	0.103	0.07	174.6
N-5	519390	5442001	176th St.	9.06	95.5	7.71	17.82	0.283	0.382	2.2	0.213	0.16	238.0
N-6	520558	5441829	Outfall at 70th/182nd, middle outfall	9.63	98.7	7.98	16.33	0.146	0.175	8.4	0.114	0.08	292.6
N-7	520553	5441832	North creek at 182nd	9.80	103.6	8.04	18.03	0.251	0.291	0.8	0.189	0.14	295.3
N-8	520360	5441330	South creek at 67th St.	10.10	105.8	7.84	17.60	0.139	0.161	2.1	0.105	0.08	282.0
N-9	520182	5441435	South creek at 180th St.	9.93	105.2	8.01	18.12	0.156	0.180	0.4	0.117	0.09	291.8
N-10	520029	5441481	South creek at 68th Ave.	10.09	104.3	8.00	16.91	0.141	0.167	0.9	0.108	0.08	273.6
N-11	519993	5441666	North creek west of 180th St.	9.57	100.4	8.05	17.65	0.204	0.238	0.3	0.154	0.11	264.9
N-12	519639	5441934	North creek	9.11	95.2	7.81	17.44	0.172	0.201	0.7	0.131	0.10	280.5
N-13	519632	5441911	Middle of detention pond	9.38	98.5	7.81	17.68	0.249	0.289	0.7	0.188	0.14	283.9
N-14	519622	5441918	North creek below additional outfall	9.52	100.9	7.74	18.12	0.324	0.373	1.4	0.243	0.13	136.0
N-15	519373	5441611	Upstream of 176th/ 98thA crossing	9.60	98.5	7.79	16.58	0.187	0.223	4.2	0.145	0.11	239.3
N-16	519390	5441901	North creek at entrance to horsefarm	8.32	87.4	7.71	17.58	0.186	0.217	1.4	0.141	0.10	231.3

Appendix C – Environmental Inventory and Assessment

North Creek Continuous Water Quality Monitoring Station

The City of Surrey has been monitoring benthic invertebrate communities and physical water quality parameters in North Creek in east-central Surrey, BC since 1999 and 2002, respectively. The purpose of the monitoring was to assess the effects on the creek from development of the East Clayton Neighbourhood. More specifically, the monitoring was intended to assess whether the variety of innovative stormwater management practices that were incorporated into development of the area have mitigated the effects of that development on the health of the North Creek watershed.

A recent report provides an update to a 2010 analysis of changes in water quality and the benthic invertebrate community in North Creek (KWL 2016). It extends the period of analysis to include additional data collected from September 2009 to March 2015. One of the main purposes of this report is to assess whether the changes and trends observed over the previous monitoring period have continued or if further changes or new trends have occurred.

Analyses of physical water quality data included calculation of annual mean values, exceedance of water quality guidelines or other informative thresholds for each water quality parameter, and tests for seasonal trends. Trends in Benthic Index of Biotic Integrity (B-IBI) values, taxa richness, individual component B-IBI metrics, and abundance of individual taxa were also examined and key findings are included in the next section. Key water quality findings of the report are as follows:

1. There was a non-significant increasing trend in water temperature from 2002 to 2009. The largest increases in temperature appear to have occurred from 2003 to 2005. Higher temperatures observed after 2005 may reflect the influence of the large stormwater detention pond in the catchment as well as the larger amount of runoff originating from hard surfaces and the lack of shading of these surfaces. Water temperature has exceeded 17 °C for over 40 cumulative days each year since 2003 (except 2013).
2. Specific conductivity increased from 2002 to 2009, and has remained at elevated levels since development has occurred in the upper watershed. Recent observed specific conductivity values are typical of highly urbanized catchments and suggest higher levels of dissolved contaminants are entering the creek in runoff.
3. pH was outside of the recommended window of 6.5 to 9.0 only for brief periods in 2003 (below pH 6.5), 2005, 2011, and 2012 (above pH 9.0). The pH values below 6.5 in 2003 may be associated with the amount of exposed soil in the catchment during the initial clearing phase of development. The high pH values above 9.0 in 2005, 2011, and 2012 are likely attributable to spills of concrete or concrete wash water from construction sites.
4. Turbidity decreased from 2002 to 2009 and has remained relatively low. Annual average turbidity was noticeably higher in 2003 and 2004 and these years also recorded the highest number of larger severity (moderate severity-of-ill-effects (SEV) category) turbidity events. It is unclear if declines in turbidity in the latter part of the development period reflect the success of the City's ESC (Erosion and Sediment Control) bylaw, the innovative stormwater management practices used in East Clayton or a combination of both.

Appendix C – Environmental Inventory and Assessment

C.3 Benthic Invertebrates

Benthic invertebrates are a commonly-used indicator of stream health and can be used to track changes in watershed health. Changes in the both the species richness and composition of invertebrate communities indicate changes in watershed conditions. B-IBI (Benthic Index of Biotic Integrity) is a 10-metric index characterizing the composition of the benthic invertebrate community (Karr 1998). B-IBI scores can range from 10 and 50, with 10 being a degraded watershed and 50 being in excellent condition. Undeveloped watersheds in Metro Vancouver have scored up a maximum of 40, which is considered good condition.

Analysis of the North Creek benthic invertebrate sampling results from 1999–2009 by Raincoast (Page and Lilley 2010) showed an overall trend of becoming more similar to typical urbanized streams over time, as sensitive taxa were lost from the stream and more tolerant taxa became established. However, mean B-IBI had increased from the beginning of the study. In interpreting the results, it was suggested that North Creek was in period of transition, resulting in high taxa richness as some sensitive taxa still remained, but tolerant taxa were becoming established. Furthermore, increases in the abundance of a single predator taxon (Turbellarian flatworms) drove an increase in the B-IBI that is not necessarily indicative of increasing stream health. An update to this analysis (described in the previous section) was recently conducted and the key findings are presented below (KWL 2016).

As part of Surrey's ongoing benthic invertebrate monitoring program, sampling was conducted in the spring and fall at two locations in North Creek from 1999 to 2013. Spring sampling was also initiated at an additional site in 162 Street Creek starting in 2012. Sampling sites are shown in Figure C-1. B-IBI and total taxa richness are summarized in Figure C-2 and C-3 and Table C-4, C-5, and C-6.

Fleetwood Catchment

Mean B-IBI scores and total taxa richness for the sampling site located in 162 Street Creek were 14 and 10 for both years, respectively (Table C-4). These scores indicate very poor condition, typical of high levels of urbanization and development around streams. The potential stability of the results indicate no significant change in taxa presence or absence over time. Although 162 Street Creek has high riparian forest cover (79.9%), the low B-IBI scores may reflect the low level of forest cover in the entire catchment (17.3%) and significant levels of development within the creek's catchment.

Table C-4: B-IBI and Total Taxa Richness at Sample Site WA1 (162 St Creek[1])

Year	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
2012	14.0	10	-	-
2013	14.0	10	-	-

[1] Known as Walnut Creek in benthic monitoring reports.

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North Creek Catchment

Mean B-IBI and total taxa richness values for North Creek are located in Table C-5 and Table C-6. The following points represent the key findings of the North Creek benthic invertebrate monitoring analysis (from KWL 2016):

1. Mean B-IBI values at Station N1 increased significantly from 1999 to 2015. In contrast, mean B-IBI value at North Creek Station N2 has declined slightly since 1999 although the change is not statistically significant.
2. At both stations, taxa richness was lower before 2001, peaked between 2002 and 2004, and then declined. This peak in taxa richness was significant at Station N1, but not at Station N2. Observed patterns were likely due to the rapid establishment of new tolerant taxa concurrent with a somewhat slower loss of sensitive taxa, which is typical in urbanizing streams.
3. Changes to mean B-IBI values at both stations were driven by changes to only some of the ten component metrics. The percent of tolerant organisms has increased since 2004. The increase in predator organisms was primarily caused by the increase in abundance of Turbellaria flatworms which thrive in fine sediments common in urban streams. Although it is not the general pattern observed in urbanizing streams, percent dominance has declined in North Creek during the study period.
4. The two most abundant taxa, Oligochaete worms and Chironomid larva, have declined since 1999. Turbellaria flatworms, Caecitodea isopods, and Ceratopogonidae (biting midges) established or increased substantially in abundance from 2006 to 2013, and then recently declined.

Table C-5: B-IBI and Total Taxa Richness at Sample Site N1 (North Creek Upstream)

Year	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
1999	14.0	12	14.0	8
2000	14.0	16	-	-
2001	14.0	17	17.3	24
2002	16.0	24	15.3	19
2003	16.7	21	18.0	20
2004	19.3	21	18.0	26
2005	17.3	27	14.7	22
2006	16.0	24	14.0	16
2007	14.7	19	18.7	17
2008	16.0	22	18.7	17
2009	17.3	17	19.3	16
2010	20.7	17	18.0	16
2011	16.7	18	18.7	12

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Year	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
2012	15.3	16	18.0	11
2013	17.3	13	18.7	8
2014	17.3	14	17.3	13
2015	22.7	23	-	-

Table C-6: B-IBI and Total Taxa Richness at Sample Site N2 (North Creek Downstream)

Year	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
1999	15.3	26	15.3	13
2000	14.0	13	-	-
2001	14.7	19	-	-
2002	15.3	27	18.7	32
2003	19.3	33	18.7	20
2004	18.7	30	16.7	24
2005	15.3	21	18.0	26
2006	14.0	17	17.3	24
2007	14.0	18	16.7	32
2008	14.7	22	14.0	19
2009	14.7	23	15.3	25
2010	15.3	28	16.7	15
2011	14.0	12	20.0	23
2012	14.0	17	16.7	22
2013	14.7	20	17.3	16
2014	14.0	18	17.3	20
2015	16.7	21	-	-

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C.4 Riparian and Watershed Forest Cover

Watershed and riparian forest cover are indicators of stream and watershed health and relate to the effect of changing land use can have on hydrology, water quality, and other components of stream ecosystems.

Watershed forest cover is strongly tied to the ability of a landscape to support biodiversity. There is evidence that protecting between 30-50 % forest cover and at least one, and preferably several, large patches (>200 ha) is necessary to maintain even marginal levels of biodiversity and aquatic ecosystem health. Protection of 50% of watershed forest cover is recommended.

Riparian forest integrity (RFI) is the amount of intact riparian forest corridor along a stream, expressed as a percentage of area within a 30 m setback on both sides of a watercourse over its entire length. Riparian (streamside) vegetation provides a source of large organic debris for fish habitat, stabilizes streambanks to reduce erosion, shades the channel to moderate water temperatures, and introduces food for aquatic life. Maintaining a 70-75% RFI is a recommended guideline for urban watersheds.

To assess watershed forest cover, vegetation mapping conducted for Surrey's recently published Biodiversity Conservation Strategy (City of Surrey 2014) was utilized. To reflect recent losses/gains associated with land development, mapping was reviewed and updated using recent (2013) orthophotos provided by the City. To assess riparian forest integrity for individual creeks, creek centrelines were buffered with a 30 m setback (60 m total width) across all permanent streams. In both cases, the proportion of the catchment or riparian area covered by forest was calculated. Figure C-4 shows the watershed and riparian forest cover mapped for the two catchments. Results are summarized in Tables C-7 and C-8 and described below.

Fleetwood Catchment

Key findings for the watershed and riparian forest cover analysis for the Fleetwood catchment were as follows:

- A total of 17.3% (88.4 ha) of the Fleetwood catchment is forested (Table C-7). The largest patch of forest, 38 ha or 43% of total forest cover in the catchment, is found in Fleetwood Urban Park. Larger patches of forest are also located in creek riparian areas with a number of smaller forest patches (<5 ha) located outside of riparian areas. Total forest cover for the catchment is below the guideline of 50%.

Table C-7: Watershed Forest Cover in the Fleetwood and North Creek Catchments

Catchment	Total Area (ha)	Forested Area (ha)	% of Area Forested
Fleetwood	512.0	88.4	17.3
North Creek	445.6	45.1	10.1
Extra Catchment	41.2	1.5	3.7

- Riparian forest cover in the watershed remains high at 75.5%, in line with the recommended guidelines (Table C-8).

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- Four of the five creeks in the catchment have greater than 70% riparian forest cover, and meet or exceed recommended guidelines. Fleetwood Creek has the highest amount of riparian forest intact with 90% due to the protection of forest in the Fleetwood Urban Park.
- 166 Street Creek is the only creek in the catchment with riparian forest cover below recommended guidelines with an RFI of only 36.8%. Historical development around the creek has encroached on the riparian area.
- The majority of forest cover in the catchment is made up of young deciduous forest (5–80 yrs). Small patches of young mixed forest (5–80 yrs) and mature forest (>80 yrs) are also present.

Table C-8: Riparian Forest Cover in the Fleetwood and North Creek Catchments

Stream	Total Riparian Area (ha)	Total Riparian Forest (ha)	Riparian Forest Integrity (%)
Fleetwood Catchment	37.8	28.5	75.5
Fleetwood Creek	12.3	11.5	93.2
161A St. Creek	2.7	2	72.0
162 St. Creek	8.5	6.8	79.9
166 St. Creek	5.3	2.0	36.8
Drinkwater Creek	8.9	6.3	71.0
North Creek Catchment	55.4	22.5	40.6
North Creek	28.5	15.0	52.8
South Creek	11.3	5.4	47.5
St. Gelais Brook	15.7	2.1	13.6

North Creek Catchment

Key findings for the watershed and riparian forest cover analysis for the North Creek catchment were as follows:

- The North Creek catchment is highly urbanized and developed, with low levels of overall and riparian forest.
- Overall forest cover in the North Creek catchment is low, covering only 10.1% (45.1 ha) of the catchment (Table C-7). Forest cover is generally concentrated around North Creek. Two other large patches of forest exist in the North Creek headwaters (7.4 ha) and surrounding 72 Ave, west of the Fraser Highway (3.6 ha).
- Only 40.6% of riparian areas remain forested, below recommended guidelines of 70–75%. The riparian areas of North Creek and South Creek remain approximately 50% forested, but St. Gelais Brook has only 13.6% remaining (Table C-8). Riparian forest creek along all creeks in this catchment is below recommended guidelines, but St. Gelais Brook is particularly lacking.
- The majority of forested areas in the North Creek catchment are made up of young deciduous and young mixed forest (5–80 yrs). There is a small section of mature forest in the North Creek riparian area (>80 years).

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C.5 Fish and Aquatic Habitat

Fish and aquatic habitat in the catchments were assessed through a combination of existing information and field investigations. As part of this assessment, all major creeks and tributaries in the catchments were walked and important habitat features mapped and characterized.

Fish Community

Information on fish communities present in the catchments were from several sources including the provincial Fisheries Information Summary System (FISS) and iMapBC, older consultant reports, fish collection permit reports, as well as through incidental observations made during field visits.

The Fleetwood catchment contains 3 salmonid species: cutthroat trout (*Oncorhynchus clarki clarki*), Coho salmon (*Oncorhynchus kisutch*), and rainbow trout (*Oncorhynchus mykiss*) (Table C-9). Other native species include threespine stickleback *(Gasterosteus aculeatus)* and the brassy minnow (*Hybognathus hankinsoni*). The brassy minnow, blue-listed in BC, was identified in a lower reach 161A Ave Creek. Just outside the boundaries of the study area for 166 St Creek, redside shiner (*Richardsonius balteatus*) and a species of lamprey have also been identified (Envirowest 1994b). Coho salmon, redside shiner, and threespine stickleback have been identified south of the study area in Fleetwood Creek (Envirowest 1994a).

The North Creek catchment also contains cutthroat trout, coho salmon and rainbow trout, as well as threespine stickleback and redside shiner. Bass/sunfish (*Lepomis gibbosus*), an aggressive invasive species, are present in lowland ditches of the North Creek catchment as well. Several spawned out coho salmon were observed in the lower reaches of North Creek, upstream of 177 St., during field visits in December 2014.

Table C-9: Fish Presence By Creek in the Fleetwood and North Creek Catchments

	Fish Presence							
Fish Species	**Fleet-wood Creek**	**Lower 161A Ave Creek**	**162 St. Creek**	**166 St. Creek**	**Drinkwater Creek**	**North Creek**	**South Creek**	**Lower St. Gelais Brook**
Coho salmon		X,Y	Z			i	i	i
Cutthroat trout	W	X,Y	Z	Z	V	i	i	i
Rainbow trout		X				i	i	
Threespine stickleback		X,Y		Z		i	i	i
Redside shiner						i		i
Lamprey sp.								
Brassy minnow		Y						
Bass/sunfish								i

X -Data from Scientific Fish Collection Permit VISU04-1301 Sampling of Numerous Streams in the Lower Mainland
Y - Report: Fish Collection Permit SU06-21421 Serpentine River, Cougar Creek, East Hoy Creek, Eugene Creek, Morgan Creek, Archibald Creek, Hunt Brook, Bolivar Creek, Fleetwood Creek, Southward Creek, Dingwall Creek, Scott Creek, Robson Creek, and trib. to Little Campbell River
Z – Envirowest 1994b.
W- Envirowest 1994a.
V - Envirowest 1994c
i – iMapBC

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Instream Habitat Conditions

Instream habitat characteristics were assessed during field visits in December 2014. Channel dimensions, substrate conditions, and instream cover were measured at 100–150 m intervals along the creeks. Bankfull width, wetted width, % boulder, % cobble, % large gravel, % small gravel and % fines, the degree of embeddedness of the substrate were all recorded. Existing watercourse mapping was used a basis for the inventory. Existing fish habitat classification mapping (e.g., Class A, Class B, Class C) developed previously be City of Surrey (City of Surrey 2010) were confirmed and checked (Figure C-7).

Large woody debris (LWD) and deep pool habitat were also mapped and quantified during the field visits (Figure C-7). LWD consisted of pieces of wood larger than 10 cm in diameter and 2 meters in length. Deep pools consisted of pools greater than 40 cm depth. LWD and deep pools provide and facilitate the development of habitat complexity in streams, and increase the habitat value for fish by providing important cover from predators, particularly for juvenile salmonids. LWD is often measured as an indicator of stream health and condition, and low quantities of LWD are indicative of urbanized watersheds and streams with little mature forest remaining in riparian areas.

Fleetwood Catchment

The results of the instream habitat conditions for the Fleetwood catchment are presented in Table C-10 and summarized as follows:

- **Channel Dimensions**: Channel dimensions varied greatly between streams in the catchment, with Fleetwood and 162 Street Creek being the largest creeks and 161A Street Creek and Drinkwater Creek being the narrowest.
- **Substrate:** Instream substrate varied greatly between streams. Creeks in the Fleetwood catchment had relatively equal amounts of cobble, large gravel and small gravel, with lower proportions of boulders and fines. Drinkwater Creek and the upper reach of 162 Street Creek contained the highest percentage of fines in the substrate, and measures of the percent embeddedness indicate higher levels of sedimentation in 161A Street Creek and 162 Street Creek.
- **Large Wood Debris**: LWD was fairly evenly distributed along creeks in the catchment with the exception of 166 Street Creek. Amounts of LWD are low compared to undisturbed streams. The number of pieces of LWD per 100 m of channel ranged from 0 to 7.5, whereas natural streams typically have between 10 and 20, indicating higher levels of development and younger forests. Mature riparian forests are the source of LWD in a stream, so maintaining healthy, older stands of riparian forest is key to stream health. Riparian forest cover is high (>70%) for most of the creeks in the catchment with the exception of 166 Street Creek (~37%), the majority of forests are relatively young (<80 yrs).
- **Deep Pools:** Deep pools (>40 cm deep) were located predominantly in the lower reaches of Fleetwood Creek and 162 Street Creek. Pools typically were associated with LWD and boulders in the stream, as well anthropogenic features such as culverts. Pools in Fleetwood Creek were often scoured down to the sandstone base of the streambed.

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Table C-10: Instream Habitat Conditions By Watercourse for Fleetwood Catchment

Stream	Instream Habitat Conditions									
	Channel Dimensions		Substrate						Cover	
	Average Bankfull Width (m)	Average Wetted Width (m)	% Boulder	% Cobble	% Large Gravel	% Small Gravel	% Fines	% Embed-dedness	Large Wood (# pieces/ 100 m)	Deep Pools (#/100 m)
Fleetwood Creek										
• Reach 1	4.4	2.8	20	30	30	15	5	20	2.11	2.11
• Reach 2	2.6 (2.5 – 2.7)	1.4 (1.2 – 1.6)	10	35	30	17.5	7.5	28	3.52	0.80
• Reach 3	2.7 (2.4 – 3.0)	1.2 (1.0 – 1.6)	13	16	17	10	7	7	3.81	0.87
161A Street Creek	2.5 (2.0 – 3.0)	0.6 (0.5 – 0.6)	5	17.5	40	16	21	30	1.64	0.23
162 Street Creek										
• Reach 1	5.5	3	0	2.5	40	50	7.5	25	2.47	2.47
• Reach 2	4.9 (3.5 – 6)	2.3 (1.7 – 2.6)	17.5	25.5	30	22.5	4.5	29	7.48	2.08
• Reach 3	3.6 (1.4 – 3.2)	1.9 (0.9 – 3)	13	20	33	27	8	33	2.00	0.83
• Reach 4	3.1	1.6	2.5	0	5	55	37.5	45	0.00	0.00
166 Street Creek									0.00	0.00
Drinkwater Creek	1.9 (1.8 – 2.1)	1.1 (0.8 – 1.4)	1.5	14	19	24	41	19	2.54	0.29

North Creek Catchment

The results of the instream habitat conditions for the North Creek catchment are presented in Table C-11 and summarized as follows:

- **Channel Dimensions**: The lowland reaches of all 3 creeks showed a large range of variation in bankfull width compared to steeper gradient reaches upstream.
- **Substrate:** The lower reaches of all streams exhibited high levels of sedimentation, indicated by significant proportions of fines in the substrate and high level of embeddedness of substrates. The upper reach of North Creek exhibited a similar pattern. In general, stream substrates are dominated by large and small gravel, followed by fines. Boulder and cobble are less significant components of substrate composition in this catchment.

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- **Large Wood Debris:** The largest concentrations of LWD in the catchment were in the middle and upper reaches of North Creek and South Creek. South Creek contained the highest levels of LWD in the catchment, with levels of LWD comparable to natural streams (10–20 pieces of LWD/100 m). In general, amounts of LWD are much lower than natural streams due to the low levels of riparian forest cover in the catchment, particularly around St. Gelais Brook. The lower reaches of all streams in the catchment had negligible concentrations of LWD. It is possibly that LWD in the lower reaches of streams in this area was historically removed for flood protection purposes.
- **Deep Pools:** Deep pools in the North Creek catchment were predominantly located in the middle reaches of North Creek, and are notably absent from South Creek and St. Gelais Brook. Deep pool formation was generally associated with LWD, instream boulders, undercutting of banks, and weirs within the stream.

Table C-11: Instream Habitat Conditions By Watercourse for North Creek Catchment

	Instream Habitat Conditions									
	Channel Dimensions		Substrate						Cover	
Stream	Average Bankfull Width (m)	Average Wetted Width (m)	% Boulder	% Cobble	% Large Gravel	% Small Gravel	% Fines	% Embed-dedness	Large Wood (# pieces/100 m)	Deep Pools (#/100m)
North Creek										
• Reach 1	5.0 (1.5 – 8.0)	1.3 (0.9 – 1.8)	0	0	0	0	100	NA	0.26	0.17
• Reach 2	4.3 (3.4 – 5.0)	2.7 (1.8 – 4.3)	4.5	20	44	25	8	31.5	4.63	1.79
• Reach 3	4.3 (3.5 – 5)	2.6 (2.5 – 2.6)	5	10	35	45	5	37.5	4.29	1.96
• Reach 4	1.2 (1 – 1.3)	0.8 (0.4 – 1.2)	1	5	10	30	54	40	0.71	0.36
South Creek										
• Reach 1	2.7 (1.6 – 5.2)	0.9 (0.6 – 1.3)	2	11	25	26	36	6.5	14.40	0.00
• Reach 2	2.0	0.7	3	12	25	55	5	20	1.10	0.00
St. Gelais Brook										
• Reach 1	4.6 (2.6 – 8.5)	1.3 (0.4 – 3.2)	6	6	23	10	29	5.5	0.33	0.13
• Reach 2	2.2	0.8	10	25	25	38	2	15	4.77	0.00

Fish Access/Passage Concerns

Fish access and passage concerns were also assessed during field visits in December 2014 (Figure C-7). Barriers to fish passage were identified in all creeks within the Fleetwood catchment area except 166 Street Creek (Table C-12). No significant barriers were identified in the North Creek catchment area, though a number of partial and seasonal barriers were mapped (Table C-13).

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- The most significant barrier is in 162 Street Creek, where a partial barrier to passage exists in the lower reach of the stream, restricting fish access to red-coded (Class A) habitat.
- Complete barriers exist in the upper reaches of Fleetwood and Drinkwater Creeks, but do not block access to large amounts of fish habitat.
- Complete barriers are located in 161A Street Creek, but the stream is not identified as fish habitat (Class B).
- No complete barriers to fish passage were identified in the North Creek catchment.

