



2026

NORTH DELTA RAVINES ISMP





Final Report North Delta Ravines ISMP

October 2014
KWL File No. 323.073

Submitted by:





Contents

Executive Summary	i
1. Introduction.....	1-1
1.1 Goals and Objectives.....	1-1
1.2 ISMP Key Issues.....	1-2
1.3 Scope of Assignment.....	1-4
1.4 Stakeholder Consultation Program.....	1-4
1.5 Stormwater and Drainage Criteria.....	1-5
2. North Delta Ravines Area Watershed.....	2-1
2.1 Background Material.....	2-1
2.2 Drainage Inventory.....	2-1
2.3 Land Use Assessment.....	2-3
2.4 Recreation and Education Assessment.....	2-4
2.5 Environmental Inventory and Assessment.....	2-6
2.6 Geotechnical Assessment.....	2-8
3. Watershed Analysis.....	3-1
3.1 Hydrologic/Hydraulic Models.....	3-1
3.2 Results of Hydrologic/Hydraulic Modelling.....	3-1
3.3 Watershed Health Tracking System.....	3-6
4. Mitigation Alternatives.....	4-1
4.1 Introduction.....	4-1
4.2 Required Hydrotechnical Upgrades.....	4-1
4.3 Mitigate Impacts of Future Development.....	4-1
4.4 Improve Watershed Health.....	4-2
4.5 Evaluation of Potential Projects.....	4-4
5. Proposed North Delta Ravines ISMP.....	5-1
5.1 Introduction.....	5-1
5.2 Required Hydrotechnical Improvements.....	5-1
5.3 Water Quality Treatment.....	5-4
5.4 Volumetric Reduction to Mitigate Frequently Occurring Flows and Sustain Baseflows.....	5-5
5.5 Flow Rate Control to Meet DFO Guidelines, and Delta and Surrey Bylaws.....	5-6
5.6 Riparian Protection.....	5-6
5.7 Restoration and Enhancement for Fish.....	5-7
5.8 Public Access and Education.....	5-7
5.9 Further Studies, Recommendations, and Monitoring Programs.....	5-8
5.10 Stakeholder Feedback.....	5-10
5.11 Capital Cost Estimates and Funding.....	5-12
6. Summary and Recommendations.....	6-1
6.1 Summary.....	6-1
6.2 Recommendations.....	6-4
7. Report Submission.....	7-1



Figures (At End of Sections)

- Figure 1-1: 2010 Air Photo of Study Area
- Figure 2-1: Culvert, Outfall and Obstruction Inventory
- Figure 2-2: Erosion Inventory
- Figure 2-3: Existing Land Use
- Figure 2-4: Future Land Use (OCP)
- Figure 2-5: Existing Riparian Corridors and Representative Reaches
- Figure 2-6: Sampling Site Locations
- Figure 2-7: Soils Map
- Figure 3-1: Minor Storm Sewer Assessment
- Figure 3-2: Major Storm Sewer Assessment
- Figure 3-3: Watershed Health Tracking System for Existing and Future Conditions
- Figure 4-1: Proposed Hydrotechnical Upgrades
- Figure 4-2: Watershed Health Improvement Alternatives
- Figure 4-3: WHTS for Improvement Alternatives
- Figure 5-1: Proposed Short Term Projects
- Figure 5-2: Proposed Medium Term Projects
- Figure 5-3: Proposed Long Term Projects

Tables

Table 1-1: Engineering Work Program	1-4
Table 1-2: Summary of Stormwater and Environmental Criteria	1-5
Table 2-1: Summary of Background Material	2-1
Table 2-2: Summary of Observed Severe Erosion Sites	2-3
Table 2-3: Summary of Observed Major Channel Obstructions	2-3
Table 2-4: Existing Land Use	2-4
Table 2-5: Existing and Future Total Impervious Areas	2-4
Table 2-6: North Delta Ravine Recreation Potential Evaluation	2-11
Table 3-1: Flows at Strategic Locations for Existing Land Use	3-2
Table 3-2: Flows at Strategic Locations for Future Land Use	3-2
Table 3-3: Existing Land Use Unit Peak Flow Comparison	3-3
Table 3-4: Water Levels at Strategic Locations for Existing Land Use	3-3
Table 3-5: Water Levels at Strategic Locations for Future Land Use	3-4
Table 3-6: Measured and Predicted B-IBI Scores	3-6
Table 4-1: Issues and Improvement Alternatives	4-5
Table 5-1: ISMP Class D Capital Cost Estimate	5-2
Table 5-2: Medium Term Hydrotechnical Improvements	5-3
Table 5-3: Long Term Hydrotechnical Improvements	5-4
Table 5-4: North Delta Ravines Watershed Adaptive Management Indicators	5-9
Table 5-5: Watershed Improvement Options as Ranked by Stakeholders	5-10



Appendices

- Appendix A: Drainage Inventory
- Appendix B: Land Use
- Appendix C: Environmental Inventory and Assessment
- Appendix D: Geotechnical Report
- Appendix E: Modelling and Assessment
- Appendix F: Measures to Mitigate Environmental Hydrologic Impacts of Development
- Appendix G: Capital Cost Estimates



Executive Summary

The Corporation of Delta (Delta) initiated an Integrated Stormwater Management Plan (ISMP) for the North Delta Ravines area, generally bounded by 80 Avenue, Highway 91, Scott Road, and the Fraser River. This area includes a number of watersheds totaling approximately 802 ha in size. A small portion of the study area is within the City of Surrey.

The study area is largely urbanized with many steep sloped ravine areas. The study area includes Sunbury (Main) Creek, Nelson View Creek, McAdam Creek, Collings Creek, Norum Creek, Gunderson Creek, Knudson Creek, Kendale Creek, Shadow Brook Creek, Regal Drive Creek, Delta Creek, and Colliers Creek. The area drains generally south to north, via storm sewers and creeks that drain to the Fraser River

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

Key Issues in Watershed

Delta identified a number of key issues in North Delta Ravines area. The field investigation program expanded and confirmed the key issues. Table i summarizes the key issues that were addressed in the ISMP.

Table i: Summary of Key Issues

Key Issues
<ul style="list-style-type: none">• Effectiveness of existing hydraulic structures;• Projecting storm outfalls causing flow and erosion on side slopes;• Poor condition of some railway culverts;• Erosion in the creek channels;• Ravine instabilities and hazards;• Fish passage barriers; and• Limited fish habitat.

The Integrated Stormwater Management Plan for the North Delta Ravines Watershed

The North Delta Ravines ISMP strives to resolve the above issues through the following strategies:

- Culvert capacity assessment and upgrade program;
- Major and minor storm sewer system assessment and upgrade program;
- Erosion assessment and stabilization projects;
- Ravine stability assessment and proposed future detailed investigations;
- Fish habitat and passage improvements;
- Water quality monitoring program and improvements;
- Improve water quality from non-point sources through the medium and long term implementation of stormwater source controls; and
- Mitigate hydrologic impacts from future development through source controls and stormwater bylaws.



ISMP Performance Monitoring and Accountability of Plan

To measure and track the levels and changes in the health of a watershed, and to provide accountability to the ISMP, a suite of performance parameters has been developed that match the key issues identified above. Table ii lists the parameters or ‘indicators’ that should be measured and tracked over time.

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

Table ii: North Delta Ravines Watershed Adaptive Management Indicators

Performance Indicator		Method of Analysis	2012	2017
1.	Total Impervious Area (% of Watershed Area)	GIS Analysis of Aerial Photos and Assessment Data	48%	Small increase expected due to development
2.	Effective Impervious Area (% of Watershed Area)	Estimated from surface cover type and source controls implemented	Flow monitoring required to quantify	decrease when source controls implemented
3.	Riparian Forrest Integrity (% of Riparian Area)	GIS Analysis of Aerial Photos	68%	Same or Increase
4.	Watershed Forest Cover (% of Watershed Area)	GIS Analysis of Aerial Photos	13%	Same or Increase
5.	Benthic Invertebrates	B-IBI scores based on methods used in this study	mean = 18.0	18
6.	Fish Populations	SFPR environmental impact assessment	7 of 11 streams support cutthroat Trout Three support coho Salmon	Confirm Data
7.	Fish Passage Barriers	SFPR environmental impact assessment	Full Barriers 5+ Partial Barriers 10	Several culverts need to be re-assessed Progressive Removal of Non-natural Barriers
8.	Water Temperature (°C)	Field Measurement (during October)	Range: 9.9-14.1 Mean: 11.0	Same or Decrease
9.	Dissolved Oxygen (DO, mg/L)	Field Measurement (during October)	Range: 11.0-14.3 Mean: 12.8	Same or Increase
10.	Water pH	Field Measurement (during October)	Range: 7.05 – 8.08 Mean: 7.71	Same or Trend Toward Neutral
11.	Water Conductivity (µS)	Field Measurement (during October)	Range: 63 – 302 Mean: 192	Same or Decrease
12.	Turbidity (NTU)	Field Measurement (during October)	Range: 0.2-785.2 Mean: 51.0	Same or Decrease
13.	Water Quality Fecal Coliforms (MPN/100mL)	Field Measurement (during October)	Range: 57.2-108 Mean: 91.5	Same (< 200)
14.	Sediment Quality	Metals in sediment	See Section 2.4	Same or Decrease
15.	No. of Erosion Sites	Field Assessment and Designation as Low, Medium, or High Severity and Consequence	See Table 2-2	Same or Decrease



1. Introduction

The Corporation of Delta (Delta) initiated an Integrated Stormwater Management Plan (ISMP) for the North Delta Ravines area, generally bounded by 80 Avenue, Highway 91, Scott Road, and the Fraser River, includes a number of watersheds totaling approximately 802 ha in size. A small portion of the study area is within the City of Surrey. Drainage of the area is generally south to north, via storm sewers and creeks that drain to the Fraser River. The study area is shown in Figure 1-1.

The study area comprises several existing land uses, primarily residential. The North Delta Ravines area is not currently expected to see significant development in the future, as the area is already largely built-out, however densification and redevelopment may be likely.

This report fulfills the goals of the ISMP process by:

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

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

1.1 Goals and Objectives

The goal of the North Delta Ravines ISMP is to develop a comprehensive plan that will seek to improve the overall watershed system by minimizing the risk of flooding, preserving aquatic and riparian habitats, and developing effective and affordable watercourse improvements.

Delta has developed the following objectives for this study:

- Meet the Ministry of Environment's criteria for ISMP acceptance;
- Compose a future vision for the study area that marries the interests of Engineering, Planning, Environment and Recreation;
- Prepare a comprehensive inventory of the study area including confirmation of its boundaries;
- Identify any deficient drainage infrastructure to minimize risks to life and property damage by flooding;
- Quantify the overall health and natural features of the study area;
- Protect watercourses and aquatic life;
- Prevent pollution and maintain/improve water quality;
- Protect and enhance the environment, wildlife, and habitat corridors;
- Provide a sampling program outline in order to achieve baseline water quality and B-IBI values;



- Identify areas of existing and future residential, commercial, recreational, and agricultural land uses;
- Inform stakeholders of the issues and objectives of the ISMP;
- Develop a comprehensive and cost effective strategy for municipal capital improvements, potential projects for streamkeeper groups and improve community awareness of watershed issues; and
- Develop a cost effective implementation plan.

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

1.2 ISMP Key Issues

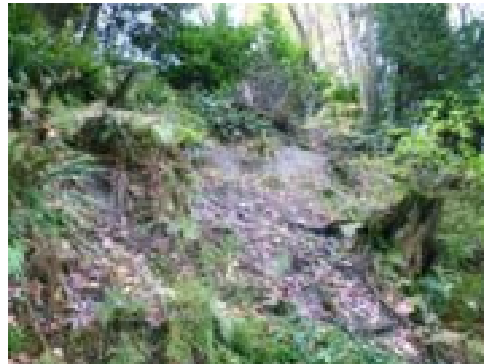
The following key issues for the watershed were identified. Refer to Figures 2-1 and 2-2 in Section 2 for more details.

Existing Erosion

- Erosion and ravine instabilities and hazards;



Undercutting of fence in McAdam Creek downstream of flow split chamber



Slope failure in McAdam Creek

- Erosion causing undercutting of fence observed in McAdam Creek between 109b Street and 110a Street; and
- Slope failure and bank erosion observed on McAdam Creek, Knudson Creek and Collings Creek.



Environmental

Barriers to Fish Passage



Culvert at the mouth of Nelson Creek

- Fish passage barriers restrict fish access from the Fraser River into most streams in the North Delta watershed;
- Steep channel gradient and historical railway development along the Fraser River have combined to create impassable barriers or seasonal obstructions; and
- Culverts restrict fish access into Sunbury Creek, Nelson View Creek, Knudson Creek, Kendale Creek, Shadow Brook, and Regal Drive Creek.

Hydraulic



Eroded culvert on Collings Creek



Projecting Outfall between Norum and Collings Creek causing erosion of bank

- Two culverts and three outfalls were identified as being in a poor condition.



1.3 Scope of Assignment

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

Table 1-1: Engineering Work Program

Major Tasks		
Phase 1	1.	Project Initiation
	2.	Background Information Review
Phase 2	3.	Engineering and Drainage Systems Inventory
	4.	Hydrogeology and Geotechnical Assessment
	5.	Land Use Assessment
	6.	Recreational Amenities
	7.	Environmental Inventory and Assessment
Phase 3	8.	Hydrology/Hydraulic Analysis
	9.	Ecological Health Analysis
	10.	Natural Hazard Assessment
	11.	Land Use Sensitivity Analysis
Phase 4	12.	Mitigation Alternatives
	13.	Project Summary and 50% Report
Phase 5	14.	Develop Strategy, Plan, and Report

This interim draft report summarizes Phases 1 and 2 of the study.

1.4 Stakeholder Consultation Program

A stakeholder consultation program will be conducted in later phases of the ISMP. Stakeholders will include:

- municipal advisory committees;
- streamkeeper volunteer groups;
- City of Surrey;
- study area residents;
- Burlington Northern Santa Fe (BNSF) Rail;
- Ministry of Transportation and Infrastructure (MOT);
- Metro Vancouver;
- BC Hydro;
- Fisheries and Oceans Canada (DFO); and
- BC Ministry of Environment (MOE).



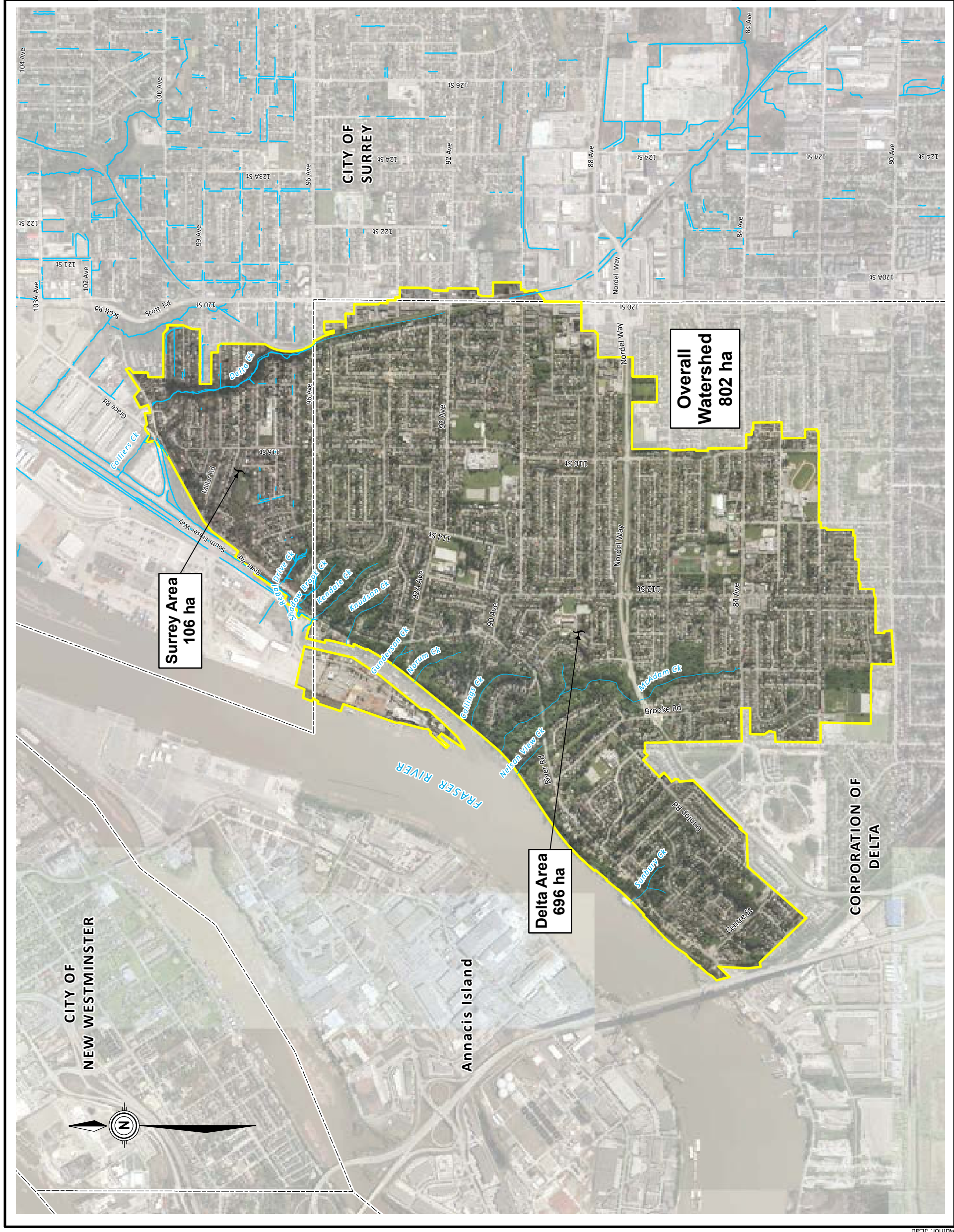
1.5 Stormwater and Drainage Criteria

Table 1-2 summarizes the applicable stormwater and environmental criteria used in this ISMP.

Table 1-2: Summary of Stormwater and Environmental Criteria

Application		Criteria/Methodology
Flood and Erosion Protection	Minor drainage system	<ul style="list-style-type: none"> 10-year return period design event typically.¹ 5-year return period design event for low density residential areas; 25-year return period design event for high value commercial or industrial development.¹
	Major drainage system (Rural, Urban, Commercial Industrial)	<ul style="list-style-type: none"> 100-year return period design event for floodway routing.¹ 25-year return period design event for dyked or reclaimed land.¹ 100-year return period design event for culverts with less than 3 meter span on BC Ministry of Transportation roads.²
Erosion & Environmental Protection	Volume Reduction (Source Controls)	<ul style="list-style-type: none"> On-site rainfall capture (runoff volume reduction) for 6-month 24-hour storm (72% 2-year 24-hour storm).³
	Water Quality Treatment	<ul style="list-style-type: none"> 6-month 24-hour storm (72% 2-year 24-hour storm).³
	Rate Control (Detention/Diversions)	<ul style="list-style-type: none"> Control post-development flows to pre-development levels for 6-month, 2-year, and 5-year 24-hour event.³ On fish bearing streams restrict post-development flows to pre-development levels for all storms up to and including the 10-year storm.¹
	Riparian	<ul style="list-style-type: none"> Establish riparian setbacks to comply with Delta Streamside Protection and Enhancement Areas Bylaw⁴ and Riparian Areas Regulation.