Table C-12: Fish Access and Passage Concerns by Creek in Fleetwood Catchment

Stream	Barrier	Location	Comments
Fleetwood Creek	Yes	120 m downstream of intersection at 158 St. and 80 Ave.	Concrete slab on creek bed creating 0.6 m falls with no pooling above
161A St Creek	Yes	80 m upstream of 76 Ave.	60 cm drop off concrete apron downstream of culvert
	Partial	160 m upstream of 76 Ave., 180 m downstream of 77A Ave.	Series of cascading pools
	Yes	210 m upstream of 76 Ave., 130 m downstream of 77A Ave.	1 m waterfall
162 St. Creek	Partial	170 m upstream of 76 Ave.	Combination of 0.5 m drop, apron and long culvert
Drinkwater Creek	Yes	200 m upstream of 170 St.	Full debris blockage with creek re-routing
	Partial	60 m downstream of 168 St.	Man-made debris weir made of 40 mm steel pipe – likely unofficial

Table C-13: Fish Access and Passage Concerns by Creek in North Creek Catchment

Stream	Barrier	Location	Comments
South Creek	Seasonal	310 m downstream of 68 Ave. crossing, 275 m upstream of 177 St.	Log jam passable during rain events, fry can pass through interstitial spaces during low flows
	Partial	263 downstream of 68 Ave. crossing, 365 upstream of 177 St.	20 cm clearance under 70cm diameter log
	No	182 m downstream of 68 Ave. crossing	Barbed wire fence across stream, no debris
	Partial	120 m downstream of 68 Ave. crossing	Stream goes around alder snag in stream, passable at high flows
	Seasonal	221 m upstream of 180 St.	Engineered boulder weir

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C.6 Terrestrial Habitat, Wildlife and Species at Risk

Terrestrial Habitat

The Fleetwood and North Creek catchments are predominantly urban with high levels of residential development. Urban areas in Surrey generally lack natural areas, and those that do exist are typically fragmented (City of Surrey 2014). In these catchments, landscaped sites, urban trees, gardens and other human influenced sites are important habitat to urban-adapted species.

Terrestrial habitat in the catchments consists of a mix of forested areas and shrub/herb/grass habitat (including agricultural lands, turf grass, etc.). Forested areas generally contain the highest value habitat, especially mature forests. Unmanaged shrub and grass habitat hold the next highest terrestrial habitat value followed by managed agricultural areas and lastly turf grass (City of Surrey 2014).

Both catchments border agricultural lands of the Serpentine-Nicomekl lowlands, a primarily agricultural area within the City. As agricultural areas provide fewer barriers to movement for wildlife, these lands allow some degree of connection to upland areas in both catchments to stream and wetland habitat along the Serpentine River. Agricultural areas generally support a more diverse assemblage of mammal, amphibian, and bird species than urban areas.

Fleetwood Catchment

The Fleetwood catchment is located in the Fleetwood Management Area identified in the Biodiversity Conservation Strategy. Total natural area in the catchment covers 139 ha of land. High value terrestrial habitat located in the Fleetwood Catchment is concentrated in Fleetwood Park, a high-value protected forest hub in the southwest corner of the catchment. Other significant forested areas are concentrated around streams, particularly along the southern border of the catchment. Young deciduous forest is the dominant habitat type (44% of natural areas), followed by young mixed forest (18%), agricultural herb and grass habitat (7%) and unmanaged shrub habitat (6%) (City of Surrey 2014). A small patch of mature forest (>80 yrs) exists in the southern portion of Fleetwood Park.

Fleetwood Park has been identified as a high-value hub in the Green Infrastructure Network, with local corridors connecting to Surrey Lake (high value corridor) and along the ALR lands along the 76 Avenue alignment on the southern border of the study area (moderate value corridor).

North Creek Catchment

The North Creek catchment is predominantly located within the urban Cloverdale Management Area, with a small area within the agricultural Serpentine Nicomekl Management Area. Natural areas in the catchment cover approximately 150 ha. Agricultural herb and grass habitat is the dominant habitat type, comprising 31% of the natural areas, with larger areas found in the northwest corner of the catchment, as well as along the riparian corridor of St. Gelais Brook and the headwaters of North Creek. Four other habitat types make up the majority of the remaining natural area: unmanaged shrub, young deciduous forest, young mixed forest, and turf grass (City of Surrey 2014). The majority of forested areas are located in the riparian corridor of North Creek.

A number of local corridors have been identified as part of the Green Infrastructure Network. These follow riparian corridors within the catchment providing linkages to hubs to the south and northwest of North Creek, as well as connecting to the ALR lands along the Serpentine River.

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Wildlife Species

Common wildlife in the Fleetwood and North Creek catchments are generally species which are tolerant of human impacts on the landscape, or have been able to adapt to the presence of humans. While most large mammals have disappeared from the area, there are still a wide variety of small mammals, amphibians and reptiles, and bird species that can be found in urban landscapes of Surrey (Table C-14). Wildlife in urban areas is typically concentrated in more intact riparian areas, larger forested patches, and wetlands.

Table C-14: Representative Species of Urban Environments in Surrey (from City of Surrey 2014)

Mammals	Amphibians/ Reptile	Birds
Common Shrew	Common Garter Snake	American Robin
Creeping Vole	Long-toed Salamander	Black-capped Chickadee
Mouse/Shrew/Vole sp.	Pacific Tree Frog	Bushtit
Raccoon		Canada Goose
Shrew Mole		Dark-eyed Junco
Vagrant Shrew		Downy Woodpecker
Virginia Opossum		House Finch
		Mallard
		Northwestern Crow
		Song Sparrow
		Spotted Towhee

Incidental sightings of wildlife during field visits to streams were recorded in December 2014 and are summarized in Tables C-15 and C-16. Due to the proximity of the catchments to agricultural areas, the diversity of species not typically found in urban areas were identified, including Black-tailed Deer (*Odocoileus hemionus*) and Beaver (*Castor canadensis*). Other species that may be present in the watershed include Coyote (*Canis latrans*), River Otter (*Lon*tra canadensis) and Mink (*Neovison vison*). It is also possible there are wetlands near forested areas that contain Northern Red-legged Frog (*Rana aurora*).

Table C-15: Wildlife Sighting/Evidence of Activity from Field Surveys in Fleetwood Catchment

Mammals	Amphibians/Reptile	Birds
Beaver	Pacific Chorus Frog	Bald Eagle
Black-tailed Deer		Raven
Raccoon		Mallard

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Table C-16: Wildlife Sighting/Evidence of Activity from Field Surveys in North Creek Catchment

Mammals	Amphibians/Reptile	Birds
Beaver	Pacific Chorus Frog	Bald Eagle
Muskrat		Red Tailed Hawk
Raccoon		Great Blue Heron
Rabbit sp.		Mallard
		Band-tailed Pigeon
		Mourning Dove
		Bufflehead

Species at Risk

The Fleetwood and North Creek catchments contain a number of confirmed or potential species at risk that should be taken into consideration in land use planning (Table C-17):

- **Great Blue Heron, *fannini* subspecies (*Ardea herodias fannini*)**: Blue-listed provincially and listed as a species of Special Concern on Schedule 1 of the federal *Species at Risk Act* (SARA). No known nesting sites in immediate vicinity although there are recent active nesting sites lower down in Serpentine-Nicomekl lowlands. Likely utilize lowland watercourses for feeding.
- **Coastal Cutthroat Trout (*Oncorhynchus clarkii*)**: Blue-listed provincially. Documented present in small numbers in lower sections of all creeks across both catchments.
- **Brassy Minnow (*Hybognathus hankinsoni*):** Blue-listed provincially. Captured during 2006 fish sampling efforts off the mainstem of 161A Street Creek.
- **Band-tailed Pigeon (*Patagioenas fasciata*)**: Blue-listed in BC and listed as a species of Special Concern on Schedule 1 of SARA. Calls were identified during field surveys of the North Creek catchment.
- **Vancouver Island Beggarticks (*Bidens amplissima*):** Blue-listed in B.C., and is listed as a species of Special Concern on Schedule 1 of SARA. There is single occurrence record from a roadside area along 160th Street between 80th Avenue and 91st Avenue in 1954. It has not been seen since at that location.
- **Northern Red-legged Frog (*Rana aurora*):** Blue-listed provincially. Although no records exist within the study area, they are known to exist nearby, and both catchments contain suitable aquatic and forest habitat.
- **Pacific Water Shrew (*Sorex bendirii*):** Red-listed in BC and listed as Endangered under Schedule 1 of SARA. Suitable habitat exists within both catchments, and catch records for Pacific Water Shrew exist in a nearby tributary of the Serpentine River.
- **Chaffweed (*Anagallis minima*):** Blue-listed in BC. There is an occurrence record from 2007 for a single plant nearby the study area. This species does well in more open disturbed sites. Potential habitat exists in the study areas.

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Table C-17: Confirmed and Potential Species at Risk in Fleetwood Greenway and North Creek Catchments

Taxa	Species
Birds	Great Blue Heron
Mammals	Pacific Water Shrew
Amphibians	Northern Red-legged Frog
Plants	Vancouver Island Beggarticks Chaffweed
Fish	Coastal Cutthroat Trout Brassy Minnow

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C.7 References

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City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Watercourse
- Culvert
- Continuous Water Quality Monitoring Station
- Flow Monitoring Station
- Benthic Invertebrate Sites (with Site Code)

In-situ Water Quality Monitoring Sites

Subcatchment

- 161A/162/166 Street Creek
- Drinkwater Creek
- Fleetwood Creek
- North Creek
- North Creek Lowlands
- South Creek
- Dry Sites

FLEETWOOD GREENWAY STUDY AREA

NORTH CREEK STUDY AREA

F-1, F-2, F-3, F-4, F-5, F-6, F-7, F-8, F-9, F-10, F-11, F-12, F-13, F-14, F-15, WA1

N-1, N-2, N-3, N-4, N-5, N-6, N-7, N-8, N-9, N-10, N-11, N-12, N-13, N-14, N-15, N-16, N1, N2

WA1	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
2012	14.0	10	-	-
2013	14.0	10	-	-

N1	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
1999	14.0	12	14.0	8
2000	14.0	16	-	-
2001	14.0	17	17.3	24
2002	16.0	24	15.3	19
2003	16.7	21	18.0	20
2004	19.3	21	18.0	26
2005	17.3	27	14.7	22
2006	16.0	24	14.0	16
2007	14.7	19	18.7	17
2008	16.0	22	18.7	17
2009	17.3	17	19.3	16
2010	20.7	17	18.0	16
2011	16.7	18	18.7	12
2012	15.3	16	18.0	11
2013	17.3	13	18.7	8
2014	17.3	14	17.3	13
2015	22.7	23	-	-

N2	Spring		Fall	
	Mean B-IBI	Total Taxa Richness	Mean B-IBI	Total Taxa Richness
1999	15.3	26	15.3	13
2000	14.0	13	NS	NS
2001	14.7	19	NS	NS
2002	15.3	27	18.7	32
2003	19.3	33	18.7	20
2004	18.7	30	16.7	24
2005	15.3	21	18.0	26
2006	14.0	17	17.3	24
2007	14.0	18	16.7	32
2008	14.7	22	14.0	19
2009	14.7	23	15.3	25
2010	15.3	28	16.7	15
2011	14.0	12	20.0	23
2012	14.0	17	16.7	22
2013	14.7	20	17.3	16
2014	14.0	18	17.3	20
2015	16.7	21	-	-

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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Project No.	Date
471-288	March 2016

Environmental Sampling Sites

Figure C-1

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Author: PdeKoning

Appendix C – Environmental Inventory and Assessment

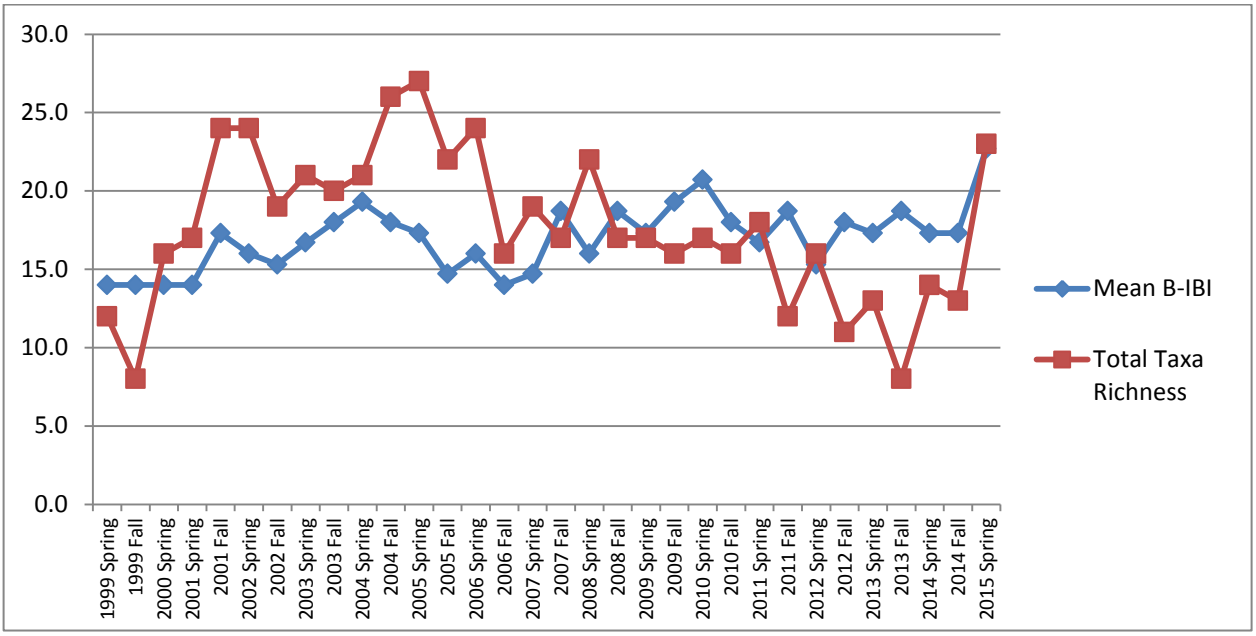


Figure C-2: B-IBI and Total Taxa Richness at Sample Site N1 (North Creek Upstream)

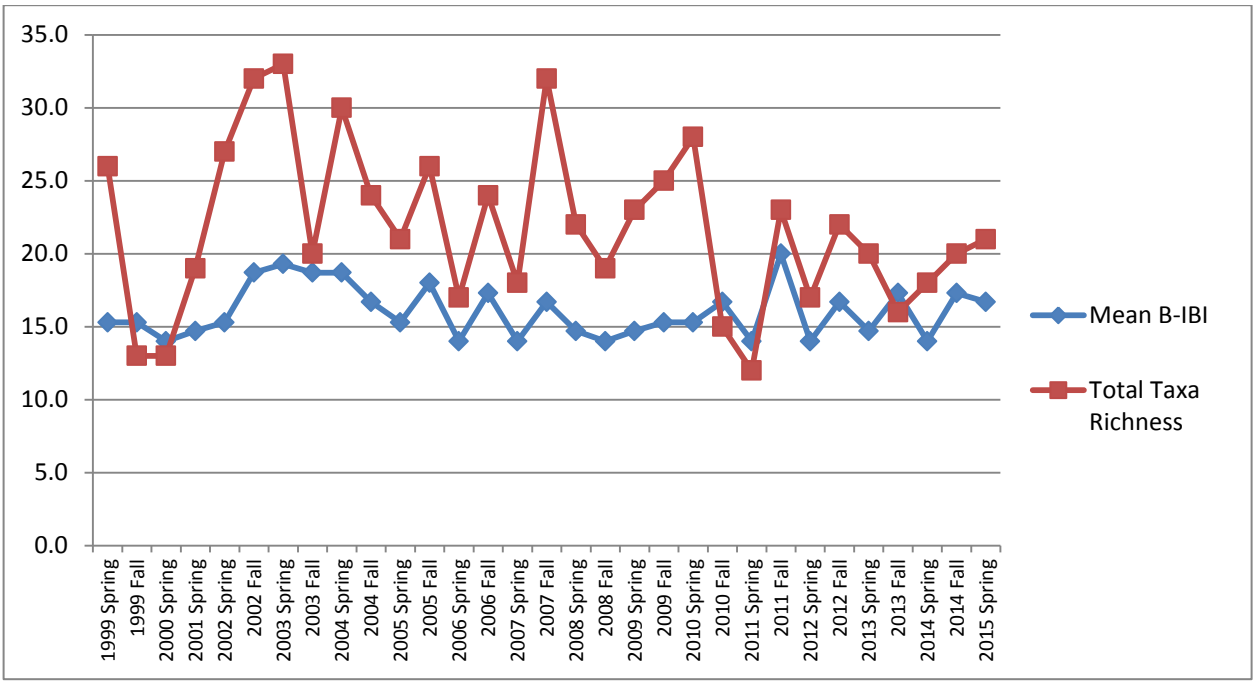
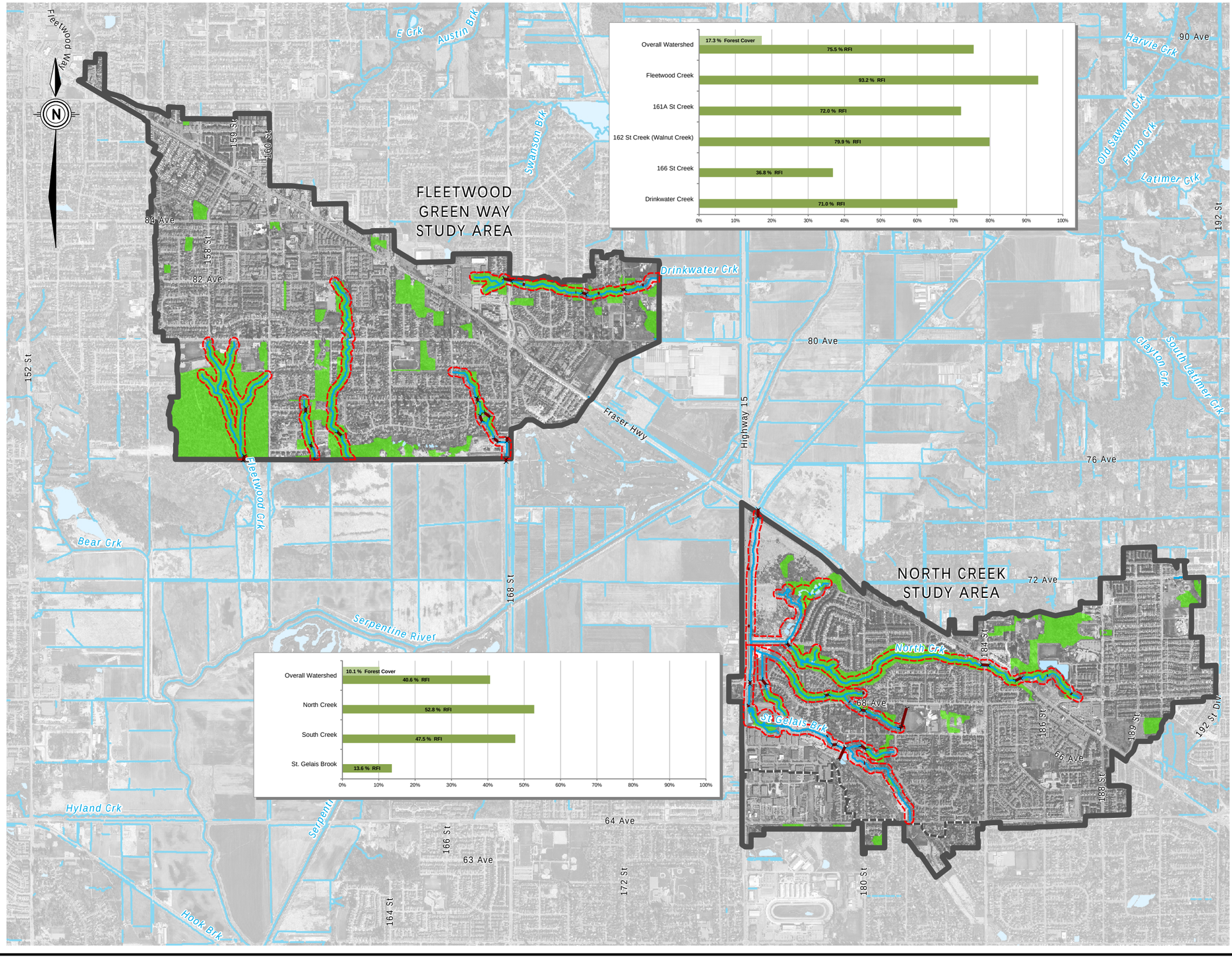


Figure C-3: B-IBI and Total Taxa Richness at Sample Site N2 (North Creek Downstream)

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan



Legend

- Study Area
- Catchment Boundary
- Watercourse
- Culvert
- 30m Riparian Buffer
- Watershed Forest Cover

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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Project No.	Date
471-288	May 2015

Riparian and Watershed Forest Cover

Figure C-4

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Author: JLau

Appendix C – Environmental Inventory and Assessment

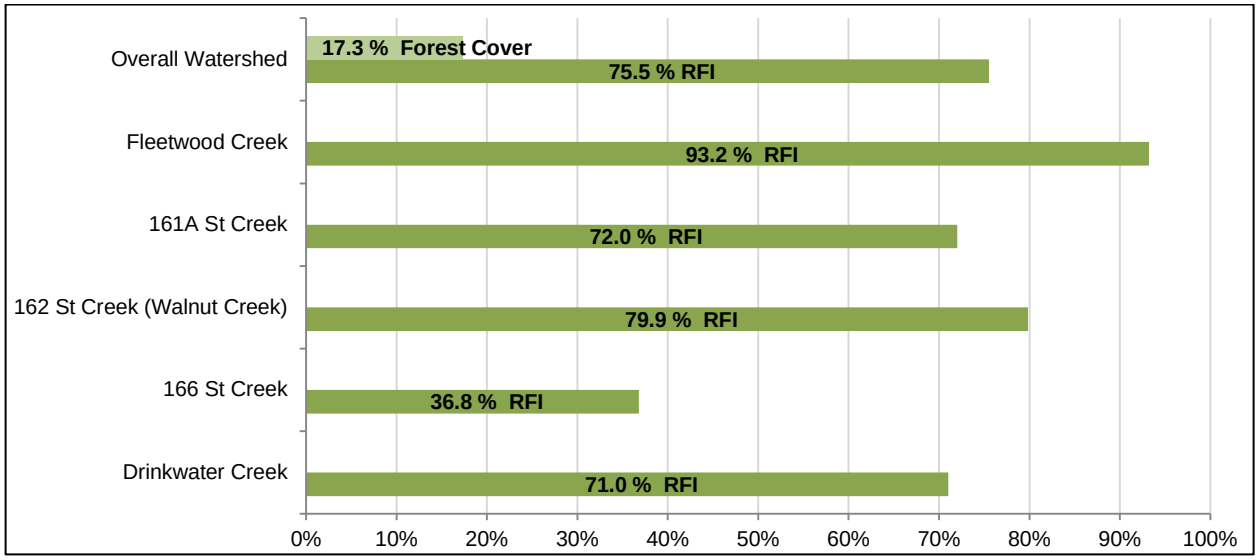


Figure C-5: Watershed and Riparian Forest Cover in the Fleetwood Catchment

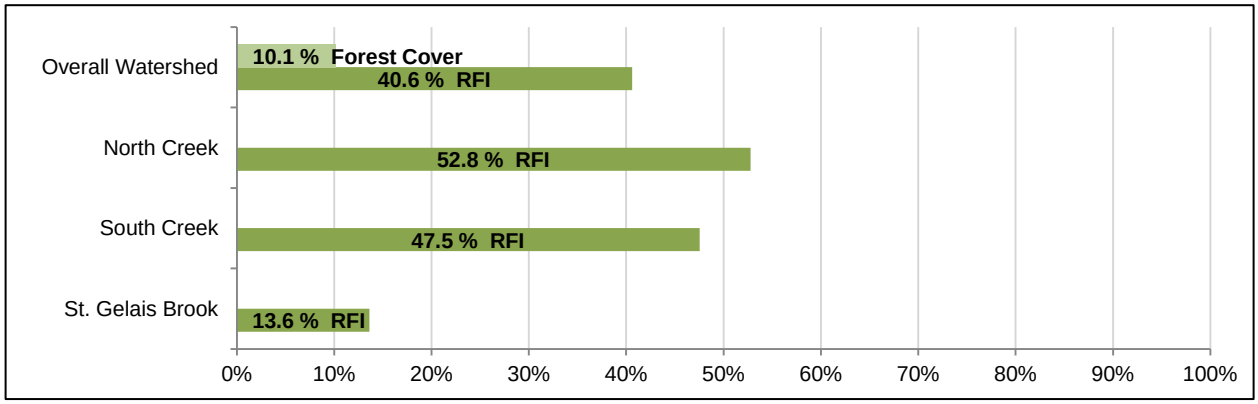
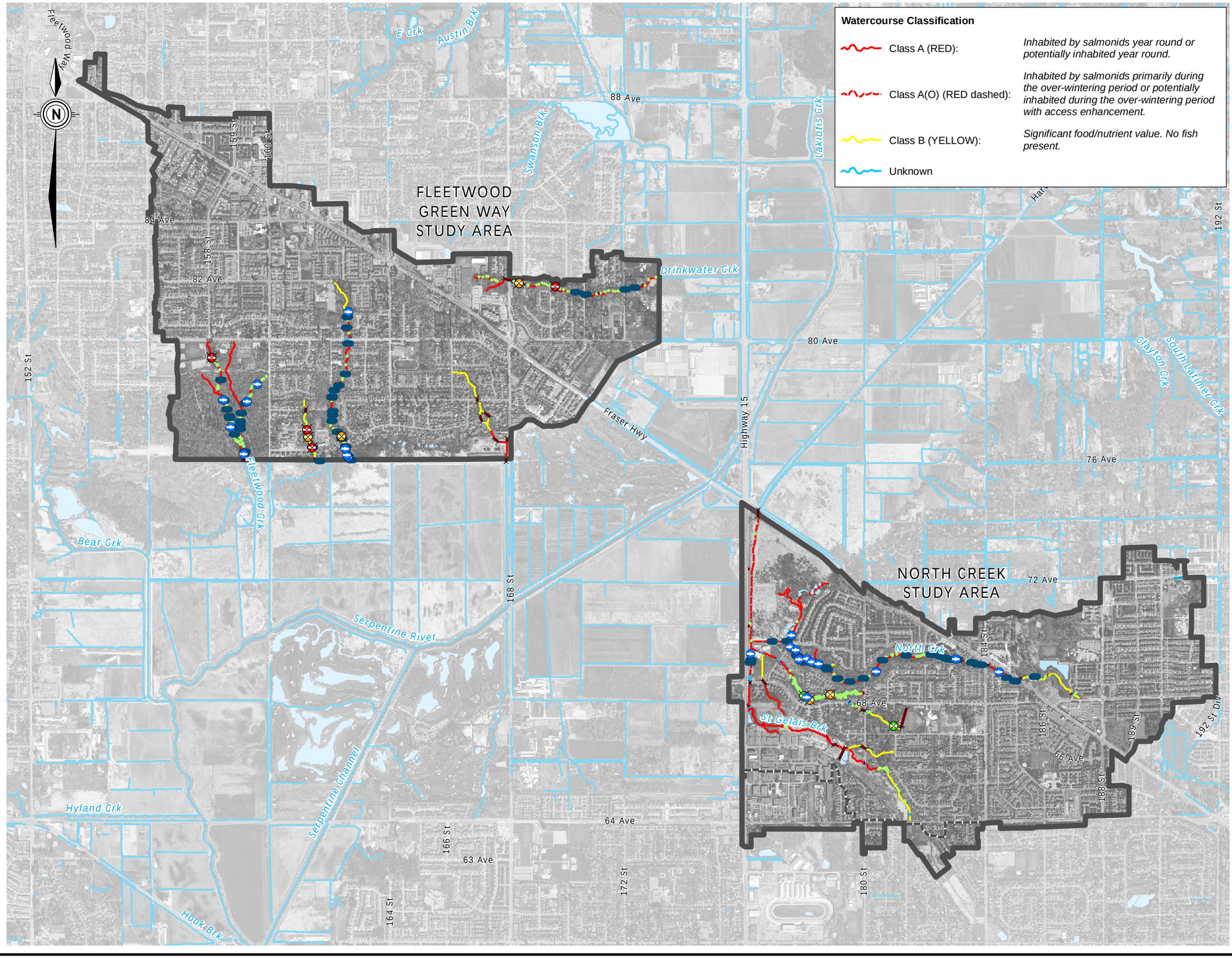


Figure C-6: Watershed and Riparian Forest Cover in the North Creek Catchment



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Catchment Boundary
- Culvert
- Large Wood Debris
- Deep Pools
- Fish Observation

Fish Passage Barrier

- Full
- Partial
- Seasonal

Reference: 2013 Orthophoto and GIS background data from the City of Surrey Open Data Catalogue.

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Project No.	Date
471-288	May 2015

Fish and Aquatic Habitat Inventory

Figure C-7

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Author: JLau

Appendix C – Environmental Inventory and Assessment

Figure C-8: Excerpt of Green Infrastructure Network Map for Study Area from Biodiversity Conservation Strategy (from City of Surrey 2014)

Appendix D – Hydrologic and Hydraulic Modelling

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Appendix D – Hydrologic and Hydraulic Modelling

D Hydrologic and Hydraulic Modelling

D.1 Introduction

This appendix outlines the development of the detailed hydrologic and hydraulic model of the Fleetwood Greenway and North Creek Drainage Basins. The appendix includes:

- Description of the detailed hydrologic and hydraulic model development using the City's GIS database; and
- Calibration and validation of the hydrologic model to ensure accurate predictions of watershed rainfall-runoff response.

The completed hydrologic/hydraulic models were used to assess the drainage system under different design event conditions. The results of this analysis are presented in Appendix E.

D.2 Rainfall and Flow Monitoring Data Collection

Rainfall Data

The rainfall data for model calibration was collected from the 71A Avenue at 190 Street rain gauge and the 68 Avenue at 176 Street rain gauge. See Figure D-1 for the rainfall and flow monitoring station locations.

The design storms used in the existing conditions analysis were those contained in the *City of Surrey Design Criteria Manual* (2004) and are described in section D.7. The IDF curves for the Kwantlen rain gauge were updated in 2015 by Dillon Consulting to include historical rainfall dating to 2013 and subsequently incorporated into the new *City of Surrey Design Criteria Manual* (2016). The design storms used in the future conditions analysis (both unmitigated and mitigated) were based on the updated IDF curves.

Flow Monitoring

The flow monitoring data was sourced from a gauge installed on North Creek just downstream of the Fraser Highway crossing. The flow monitoring station has been in operation and continuously recording data since 1996. Water level at the station is recorded in a Data Logger then transmitted via cellular modem to the FlowWorks server which can be accessed by logging into www.flowworks.com. The water levels are converted to flow using the stage-discharge relationship shown on Figure D-2.

D.3 Percentage Impervious

The existing land use total impervious percentages used in the model were based on the *City of Surrey Design Criteria Manual* (2004) values, repeated in Table D-2 below. In addition to the City's values, road catchments were assigned total percent impervious value of 70%. These values were visually compared to a 2013 Orthophoto of the study area and, where applicable, adjusted to better represent the current percent impervious of the land. Figures D-3 and D-4 show the total impervious area for the catchments prior to calibration.

Appendix D – Hydrologic and Hydraulic Modelling

For the future land use, total impervious percentages of most residential zones were increased due to tendency for redevelopment to encompass larger housing footprints; however, some existing residential lots are already highly developed (up to 85% impervious). Therefore, the future total impervious percentages for residential zones were capped at 85%. Total impervious percentages were not increased for commercial and industrial land use zones that had an existing impervious percentage of 90% or greater as there is limited area to increase the impervious percentage of these lots. Figures D-5 and D-6 show the future total impervious area for the catchments after build-out to the OCP.

Table D-1: Land Use Impervious Percentages (Prior to Calibration)

Land Use	Total Existing Impervious Percentage[1]	Total Future Impervious Percentage
Commercial	90[2]	90
Industrial	90[2]	90
Suburban	-	55
Half Acre/One Acre Residential	50	50
Single Family Residential	65[3]	65 - 80
Multi-Family Residential	80	75 - 85
Parks, Playgrounds, Cemeteries; Agricultural Land	20	10 - 20
Institution; School; Church	80	80
Comprehensive Development	Varies	-
ROW	70	70

1. Based on the City of Surrey's *Design Criteria Manual* (2004) Values; TIA for many individual lots differ from these values based on a comparison with 2013 orthophotography
2. Some lots changed to 100% based on orthophotography
3. Lots range from 50% impervious to 80% impervious based on orthophotography

The 999 ha covered by the Fleetwood Greenway and North Creek watersheds has an existing effective percentage impervious area (EIA) of 46%. The EIA is expected to increase to 55% once the catchments are built-out to the OCP. Figures D-7 to D-10 show the distribution of effective impervious area in the watersheds based on existing and future land uses.

Appendix D – Hydrologic and Hydraulic Modelling

D.4 PC SWMM Model Development

Model Network

The model includes most storm sewer pipes, culverts, and watercourses within the Fleetwood Greenway and North Creek watersheds as supplied by the City in their GIS databases. Nodes in the model consist of manholes, intakes, outfalls, junctions, and storage. There was some missing or inaccurate information in the database including:

- Missing attribute information such as pipe sizes, inverts, and manhole rim elevations. Where this information was not available from the City, it was estimated based on nearby pipe information. Rim elevations were estimated based on the DEM and invert elevations were linearly interpolated from nearby entities.
- Missing pipe connections. Where this information was not available from the City, it was estimated based on nearby pipe information.

The drainage system includes:

- 115 km of pipes;
- 2288 manholes/nodes/junctions;
- 8 detention facilities; and
- Major creeks (Fleetwood Creek, 161A Street Creek, 162 Street Creek, 166 Street Creek, Drinkwater Creek, North Creek, South Creek, St. Gelais Brook).

Creek cross sections were estimated based on typical cross sections measured during the field inventory. Channel and conduit roughness values were assigned based on typical values for the various conduit materials.

Figures 2-5 and 2-6 in the body of the main report show an overview of the Fleetwood Greenway and North Creek model network.

Model Catchments

The Fleetwood Greenway and North Creek drainage areas were divided into lot catchments and road catchments. Data for the lot catchments was taken from the City's cadastral land use GIS mapping. Each parcel was paired with the nearest node representing a manhole, a junction, or an end of a culvert.

Rights-of-way were split using a Thiessen polygon methodology to assign ROW subcatchments to nearest nodes. This method involves using a GIS algorithm. The algorithm takes all the manholes used in the model and allocates areas to each one by determining which ROW areas are closer to a particular manhole than any other.

Appendix D – Hydrologic and Hydraulic Modelling

In total, 5,441 lot catchments and 1,983 road catchments were created and imported into the PC SWMM model. Catchments were assigned the following attributes:

- Slopes, using digital elevation mapping (DEM) information;
- Existing land use impervious percentage, using the City of Surrey's GIS information for lot catchments; and impervious percentage for future land use scenarios, using the City's OCP Zoning and Neighbourhood/Town Centre Plans; and
- Groundwater parameters based on soils mapping.

Groundwater and Soil Parameters

The groundwater feature of PC-SWMM was used to better estimate the groundwater and interflow portions of the runoff hydrograph. Infiltration rates, soil depths, and soil hydraulic conductivity inputs were based on previously used values and/or typical values for parameters as initial values prior to calibration.

Figure 2-7 in the body of the main report shows the surficial geology of the Fleetwood Greenway and North Creek Basins that was used to determine soil parameters.

D.5 Model Calibration

Introduction

The 5-minute rainfall data from the 71A Ave at 190 St and the 68 Ave at 176 St rain gauge stations were used for the model calibration and validation. Calibration and validation events were chosen by selecting significant storm events with the fewest data gaps.

The North Creek at Fraser Highway flow monitoring station is located geographically midway between the two rain gauge stations, as shown in Figure D-1. Local variation in rainfall was exhibited at the two gauges for different storms; hence, it was not possible to determine the exact distribution of the rainfall over the portion of the catchment contributing to the overall flow at the gauge. For calibration purposes, the rainfall data most closely resembling the observed gauge flow for each storm was chosen. See Table D-2 for the dates and return period of the storm events, as well as the rainfall gauge used.

Table D-2: Storm Events Modelled for Calibration

Date	Storm Event	Rain Gauge	Calibration/ Validation
11-20 October 2012	< 2-year	68 Ave at 176 St	Dry Validation
27 September-2 October 2013	2-year 15- and 30-minute	68 Ave at 176 St	Dry Calibration
9-12 January 2014	5-year 2-, 6-, and 12-hour	71A Ave at 190 St	Wet Calibration
3-7 May 2014	5-year 6-hour	71A Ave at 190 St	Wet Validation

Appendix D – Hydrologic and Hydraulic Modelling

Model calibration involved the adjustment of parameters, within reasonable ranges, until a set of objectives was met. The Fleetwood Greenway and North Creek model was calibrated to all respects of the runoff hydrograph (peak flow, volumes, the receding portion of the hydrograph from groundwater). Some differences may be attributed to variation in the rainfall distribution over the catchment and uncertainty in the storage-discharge curve for the pond located directly upstream of the flow gauge due to a lack of as-built drawings.

Dry Calibration Event

The September 27, 2013 storm was used as the dry event calibration, utilizing rainfall data from the 68 Avenue at 176 Street rain gauge. This storm was a 2-year 15- and 30-minute event compared to the Surrey Kwantlen Park IDF. After calibration, the modelled peak flow was 1% lower than the observed peak flow, while the volume of modelled flow was approximately 15% higher than observed. The dry event calibration is presented in Image D-1.

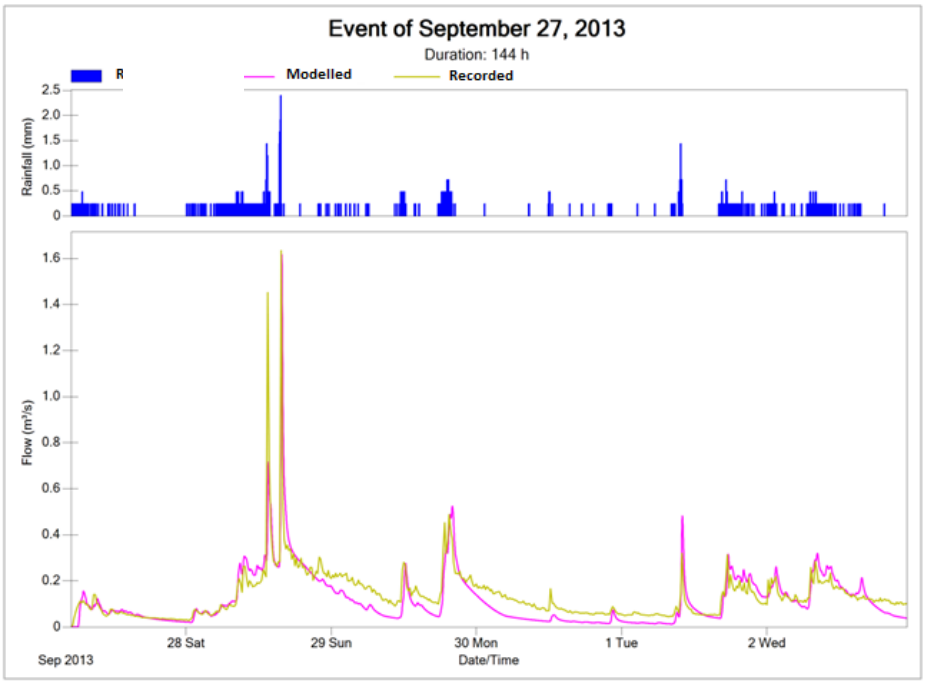

Image D-1: Dry Event Calibration (September 2013)

Wet Calibration Event

The wet calibration was carried out using the January 9, 2014 storm event with rainfall recorded at the 71A Avenue at 190 Street rain gauge. This was a 5-year 2-, 6-, and 12-hour storm event. The peak modelled flow was approximately 10% less than the peak observed flow, while the volume of modelled flow was 5% higher than the volume observed. The wet event calibration is presented in Image D-2.

Appendix D – Hydrologic and Hydraulic Modelling

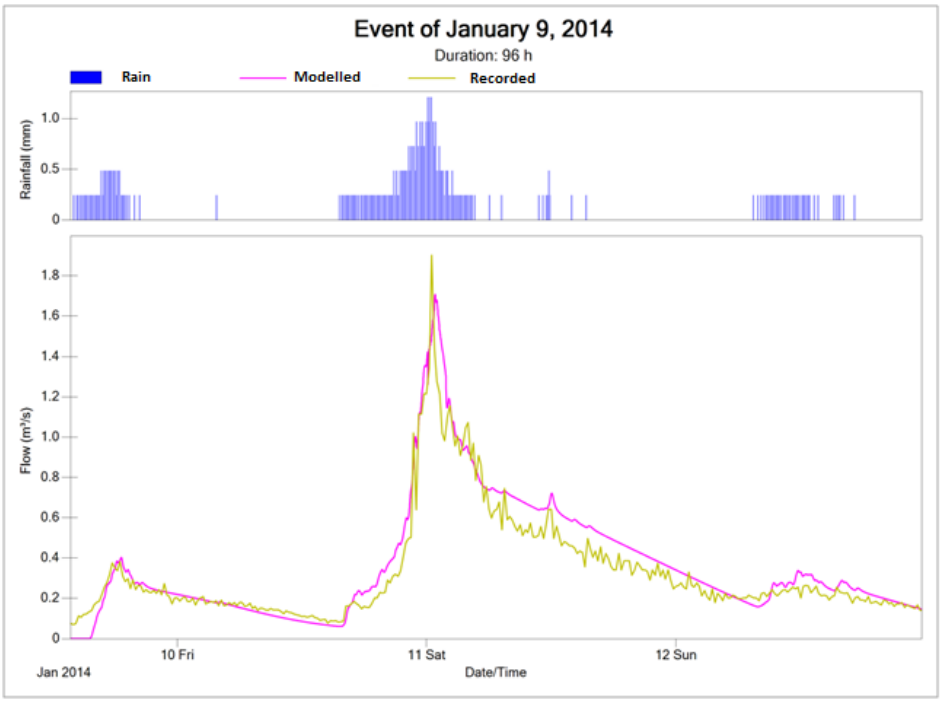

Image D-2: Wet Event Calibration (January 2014)

D.6 Calibrated Parameters

During the calibration of the model, the percentage impervious of catchments and the groundwater parameters were adjusted.

For the dry event calibration, the percentage impervious of single family residential lots and comprehensive development lots were reduced to replicate the observed flow rates at the North Creek at Fraser Highway flow station. Their overall imperviousness coverage was reduced to 40%, reflecting the fact that the majority of residential homes in the Fleetwood Greenway and North Creek watersheds should have disconnected roof leaders as this is required by bylaw in the City of Surrey. Table D-3 summarizes the total and calibrated effective impervious percentages used in the model by existing land use.

Appendix D – Hydrologic and Hydraulic Modelling

Table D-3: Land Use Effective Impervious Percentages

Land Use	Total Existing Impervious Percentage[1]	Calibrated Existing Effective Impervious Percentages
Commercial	90[2]	90[2]
Industrial	90[2]	90[2]
One Acre Residential	50	50
Single Family Residential	50-80[3]	40
Multi-Family Residential	65-85[3]	65-85[3]
Parks, Playgrounds, Cemeteries; Agricultural Land	20	20
Institution; School; Church	80	80
Comprehensive Development	Varies	Varies
ROW	70	70

1. Based on the City of Surrey's *Design Criteria Manual* (2004) Values; TIA for many individual lots differ from these values based on a comparison with 2013 orthophotography
2. Some lots changed to 100% based on orthophotography
3. Lots range in impervious percentage based on orthophotography

The effective impervious percentages determined during the dry calibration were applied to the wet calibration events. The groundwater parameters were then adjusted to replicate the shape of the storm hydrographs. The groundwater flow coefficient, A1, and the groundwater flow exponent, B1, were set to 1.5 and 2 respectively, to match the peaks and the tails of the recorded flows.

D.7 Design Storms

The calibrated model was used to simulate 5- and 100-year return period 1-, 2-, 6-, 12-, and 24-hour duration design events and to determine governing peak flows and volumes for each conduit. The design rainfall for the existing conditions analysis was sourced from the *City of Surrey Design Criteria Manual* (2004) for Kwantlen Park. The design criteria manual and the IDF curves were updated during the course of the project. Design storms for the future land use analysis were based on the Kwantlen Park IDF curves updated by Dillon Consulting in 2015 and included in the *2016 City of Surrey Design Criteria Manual*. Table D-4 shows the design storm precipitation totals for all modelled events.

Appendix D – Hydrologic and Hydraulic Modelling

Table D-4: Design Storms for Fleetwood Greenway and North Creek

Duration	Existing Conditions Model		Future Conditions Model	
	5-year Total Rainfall (mm)	100-year Total Rainfall (mm)	5-year Total Rainfall (mm)	100-year Total Rainfall (mm)
1-hour	13.90	22.00	15.00	23.90
2-hour	19.80	29.80	21.20	31.90
6-hour	37.30	59.79	40.30	59.10
12-hour	57.00	84.51	61.60	94.70
24-hour	82.91	133.00	86.10	137.81

All events were modelled using saturated soil conditions typical of winter conditions.

D.8 Peak Flow Estimates

Unit peak flows from the calibrated existing model were checked against unit flows estimated for similar creeks in the Lower Mainland. Table D-5 shows the unit peak flow comparison.

Table D-5: Unit Peak Flow Comparison

Location	Peak Flow (L/s/ha)	
	5-year	100-year
Largely developed Catchments		
Fleetwood Greenway North Creek ISMP, North Creek – 444ha – 28% EIA	14	28
Fleetwood Greenway North Creek ISMP, 166 St. Creek – 133ha – 50% EIA	17	39
Quibble Creek – 656ha – 47% EIA	19	24
Hyland Creek – 466ha – 58% EIA*	16	27
Bear Creek – 1147ha – 52% EIA*	21	43

** Data referenced from "Pilot Stormwater Quantity Monitoring Program", 1998, Kerr Wood Leidal*

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

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Rainfall Station
- Hydrometric Station
- Creek
- Ditch

NORTH CREEK STUDY AREA

Rainfall Station
68 Ave at 176 St

Rainfall Station
71A Ave at 190 St

Hydrometric Station
North Creek at Fraser Highway

Serpentine River
North Crk
South Crk
St Gelotik Brk
McLellan Crk
Fraser Hwy
72 Ave
68A Ave
68 Ave
66 Ave
64 Ave
180 St
184 St
186 St
188 St
189 St
192 St
192 St Div
Highway 15

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	April 2015

North Creek Gauge Locations for Calibration

Figure D-1

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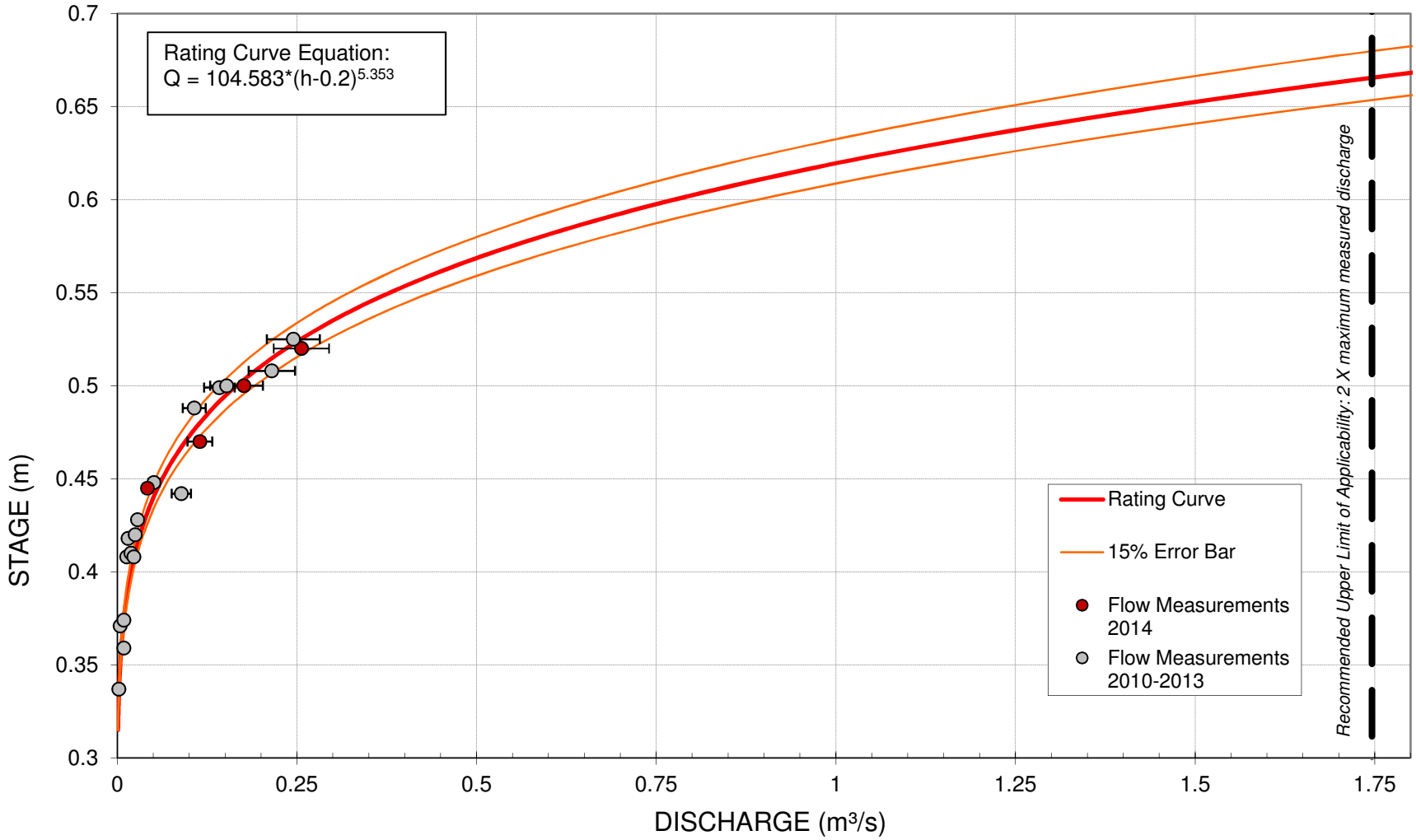

Figure D-2: 2013-2014 North Creek at Fraser Highway Stage-Discharge (Curve is unchanged from 2010)

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City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Ditch

Existing TIA

Based on Surrey Design Manual Land Use Codes, adjusted with reference to 2013 Orthophoto

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	April 2015

Fleetwood Greenway Existing Total Impervious Area

Figure D-3

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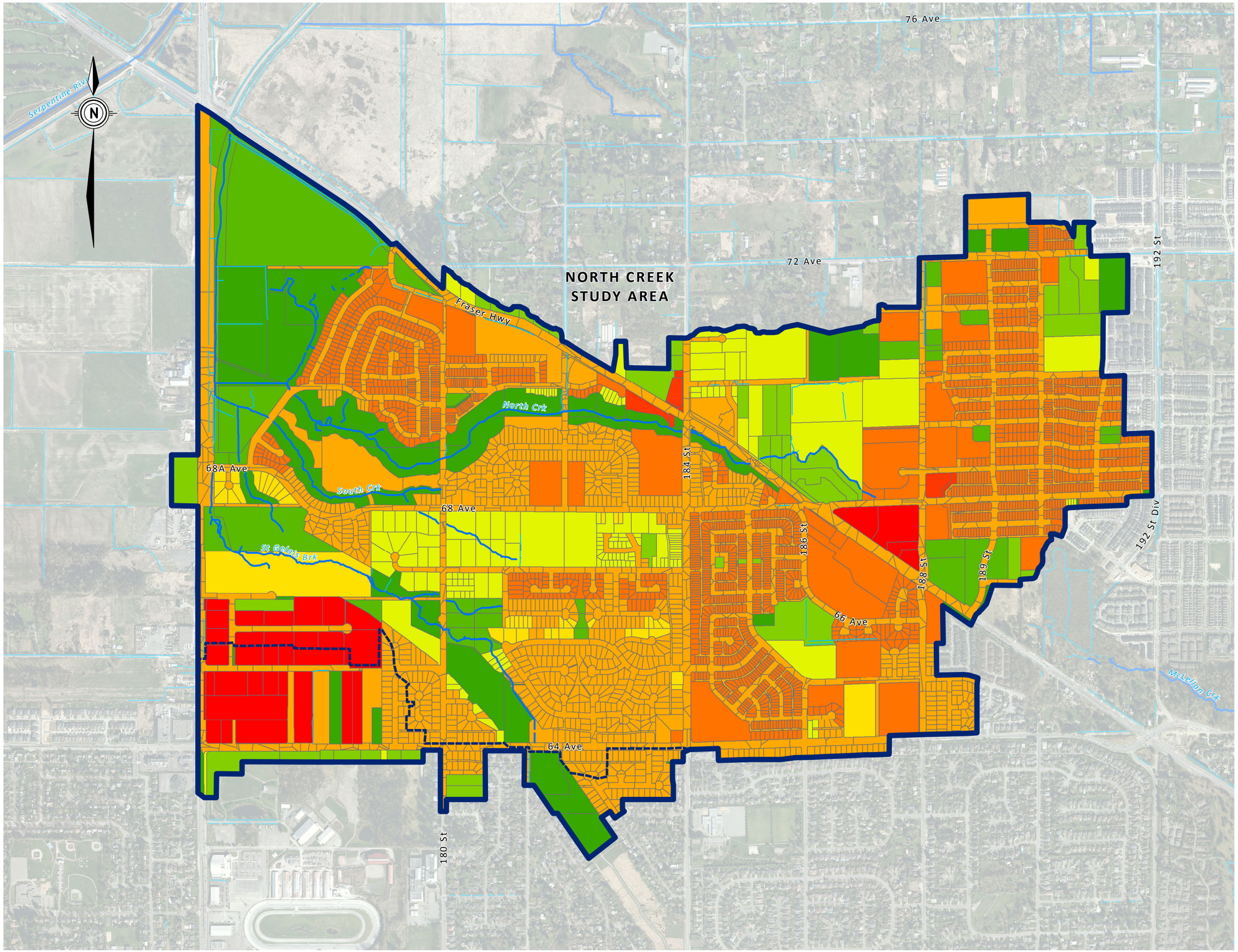

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

Existing TIA

Based on Surrey Design Manual Land Use Codes, adjusted with reference to 2013 Orphoto

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	April 2015

North Creek Existing Total Impervious Area

Figure D-4

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Ditch

Existing EIA

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	April 2015

Calibrated Fleetwood Greenway Existing Effective Impervious Area

Figure D-5

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

Existing EIA

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.