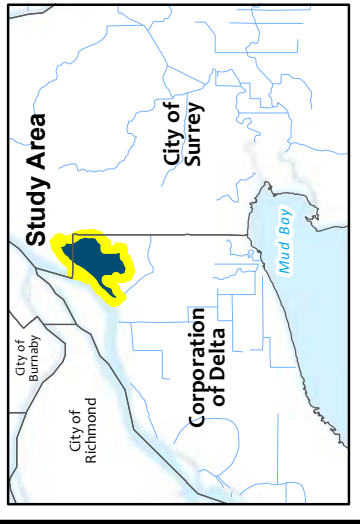
¹ Corporation of Delta Stormwater Management Design Manual, February 1989, Revised January 1994.
² BC Ministry of Transportation supplement to TAC Geometric Design Guide, 2007.
³ DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat, 2001.
⁴ Corporation of Delta Development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



**Corporation of Delta
North Delta Ravines
ISMP**

Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse

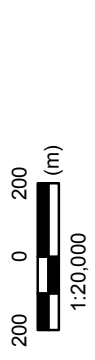


Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



KERR WOOD LEIDAL
consulting engineers

© 2014 Kerr Wood Leidal Associates Ltd.
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey have granted KWL the right to use these materials to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073	Date May 2014
------------------------	------------------

**2010 Air Photo of
Study Area**

Figure 1-1



2. North Delta Ravines Area Watershed

2.1 Background Material

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

Table 2-1: Summary of Background Material

Date	Title
1972	Exploratory Investigations of the Major Ravine Drainage Courses in the North Delta Area, Associated Engineering Services Ltd.
February 1989	Corporation of Delta Stormwater Management Design Manual, Dayton and Knight Ltd.
May 1989	North Delta Fraser Drainage Area and Boundary Bay Drainage Area, Dayton and Knight Ltd.
November 1999	Manson & Gunderson's Slough Watersheds Stormwater Management Review & Feasibility/Functional Plan, Associated Engineering Ltd.
March 2000	Delta-Surrey Inter-municipal Drainage Cooperation Issues, New East Consulting Services Ltd.
March 2002	North Delta Outfall Study Supplement Output Database Report, UMA Engineering Ltd.
July 2002	Long Range Drainage Plan, New East Consulting Services Ltd.
June 2003	Fish and Amphibians in Delta, British Columbia, Species Occurrence and Habitat Utilization Study 2000-2003, Western BioAquatics
June 2003	Delta Timing Schedule for In-stream Works, Western BioAquatics
June 2005	Stormwater Best Management Practices Integration Plan, Kerr Wood Leidal Associates Ltd.
August 2006	Drainage Control Structures Inventory, Corporation of Delta Engineering Department
September 2006	South Fraser Perimeter Road Fish Habitat Impact Assessment, Coast River Environmental Services Ltd.
December 2008	South Fraser Perimeter Road Concept Drawings, Ministry of Transportation and Infrastructure

2.2 Drainage Inventory

The North Delta Ravines study area is located in both the Delta and Surrey, with approximately 87% of the watershed within Delta (see Figure 1-1 in Section 1). The study area is approximately bounded by 80 Avenue, Highway 91, Scott Road, and the Fraser River, and includes a number of watersheds totaling approximately 802 ha in size:

- Study area is approximately 802 ha with both the Surrey area (106 ha) and the Delta area (696 ha) largely developed;
- Drainage direction is generally toward the North, via storm sewers, culverts, and creeks; and
- Study area drainage discharges into the Fraser River.

Refer to Figure 1-1 for the study area extents.



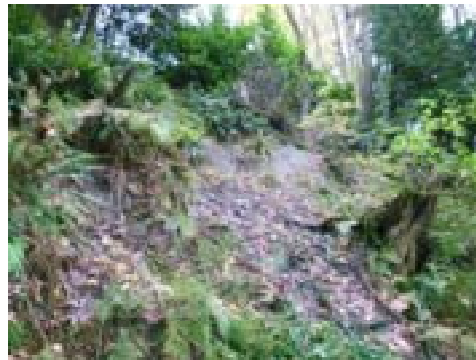
Field Inventory

Field inventories were completed between October 18 and November 2, 2012 for the Ravine area. The creek beds were traversed on foot and locations of interest were identified and recorded with a Trimble GeoXT handheld global positioning system (GPS) receiver. Measurements, photographs and additional observations were recorded as attributes associated with these positions to create a comprehensive geographical information system (GIS) database. Figures 2-1 and 2-2 show the field inventory and locations of interest.

Field inventory work included gathering information on culverts, outfalls, erosion, deposition, and obstructions. Tables 2-2 and 2-3 summarize the erosion and obstruction locations. See Appendix A for the culvert and outfall summary tables and photo overview. In general, the following observations were made:



Undercutting of fence in McAdam Creek downstream of flow split chamber



Slope failure in McAdam Creek

- Two culverts were identified as being in poor condition. One is located on Collings Creek (ID 249) and the other is located between Sunbury Creek and Nelson View Creek (ID 245).
- Three outfalls were identified as being in a poor condition. The outfalls are located on Nelson Creek (ID 240), McAdam Creek (ID 200) and between Collings and Norum Creek (ID 259).
- Erosion causing undercutting of fence observed in McAdam Creek (ID E4) between 109b Street and 110a Street.
- Slope failure on McAdam Creek (ID E6) north of the culvert on Nordel Way.
- Kendale Creek has slope failures (ID E14) that appear to be localized with the most significant one occurring approximately 120 m west of the outfall at the east end of the ravine.
- Knudson Creek has a localized slide scarp (ID E13) approximately 20 m long was noted near the toe of the north slope in the eastern portion of the ravine.
- Collings Creek has several areas of undulating topography and curved trees were noted, which is typical of surficial soil movement. A slide area (ID E12) coincided with a localized widening of the ravine indicating that soil movement has likely been occurring in this area for some time.
- Nelson View Creek has a slide scarp (ID E3) approximately 10 m in length and 2 m in height noted on the north slope near the east end of the ravine.



Table 2-2: Summary of Observed Severe Erosion Sites

Site ID	Comment	Creek
E1	Slide Scarp	Main
E2	Constructed Tire and Rock Slope	Nelson
E3	Wood Crib Retaining Wall	Nelson
E4	Undermined Fence and Trees	McAdam
E5	Approximate Location Gabion Blocks	McAdam
E6	Slope Failures Right Bank	McAdam
E7	Sloughing Both Banks	McAdam
E8	Sloughing Laminated Silty Clay	McAdam
E9	Right Bank - Historical Scarp / Left Bank - Slough	McAdam
E10	Riprap Bottom and Sides	McAdam
E11	Approximate Location Undulating Topography and Slide Scarps	Collings
E12	Approximate Location Slide Area	Collings

Table 2-3: Summary of Observed Major Channel Obstructions

Site ID	Cause	Risk	Comment	Photo #
193	Natural	Low	Fallen log and debris build up. (Note: A lot of erosion at property line)	297-299
202	Natural	Low	Debris in creek	316
212	Natural	Low	Debris build up in creek	334-335
214	Natural	Low	Debris, Fallen logs, Shopping cart	336-338
215	Natural	Low	Debris build up, Low Priority	339
216	Natural	Low	Deposition behind debris build-up of fallen logs, Low Priority	340
218	Natural	Low	Wood debris and logs, Medium Priority	342-344
223	Natural	Low	Fallen logs, seems to be a barrier for sprat fish	361
224	Natural	Low	Log debris, blocking flow, 1m drop,	362-366
226	Natural	Low	Fallen Log	376
228	Natural	Low	Log debris in creek	378
230	Natural	Low	Fallen Log	388
232	Natural	Low	Fallen Log	391
261	Natural	Low	Fallen Log	170
262	Natural	Low	Log debris in creek	171
263	Natural	Low	Fallen Log	172
264	Natural	Low	Fallen Log	173
265	Natural	Low	Log debris in creek	174

2.3 Land Use Assessment

Golder Associates Ltd. (Golder), as part of the consulting team, conducted a review of the North Delta Ravines study area in order to estimate existing and potential development impacts to the hydrological functioning of ravines and related stormwater management protocols. The project area was assessed in terms of existing and future land use, impervious area coverage, and stormwater management plans and policies in both Delta and Surrey. The study area includes a large portion of North Delta and a small portion of Surrey as outlined in Figure 1-1.



The existing land uses within the study area are summarized in Table 2-4.

Table 2-4: Existing Land Use

Delta	Surrey
Single family residential Parks/recreation Commercial mainly along Scott Road Industrial Infrastructure	Mainly residential Some commercial along Scott Road
Refer to Figure 2-3 for existing land use and associated impervious percentages.	

The anticipated future land use in the study area is shown on Figure 2-4 and includes:

- Minor zoning changes expected to result in a change from lower density single family uses to higher density, infill single family uses and increased medium density development;
- Mainly redevelopment at higher impervious percentages; and
- Potential for higher density along Scott Road and 84th Avenue near 112 Street.

Although the North Delta Ravines study area is quite mature in terms of build out, it is not expected that significant amounts of change are going to occur with respect to total impervious areas. There are only two land use zones in the City that have been identified as undergoing intensification that may result in an increase in total impervious area. These are single family residential zones where the average TIA will increase from 35% to 40% and the North Delta Commercial and Mixed-Use zones, which will see an increase in TIA from 57% to 64% and 56% to 68% respectively.

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

Table 2-5: Existing and Future Total Impervious Areas

Existing Land Use			Future Land Use (Estimated 2030)		
Delta Area Only	Surrey Area Only	Total Study Area	Delta Area Only	Surrey Area Only	Total Study Area
47%	52%	48%	50%	55%	51%

Average total impervious area for the entire study area will increase from 48% to 51%. Based on interviews within City staff and an analysis of existing planning documents, no additional changes are expected to occur in other land use zones.

Refer to Appendix B for more details on the land use changes in the North Delta Ravines study area.

2.4 Recreation and Education Assessment

Summary of Ravine Access and Education

Golder Associates Ltd. (Golder), as part of the consulting team, conducted a review of the project area for the existence and potential for recreational facilities and trails. Golder also reviewed the potential for public education regarding the ravines and identified potential actions for Delta to consider.



Each ravine was reviewed according to the following criteria:

- Ravine area and slope;
- Ownership;
- Existing and potential public access;
- Presence of formal or informal trails; and
- Presence of accessible viewpoints.

No formal development or programming for public uses was observed for the ravines, except for the commemorative signage marking the 1861 Kenned Trail. Potential access points to the ravines were identified from satellite photos and each access point was visited and assessed. Table 2-6 summarizes the results of the field assessment.

McAdam Ravine provides the best opportunities for the development of recreational trails and public education in the study area ravines. It is the largest of all the ravine areas and the only one that has viable access points for public entry. Increasing public access to the stream areas at the bottom of any of the ravines would be difficult, potentially disruptive to habitat and would likely require physical structures such as stairs and viewing platforms, slope stabilization and other mitigation measures. In addition, regulatory approvals from DFO would be required and the requirements for obtaining approval of a Development Permit would have to be met.

Although the potential to provide direct access to the ravines themselves is very limited there is a range of other means to provide information and public education about the ravines and their ecological and stormwater function and to raise awareness of their importance and vulnerability, including signage, public information, outreach campaigns and public access. Public education and programming for the ravines is a shared responsibility amongst Parks Recreation and Culture, Engineering and the Office of Climate Action and Environment and efforts need to be coordinated to ensure coherence and effective implementation.

Refer to Appendix B for more details on the recreation and education opportunities in the North Delta Ravines.

Integration with Municipal Plans

Golder was asked to make recommendations to be considered in the Official Community Plan and Subdivision and Development Standards Bylaw and to recommend modifications to other municipal master plans and/or zoning that address desired watershed impervious area and riparian condition targets in order to maintain watershed ecological health. Golder assessed and reviewed Delta's Planning regulations to determine their appropriateness and adequacy to govern development in the ravine areas and protect their stormwater function.

Delta has a robust set of land use policies to protect ravines from development and permit them to perform their stormwater function.