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consulting engineers

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Project No.	Date
471-288	April 2015

Calibrated North Creek Existing Effective Impervious Area

Figure D-6

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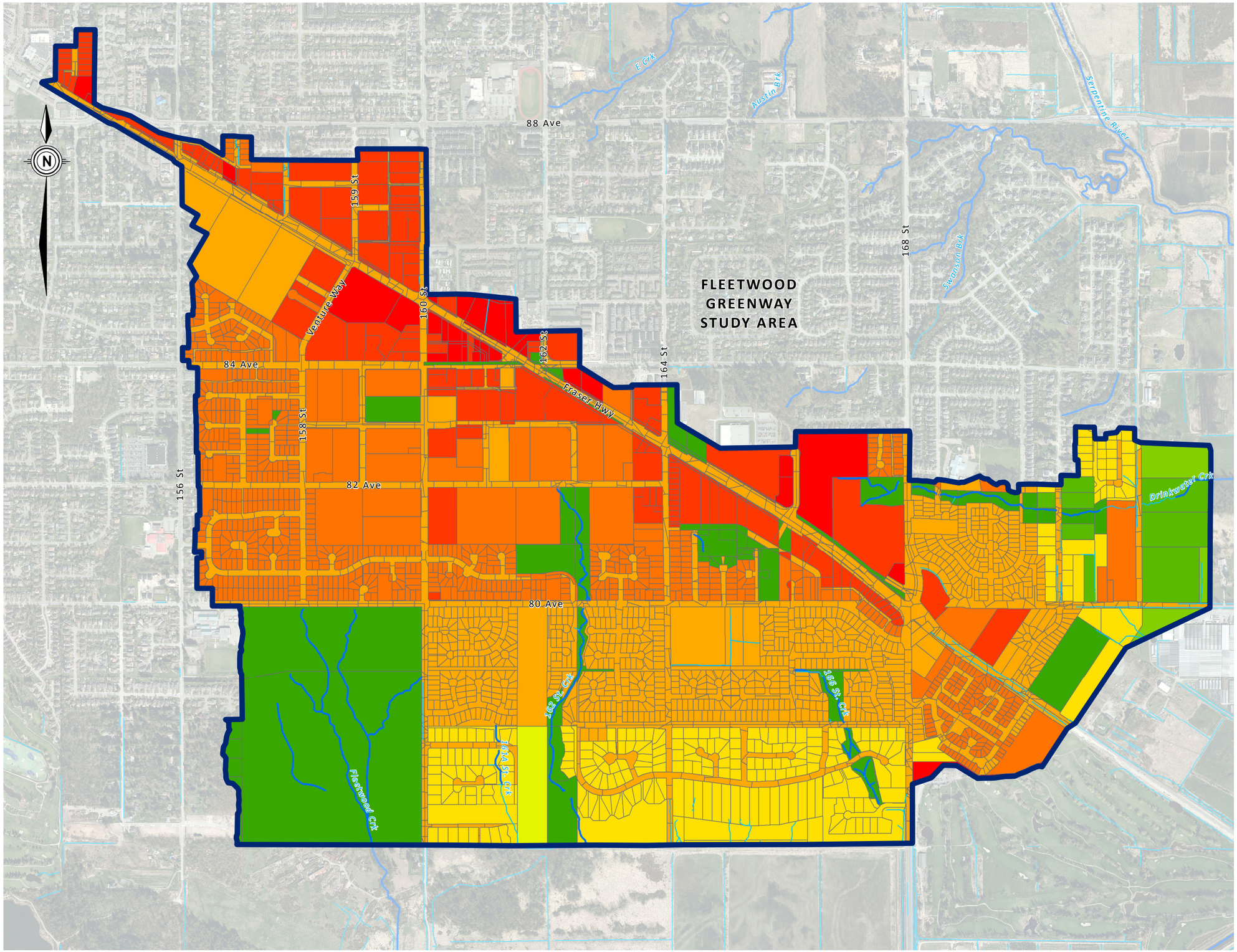

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

Study Area
Creek
Ditch

Future Land Use TIA

Based on City of Surrey OCP, 2014

10
20
30
40
50
60
70
80
90
100

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.
OCP Land Use Zoning provided by the City of Surrey, 2014
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Project No.	Date
471-288	June 2016

Fleetwood Greenway OCP Future Land Use Total Impervious Area

Figure D-7

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

Future Land Use TIA

Based on City of Surrey OCP, 2014

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Reference: 2013 Orthophoto and GIS background data from the City of Surrey open Data Catalogue.
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Project No.	Date
471-288	June 2016

North Creek
OCP Future Land Use
Total Impervious Area

Figure D-8

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Creek
- Ditch

Future EIA

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

FLEETWOOD GREENWAY STUDY AREA

88 Ave
84 Ave
82 Ave
80 Ave
156 St
158 St
159 St
160 St
162 St
164 St
168 St
Venture Way
Fraser Hwy
E Crk
Austin Brk
Serpentine River
Swanson Brk
Drinkwater Crk
Fleetwood Crk
162A St Crk
166A St Crk
166 St Crk

N

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Project No.	Date
471-288	June 2016

Fleetwood Greenway OCP Future Land Use Effective Impervious Area

Figure D-9

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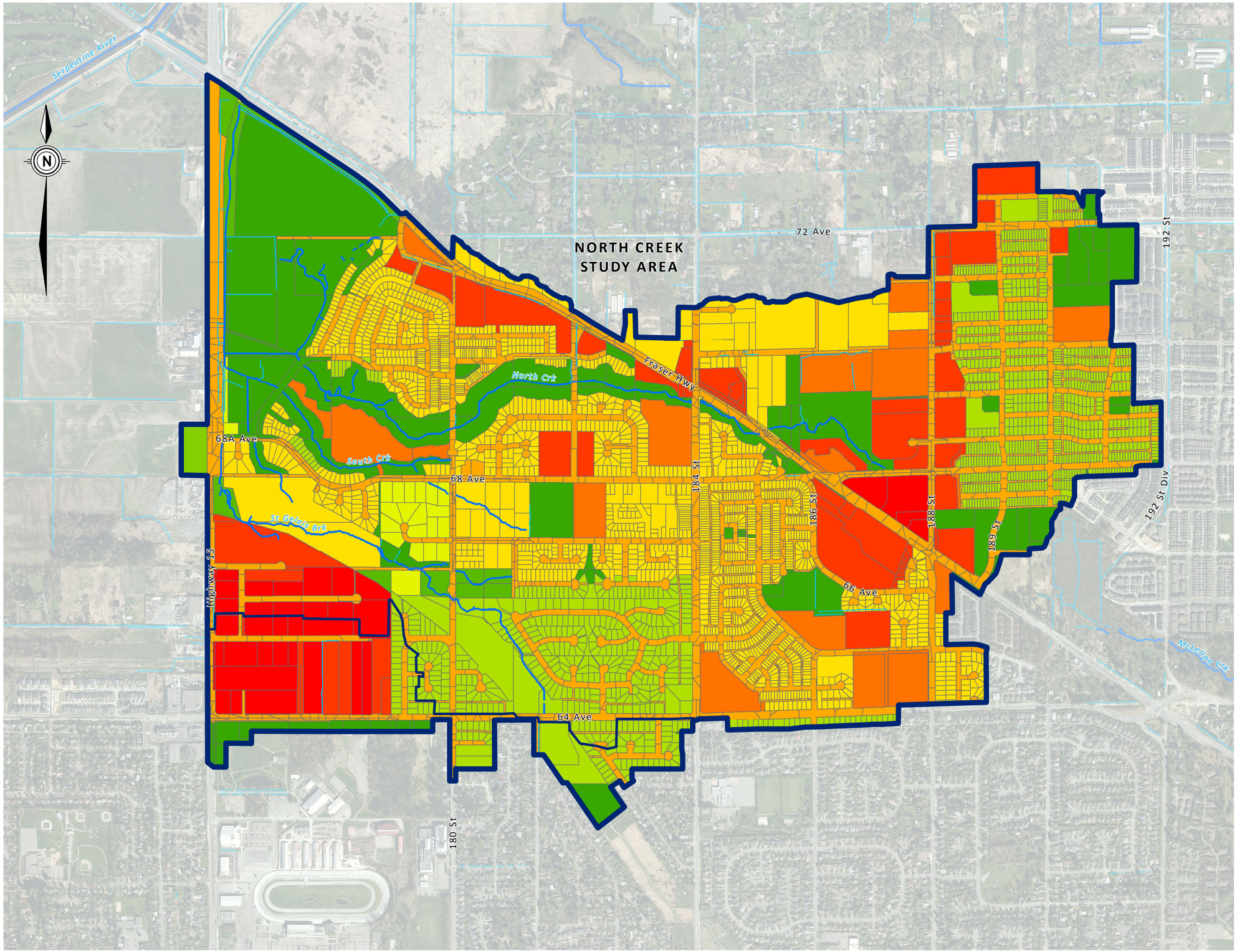

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Extra Catchment
- Creek
- Ditch

Future EIA

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

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Project No.	Date
471-288	June 2016

North Creek OCP Future Land Use Effective Impervious Area

Figure D-10

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Author: SScott

Appendix E – Drainage Assessment

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Appendix E – Drainage Assessment

E Drainage Assessment

E.1 Introduction

This section summarizes the assessment of the existing drainage system for existing and future OCP land use conditions. The system was assessed under 5-year and 100-year return period design storm events, as well as the same rainfall events adjusted for climate change. The assessment did not take into consideration pipe condition or age.

E.2 Urban Storm Sewers

Results from modeling the watershed's pipe network highlighted a number of areas where pipes are undersized and surcharging.

Minor System

The drainage system was assessed to determine its ability to convey the minor flow, generated by the 5-year return period rainfall event. The following three criteria were used to determine whether each sewer is undersized:

- Modelled instantaneous peak flow is larger than pipe capacity under free-flowing conditions;
- Pipe surcharged for longer than 15 minutes; and
- Water surcharged higher than 0.3 m above the crown of the pipe.

Existing Conditions Minor System

Figure 5-1 and Figure 5-2 schematically show the pipes that exceeded the three criteria during the existing conditions 5-year event model runs, (used the old IDF curves). In total, 43 pipes exceeded the criteria of the 1,943 total pipes in the study area. Recommended sizes and prioritization of upgrades are found in Appendix H.

Appendix E – Drainage Assessment

Mitigated Future Conditions Minor System

An additional 19 pipes have been flagged as being under capacity in the mitigated future land use scenario models (used the updated IDF curves). These flagged pipes are adequately sized for the existing conditions but would need to be upgraded to accommodate the mitigated future conditions flows. Figure 5-3 and Figure 5-4 show the flagged pipes.

When developing a capital works program for upgrading the storm sewer system, many of the pipes may not need to be upgraded immediately. They can continue to operate surcharged, and as they deteriorate and near the end of their design life, should be replaced with the recommended sizes. Recommendations for upgrades and priorities are included in Appendix H.

Unmitigated Future Conditions Minor System

An additional 72 pipes fail the minor system criteria under unmitigated future land use conditions. The unmitigated future conditions models did not account for potential detention that may be implemented as part of ongoing development in the watershed. This gives an indication of the number of pipes that would likely need replacing if detention is not incorporated into future development plans; however, the results were not used for prioritization of pipe upgrades or sizing.

Major System

The major system is the conveyance system that carries large storms, greater than the 5-year event and up to the 100-year event. The ditches and creeks make up the majority of the major system in this watershed. Additionally, culverts have been designated as part of the major system. This is to ensure that major flows from the creeks have a major flow route and do not cause damage to neighbouring properties.

Using the model results and field inventory, the culverts were assessed on their ability to pass the required 100-year peak flow while limiting surcharging and without flooding the land upstream. The assessment criteria were:

- Flooding above the ground for any duration with 100-year event instantaneous peak flow.

In each case, the proposed upgrades were sized for the greater of the existing or mitigated future scenario flow.

Existing Conditions Major System

No culverts were found to exceed the above criteria under existing land use conditions.

Appendix E – Drainage Assessment

Mitigated Future Conditions Major System

One culvert was flagged as exceeding the criteria under mitigated future conditions.

Six culverts were found to operate under surcharged conditions. These culverts can continue to operate surcharged, and as they deteriorate and near the end of their design life, should be replaced with the recommended sizes. These culverts are shown schematically in Figure 5-5 and Figure 5-6. Recommended sizes and priorities for upgrade are found in Appendix H.

Unmitigated Future Conditions Major System

No additional culverts were flagged as exceeding the major system criteria under unmitigated future conditions.

E.3 Climate Change Analysis

The design storm rainfall volumes were increased by 10%, 20%, and 30% to determine how the system would respond under increased rainfall predicted by climate change projections. The results of these three scenarios were compared to the existing and future land use scenarios described above, and are summarized in the table below.

Table E-1: Minor and major system conduits failing criteria under existing land use, future land use, and climate change scenarios

	Existing Land Use	Mitigated Future Land Use	Unmitigated Future Land Use	Unmitigated Future Land Use with Climate Change		
				10%	20%	30%
Minor System - Surcharged	33	52	113	124	215	282
Minor System - Flooding	10	10	21	58	82	108
Major System - Flooding	0	1	1	1	1	1

Appendix F – Stakeholder Outreach

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Appendix F – Stakeholder Outreach

F Stakeholder Outreach

F.1 City Speaks Survey

This appendix summarizes the feedback received from the City Speaks survey. The City of Surrey's City Speaks public information and consultation platform was used to reach out to residents and business that are registered with the City Speaks program and that are located within the study areas for this ISMP. A series of questions was developed to engage the public to think about and provide feedback on:

- the importance of the creeks in their neighbourhoods,
- what values the creeks provide to the public and neighbourhoods,
- any issues the public may be aware of related to flooding or creek health, and
- what values and watershed assets need to be preserved and enhanced for the future.

The City Speaks survey included reference maps as well as drop-downs and 'cards' for multiple-choice answers, and a few open questions with space for write-in answers. The survey was open to City Speaks participants for three weeks. The results of the survey are summarized below.

Familiarity

The creeks in the study area include: Fleetwood Creek, Drinkwater Creek, North Creek, South Creek and St. Gelais Brook. Other Creeks are identified by streets they are near or aligned with, such as 161A St. Creek, 162 St. Creek, and 166 St. Creek. Are you familiar with the creeks in your neighborhood regardless whether or not you know their names?

Table F- 1: Familiarity

	Total
Yes	39%
No	61%
23 Participants	

Interaction

Do you interact with any of the listed creeks or other creeks in your neighborhood? Examples of how you may interact with a creek:

- Your home's property border's a creek
- You walk on a trail near one of the creeks a couple of times a week
- Your kids have done a school activity by the creek in the past year
- Your favorite park includes a creek that you walk into in the summer.

Appendix F – Stakeholder Outreach

Table F- 2: Interaction

	Total
Yes	39%
No	61%
23 Participants	

Creek Interaction

Please tell us how often you've interacted with the following creeks in the past 12 months, if you know their names.

Table F- 3: Creek Interaction

Creek	A few times per week	A few times per month	A few times per year	Maybe once per year	Never/Don't recall
Fleetwood Creek	0%	14%	29%	14%	43%
Drinkwater Creek	0%	0%	0%	14%	86%
North Creek	0%	0%	29%	0%	17%
South Creek	0%	14%	0%	0%	86%
St. Gelais Brook	0%	14%	29%	0%	57%
Other	14%	14%	14%	0%	57%
7 Participants					

If you selected other creeks above and know their names please list them below.

1. I don't know the names of the creeks nearest me

   162 St. Creek
   166 St. Creek

Wildlife – Environmental Impacts

Do you see fish and wildlife living in our near your neighborhood creeks?

Table F- 4: Wildlife

	Yes	No	Never Close Enough
Fish	40	35	25
Birds	85	5	10
Other	80	5	15
20 Participants			

Appendix F – Stakeholder Outreach

Issues

Are you aware of any issues related to water quality or fish and wildlife habitat in the nearby creeks?

Table F- 5: Issues

	Total
Yes	20%
No	80%
20 Participants	

If yes, please note issues.

1. Contaminated water run off from roads, oil, gas, antifreeze etc...
2. Squirrels raccoons
3. Barnyards leaching into waterways. Truck parks near waterways.
4. Garbage in the creeks

Flooding – Drainage Improvements

Have you noticed flooding in your neighborhood?

Table F- 6: Flooding

	Total
Never	50%
Seldom - Only in very heavy rains	25%
Occasionally – Only with heavy rain	15%
Frequently - When it rains	10%
20 Participants	

Vision for the Future

What aspects of your neighborhood creeks do you want to see protected for the future?

1. Surrounding nature as well as creek
2. Would want the creek, the area around the creek and the wildlife around it protected
3. Protect the natural drainage and prevent contamination from human activity in the area...keep the areas clean by adding suitable waste disposal and appropriate signage
4. For them to be clear of garbage and debris
5. Try to keep creeks as 'natural' as practical/possible.
6. Green space around them for walking and wildlife habitat
7. Vegetation
8. Leave them as they are
9. Preserve fish hatcheries and related creeks

Appendix F – Stakeholder Outreach

Improvements

What aspects of your neighbourhood creeks would you want to see improved for the future?

1. I'm glad people like to get out with their dogs. I would like them to always clean up after their dogs and never leave the baggies of poo lying around.
2. Improve trails bordering the creeks by adding waste disposal bins and signs (keep pets on leash) (keep area clean, use waste bins) etc...
3. Accessible for people to see in order to teach children about the importance of creeks.
4. Additional cleaning
5. Kept clean if possible
6. Leave them as they are

Appendix G – Application of Source Controls

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Appendix G – Application of Source Controls

G Mitigation Measures

G.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 Puget Sound, 2005. http://www.psparchives.com/our_work/stormwater/lid.htm

Appendix G – Application of Source Controls

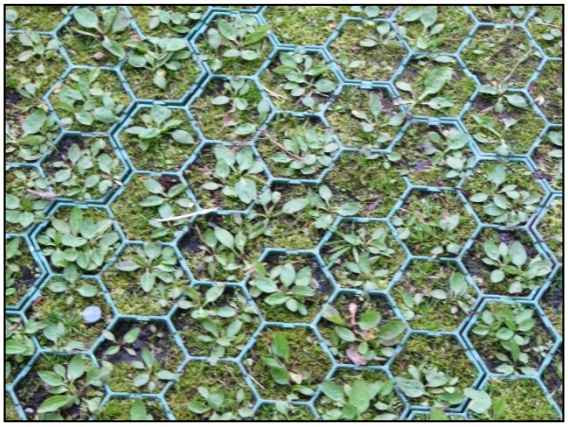
Limiting Surface Parking

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



Geogrid

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.

Appendix G – Application of Source Controls

G.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 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.

[2] Metro Vancouver, Stormwater Source Control Design Guidelines, 2012, http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/StormwaterSourceControlDesignGuidelines2012.pdf

Appendix G – Application of Source Controls

Absorbent Landscaping

Absorbent Landscaping

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.

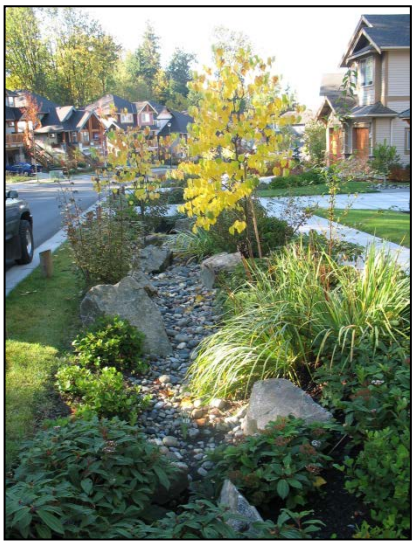
Surface infiltration can also be promoted by the used of permeable pavers or other pervious surfacing materials.

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 G – Application of Source Controls



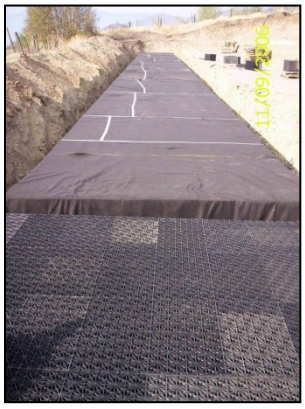
Bio-Retention Swale

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

Green Roofs

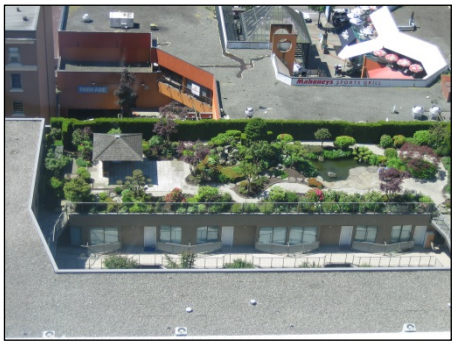
Installing a green roof rather than a conventional impervious roof can significantly reduce the volume and rate of runoff from a building lot particularly for the smaller, more frequent storm events.

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.

Appendix G – Application of Source Controls

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, it includes 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 G – Application of Source Controls

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.

Appendix G – Application of Source Controls

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 (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 provides: 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

Appendix G – Application of Source Controls

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 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.

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 G – Application of Source Controls

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]

G.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.

G.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.

[3] BC Ministry of Environment's *Standards and Best Practices for Instream Works* (draft March 2004) http://www.env.gov.bc.ca/wld/documents/bmp/iswstdsbpsmarch2004.pdf.