The ravines are designated "Development Permit" areas by the Official Community Plan and subject to Guidelines approved by Corporation Council. All the ravines in the study area are subject to the *SPEA Streamside Protection and Enhancement Area Development Permit Guidelines – Bylaw 6349*. Delta's policy is to not permit development in the ravines or within 30 meters from the top of the slope of the ravines. These are "no go" areas. In practice, there is little or no development or land alteration method that could fully mitigate development impacts. Corporation staff advise that these regulations work well and provide the authority needed to protect the ravines and streams from inappropriate development. Delta's Planning regulations to protect the environmental quality and stormwater function of the ravines are comprehensive well co-ordinated and conform to the requirements of *the Local Government Act*. No additional Planning regulations are required.



2.5 Environmental Inventory and Assessment

Summary of Environmental Values and Issues

An environmental inventory of watercourses and riparian areas in the North Delta watershed was undertaken to summarize information on watershed and riparian forest cover, water and sediment quality, benthic invertebrate communities, fish and fish habitat, fish passage, and instream habitat. In addition, habitat restoration sites and enhancement opportunities were also identified. The inventory focused on ten streams that are within the Corporation of Delta's boundaries.

There is relatively little specific information on fish and fish habitat, water quality, and other characteristics of the study area streams. Previous stream inventories were undertaken by Coast River Environmental Services to characterize fish use and habitat conditions as part of the planning and design of the South Fraser Perimeter Road (SFPR).

Watershed and Riparian Forest Cover

Watershed and riparian forest cover was mapped using the most up-to-date 2012 rectified Google imagery which shows some of the SFRP impacts, and 1995 orthophotos in GIS based on visual interpretation of forest cover. Riparian forest cover was measured within a 30 m buffer on either side of the centerline of permanent stream channels.

A total of 87.5 ha (13%) of the 802.4 ha study area was forested in 2012. Concentrations of forest were found in the stream ravines and along the Fraser River escarpment. Approximately 10.8 ha (1.3%) of forest cover have been lost in the past 17 years. The largest losses have occurred recently during construction of the SFPR.

Approximately 68% (30.1 ha) of the riparian zones surrounding the study streams is currently forested. It varies from 41% surrounding Regal Drive Creek to 82% around McAdam Creek. Most of the riparian area is vegetated with deciduous forest (red alder and black cottonwood). Riparian forest cover has declined 1.8 ha (4%) over the past 17 years. The difficulty in developing on steep ravine slopes and the regulation of development in riparian areas has limited riparian forest loss. However, recent losses have occurred because of construction of the SFPR.

Refer to Figure 2-5 for existing riparian corridors.

Water and Sediment Quality

Three methods were used to assess water and sediment quality in the study area streams: (1) a survey of general water quality parameters; (2) lab-based measurement of total metals, nutrients, and fecal coliforms was completed at six streams; and (3) concentrations of total metals were also measured in streambed sediments from six streams. No historic information on water and sediment quality in the study streams was available.

The survey did not find any specific sites or stream sections with unusual water quality which would indicate specific sources of contaminations (e.g., "hot spots"). Measurements of general water quality parameters were consistent with regional observations in urban streams. The study streams have similar water quality characteristics although Sunbury and Knudson creeks had higher specific conductivity, higher turbidity, and lower Oxygen Reduction Potential (ORP) which may indicate more urban influences.



Lab measurements showed that total metals concentrations were mainly below BCWQ guidelines. Total copper was marginally higher than the BCWQ guideline in Sunbury and McAdam creeks, and total antimony was elevated in the sample from McAdam Creek. Fecal coliforms were lower than the BCWQ guideline for primary contact recreation. Nutrients concentrations were similar to moderately urbanized streams in Metro Vancouver.

Total metals in streams sediments were also similar to moderately urbanized watersheds in Metro Vancouver. Samples from four streams (Sunbury, Collings, Knudson, and Kendale Creeks) had concentrations of total nickel above the BC Working Sediment Quality Guidelines (BCSQGs). Total arsenic in the sample from Knudson Creek was also above BCSQG. These elevated metal concentrations are not considered unusual for urban streams in Metro Vancouver.

Refer to Figure 2-6 for an overview of the sampling sites.

Benthic Invertebrates

Four benthic invertebrate samples were collected from the lower 500 m of McAdam Creek using a field sampling protocol developed for streams in Metro Vancouver. McAdam Creek was selected both as an indicator of the typical land use conditions in the North Delta watershed, and also as the stream with the highest ecological values. A ten metric B-IBI (Benthic Index of Biotic Integrity) was used to summarize the condition of the stream based on the structure and composition of the benthic community.

Mean B-IBI for McAdam Creek was 18.0 which is consistent with the level of urbanization in the watershed. B-IBI ranges from 10 to 50 and a mean score of 18.0 indicates McAdam Creek is transitional between fair and poor condition. Mean taxa richness for all samples was 13.3 (range of 9 to 19). Mean EPT taxa richness (stoneflies, mayflies, caddisflies) was 4.5 (range of 3 to 7). The most abundant taxa were a larval midges (Chironomids: 43% of individuals sampled), Oligochaete worms (25%), and the pollution-tolerant stonefly *Baetis tricaudatus* (14%).

Fish Community

Information on fish presence was derived from the detailed fisheries assessment completed previously by Coast River Environmental Services for the SFPR environmental impact assessment. No new fish sampling was used to confirm or update information on the fish community.

Seven of the eleven streams support resident or searun cutthroat trout populations, and three (McAdam, Delta and Regal Drive Creek) support coho salmon. Additional streams may support coho salmon or chum salmon but presence is not confirmed.

Instream Habitat

Instream habitat characteristics were assessed using field surveys. Channel dimensions and substrate conditions were measured at 41 points at intervals along the study streams. In addition, pieces of large instream wood and pools >40 cm deep were mapped as indicators of fish habitat value.

Mean bankfull width in the study streams ranged from 0.6 m in Kendale Creek to 2.2 m in McAdam Creek with an overall mean of 1.6 m. Wetted width during the survey ranged from 0.4 m in Kendale Creek to 1.4 m in McAdam Creek (overall mean of 1.0 m). Channel dimensions are characteristic of small first or second-order streams.

Stream channel substrate is predominantly cobble and gravel with lesser amounts of boulder and fine sediment (sand and silt). Mean substrate was approximately 10% boulder, 26% cobble, 34% large gravel, 20% small gravel, and 10% fines.



Large instream wood is widely distributed in the study area streams but rarely abundant compared to undisturbed streams. A total of 381 pieces were recorded with an average length of 4.4 m, diameter of 27 cm and volume of 0.45 m³. The density of large instream wood was 5.3 pieces per 100 m which is less than half the large instream wood found in natural streams. Large wood is concentrated in the upper ravine areas rather than the higher productivity fish habitat in the lower reaches.

Twenty pools deeper than 40 cm deep were recorded; all were found in McAdam Creek. Mean depth was 47 cm (range of 40 to 70 cm).

In general, the instream habitat is as would be expected for a developed watershed.

Barriers to Fish Passage

Fish passage barriers restrict fish access from the Fraser River into most streams in the North Delta watershed. Steep channel gradient and historical railway development along the Fraser River have combined to create impassable barriers or seasonal obstructions. Culverts restrict fish access into Sunbury Creek, Nelson View Creek, Knudson Creek, Kendale Creek, Shadow Brook, and Regal Drive Creek.

Environmental Enhancement and Restoration Opportunities

Restoration and enhancement opportunities were identified at four scales: (1) landscape-level actions that support the broader ecological network and watershed-scale functions; (2) riparian restoration and management; (3) instream habitat restoration to enhance fish populations; and (4) fish passage improvements. Important opportunities include:

The streams and forested ravines of the North Delta watershed should be recognized as a critical component of the ecological network of North Delta and the adjacent portion of Surrey. Construction of the SFPR has increased habitat fragmentation and options for increasing connectivity between the ravine areas through adjacent residential areas should be reviewed.

There are limited opportunities to increase riparian forest cover mainly because the existing riparian ravines are forested and surrounded by existing residential land use. Opportunities for additional riparian protection may occur during redevelopment. Some private land use occurs in ravine areas and landowners should be encouraged to minimize forest loss.

Given the limited access into ravine areas, enhancement of instream habitat is not recommended as a mitigation strategy. Some opportunity exists for instream habitat complexing in McAdam Creek combined with the riparian restoration efforts described above.

Fish passage in to Knudson Creek, Kendale Creek, Shadow Brook, and Regal Drive Creek should be restored by addressing culvert barriers.

Refer to Appendix C for more details on the environmental inventory for the North Delta Study area.

2.6 Geotechnical Assessment

Geotechnical

A geotechnical review of the nine ravines in North Delta was completed by exp Services Inc. The following observations were made during the geotechnical review:

- The study area lies within an area of Pre-Vashon Drift deposits consisting of fluvial, glacio-fluvial and marine deposits;



- Soils generally consisted of cross bedded sands with silt and gravel lenses, cross bedded sand to gravel and inter bedded fine sand to clayey silt; and
- Groundwater was not typically encountered along the ravine banks except in localized seepage areas.

Refer to Figure 2-7 for an overview of the soils in the study area.

Erosion and Ravine Instabilities

A geotechnical review of slope stability and erodibility was conducted as part of the geotechnical review of the ravines:

- The granular nature of the soils encountered within the ravines were typically considered to be susceptible to erosion, with the exception of McAdam and Nelson View Creeks in which clayey soils were encountered which would be more resistant to erosion.
- Erosion within the ravines was generally limited to localized areas.
- Shadow Brook Creek - relatively stable bank inclination and limited erosion. Some localized surficial sloughing noted, particularly in fill slopes.
- Kendale Creek - The slopes were generally steeply inclined (up to 1.3H: 1V) resulting in sloughing and slope failures. The slope failures appeared to be localized with the most significant one occurring approximately 120 m west of the outfall at the east end of the ravine.
- Knudson Creek - The slopes were generally inclined less steeply than 2H: 1V which would be considered a stable inclination for the soil type encountered. A localized slide scarp approximately 20 m long was noted near the toe of the north slope in the eastern portion of the ravine.
- Gunderson Creek - Largely infilled ravine limiting the potential for slope instabilities.
- Norum Creek - No significant indications of slope instabilities were noted.
- Collings Creek - Slopes within the ravine were inclined at approximately 1.8H: 1V and several areas of undulating topography and curved trees were noted, which is typical of surficial soil movement. Erosion of the creek banks may further destabilize slopes particularly in the western portion of the ravine where creek flows were noted to be higher. A slide area coincided with a localized widening of the ravine indicating that soil movement has likely been occurring in this area for some time.
- McAdam Creek - The higher slopes frequently had areas of exposed ground and undulating topography. These features are indicative of marginally stable slopes being destabilized by erosion at the slope toes. The ravine below River Road consisted of slopes with inclinations in the order of 2.3H: 1V, which would generally be considered to be a stable slope angle for granular soils.
- Nelson View Creek - Slopes within the ravine were inclined at approximately 2H: 1V with a slide scarp approximately 10m in length and 2 m in height noted on the north slope near the east end of the ravine.
- Sunbury Creek - Slopes within the ravine were gently inclined (3H: 1V) at what would typically be considered a stable slope angle. Minor indications of previous slope movement were noted (curved tree trunks, small slide scarps); however, these instabilities are limited in extent and are unlikely to be significantly affected by toe erosion along the creek banks.