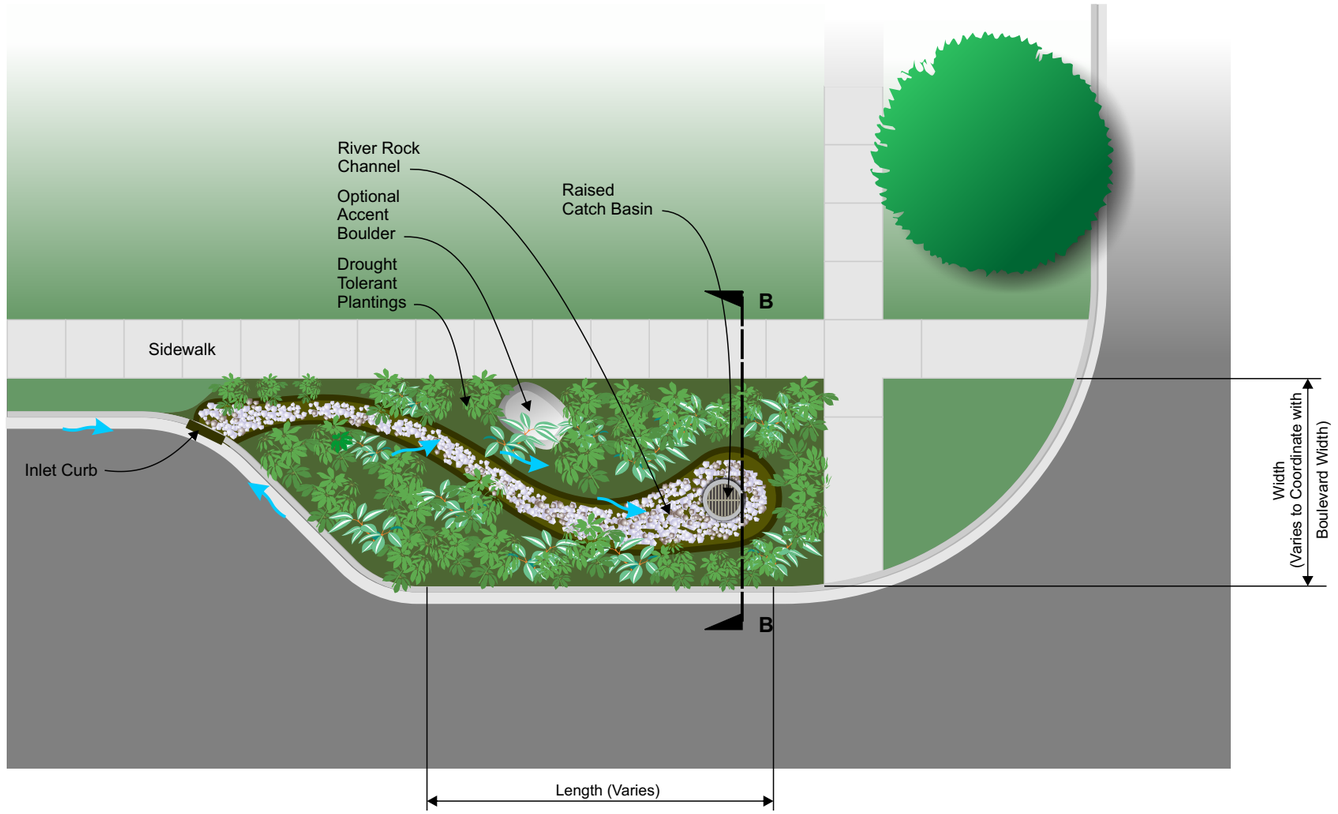
Appendix G – Application of Source Controls

G.5 Roadside Rain Gardens

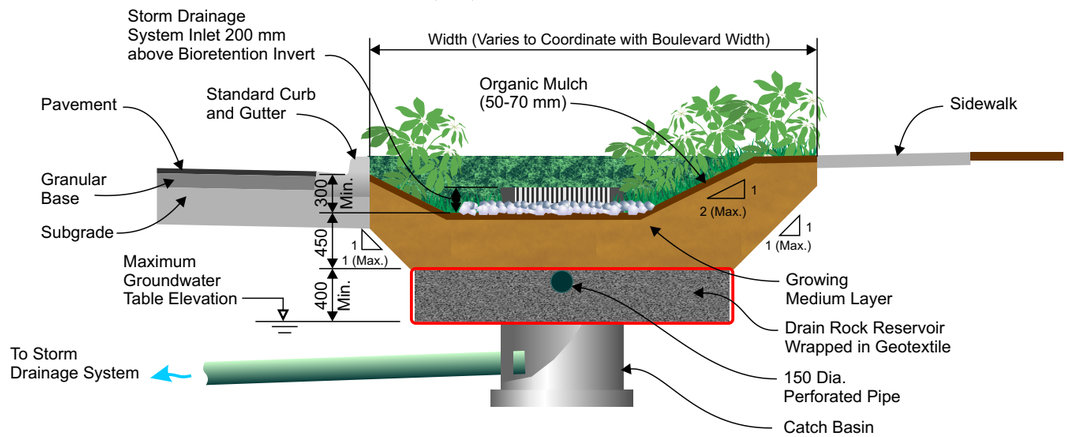
As part of the Quibble Creek ISMP (2014), the City wished to further explore the possibility of incorporating rain gardens along the roadways. Preliminary design sketches and guidelines were produced to illustrate how the rain gardens could be situated within the road ROW. Three options were developed:

1. Bump-out rain garden at intersections (see Figure G-1);
2. Bump-out rain gardens mid-block (see Figure G-2); and
3. Modular rain garden contained within the boulevard (see Figure G-3).

These roadside rain garden sketches and guidelines were developed with input from City Staff.



Plan
(NTS)



Section B-B
(NTS)

DESIGN PRINCIPLES

- The rain garden area, calculated as length times width, should be 5% of the upstream impervious area that it serves in areas of poor infiltration.
- At point-source inlets, install non-erodable material, sediment cleanout basins, and weir flow spreaders from the forebay to the rain garden.
- Rain garden bottom width - 600mm (min.) to 3000mm (desirable).
- Side slopes - 2:1 maximum, 4:1 preferred for maintenance. Maximum ponded depth - 300mm.
- Draw-down time for maximum ponded volume - 72 hours.
- Treatment soil depth - 450mm; (composition: <30% silt and clay, 8-15% organics, 0-10% gravel, 50-70% sand) minimum infiltration rate of 20mm/hr.
- Surface planting should be primarily evergreen trees, evergreen shrubs, and groundcovers, with planting designs respecting the various soil moisture conditions in the garden. Plantings may include rushes, sedges and grasses as well for erosion control.
- Apply a 50-75mm layer of organic mulch for both erosion control and to maintain infiltration capacity.
- Avoid utility or other crossings of the rain garden. Where utility trenches must be constructed below the garden, install trench dams to avoid infiltration water following the utility trench.
- For large length rain gardens on slopes steeper than 2%, add timber weirs to achieve $\leq$ 2% slope. (Max. drop per weir is 200mm).
- Planting area for trees adjacent to pavement to use a minimum of 800mm x 800mm x 800mm of structural soil. Exact required quantities will depend on tree selection.

KERR WOOD LEIDAL
consulting engineers

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City of Surrey Quibble Creek ISMP

Typical Bump Out Raingarden at Intersection

Sheet **Figure G-1**
File Number

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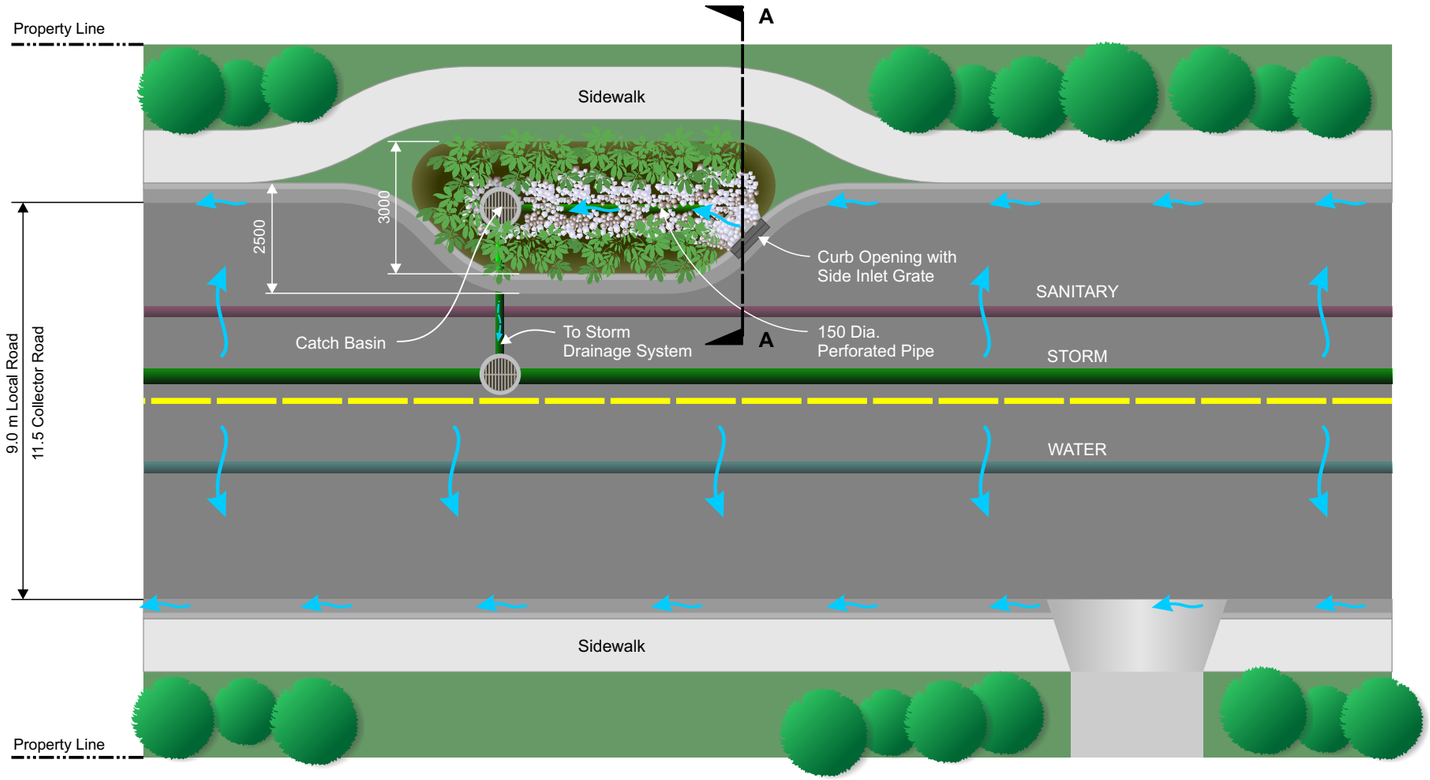
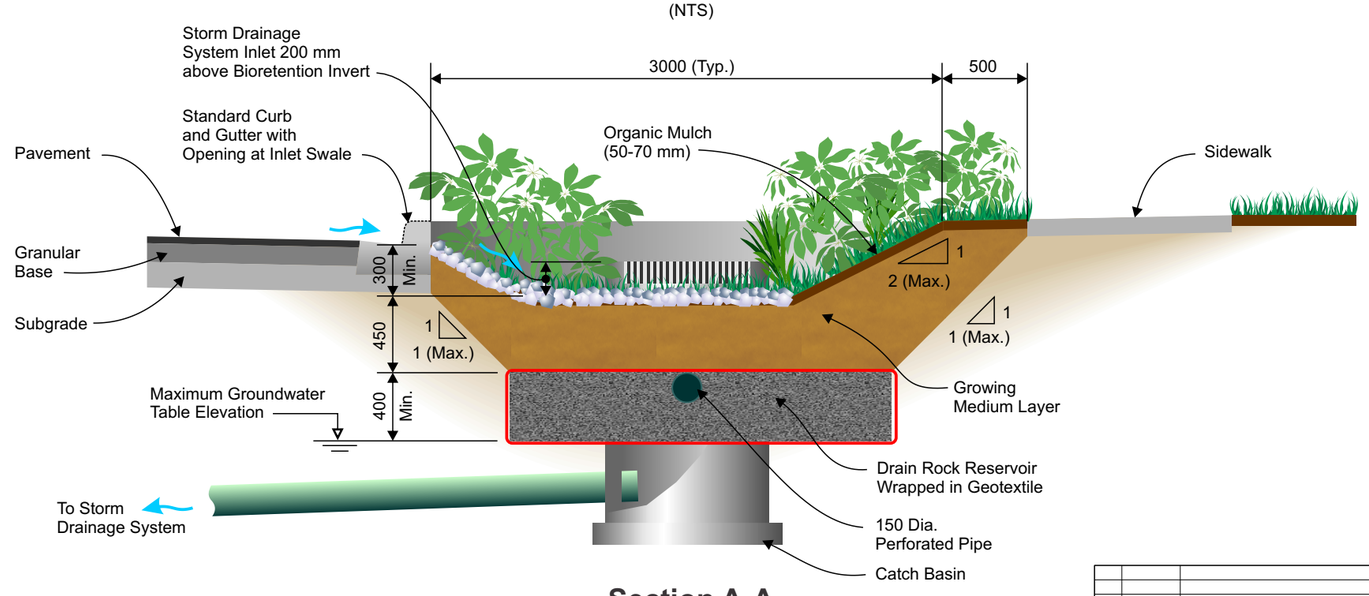


Plan
(NTS)



Section A-A
(NTS)

DESIGN PRINCIPLES

- The rain garden area, calculated as length times width, should be 5% of the upstream impervious area that it serves in areas of poor infiltration.
- At point-source inlets, install non-erodable material, sediment cleanout basins, and weir flow spreaders from the forebay to the rain garden.
- Rain garden bottom width - 600mm (min.) to 3000mm (desirable).
- Side slopes - 2:1 maximum, 4:1 preferred for maintenance. Maximum ponded depth - 300mm.
- Draw-down time for maximum ponded volume - 72 hours.
- Treatment soil depth - 450mm; (composition: <30% silt and clay, 8-15% organics, 0-10% gravel, 50-70% sand) minimum infiltration rate of 20mm/hr.
- Surface planting should be primarily evergreen trees, evergreen shrubs, and groundcovers, with planting designs respecting the various soil moisture conditions in the garden. Plantings may include rushes, sedges and grasses as well for erosion control.
- Apply a 50-75mm layer of organic mulch for both erosion control and to maintain infiltration capacity.
- Avoid utility or other crossings of the rain garden. Where utility trenches must be constructed below the garden, install trench dams to avoid infiltration water following the utility trench.
- For large length rain gardens on slopes steeper than 2%, add timber weirs to achieve $\leq$ 2% slope. (Max. drop per weir is 200mm).
- Planting area for trees adjacent to pavement to use a minimum of 800mm x 800mm x 800mm of structural soil. Exact required quantities will depend on tree selection.

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DIMENSIONS ARE MILLIMETRES
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City of Surrey Quibble Creek ISMP

Typical Bump Out Raingarden Mid-Block

Sheet **Figure G-2**
File Number

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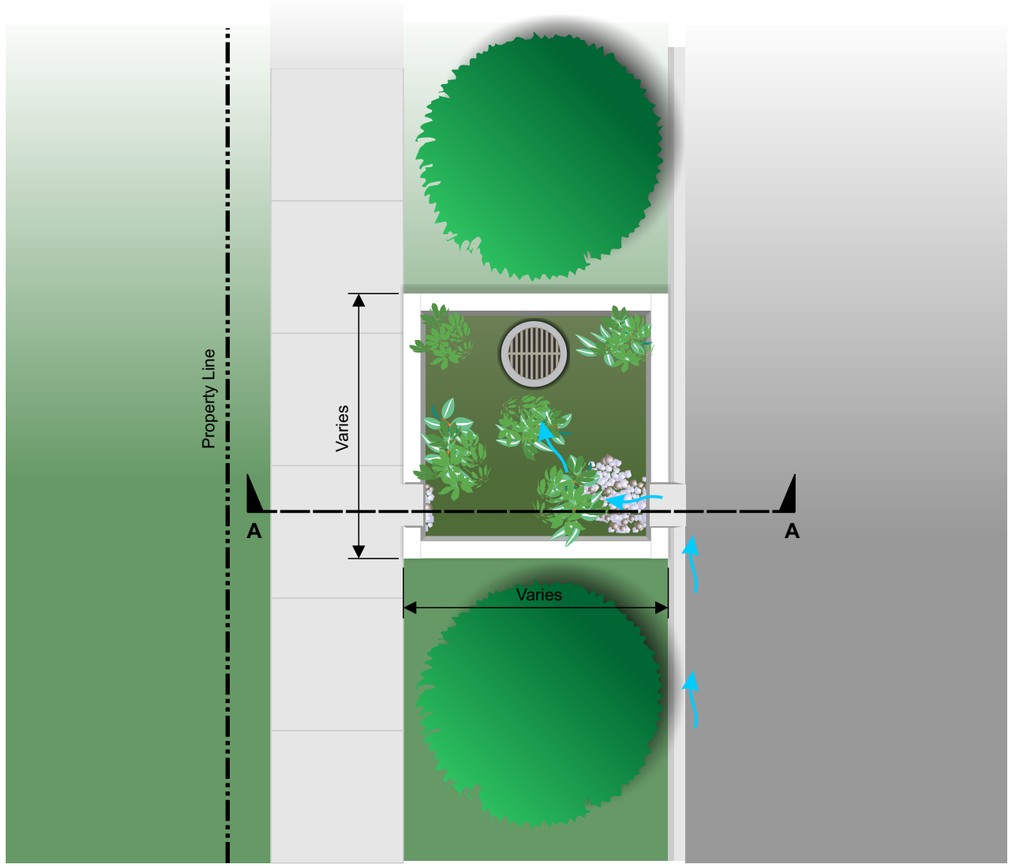
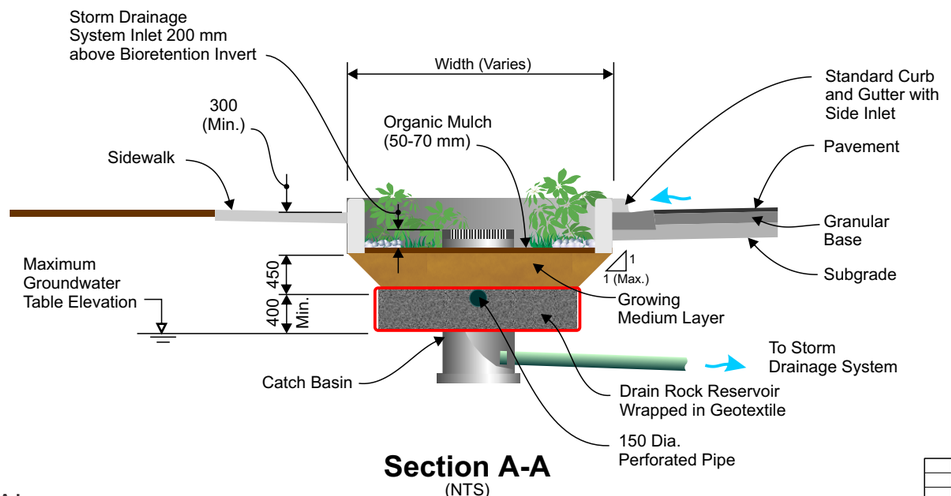
471-239\500-Drawings\471239_FigG-2_Bioretention.CDR



Modular Rain Garden - Plan
(NTS)



Section A-A
(NTS)

DESIGN PRINCIPLES

- The rain garden area, calculated as length times width, should be 5% of the upstream impervious area that it serves in areas of poor infiltration.
- At point-source inlets, install non-erodable material, sediment cleanout basins, and weir flow spreaders from the forebay to the rain garden.
- Rain garden bottom width - 600mm (min.) to 3000mm (desirable).
- Side slopes - 2:1 maximum, 4:1 preferred for maintenance. Maximum ponded depth - 300mm.
- Draw-down time for maximum ponded volume - 72 hours.
- Treatment soil depth - 450mm; (composition: <30% silt and clay, 8-15% organics, 0-10% gravel, 50-70% sand) minimum infiltration rate of 20mm/hr.
- Surface planting should be primarily evergreen trees, evergreen shrubs, and groundcovers, with planting designs respecting the various soil moisture conditions in the garden. Plantings may include rushes, sedges and grasses as well for erosion control.
- Apply a 50-75mm layer of organic mulch for both erosion control and to maintain infiltration capacity.
- Avoid utility or other crossings of the rain garden. Where utility trenches must be constructed below the garden, install trench dams to avoid infiltration water following the utility trench.
- For large length rain gardens on slopes steeper than 2%, add timber weirs to achieve $\leq$ 2% slope. (Max. drop per weir is 200mm).
- Planting area for trees adjacent to pavement to use a minimum of 800mm x 800mm x 800mm of structural soil. Exact required quantities will depend on tree selection.

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consulting engineers

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City of Surrey Quibble Creek ISMP

Typical Modular Raingarden in Boulevard

Sheet **Figure G-3**
File Number

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the future lives here.

471-239\500-Drawings\471239_FigG-3_ModularRainGarden.CDR

Appendix H – Capital Plan

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Appendix H – Capital Plan

H Capital Upgrades Program

H.1 Introduction

Based on the results from the drainage system assessment in Section 5 and the recommendations for erosion mitigation and environmental enhancement projects in Section 7, this section summarizes the capital upgrade program developed for the Fleetwood Greenway North Creek watersheds. Criteria for prioritization and cost estimates are included in the following sections.

H.2 Capital Upgrades Program

Recommended capital projects are summarized in the following tables.

Table H-1: Flood Management Upgrades

Project	Description	Timeline	Funding Source	Cost ($)
Flood Management				
Major System - Priority 1	Flooding on Surface, 100-Year Analysis *(NONE)*	0 – 5 years	City	-
Minor System - Priority 2	Flooding on Surface, Two Incremental Dia. or More Upgrade, Existing 5-Year Analysis *(10 pipes)*	6 – 10 years	City	$1,570,000
Minor System - Priority 3	Flooding on Surface, One Incremental Dia. Upgrade, Existing 5-Year Analysis *(NONE)*	6 – 10 years	City	-
Minor System - Priority 4	Surcharge >0.3 m for >15 min, Existing 5-Year Analysis *(33 pipes)*	End-of-Life	City	$5,068,000
Major/Minor System - Priority 5	Undersized, Future Mitigated 5-Year and 100-Year Analysis *(25 pipes)*	End-of-Life	City & DCCs	$3,532,000

Table H-2: Erosion Management Projects

Project	Description	Timeline	Funding Source	Cost ($)
Erosion Management				
162 St. Creek Diversion	Complete 162 St. Creek diversion	0 - 5 years	City	$2,535,000
Fleetwood Creek Diversion	Divert stormwater entering Fleetwood Creek by creating diversion along 80th Ave. from 158 to 160 St. and along 160 St. from 80th Ave. to Fleetwood Pump Station	6 - 10 years	City	$8,735,000

Table H-3: Environmental Restoration and Enhancement Projects

Project ID[1]	Project Type	Description	Priority	Funding Source[2]	Cost
Fish Passage Improvements					
1	*Investigate obstruction to fish passage downstream of Fleetwood Park*	A possible barrier to fish passage has been identified by City staff downstream of Fleetwood Park outside the study area. High value fish habitat in Fleetwood Park cannot be utilized until fish passage downstream is addressed.	High	Drainage	Staff Time
2	*Work with landowner to upgrade private twin culvert crossing on 162 Street Creek*	A long twin culvert, apron, and 0.5 m drop likely prevents fish movement between the lower and upper watershed approximately 170 m upstream of 76 Ave. 162 Street Creek has high fish habitat value, but reaches of the stream are likely not being well utilized. Upgrading can include replacement with a clear span bridge, open bottom arch culvert, or a box culvert with fish baffles.	High	Drainage	$2,470,000
3	*Remove debris blockage on Drinkwater Creek*	A debris blockage is creating a barrier to fish passage on Drinkwater Creek, restricting access to approximately 650 m of upstream habitat.	High	Drainage	Staff Time
4	*Remove barriers on 161A Street Creek*	A series of barriers on 161A Street Creek could be removed, but the creek is not classified as fish habitat.	Low	Drainage	Staff Time
5	*Remove partial barriers on South Creek*	A number of partial barriers due to debris and logs exist on South Creek, but they are not significant issues for fish passage	Low	Drainage	Staff Time
In-Stream Habitat Complexing					
6	*Increase channel complexity along ALR boundary upland/lowland transition*	Along the southern of edge of the catchment, 162 Street Creek drains along the ALR boundary. Instream habitat value can be enhanced through the addition of channel meanders, wood and boulder structures.	High	Drainage	$120,000
7	*Add spawning gravels to creeks*	Spawning gravels and habitat were identified in Fleetwood and 162 Street Creek. Additional sites for gravel placement could be identified to promote the return of adult salmon to the catchment.	Low	Drainage	Not Costed
8	*Stabilize banks, add meanders and plant native species in the lower reaches of North Creek*	The lower reaches of North Creek can be enhanced by increasing channel complexity by creating channel meanders, planting native shrub and tree species in the riparian area, and stabilizing stream banks using bioengineering techniques. Accumulation of fine sediment remains an on-going issue in this reach; enhancement plans should meet agricultural standards for ditch maintenance.	High	Drainage	$130,000
Off-Channel Habitat Creation					
9	*Create off-channel habitat and wetland habitat for over-wintering fry*	Off-channel habitat and wetland habitat is scarce in the North Creek catchment. Construction of off-channel habitat in the low-middle reaches of North Creek would provide shelter and rearing habitat for juvenile salmon.	High	Drainage	$50,000

Table H-3: Environmental Restoration and Enhancement Projects

Project ID[1]	Project Type	Description	Priority	Funding Source[2]	Cost
Riparian Protection, Restoration and Planting					
10	*Enhance riparian corridor at south of Fleetwood Catchment*	Identified as a moderate value corridor (Corridor 80) in the Green Infrastructure Network, this corridor provides important habitat linkages for wildlife between Fleetwood Park and the Serpentine River corridor. To enhance the value of corridor, riparian habitat can be enhanced by planting native tree and shrub species, and controlling invasive species including reed canary grass. Steep slopes, saturated soils and private land ownership adjacent to the site may make access to for works difficult.	High	Drainage	$420,000
11	*Protect and/or convey riparian areas during re-development along Drinkwater Creek*	In order to better protect the riparian area of Drinkwater Creek and allow future enhancement activities to be undertaken, identify opportunities to convey land as it becomes available.	High	Drainage	Market Land Rates
12	*Protect and/or convey riparian areas during re-development along 162nd Street Creek*	Intact forested areas adjacent to 162 Street Creek may be conveyed to the City during re-development. Forested cover in the Fleetwood Catchment is low and remaining opportunities to protect forested areas are a priority.	Medium	Drainage	Market Land Rates
13	*Discourage access to 162 Street Creek from 80th Avenue*	Access to 162 Street Creek has degraded the riparian area of the creek. Access to the creek can be discouraged through the planting of native species and the installation of railings to create a visual barrier.	Low	Drainage	Not Costed
14	*Create a forested riparian corridor adjacent to 176th Street*	Where North Creek, South Creek and St. Gelais Brook join and flow towards Fraser Highway has been identified as an important wildlife corridor in the Green Infrastructure Network (Corridor 140). A corridor on crown land could be enhanced between the Cloverdale Greenway and North Creek, with a possible widening of the buffer east of the creek in conjunction with private landholders. Native trees and shrubs could be established beside the trail to provide cover and shading to the stream, as well as increase the aesthetic value of the stream for trail users.	High	Drainage	$350,000
15	*Monitor erosion sites in North Creek ravine*	A number of erosion sites have been identified in the North Creek ravine with the potential to significantly impact North Creek and its associated fish populations. Sites should be monitored over time and when appropriate, erosion controls put in place.	High	Drainage	Not Costed
16	*Protect and/or convey riparian areas along the lower reaches of St. Gelais Brook when opportunities become available*	Opportunities to protect the lower reaches of St. Gelais Brook should be explored to maintain and enhance a natural riparian corridor. Shrub communities could be established as well. The lower reaches of St. Gelais Brook are part of Corridor 143 in the Biodiversity Conservation Strategy.	Medium	Drainage	Market Land Rates
17	*Remove garbage from North Creek*	Significant amount of garbage has accumulated in the middle and upper reaches of North Creek and could be removed.	Medium	Drainage	Staff Time
18	*Plant coniferous tree species and remove invasive species from North Creek riparian area*	The riparian area of North Creek, centering around the pedestrian walkway at 180th Street, can be enhanced through plantings and invasive plant removals. Much of the forested area in the North Creek catchment is young deciduous forest; planting coniferous species will accelerate forest succession.	Low	Drainage	Not Costed

Table H-3: Environmental Restoration and Enhancement Projects

Project ID[1]	Project Type	Description	Priority	Funding Source[2]	Cost
Wildlife/Biodiversity Habitat and Corridors					
19	*Work with private landowners to enhance a wildlife corridor along the southern edge of the Fleetwood Catchment adjacent to the ALR lands between 160th Street and 161A Street Creek*	The enhancement of a 50m wide forested corridor along the ALR lands would provide important habitat linkages to the Serpentine River corridor. This corridor is identified as a moderate value in the Green Infrastructure Network (Corridor 80), but is fragmented by housing developments along 76th Avenue between Fleetwood Park and 161A Street. By working with private landowners, the corridor can be expanded and enhanced through plantings of native tree and shrub species.	Medium	BCS	Not Costed
20	*Enhance wildlife habitat through the creation of a wildlife refuge in Fleetwood Park*	Fleetwood Park is an important hub for wildlife with high ecological value identified in the Biodiversity Conservation Strategy. The creation of a wildlife refuge with restricted access would promote forest health and provide important habitat for wildlife with reduced disturbance. This work could be combined with the control of invasive species and underplanting with coniferous trees to speed up the succession of the young deciduous forest already present.	Low	BCS	Not Costed
21	*Establish hedgerow, shrub pockets and native grassland where possible along the right-of-way along St. Gelais Brook*	Although the ability to plant tree species in this area is limited, habitat can still be enhanced by creating shrub communities and hedgerows to improve wildlife usage and migration. Identified as Corridor 143 in the Biodiversity Conservation Strategy), this corridor connects the North Creek catchment to natural areas in the south.	Medium	BCS	Not Costed
22 (not shown)	*Increase forest cover throughout the catchment area*	The North Creek catchment has low overall and riparian forest cover. Promote backyard naturalization projects with landowners and identify locations owned by the City of Surrey.	Medium	BCS	Not Costed
Water Treatment Opportunities					
23	*Incorporate water quality treatment devices such as oil-grit separators along the Fraser Highway*	Runoff from large portions of the Fraser Highway could be treated with oil-grit separators located on the Fraser Highway at 162a St. and 168 St., 180 St., 182 St., and 185a St.	High	Drainage	$1,000,000
24	*Monitor temperatures at the detention pond in the headwaters of North Creek*	Water temperature can be monitored at the inlet and outlet of the stormwater detention pond in the headwaters of North Creek to better identify the source of high temperature water entering North Creek.	Medium	Drainage	Not Costed

1. Project ID refers to environmental enhancement and protection sites identified in Figures 7-2 and 7-3.
2. BCS = Biodiversity Conservation Strategy

Appendix H – Capital Plan

H.3 Criteria for Prioritization

Drainage System Upgrades

Major and minor system upgrades were prioritized by the following criteria:

Priority 1. Based on the existing land use model results, major storm pipes (culverts) that have inadequate capacity to convey the 100-year design flow and result in flooding on the surface, are sized to meet the 100-year flow as calculated in the mitigated future land use model.

Priority 2. Based on the existing land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow, result in flooding on the surface, and require two or more incremental pipe diameter increases, are sized to meet the 5-year flow as calculated in the mitigated future land use model.

Priority 3. Based on the existing land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow, result in flooding on the surface, and require one incremental pipe diameter increase, are sized to meet the 5-year flow as calculated in the mitigated future land use model.

Priority 4. Based on the existing land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow and result in surcharging higher than 0.3 m above the pipe crown for over 15 minutes, are sized to meet the 5-year flow as calculated in the mitigated future land use model. These are recommended as end of service life upgrades only.

Priority 5. Based on the mitigated future land use model results, major storm pipes (culverts) that have inadequate capacity to convey the 100-year design flow (regardless of whether or not surface flooding occurs) are sized to meet the 100-year flow as calculated in the mitigated future land use model.
Based on the mitigated future land use model results, storm sewer pipes that have inadequate capacity to convey the 5-year design flow (regardless of amount of surcharge) are sized to meet the 5-year flow as calculated in the mitigated future land use model.
Both of these (major and minor) system upgrades are recommended as end of service life upgrades only.

Pipes downstream of those recommended for upgrades should be analyzed for concerns of potential sewer blockage and upsized if necessary.

Figures H-1 to H-12 show the recommended capital upgrades for the Fleetwood Greenway and North Creek watersheds.

Appendix H – Capital Plan

H.4 Cost Estimate

The cost estimates for the major and minor system proposed capital upgrades are found in Tables H-1 to H-3 along with pipe identification, recommended sizing, and associated cost estimate for priorities 2, 4, and 5. Note that no pipes or culverts were found to fit the criteria for priority 1 and 3 capital upgrades. Figures H-1 to H-12 show the location of each upgrade symbolized by priority.

Table H-4 and Table H-5 summarize the cost estimates for the proposed Fleetwood Creek Diversion and for completion of the 162 St. Creek Diversion, respectively. The location of each diversion is shown on the key plan in Figure H-1.

Table H-6 summarizes the cost estimate for replacement of the twin 1200 mm diameter culverts on 162 St. Creek that present a barrier to fish passage. The location of this culvert is shown in Figure 7-2.

The accuracy of the cost estimates is Class D meaning 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 (water, hydro, etc.);
- Special permitting requirements (contaminated sites, etc.);
- Geotechnical issues requiring special construction such as pile-supported piping, buoyancy problems or rock blasting; and
- Critical market shortages of materials.

Surveys and more detailed assessments of the proposed capital upgrades should be conducted prior to design and construction.

As the factors above have not been included in the cost estimates, the following allowances are applied to all projects:

- Mobilization/Demobilization/Bonding – 8%;
- Engineering – 20%; and
- Contingency – 40%.

The unit prices reflect KWL's recent experience with similar work, and therefore represent the best prediction of actual (2015) costs as of the date prepared. Actual tendered costs will depend on market conditions, location factors, time of year, contractors' workloads, and perceived risk exposure associated with the work and unknown conditions.

Table H-4: Storm Sewer Priority 2 Upgrades Cost Estimate

Conduit ID	Existing Size (mm)	Upgrade Type	Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Storm Pipe Cost	Manhole Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
1000736746	450	5-Yr Flooding-Existing	1.51	900	58	$124,000	$30,000	$154,000	$259,000
1000736745	450	5-Yr Flooding-Existing	1.46	675	66	$52,000	$30,000	$82,000	$138,000
1000765868	450	5-Yr Flooding-Existing	1.50	750	18	$30,000	$30,000	$60,000	$101,000
1000744273	450	5-Yr Flooding-Existing	0.47	675	138	$108,000	$30,000	$138,000	$232,000
1000750678	375	5-Yr Flooding-Existing	0.31	525	102	$61,000	$30,000	$91,000	$153,000
1000816847	375	5-Yr Flooding-Existing	0.21	525	153	$92,000	$45,000	$137,000	$230,000
1000852018	300	5-Yr Flooding-Existing	0.52	600	54	$78,000	$30,000	$108,000	$181,000
1000741909	250	5-Yr Flooding-Existing	0.71	750	5	$12,000	$30,000	$42,000	$71,000
1000742079	250	5-Yr Flooding-Existing	0.23	375	149	$68,000	$12,000	$80,000	$134,000
1000751128	200	5-Yr Flooding-Existing	0.25	375	34	$30,000	$12,000	$42,000	$71,000
								Priority 2 Subtotal	**$1,570,000**

1. Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
2. These cost estimates are based on City of Surrey's previous project experience. Actual costs may vary depending on unforeseen project design requirements, construction and economic market conditions, local interest in the project(s) and currency fluctuations. These cost estimates must not be construed as guarantee that the projects can be delivered for the estimated price.

Table H-5: Storm Sewer Priority 4 Upgrades Cost Estimate

Conduit ID	Existing Size (mm)	Upgrade Type	Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Storm Pipe Cost	Manhole Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
1000762702	675	5 Yr Surcharge-Exist	1.07	900	26	$56,000	$30,000	$86,000	$144,000
1000744168	675	5 Yr Surcharge-Exist	1.05	900	55	$118,000	$30,000	$148,000	$249,000
1000744287	675	5 Yr Surcharge-Exist	1.09	1050	57	$176,000	$30,000	$206,000	$346,000
1000744070	600	5 Yr Surcharge-Exist	0.72	900	18	$40,000	$30,000	$70,000	$118,000
1000736800	600	5 Yr Surcharge-Exist	0.79	750	55	$92,000	$30,000	$122,000	$205,000
1000751067	600	5 Yr Surcharge-Exist	1.41	900	39	$84,000	$30,000	$114,000	$192,000
1000751069	600	5 Yr Surcharge-Exist	1.42	1050	24	$76,000	$30,000	$106,000	$178,000
1000744274	450	5 Yr Surcharge-Exist	0.52	900	58	$124,000	$30,000	$154,000	$259,000
1000744059	450	5 Yr Surcharge-Exist	0.77	525	65	$39,000	$30,000	$69,000	$116,000
1000762696	450	5 Yr Surcharge-Exist	0.59	900	96	$103,000	$30,000	$133,000	$223,000
1000744058	450	5 Yr Surcharge-Exist	0.76	750	28	$48,000	$30,000	$78,000	$131,000
1000816859	450	5 Yr Surcharge-Exist	0.53	600	64	$46,000	$30,000	$76,000	$128,000
1000761399	450	5 Yr Surcharge-Exist	1.52	900	16	$34,000	$30,000	$64,000	$108,000
1000744171	450	5 Yr Surcharge-Exist	0.45	900	96	$103,000	$30,000	$133,000	$223,000
1000751065	450	5 Yr Surcharge-Exist	0.58	675	55	$86,000	$30,000	$116,000	$195,000
1000744293	450	5 Yr Surcharge-Exist	0.77	600	136	$98,000	$30,000	$128,000	$215,000
1000736747	450	5 Yr Surcharge-Exist	1.55	600	62	$45,000	$30,000	$75,000	$126,000
1000816864	450	5 Yr Surcharge-Exist	0.56	600	140	$101,000	$30,000	$131,000	$220,000
1000816861	450	5 Yr Surcharge-Exist	0.55	600	86	$62,000	$30,000	$92,000	$155,000
1000744072	375	5 Yr Surcharge-Exist	0.27	525	63	$38,000	$30,000	$68,000	$114,000
1000750702	375	5 Yr Surcharge-Exist	0.54	600	51	$74,000	$30,000	$104,000	$175,000
1000736938	375	5 Yr Surcharge-Exist	0.36	525	39	$46,000	$30,000	$76,000	$128,000
1000750701	375	5 Yr Surcharge-Exist	0.41	525	95	$57,000	$30,000	$87,000	$146,000
1000744170	375	5 Yr Surcharge-Exist	0.33	600	39	$56,000	$30,000	$86,000	$144,000
1000767019	300	5 Yr Surcharge-Exist	0.18	375	40	$36,000	$12,000	$48,000	$81,000
1000750698	300	5 Yr Surcharge-Exist	0.29	450	48	$50,000	$12,000	$62,000	$104,000
1000736946	300	5 Yr Surcharge-Exist	0.27	450	108	$56,000	$12,000	$68,000	$114,000
1000743928	300	5 Yr Surcharge-Exist	0.27	375	45	$40,000	$12,000	$52,000	$87,000

Table H-5: Storm Sewer Priority 4 Upgrades Cost Estimate

Conduit ID	Existing Size (mm)	Upgrade Type	Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Storm Pipe Cost	Manhole Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
1000743929	300	5 Yr Surcharge-Exist	0.38	450	28	$30,000	$12,000	$42,000	$71,000
1000736935	250	5 Yr Surcharge-Exist	0.12	375	51	$46,000	$12,000	$58,000	$97,000
1000736940	250	5 Yr Surcharge-Exist	0.10	300	45	$34,000	$12,000	$46,000	$77,000
1001211413	250	5 Yr Surcharge-Exist	0.16	450	56	$58,000	$12,000	$70,000	$118,000
1001211411	200	5 Yr Surcharge-Exist	0.10	300	48	$36,000	$12,000	$48,000	$81,000
								Priority 4 Subtotal	**$5,068,000**

1. Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
2. These cost estimates are based on City of Surrey's previous project experience. Actual costs may vary depending on unforeseen project design requirements, construction and economic market conditions, local interest in the project(s) and currency fluctuations. These cost estimates must not be construed as guarantee that the projects can be delivered for the estimated price.

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Table H-6: Storm Sewer Priority 5 Upgrades Cost Estimate

Conduit ID	Existing Size (mm)	Upgrade Type	Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Pipe/ Culvert Cost	Manhole / Headwall Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
1001195671	375	100Yr-Future Mitigated	0.35	600	8	$30,800	$10,000	$40,800	$69,000
1001194706	375	100Yr-Future Mitigated	0.32	600	27	$106,000	$7,000	$113,000	$190,000
1000757694 1000767695	600	100Yr-Future Mitigated	1.31	1050	22	$149,000	$12,000	$161,000	$270,000
1001561797	450	100Yr-Future Mitigated	2.02	1350	7	$37,800	$12,000	$49,800	$84,000
1001561761	675	100Yr-Future Mitigated	1.12	1050	9	$85,000	$12,000	$97,000	$163,000
1000744354	600	100Yr-Future Mitigated	0.60	750	27	$130,000	$10,000	$140,000	$235,000
1000750699	300	5 Yr-Future Mitigated	0.17	375	88	$40,000	$12,000	$52,000	$87,000
1000762693	300	5 Yr-Future Mitigated	0.17	375	100	$45,000	$12,000	$57,000	$96,000
1000744095	300	5 Yr-Future Mitigated	0.19	450	24	$26,000	$12,000	$38,000	$64,000
1000762081	300	5 Yr-Future Mitigated	0.24	375	69	$32,000	$12,000	$44,000	$74,000
1000834082	300	5 Yr-Future Mitigated	0.25	375	18	$16,000	$12,000	$28,000	$47,000
1000750700	300	5 Yr-Future Mitigated	0.27	375	46	$42,000	$12,000	$54,000	$91,000
1000736944	375	5 Yr-Future Mitigated	0.33	525	52	$62,000	$30,000	$92,000	$155,000
1000816821	450	5 Yr-Future Mitigated	0.42	525	79	$47,000	$30,000	$77,000	$129,000
1000816818	450	5 Yr-Future Mitigated	0.40	525	45	$54,000	$30,000	$84,000	$141,000
1000736905	525	5 Yr-Future Mitigated	0.70	600	50	$72,000	$30,000	$102,000	$171,000
1000765879	450	5 Yr-Future Mitigated	0.69	675	59	$92,000	$30,000	$122,000	$205,000
1000736939	450	5 Yr-Future Mitigated	0.72	675	36	$56,000	$30,000	$86,000	$144,000
1000816891	525	5 Yr-Future Mitigated	0.60	600	77	$56,000	$30,000	$86,000	$144,000
1000750757	600	5 Yr-Future Mitigated	0.82	675	101	$79,000	$30,000	$109,000	$183,000
1000751064	600	5 Yr-Future Mitigated	0.80	900	92	$99,000	$30,000	$129,000	$217,000
1000751066	600	5 Yr-Future Mitigated	0.83	750	11	$18,000	$30,000	$48,000	$81,000
1000816925	600	5 Yr-Future Mitigated	0.93	675	99	$77,000	$30,000	$107,000	$180,000
1000751077	600	5 Yr-Future Mitigated	1.67	900	33	$70,000	$30,000	$100,000	$168,000
1000751076	600	5 Yr-Future Mitigated	1.68	900	26	$56,000	$30,000	$86,000	$144,000
							Priority 5 Subtotal		**$3,532,000**

1. Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
2. These cost estimates are based on City of Surrey's previous project experience. Actual costs may vary depending on unforeseen project design requirements, construction and economic market conditions, local interest in the project(s) and currency fluctuations. These cost estimates must not be construed as guarantee that the projects can be delivered for the estimated price.

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Table H-7: Fleetwood Creek Diversion Cost Estimate

Location	Upgrade Type	5-Year Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Upgrade Material	Storm Pipe Cost	Manhole Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
80 Ave from 158 to 160 St	Erosion Mitigation	2.15	1200	406	CP	$731,000	$45,000	$776,000	$1,304,000
160 St from 80 Ave to 160 St	Erosion Mitigation	4.93	1200	969	CP	$1,744,000	$60,000	$1,804,000	$3,031,000
160 St from 160 St to Fleetwood Pump Station	Erosion Mitigation	4.93	1500	969	CP	$2,558,000	$60,000	$2,618,000	$4,398,000
								Fleetwood Diversion Subtotal	**$8,733,000**

1. Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
2. These cost estimates are based on City of Surrey's previous project experience. Actual costs may vary depending on unforeseen project design requirements, construction and economic market conditions, local interest in the project(s) and currency fluctuations. These cost estimates must not be construed as guarantee that the projects can be delivered for the estimated price.
3. Creek baseflows were not considered in sizing. Outlets to Fleetwood Creek should be designed to maintain environmental baseflows.

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Table H-8: Completion of 162 St. Creek Diversion Cost Estimate

Existing Conduit ID	Existing Size (mm)	Upgrade Type	5-Year Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Upgrade Material	Storm Pipe Cost	Manhole Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
1001169030	1050	Erosion Mitigation	0.61	1200	11	CP	$20,000	$30,000	$50,000	$84,000
1000852024	1050	Erosion Mitigation	0.61	1200	27	CP	$48,000	$15,000	$63,000	$106,000
1000852020	1050	Erosion Mitigation	0.61	1200	89	CP	$160,000	$15,000	$175,000	$294,000
1000852018	300	Erosion Mitigation	0.61	1200	54	CP	$97,000	$15,000	$112,000	$188,000
-	-	Erosion Mitigation	0.61	1200	94	CP	$169,000	$15,000	$184,000	$309,000
-	-	Erosion Mitigation	0.61	1200	162	CP	$292,000	$30,000	$322,000	$541,000
-	-	Erosion Mitigation	0.61	1200	230	CP	$414,000	$30,000	$444,000	$746,000
-	-	Erosion Mitigation	0.61	1200	80	CP	$144,000	$15,000	$159,000	$267,000
								162 St. Creek Diversion Subtotal		**$2,535,000**

1. Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
2. These cost estimates are based on City of Surrey's previous project experience. Actual costs may vary depending on unforeseen project design requirements, construction and economic market conditions, local interest in the project(s) and currency fluctuations. These cost estimates must not be construed as guarantee that the projects can be delivered for the estimated price.

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Table H-9: Replacement of twin culverts on 162 St. Creek for fish passage

Existing Conduit ID	Existing Size (mm)	Upgrade Type	100-Year Future Mitigated Peak Flow (m^3/s)	Upgrade Size (mm)	Length (m)	Upgrade Material	Materials and Delivery	Installation	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. taxes)[1]
1000736870 and 1000851965	2 @ 1200	Fish Passage	2.56	2400W X 2100H Box w/ Baffles	35	CP	$480,000	$990,000	$1,470,000	$2,470,000
								162 St. Creek Culvert Subtotal		**$2,470,000**

1. Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
2. Cost estimate includes replacement of the 1200 mm diam. sewer line crossing above the culvert and required bypass pumping.
3. These cost estimates are based on City of Surrey's previous project experience. Actual costs may vary depending on unforeseen project design requirements, construction and economic market conditions, local interest in the project(s) and currency fluctuations. These cost estimates must not be construed as guarantee that the projects can be delivered for the estimated price.

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main
- Creek
- Ditch

Drainage Improvement Projects

Flood Management Upgrades

- (Priority 2) Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4) Fail Existing - 5 Year - Surcharge >15 min and .3 m
- (Priority 5) Fail Future Mitigated

Erosion Management

- Proposed Diversion Projects

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-1

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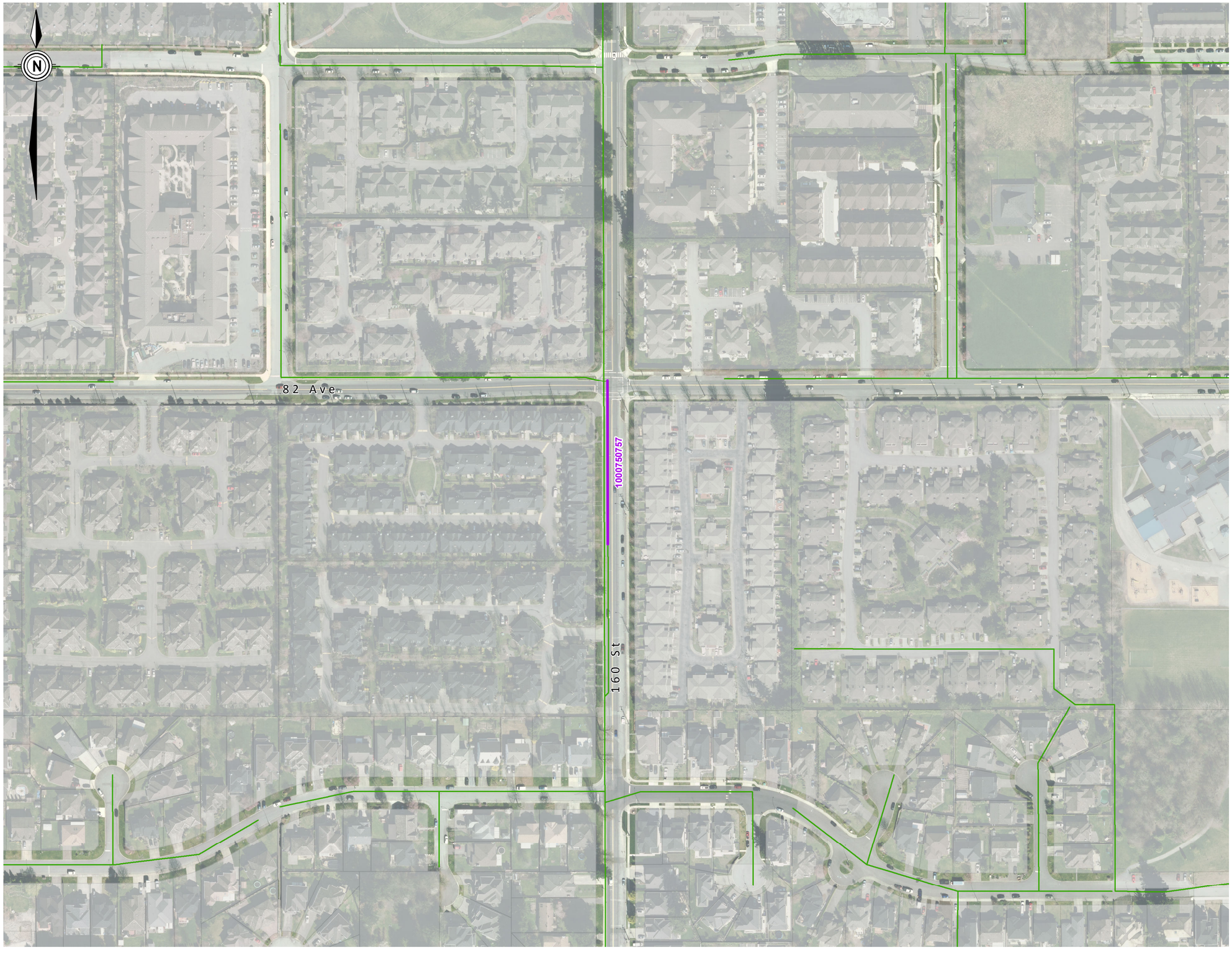

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main
- Creek
- Ditch

Drainage Improvement Projects

Flood Management Upgrades

- (Priority 2) Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4) Fail Existing - 5 Year - Surcharge >15 min and .3 m
- (Priority 5) Fail Future Mitigated

Erosion Management

- Proposed Diversion Projects

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-2

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City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main
- Creek
- Ditch

Drainage Improvement Projects

Flood Management Upgrades

- (Priority 2) Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4) Fail Existing - 5 Year - Surcharge >15 min and .3 m
- (Priority 5) Fail Future Mitigated

Erosion Management

- Proposed Diversion Projects

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-3

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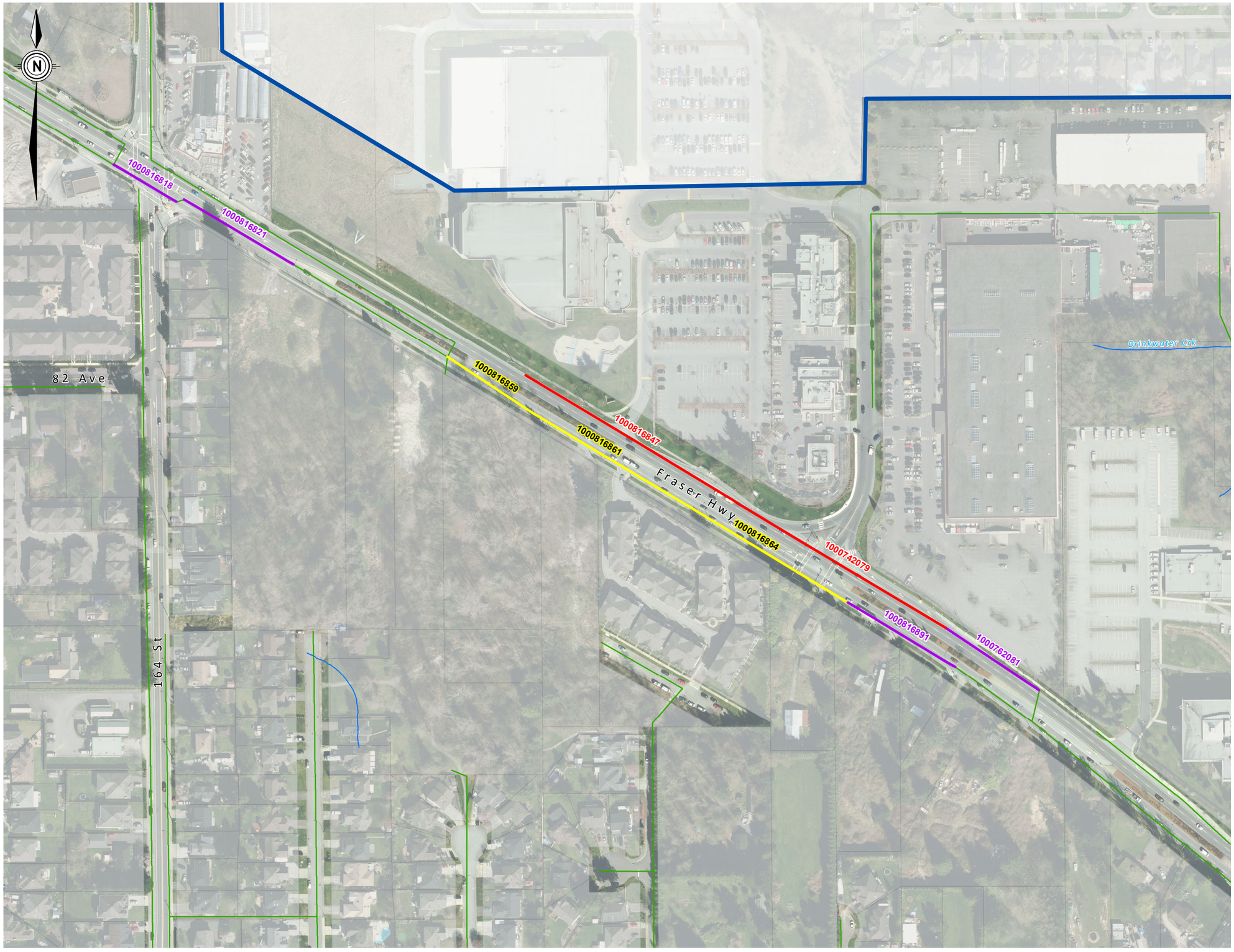