- Regular reviews of Shadow Brook, Kendale, Collings and McAdam Creek ravines is recommended to monitor progression of existing slope movement and/or erosion of creek banks.
- Some localized erosion protection for areas within McAdam Creek ravine is recommended.
- Confirmation of sufficient setbacks for homes adjacent to Gunderson Creek ravine is recommended.






Refer to Appendix D for more details on the geotechnical review.

Table 2-6: North Delta Ravine Recreation Potential Evaluation

Name of Ravine	Area of Ravine (ha)	Slope Ver:Hor	Potential Public Assess Points Reviewed	Existing Public Assess	Existing Formal or Informal Trails	Ownership	Viewpoints	Notes
Shadow Brook	3.35	1:2	4	No	No	Public and Private	From 96 th Ave	Partly in Surrey
Kendale	3.65	1:13	2	No	No	Private	Private only	Partly in Surrey
Knudson	2.5	1:2	4	No	No	Private	No	
Gunderson	1.12	1:116	2	No	No	Public	From Nordel Way Bridge	
Norum	2.07	1:25	4	No	No	Private	Private only	
Collings	3.15	1:18	4	No	Kennedy Historic Trail	Public park reserve	Private only	Outside park reserve
McAdam	10.7*	1:10 to 1:23	10	2 from 86 th Ave to path in forest at top of bank; 1 of bank, and 1 from south east portion of River Rd Bridge	2 from 86 th Ave to path in forest at top of bank; 1 from 111 th St. and 1 from south east portion of River Rd bridge	Public north of Nordel Way; public on east bank south of Nordel; and private on west bank; some area south of Nordel is park reserve	From MacAdam Rd and from Nordel Way and River Rd bridge	*upstream from River Rd Informal BMX track on north side of ravine running east from River Rd
Nelson View	1.36*	1:136	3	No	No	Public and Private	From River Rd bridge though security fence	*downstream from River Rd
Sunbury	2.44	1:244	1	No	No	Public part is Park Reserve	Private only	

Corporation of Delta
North Delta Ravines
ISMP

Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse
-  Culvert
-  Storm Main

Field Inventory

-  Obstruction - Low Risk

Outfall (Condition Assessment)

-  Good
-  Fair
-  Poor

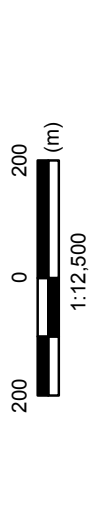
Culvert (Condition Assessment)

-  Good
-  Fair
-  Poor
-  Inventory ID

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



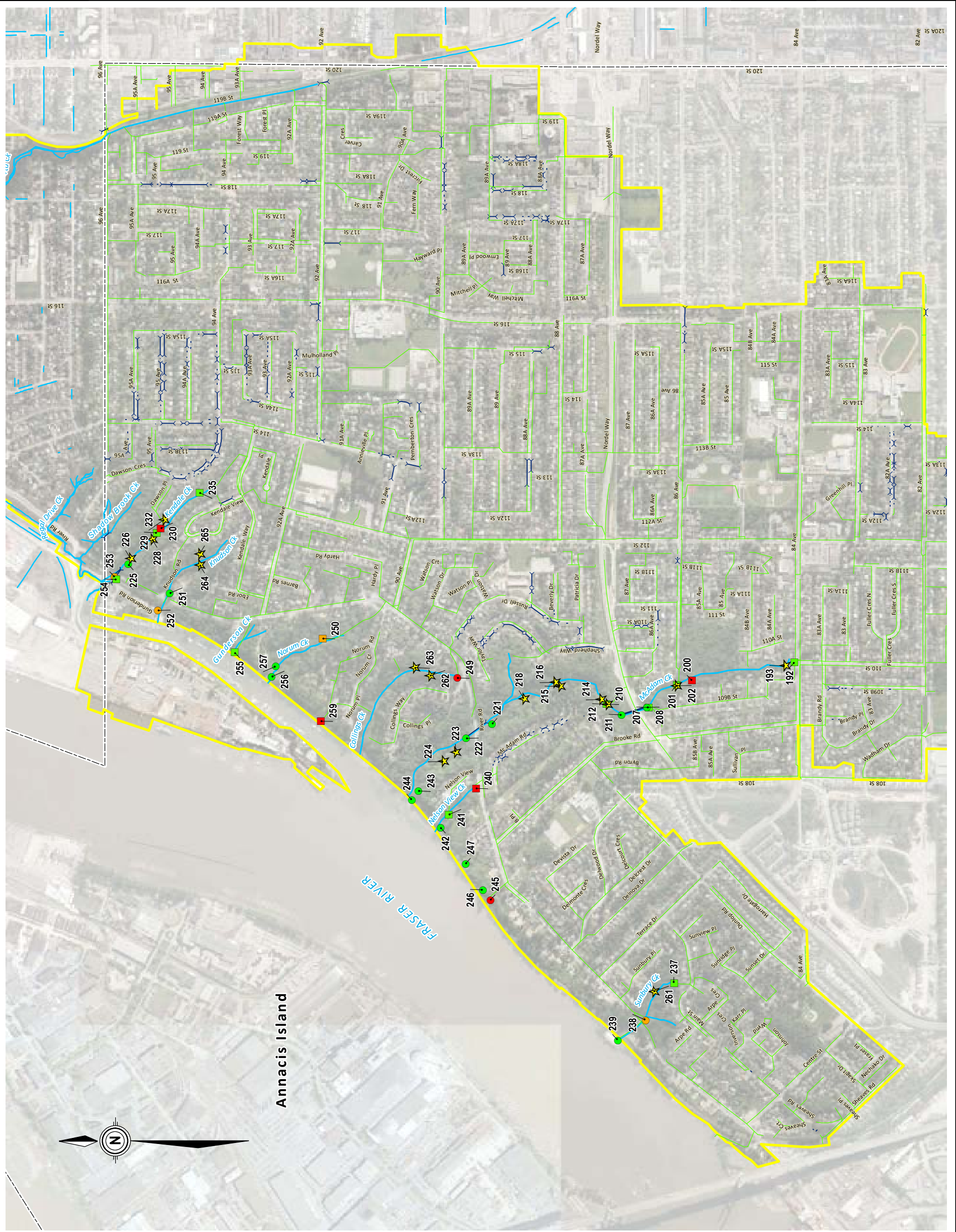
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta North Delta Ravines specifically relating to the Corporation of Delta North Delta Ravines (ISMP). Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073 Date May 2014








Culvert, Outfall and
Obstruction Inventory

Figure 2-1



Corporation of Delta
North Delta Ravines
ISMP

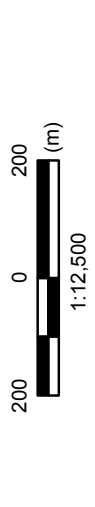
Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse
-  Culvert
-  Storm Main
-  Observed Erosion Site
-  Erosion ID

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



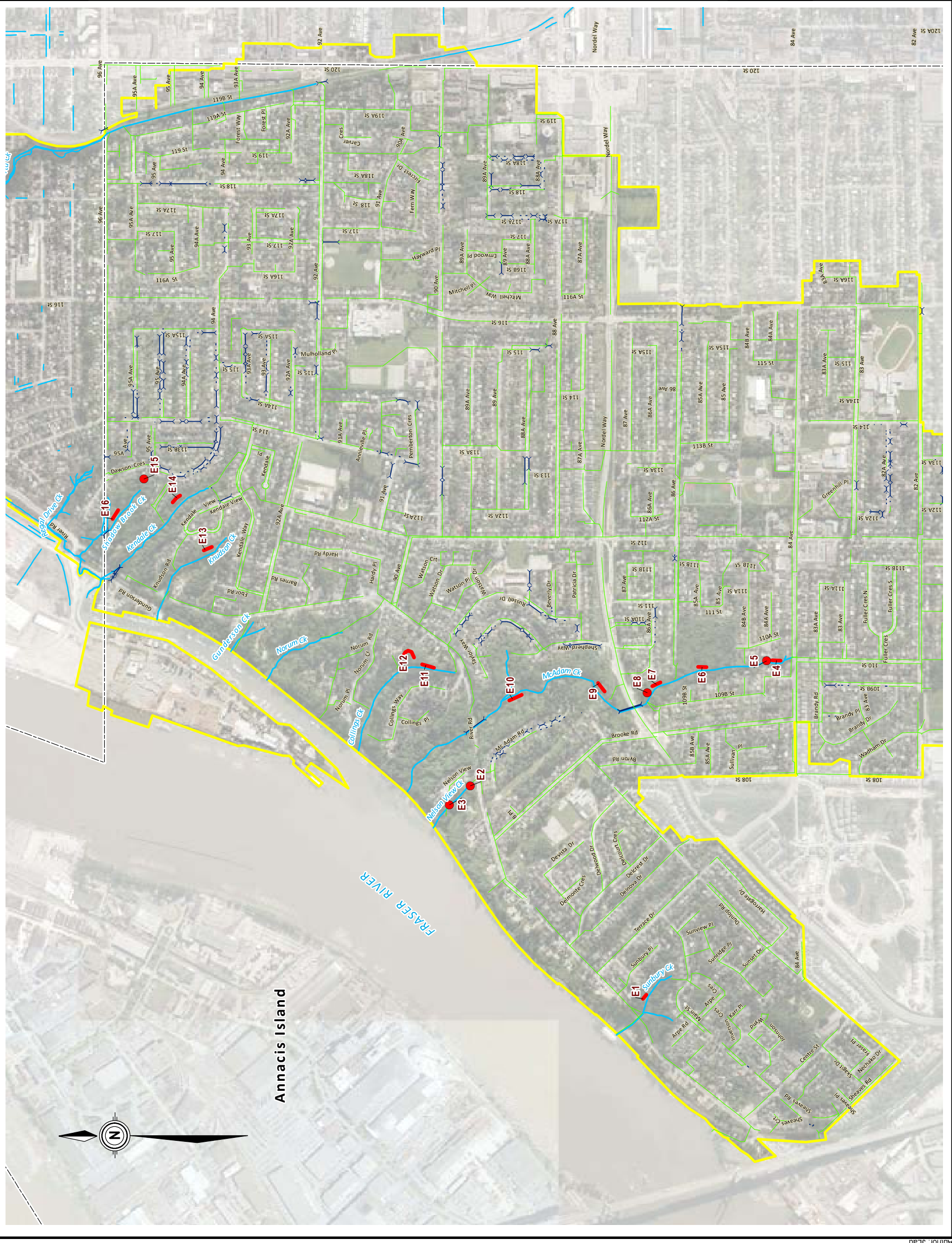
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.

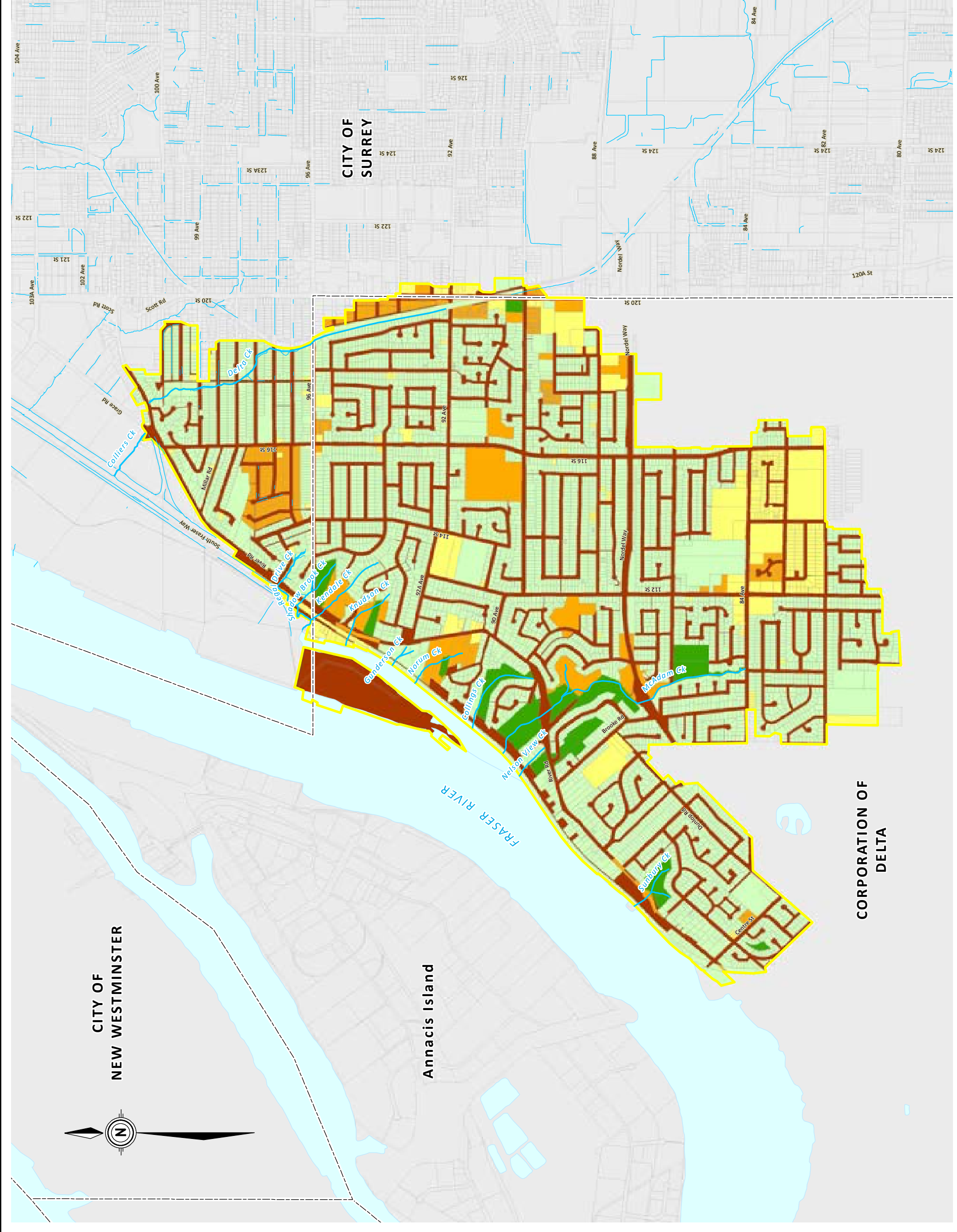


Project No. 323-073 Date May 2014

Erosion Inventory

Figure 2-2





CITY OF
NEW WESTMINSTER

Annacis Island

CITY OF
SURREY

CORPORATION OF
DELTA

Corporation of Delta
North Delta Ravines
ISMP

Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse

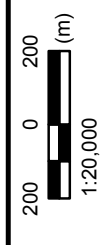
Existing Percent Impervious Area

-  0 - 19.9 %
-  20 - 39.9 %
-  40 - 59.9 %
-  60 - 79.9 %
-  80 - 100 %

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



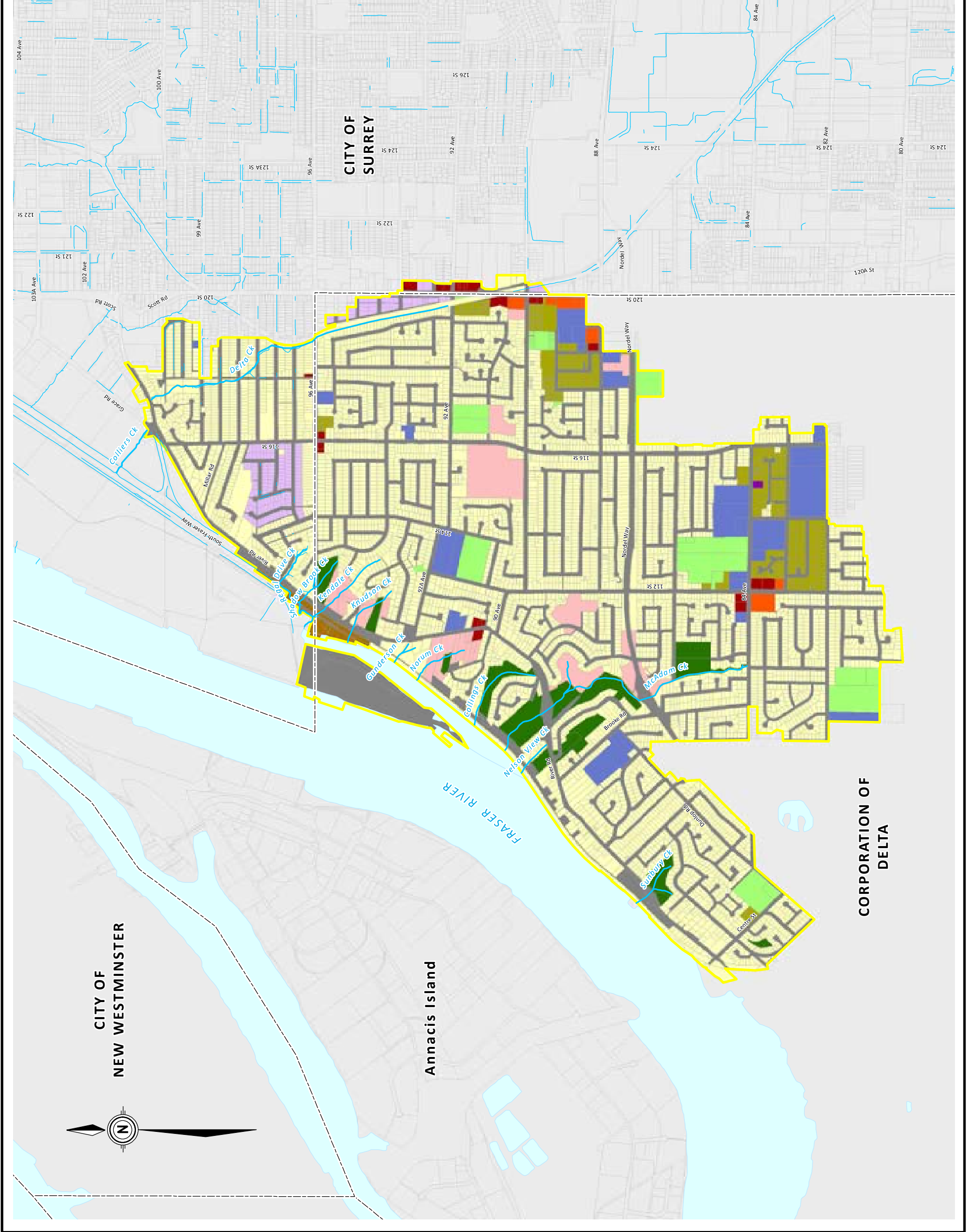
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No.	Date
323-073	May 2014

**Existing
Impervious Area
by Parcel**

Figure 2-3















**Corporation of Delta
North Delta Ravines
ISMP**

Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse

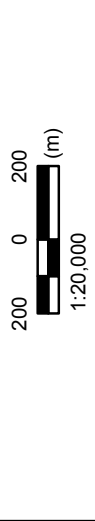
OCP Land Use (Total Impervious Area)

-  Commercial (64%, 73 %)
-  Industrial (47 %)
-  Institutional (51 %)
-  Environmentally Sensitive Area (7 %)
-  Parks and Recreation (26 %)
-  Mixed Use (39 %, 50 %, 68 %)
-  Special Development Area (79 %)
-  Split (61 %)
-  Road /ROW (68 %, 80 %)
-  Residential Ground Oriented (45 %)
-  Single Family Residential (40 %, 47 %)
-  Multi-Family Residential (26 %, 41 %, 54 %, 63 %, 77 %)