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main
- Creek
- Ditch

Drainage Improvement Projects

Flood Management Upgrades

- (Priority 2) Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4) Fail Existing - 5 Year - Surcharge >15 min and .3 m
- (Priority 5) Fail Future Mitigated

Erosion Management

- Proposed Diversion Projects

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-4

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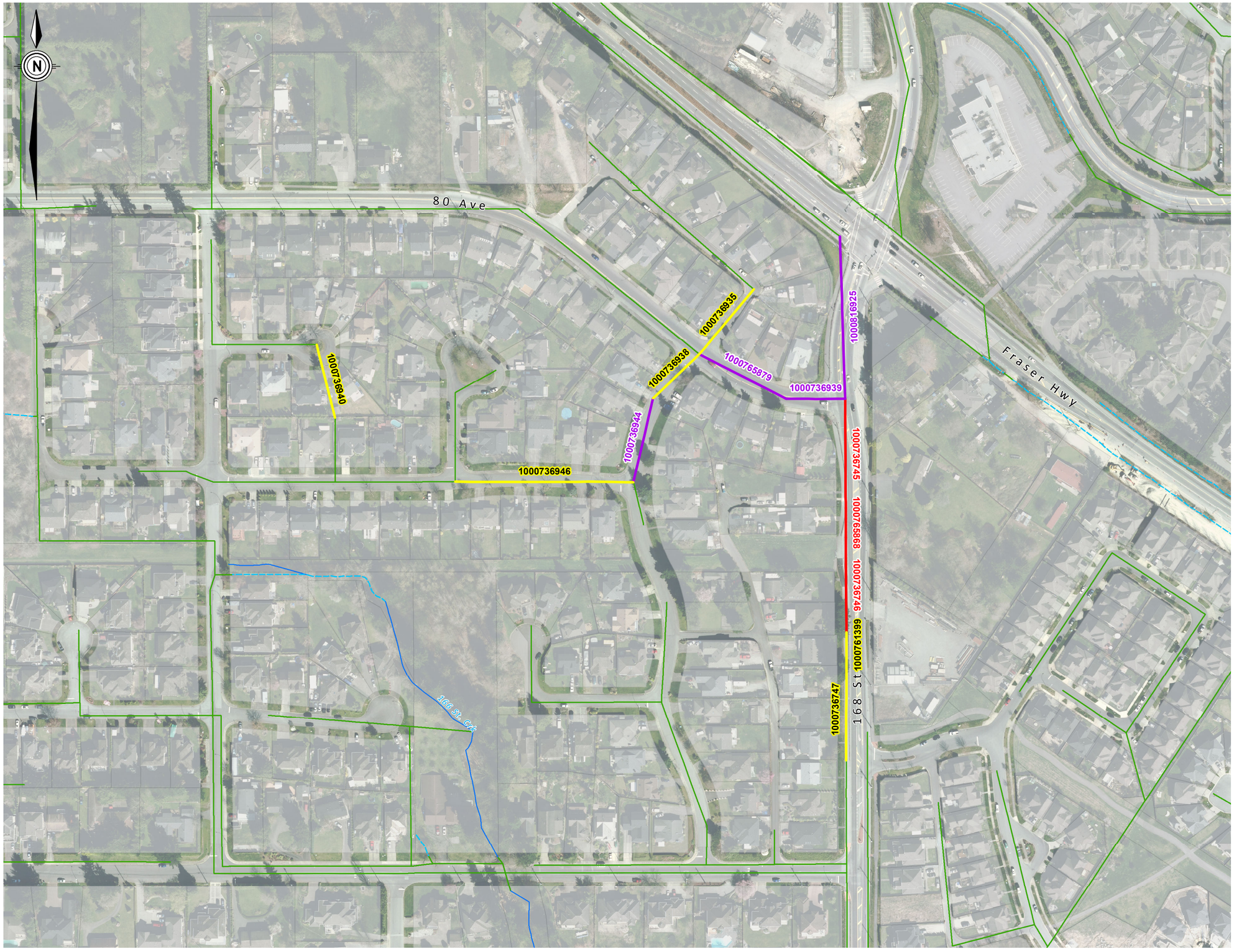

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main
- Creek
- Ditch

Drainage Improvement Projects

Flood Management Upgrades

- (Priority 2) Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4) Fail Existing - 5 Year - Surcharge >15 min and .3 m
- (Priority 5) Fail Future Mitigated

Erosion Management

- Proposed Diversion Projects

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-5

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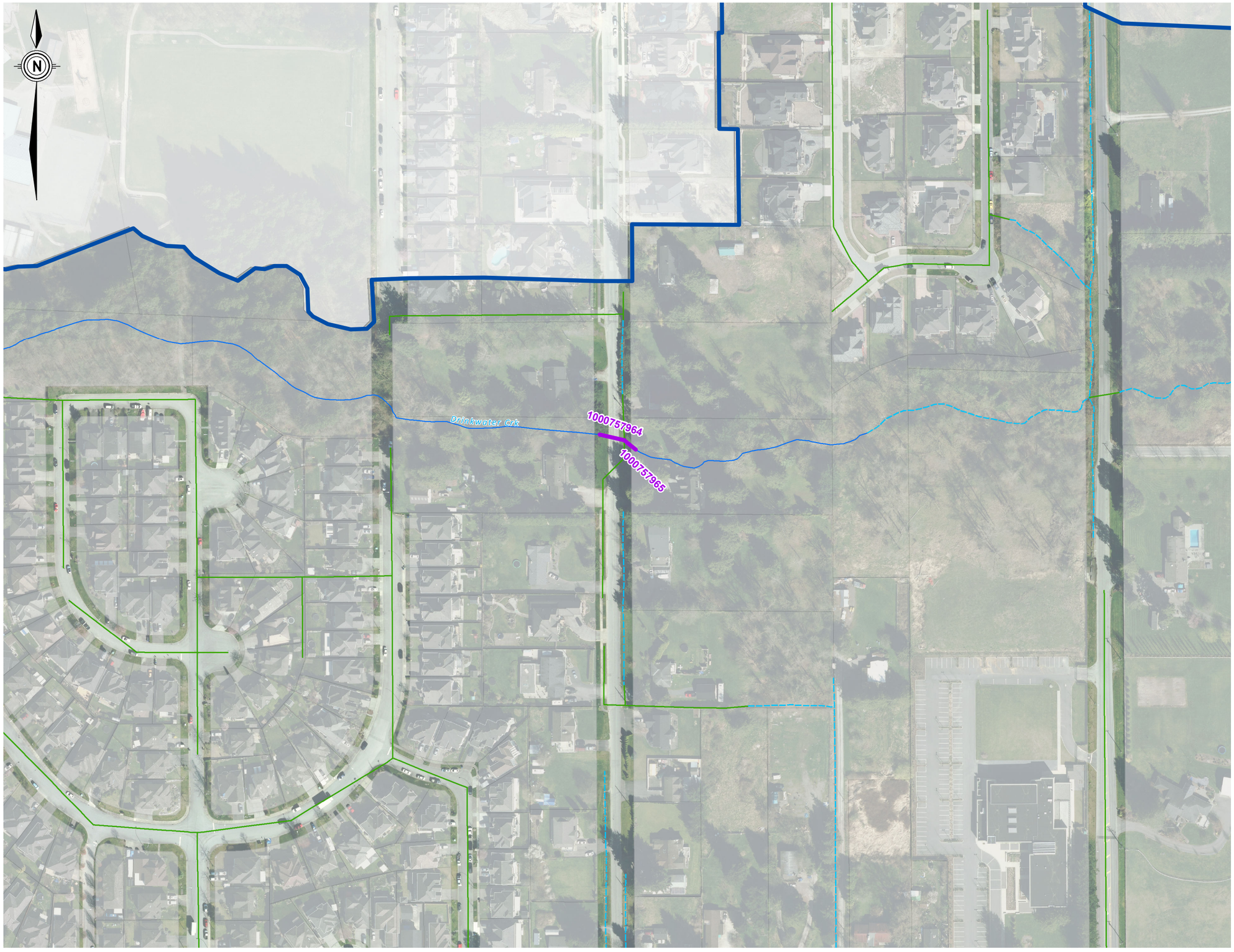

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

- Study Area
- Storm Main
- Creek
- Ditch

Drainage Improvement Projects

Flood Management Upgrades

- (Priority 2) Fail Existing - 5 Year - Flooding on Surface, 2+ Diameter Upgrade Required
- (Priority 4) Fail Existing - 5 Year - Surcharge >15 min and .3 m
- (Priority 5) Fail Future Mitigated

Erosion Management

- Proposed Diversion Projects

Reference: 2013 Orthophotoand GIS background data from the City of Surrey open Data Catalogue.

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-6

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City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

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Drainage Improvement Projects

Flood Management Upgrades

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-7

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Author: SScott

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

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Drainage Improvement Projects

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-8

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City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

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Drainage Improvement Projects

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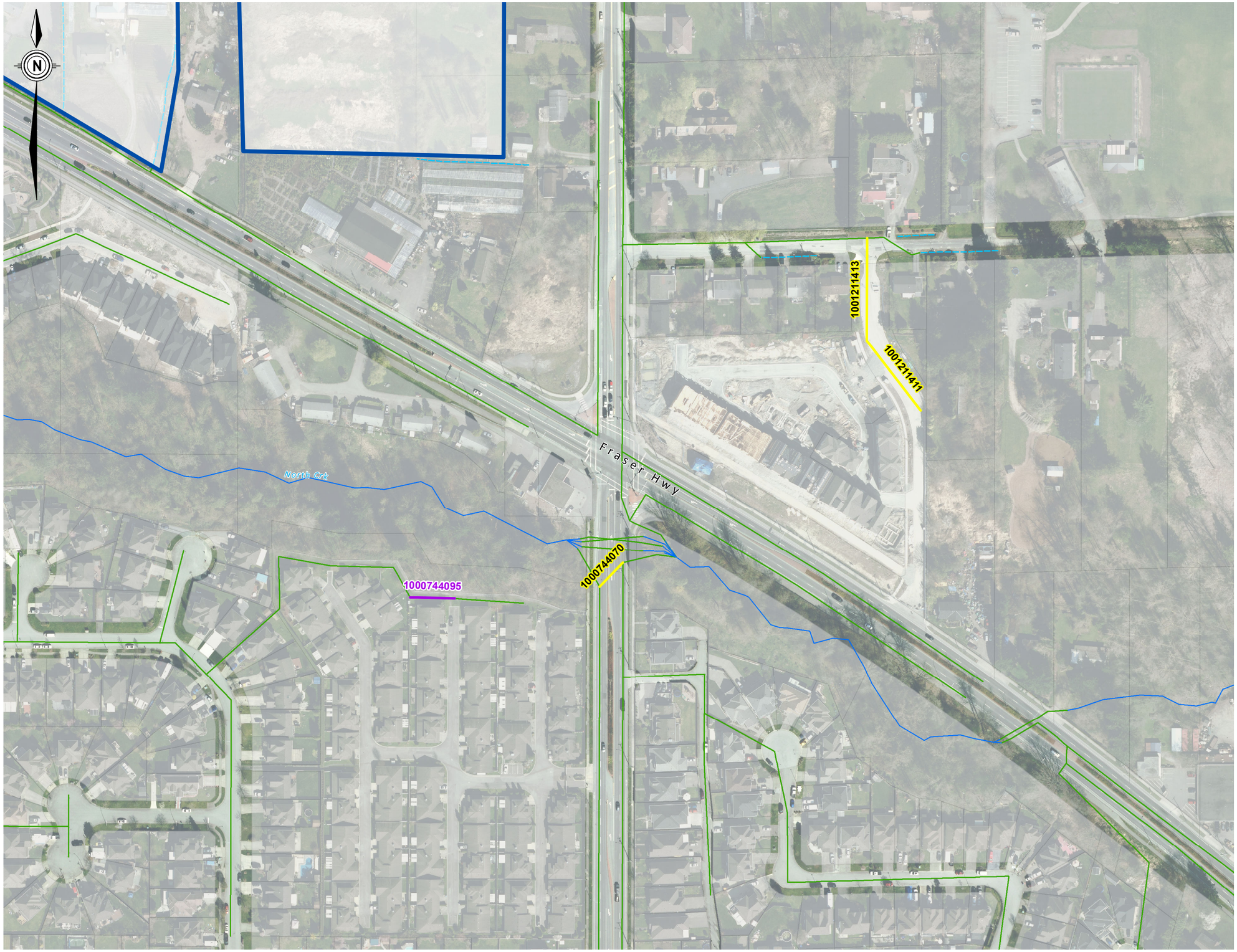
Erosion Management

- Proposed Diversion Projects



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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-9

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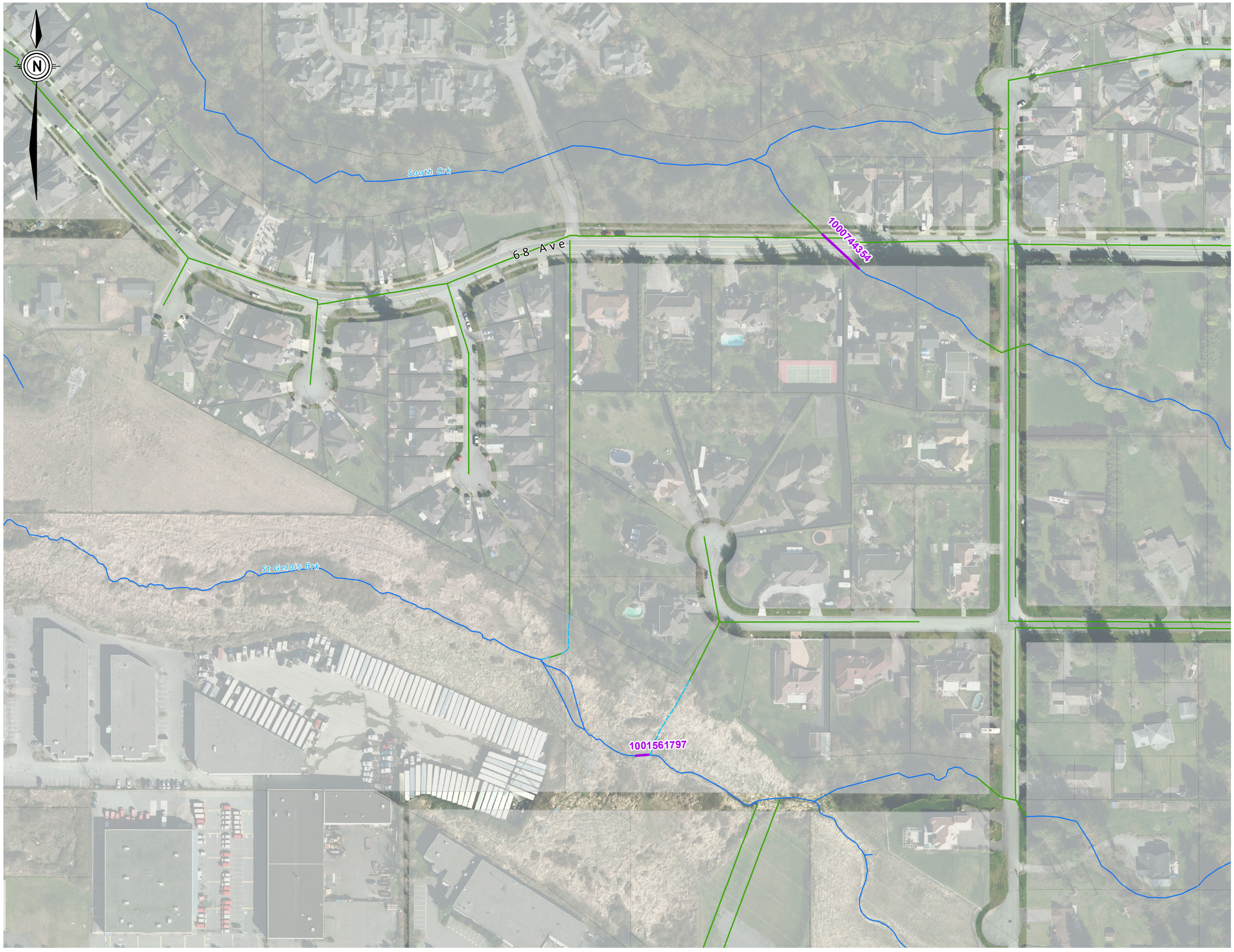

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

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Drainage Improvement Projects

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Erosion Management

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-10

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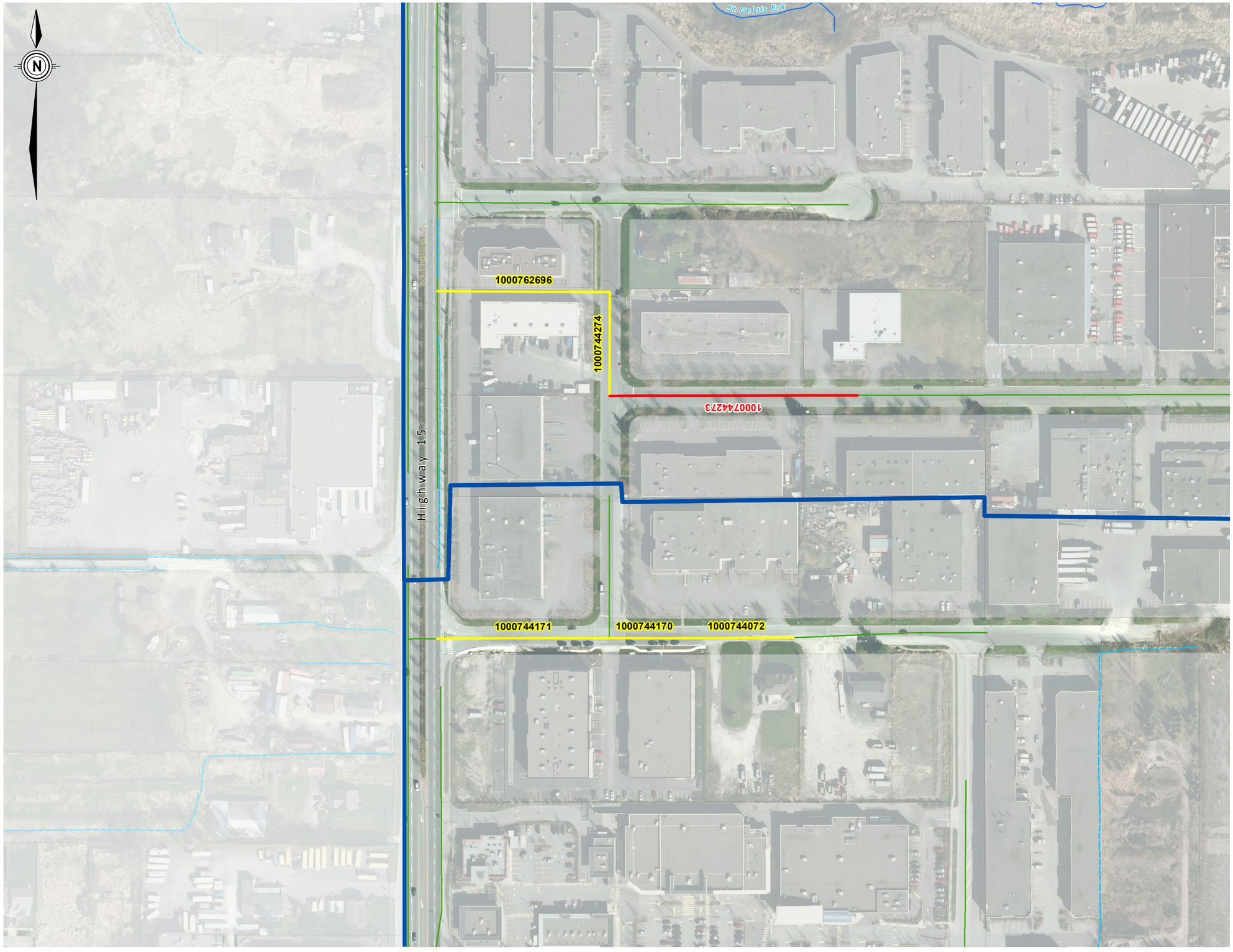
Author: SScott



City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

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Drainage Improvement Projects

Flood Management Upgrades

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Erosion Management

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-11

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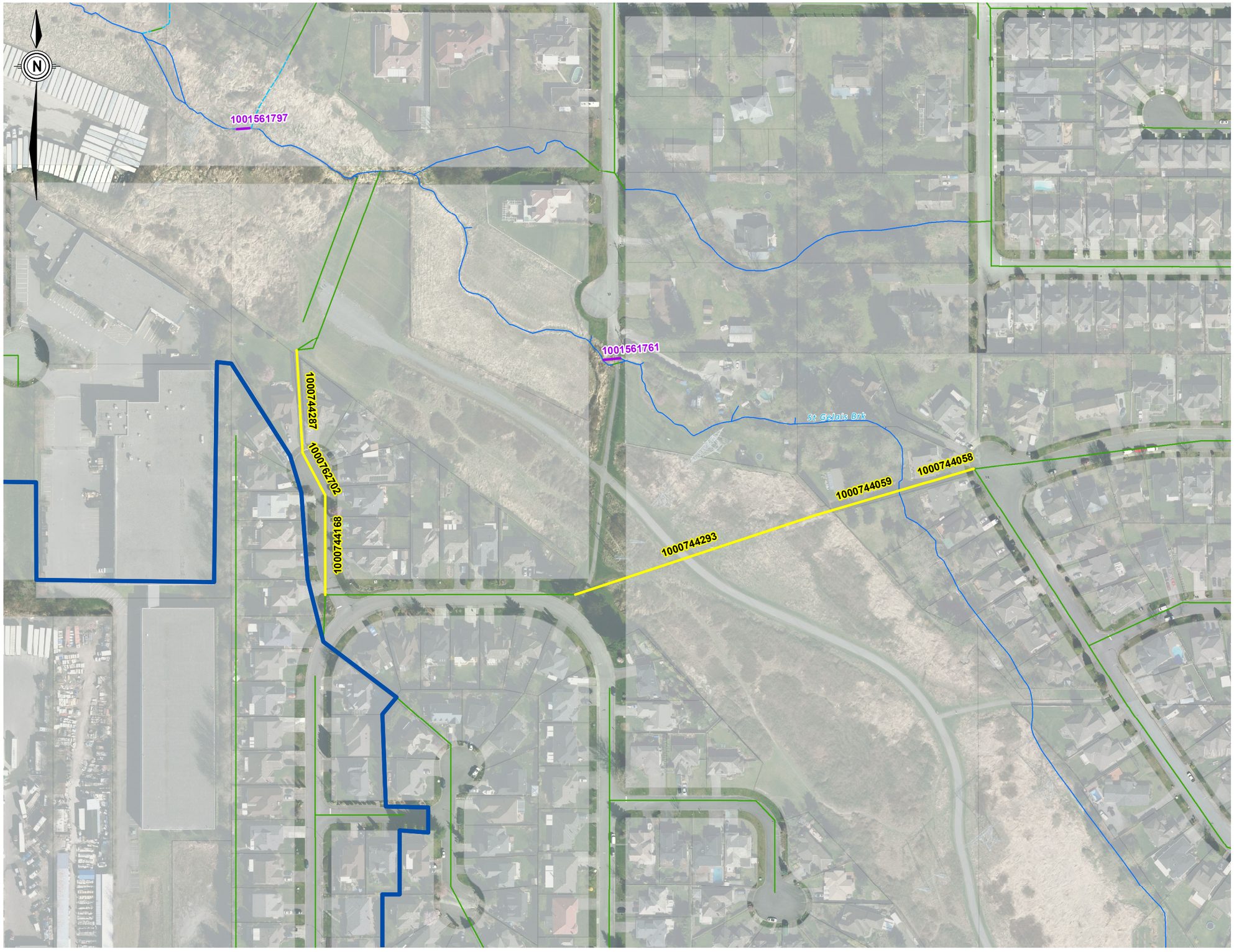

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

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Drainage Improvement Projects