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



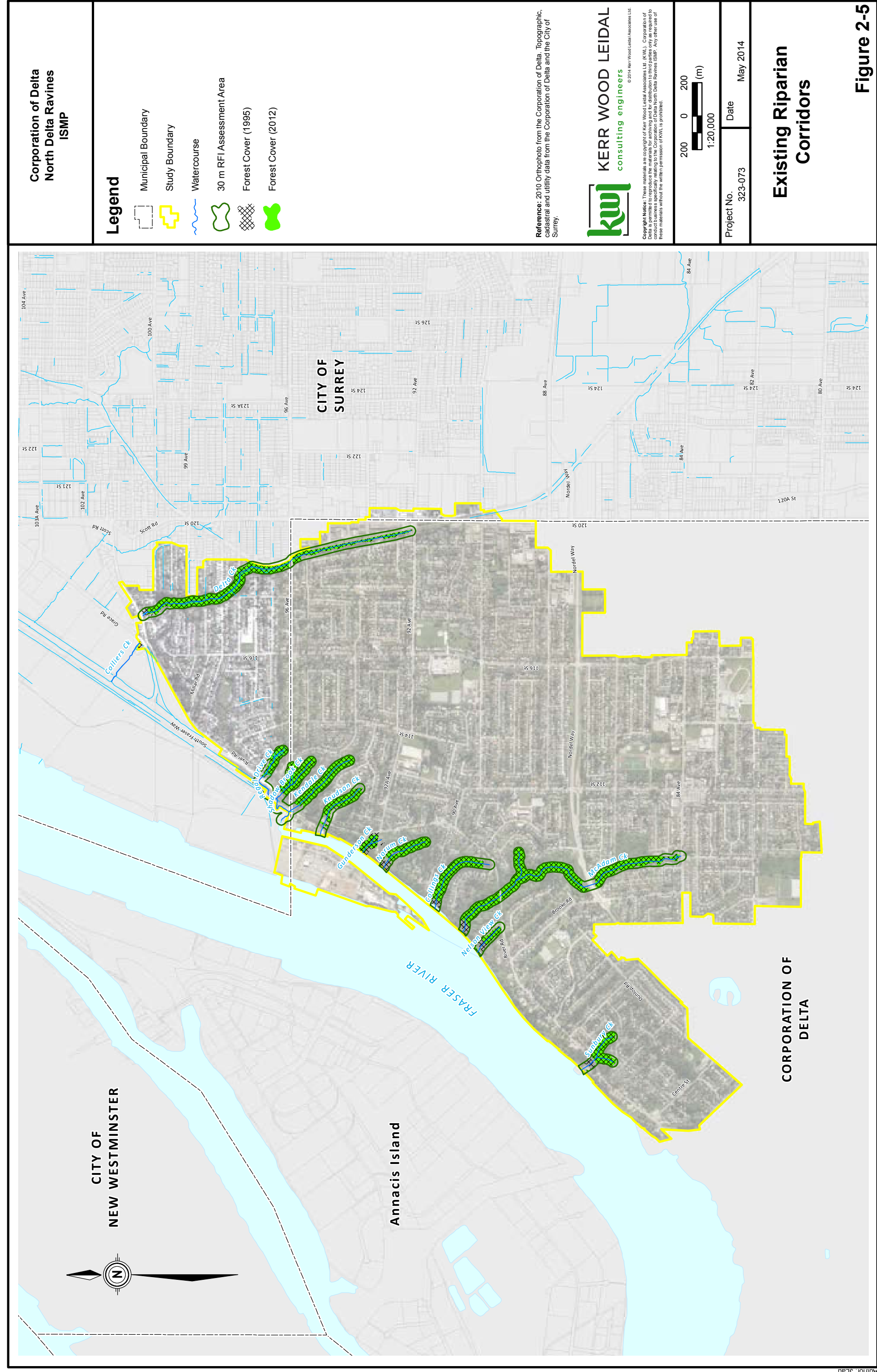
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are authorized to use these materials to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.

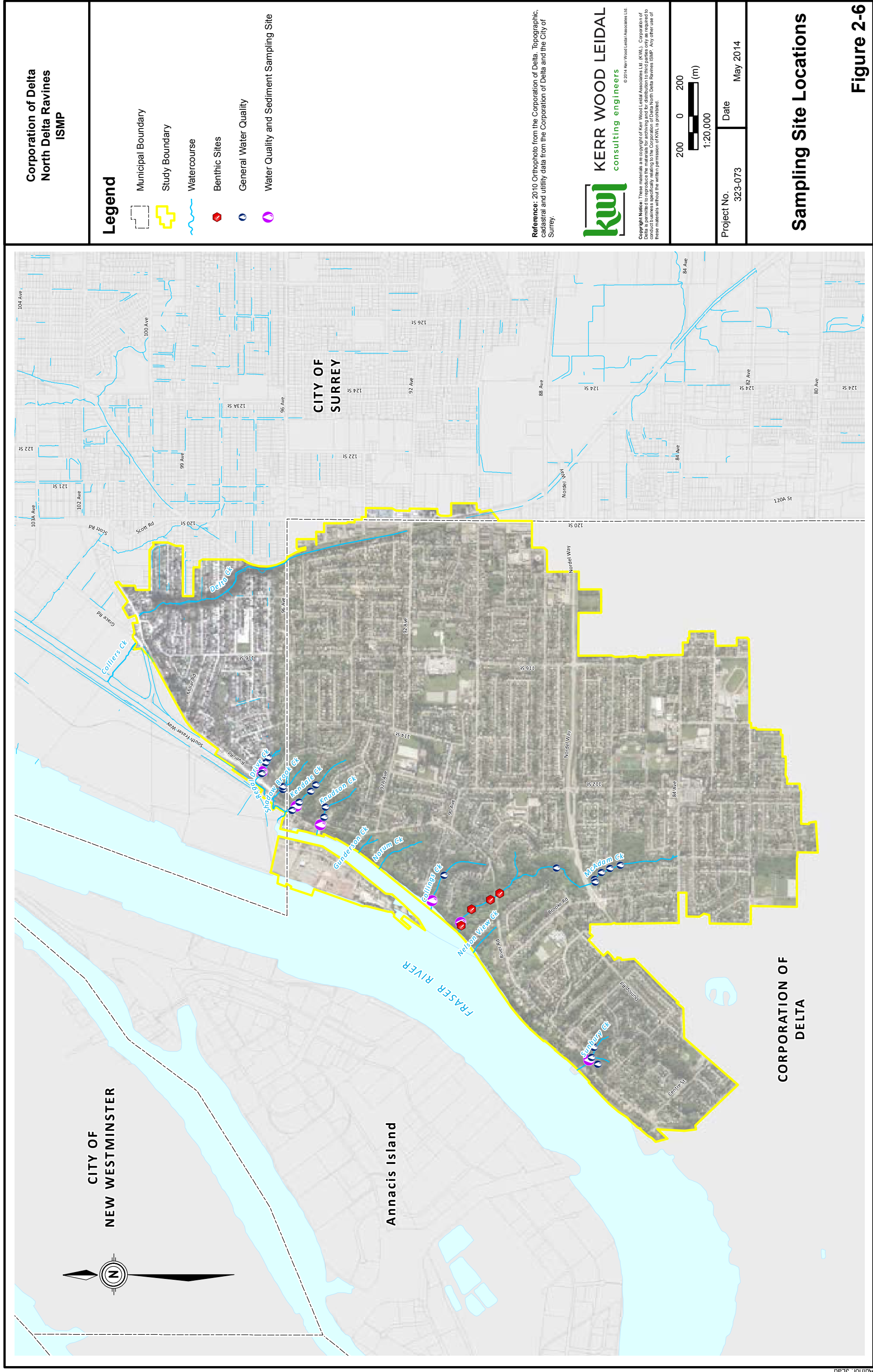


Project No. 323-073 Date May 2014

**Future Land Use
(OCP)**







Figure 2-4





**Corporation of Delta
 North Delta Ravines
 ISMP**

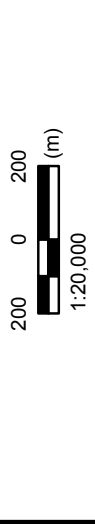
Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse
-  Benthic Sites
-  General Water Quality
-  Water Quality and Sediment Sampling Site

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



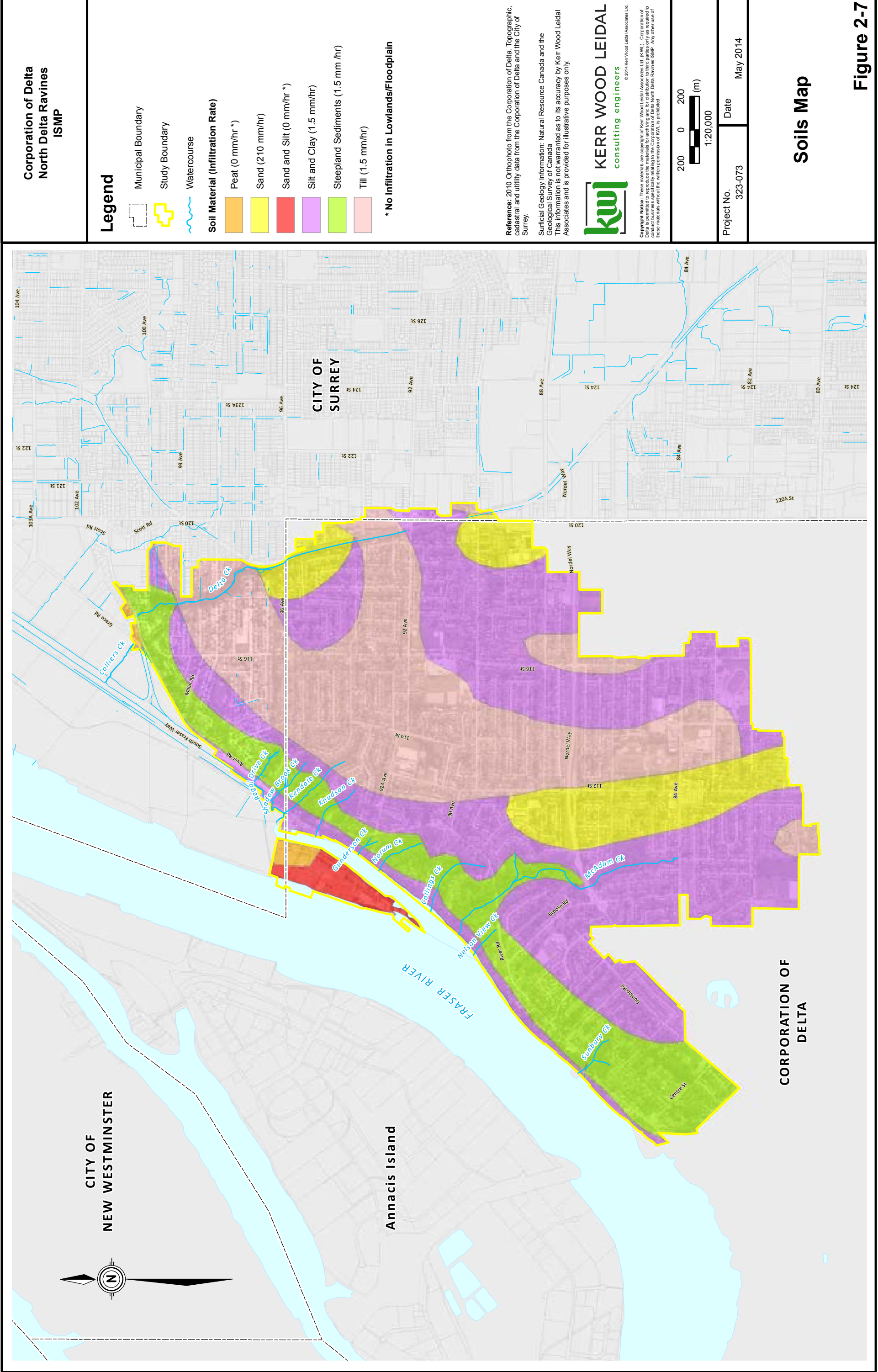
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are permitted to use these materials to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No.	323-073	Date	May 2014
-------------	---------	------	----------


Sampling Site Locations

Figure 2-6









**Corporation of Delta
North Delta Ravines
ISMP**

Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse

Soil Material (Infiltration Rate)

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

* No Infiltration in Lowlands/Floodplain

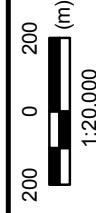
Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

Surficial Geology Information: Natural Resource Canada and the Geological Survey of Canada
This information is not warranted as to its accuracy by Kerr Wood Leidal Associates and is provided for illustrative purposes only.