Flood Management Upgrades

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-12

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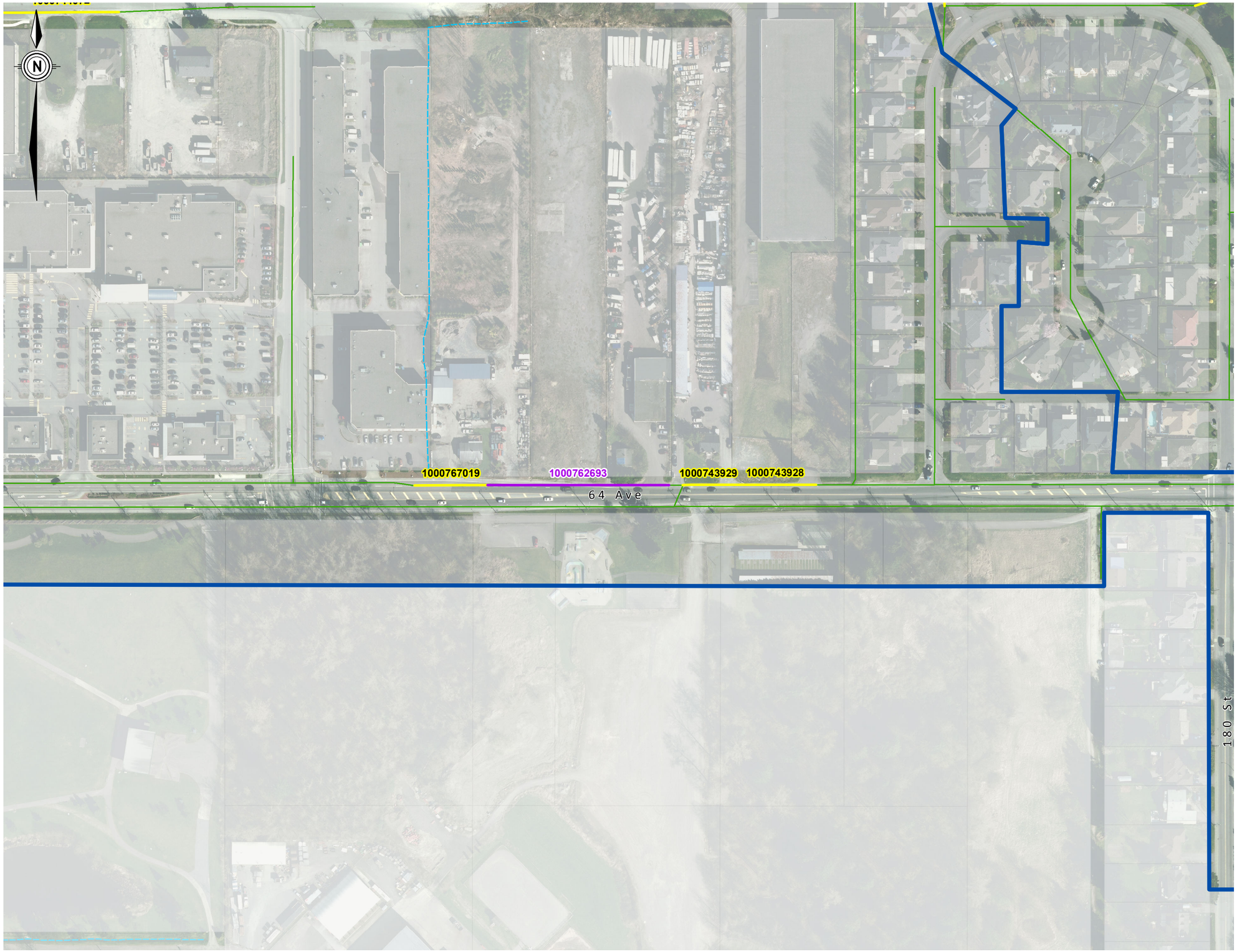

City of Surrey
Fleetwood Greenway North Creek
Integrated Stormwater Management Plan

Legend

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Drainage Improvement Projects

Flood Management Upgrades

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Project No.	Date
471-288	June 2016

Flood and Erosion Management Projects

Figure H-13

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Appendix I – Design and Maintenance Checklists

Contents

I Design and Maintenance Checklists 1
1.1 Absorbent Landscaping Assessment Checklist 1
1.2 Bioretention Area Design Assessment Checklist 2
1.3 Bioswale Design Assessment Checklist 3
1.4 Design Checklist 4
1.5 Maintenance Assessment Checklist 6

Absorbent Landscaping Assessment Checklist

CITY OF SURREY

File No.: _____

Project: _____ **Reviewer:** _____

Site: _____ **Date/Time:** _____

Swale Location					
Hydraulics	Minor design flow (m^3/s):		Major design flow (m^3/s):		
Area	Catchment area (ha):		Absorbent Landscape area (ha):		
Design sizing				**Y**	**N**
I/P Ratio determined based on curves to achieve treatment and volume reduction?					
Absorbent growing media depth between 150 – 450 mm?					
Inlet Zone/Hydraulics				**Y**	**N**
Overall flow conveyance system, including overflow, sufficient for minor system design flow?					
Slope of absorbent lanscaping >1% and 2%?					
Mannings '*n*' used appropriate for proposed vegetation and flow depth?					
Designed high flow route over or bypassing absorbent landscaping for major design flow?					
Inlet flows appropriately distributed?					
Energy dissipation provided at inlets/ concentrated flows?					
Velocities will not cause scour?					
Drop/set down of 50 to 100 mm below kerb invert incorporated?					
Safety and Maintenance				**Y**	**N**
Maintenance access provided as required (mowing or other)?					
Vegetation				**Y**	**N**
Plant species selected can tolerate periodic inundation and drought and design velocities?					
Plant species selected integrate with surrounding landscape design?					
Standard soil specification or custom soil by Professional Agrologist?					

Bioretention Area Design Assessment Checklist

CITY OF SURREY

File No.: _____

Project: _____ **Reviewer:** _____

Site: _____ **Date/Time:** _____

Bioretention Area Location					
Hydraulics	Minor design flow (m^3/s):		Major design flow (m^3/s):		
Area	Catchment area (ha):		Bioretention area (ha):		
Design Sizing				**Y**	**N**
Base area sized for Maximum I/P ratio (longevity) and water quality treatment?					
Base area sized for Volume Reduction?					
Footprint includes required base area and at least minimum side slopes?					
Inlet Zone/Hydraulics				**Y**	**N**
Overall flow conveyance system, including overflow, sufficient for minor system design flow?					
Designed high flow route through or bypassing bioretention for major design flow?					
Maximum upstream flood conveyance width does not impact on traffic amenity?					
Velocities at inlets and within bioretention system will not cause scour?					
Drop/setdown of 50-100 mm provided for flat inlet/entry areas?					
Erosion protection for all point/concentrated flows?					
Collection System				**Y**	**N**
Perforated underdrain capacity > infiltration capacity of filter media?					
Direct connection to storm sewer at least minimum slope and within required length?					
Granular filter layer or geotextile barrier provided to prevent clogging of rock drainage layer?					
Underdrain at top of drain rock for infiltration or bottom of rock for non-infiltration facility?					
Trench dams included for utility crossings?					
Basin				**Y**	**N**
Maximum ponding depth and velocity will not create safety hazards?					
Base of bioretention flat or sloped less than 1%?					
Base area accessible for appropriate maintenance (4:1 side slopes if mowing)?					
Groundwater > 0.6 m below rock drainage layer?					
Vegetation				**Y**	**N**
Plant species selected can tolerate periodic inundation and drought?					
Plant species selected integrate with surrounding landscape design?					
Standard soil specification or custom soil by Professional Agrologist?					

Bioswale Design Assessment Checklist

CITY OF SURREY

File No.: _____

Project: _____ **Reviewer:** _____

Site: _____ **Date/Time:** _____

Swale Location					
Hydraulics	Minor design flow (m^3/s):		Major design flow (m^3/s):		
Area	Catchment area (ha):		Bioretention area (m^2):		
Design Sizing				**Y**	**N**
Base area sized for Maximum I/P ratio (longevity) and water quality treatment?					
Base area sized for Volume Reduction?					
Footprint includes required base area and at least minimum side slopes?					
Inlet Zone/Hydraulics				**Y**	**N**
Overall flow conveyance system, including overflow, sufficient for minor system design flow?					
Longitudinal slope of swale invert >1% and 24%?					
Mannings '*n*' used appropriate for proposed vegetation and flow depth?					
Designed high flow route through or bypassing bioswale for major design flow?					
Maximum upstream flood conveyance width does not impact on traffic amenity?					
Inlet flows appropriately distributed?					
Energy dissipation provided at inlets/ concentrated flows?					
Velocities within bioretention cells will not cause scour?					
Drop/set down of 50 to 100 mm below curb invert incorporated?					
Collection System				**Y**	**N**
Perforated underdrain capacity > infiltration capacity of filter media?					
Direct connection to storm sewer at least minimum slope and within required length?					
Granular filter layer or geotextile barrier provided to prevent clogging of rock drainage layer?					
Underdrain at top of drain rock for infiltration or bottom of rock for non-infiltration facility?					
Trench dams included for utility crossings?					
Safety and Maintenance				**Y**	**N**
Maximum ponding depth and velocity will not create safety hazards?					
Groundwater > 0.6 m below rock drainage layer?					
Maintenance access provided to invert of conveyance channel?					
Vegetation				**Y**	**N**
Plant species selected can tolerate periodic inundation and drought and design velocities?					
Plant species selected integrate with surrounding landscape design?					
Standard soil specification or custom soil by Professional Agrologist?					

Design Review Checklist

CITY OF SURREY

File No.: _____

Project: _____ **Inspector:** _____

Site: _____ **Date/Time:** _____

This is a: ☐ Field Visit ☐ Design Review

1. Native Soil Infiltration Rates

Water does infiltrate into rock, clay, and glacial till…just slowly.
Source Controls are focusing on the small storms, not the large infrequent storms
An infiltration test on the native soils is a good starting test, does the project have:

- ☐ Native soils infiltration testing
- ☐ Surface hydraulic conductivity
- ☐ Subsurface hydraulic conductivity

2. Rainwater Design Criteria (check one)

- ☐ Rainfall Capture Depth 32 mm
- ☐ Water Quality- Remove 80 % TSS

Calculation Method (check one)

- ☐ Metro Vancouver Stormwater Source Control Design Guidelines 2012 Manual Calculations
- ☐ Stormwater Models (i.e. XP-SWMM, PC SWMM, etc.)
- ☐ Other Manual Methods (describe)

- ☐ Other Municipal Criteria (describe) _____
- ☐ Design Rainfall Capture Depth (mm) _____
- ☐ Inflow Runoff Volume:
  Tributary Area x Design Rainfall Capture Depth (cu.m) _____
- ☐ Capture Volume (sum of 6 values below): _____
  - ☐ 24 hour evaporation x soil surface area: _____
  - ☐ Volume of source control soil x (field capacity – wilting point): _____
  - ☐ Volume of lawn soil x (field capacity – wilting point): _____
  - ☐ Volume of rock pit x percentage pore space: _____
  - ☐ 24 hour subsurface exfiltration x lawn area: _____
  - ☐ 24 hour subsurface exfiltration x rock pit bottom area: _____

3. Adequate water quality treatment

☐ Yes ☐ No

4. Overflow Drain Heights and Soil Selection

Ponding in surface source controls should be allowed for storm events when rainfall intensity exceeds soil infiltration capacity for the inflow up to the design capture volume.

- ☐ Soil mix infiltration rate:
- ☐ Above Ground Ponding Volume:
  Is ponding volume sufficient? ☐ Yes ☐ No
  Underdrain system required if low permability soils: ☐ Required ☐ Not Required

5. Deciduous Trees

- ☐ Minimize deciduous trees above rain gardens
  Leaves can reduce infiltration rates and interfere with growth of vegetation needed to regenerate soil surface.
  ☐ None/few (preferred) ☐ Some (okay) ☐ Many (not desirable)

6. Infiltrated Water

Where's the infiltrated water going? Will it lift asphalt down slope? Will it end up at a foundation wall? Use trench dams to contain water.

☐ Trench dams ☐ Underdrain system ☐ Overflow system to storm sewers

☐ Major flood route

7. Rock Trench/Pit Depths

☐ Caution building rock trenches deeper than 0.8 m in low permeable soils

☐ Surrounding Native Soil Inundated with Upslope Interflow

☐ Risk of upslope interflow? _____

☐ Rock trench depth: _____ (0.8 m or less preferred)

8. Construction Phasing

Contractor Construction Plan

☐ Meets the Metro Vancouver Stormwater Source Control Design Guidelines 2012 Construction Staging Considerations

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Maintenance Assessment Checklist

CITY OF SURREY

File No.: _____

Project: _____ **Inspector:** _____

Site: _____ **Date/Time:** _____

This is a: ☐ Field Visit ☐ Design Review

1. Weed Control

- If using an amended soil mix developed on site:
  - Germination test to check for viable unwanted seed: ☐ Yes ☐ No
  - Result? _____
  - If weed seeds are a problem, treat with: ☐ Composting ☐ Mulch
  - Note: mulch should be ground wood not bark, chips, or sawdust
  - Mulch depth: ☐ 50 to 75 mm layer (preferred) ☐ Other:_____ mm

2. Binding Off Of Sand Layer

- Sand layer between drain rock and growing medium? ☐ Yes ☐ No
  - If yes, was sand layer exposed to weather (wetting and drying) before placement of growing medium? ☐ Yes ☐ No
  - If yes, sand surface may be damaged – repair required before placement of growing medium? ☐ Yes ☐ No

3. Builder Management

- Education provided on building site management and the impact their activities can have on rain garden areas and other stormwater measures? ☐ Yes ☐ No
- Builders and trades have adequate access to lots, stockpiling area, etc. ☐ Yes ☐ No
- No-go areas clearly marked with signage and orange fence around rain garden depression area? ☐ Yes ☐ No
- Roof gutters not installed before site has been landscaped and rain gardens planted? ☐ Yes ☐ No
- Building is fully completed prior to removal of sacrificial soil and poly and planting of rain garden ☐ Yes ☐ No
- Soils on the lot tilled and scarified prior to placing the finishing layer of growing medium? ☐ Yes ☐ No

9. Maintenance Responsibility

- Two to three year warranty period required when developer (public areas) and builder (on-lot) will be responsible for maintenance of rain gardens? ☐ Yes ☐ No
- Plan in place for watering (automatic or manual) until plantings established? ☐ Yes ☐ No
- Plant and soil maintenance and weed control planned for twice annually, spring and fall? ☐ Yes ☐ No

  Which of the following options are being used for ongoing maintenance?
  ☐ Restrictive covenant.
  ☐ City staff responsibility.
  ☐ Local area improvement agreement amongst homeowners.
  ☐ Other? Describe: _____

9. Road Maintenance Issues

- Snow storage areas designated? ☐Yes ☐No
- Street sweeping program in place? ☐Yes ☐No
- Regular inspections for sheet flow impediments or concentrated flow damage? ☐Yes ☐No
- Expected lifespan for topsoil and planting replacement (years)? _____

10. Performance Monitoring and Warranty Period

- Will post-construction continuous flow, rainfall and water quality monitoring be required? (This is the best way of measuring, but can be very expensive.) ☐Yes ☐No
- Observations that indicate poor performance (should not be observed):
- Mud forming in rain garden? ☐Yes ☐No
- Standing water after a 24 hour storm? ☐Yes ☐No
- Vegetation wall forming at the interface with the flat panel curb? ☐Yes ☐No
- Excessive sediment accumulation (above planned)? ☐Yes ☐No
- Concentrated flows or flow damage? ☐Yes ☐No
- Clogged or submerged overflow? ☐Yes ☐No

Appendix J – Unit Release Rates

FIGURES

Figure J - 1: 2-year 24-hour 2
Figure J - 2: 5-year 24-hour 3
Figure J - 3: 6-month 24-hour 4

Appendix J – Unit Release Rates

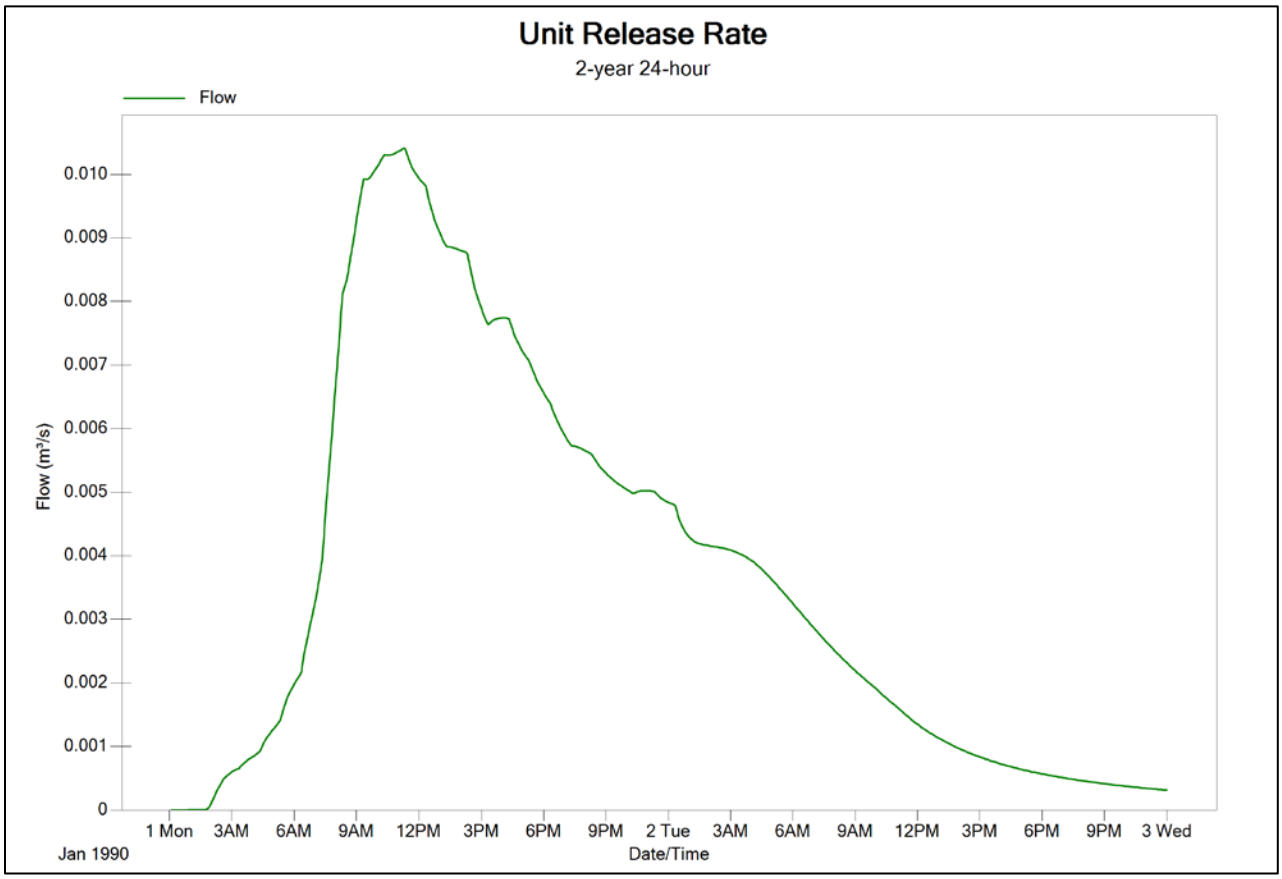

Figure J - 1: 2-year 24-hour

Appendix J – Unit Release Rates

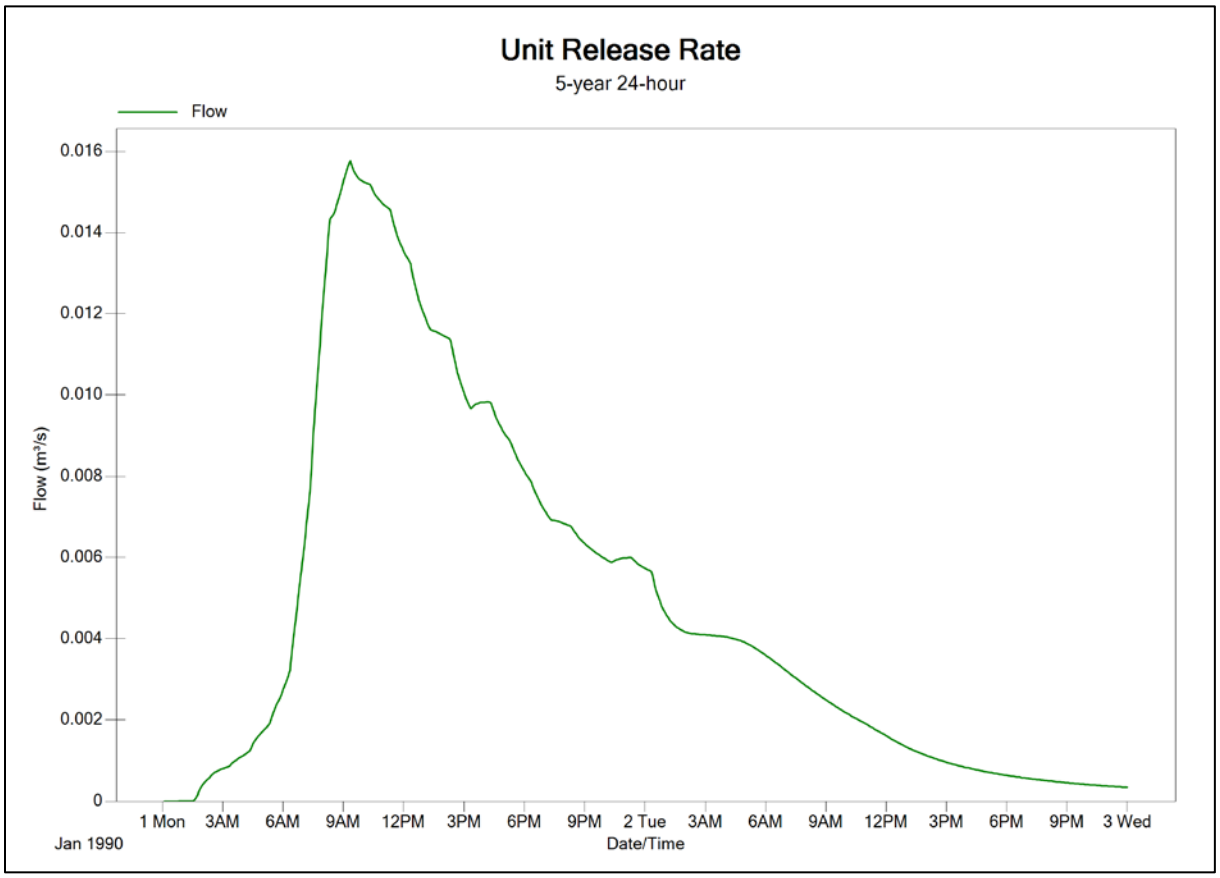

Figure J - 2: 5-year 24-hour

Appendix J – Unit Release Rates

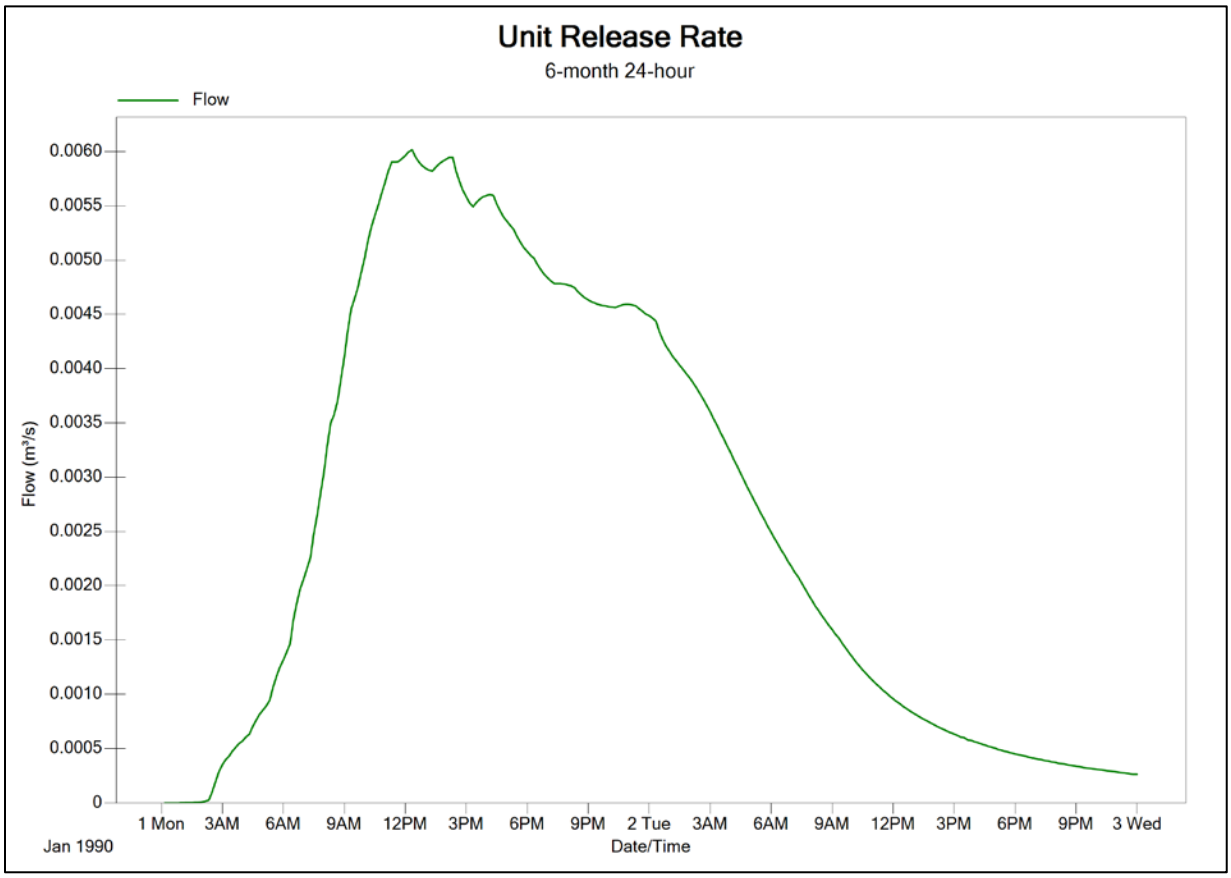

Figure J - 3: 6-month 24-hour