KERR WOOD LEIDAL
consulting engineers

© 2014 Kerr Wood Leidal Associates Ltd.
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta North Delta Ravines (ISMP). Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073	Date May 2014
------------------------	------------------

Soils Map

Figure 2-7



3. Watershed Analysis

3.1 Hydrologic/Hydraulic Models

PC SWMM Model Development

A stormwater model was developed for the North Delta Ravines area. PC SWMM was used for both the hydrology and hydraulic simulations. The hydrology portion of PC SWMM uses inputs such as rainfall and catchment characteristics (area, slope, soil type, etc.) to estimate catchment flows. The hydraulic portion of PC SWMM use hydraulic system inputs (culvert/pipe/channel characteristics) to simulate flow routing, and water levels.

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

Details of the model development are provided in Appendix E.

Design Storms

The design storms used in the analysis were generated from the IDF curve for the GVRD DT34 rain gauge. The rain gauge is located in North Delta at 8544 - 116th Street. The 1-, 2-, 6-, 12- and 24-hour design storms were used for the storm sewer and culvert capacity assessments.

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

3.2 Results of Hydrologic/Hydraulic Modelling

Peak Flow Estimates at Strategic Locations

The model was used to simulate the hydrology and hydraulics and to determine peak flows at strategic locations in the watershed. Flows were estimated for the 2-, 5-, 10-, 25-, 50-, and 100-year storms for the following scenarios:

- Existing land use conditions; and
- Future land use conditions.

Peak flow estimates are shown in Tables 3-1 and 3-2 below. Because the catchment is largely built out, the future land use changes would increase the peak flows by less than 10%.



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

Location	Peak Instantaneous Flow Estimate (m ³ /s)					
	2-year	5-year	10-year	25-year	50-year	100-year
Sunbury Creek at Outfall	1.06	1.57	1.69	1.88	1.98	2.05
Nelson View Creek at Outfall	0.55	0.87	1.07	1.37	1.57	1.84
McAdam Creek at Outfall	3.29	5.63	7.10	8.87	10.44	11.74
McAdam Creek at Nordel Way	3.13	5.34	6.85	8.71	10.16	11.59
Collings Creek at Outfall	0.28	0.50	0.65	0.84	0.98	1.12
Norum Creek at Outfall	1.62	2.41	2.88	4.44	5.14	5.87
Knudson Creek at Outfall	0.29	0.46	0.57	0.71	0.81	0.91
Kendale Creek at River Road	1.13	1.67	1.99	2.41	2.72	3.14
Shadow Brook Creek at River Road	0.44	0.72	0.82	1.02	1.18	1.23
Shadow Brook Creek at 96th Avenue	0.50	0.79	0.98	1.24	1.43	1.63
Regal Drive Creek at River Road	0.80	1.26	1.58	1.99	2.30	2.61
Delta Creek at River Road	2.07	3.03	3.59	4.43	5.02	5.57
Delta Creek at 96th Avenue	1.57	2.18	2.50	2.84	3.05	3.20

Table 3-2: Flows at Strategic Locations for Future Land Use

Location	Peak Instantaneous Flow Estimate (m ³ /s)					
	2-year	5-year	10-year	25-year	50-year	100-year
Sunbury Creek at Outfall	1.09	1.62	1.73	1.91	2.01	2.07
Nelson View Creek at Outfall	0.57	0.89	1.10	1.41	1.61	1.98
McAdam Creek at Outfall	3.32	6.08	7.17	9.14	10.55	11.99
McAdam Creek at Nordel Way	3.25	5.91	6.95	8.95	10.36	12.02
Collings Creek at Outfall	0.30	0.53	0.68	0.87	1.01	1.15
Norum Creek at Outfall	1.65	2.50	2.94	4.62	5.33	6.04
Knudson Creek at Outfall	0.30	0.46	0.57	0.72	0.82	0.92
Kendale Creek at River Road	1.15	1.70	2.03	2.47	2.81	3.21
Shadow Brook Creek at River Road	0.44	0.73	0.84	1.05	1.21	1.24
Shadow Brook Creek at 96th Avenue	0.52	0.81	1.01	1.28	1.47	1.67
Regal Drive Creek at River Road	0.82	1.29	1.61	2.03	2.35	2.66
Delta Creek at River Road	2.15	3.11	3.71	4.56	5.16	5.71
Delta Creek at 96th Avenue	1.61	2.23	2.54	2.89	3.09	3.30

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



Table 3-3: Existing Land Use Unit Peak Flow Comparison

Location	Peak Flow (L/s/ha)			
	2-year	5-year	10-year	100-year
Sunbury Creek at Outfall	22.0	32.7	35.3	42.7
Nelson View Creek at Outfall	20.8	32.5	40.4	69.0
McAdam Creek at Outfall	14.6	25.0	31.6	52.2
McAdam Creek at Nordel Way	15.0	25.6	32.9	55.6
Collings Creek at Outfall	24.6	43.9	57.0	97.6
Norum Creek at Outfall	22.8	34.0	40.6	82.7
Knudson Creek at Outfall	34.9	54.7	68.0	109.6
Kendale Creek at River Road	15.3	22.7	27.1	42.8
Shadow Brook Creek at River Road	18.7	30.5	35.0	52.5
Shadow Brook Creek at 96th Avenue	24.2	38.0	47.5	78.6
Regal Drive Creek at River Road	16.7	26.3	32.9	54.4
Delta Creek at River Road	14.5	21.1	25.1	38.9
Delta Creek at 96th Avenue	14.3	20.0	22.8	29.2
<i>Similar Residential Catchments</i>				
Shaw Creek ISMP	16.7	22.4	26	36.6
Quibble Creek 619ha 44% TIA (Surrey) – calibrated model	14	24	-	48
Upper Serpentine 199ha 66% TIA (Surrey) – calibrated model	19	29	-	45
Surrey Design Criteria Manual - Table 5.3 (j) – SFR Runoff Design Value	17	-	-	-

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

Peak water level estimates are shown in Tables 3-4 and 3-5 below. Because the catchment is largely built out, the future land use changes would increase the peak water levels by less than 0.2 m.

Table 3-4: Water Levels at Strategic Locations for Existing Land Use

Location	Invert (m) Geodetic	Peak Instantaneous Water Level Estimate (m)					
		2-year	5-year	10-year	25-year	50-year	100-year
Sunbury Creek at Outfall	2.01	2.90	3.51	3.69	3.99	4.17	4.29
Nelson View Creek at Outfall	5.03	5.12	5.14	5.15	5.17	5.18	5.19
McAdam Creek at Outfall	7.76	8.10	8.20	8.25	8.30	8.33	8.36
McAdam Creek at Nordel Way	17.42	17.68	17.75	17.78	17.82	17.85	17.87
Collings Creek at Outfall	10.84	10.91	10.94	10.96	10.97	10.99	11.00
Norum Creek at Outfall	14.35	14.51	14.54	14.56	14.62	14.64	14.66
Knudson Creek at Outfall	2.90	3.16	3.23	3.27	3.33	3.37	3.41
Kendale Creek at River Road	16.41	16.62	16.67	16.69	16.72	16.74	16.76
Shadow Brook Creek at River Road	5.77	5.80	5.81	5.82	5.82	5.83	5.87
Shadow Brook Creek at 96th Avenue	37.98	38.08	38.10	38.11	38.12	38.13	38.14
Regal Drive Creek at River Road	13.69	13.73	13.74	13.75	13.76	13.77	13.77
Delta Creek at River Road	10.87	10.96	10.98	10.99	11.01	11.02	11.02
Delta Creek at 96th Avenue	77.80	79.38	81.51	82.73	84.22	84.80	85.40



Table 3-5: Water Levels at Strategic Locations for Future Land Use

Location	Invert (m) Geodetic	Peak Instantaneous Water Level Estimate (m)					
		2-year	5-year	10-year	25-year	50-year	100-year
Sunbury Creek at Outfall	2.01	2.94	3.59	3.74	4.05	4.21	4.33
Nelson View Creek at Outfall	5.03	5.12	5.14	5.15	5.17	5.18	5.19
McAdam Creek at Outfall	7.76	8.11	8.21	8.25	8.30	8.34	8.37
McAdam Creek at Nordel Way	17.42	17.69	17.76	17.79	17.83	17.85	17.88
Collings Creek at Outfall	10.84	10.92	10.94	10.96	10.98	10.99	11.00
Norum Creek at Outfall	14.35	14.51	14.55	14.57	14.62	14.64	14.66
Knudson Creek at Outfall	2.90	3.16	3.23	3.28	3.33	3.37	3.41
Kendale Creek at River Road	16.41	16.62	16.67	16.69	16.72	16.74	16.76
Shadow Brook Creek at River Road	5.77	5.80	5.81	5.82	5.82	5.83	5.92
Shadow Brook Creek at 96th Avenue	37.98	38.08	38.10	38.11	38.12	38.13	38.14
Regal Drive Creek at River Road	13.69	13.73	13.74	13.75	13.76	13.77	13.77
Delta Creek at River Road	10.87	10.96	10.98	10.99	11.01	11.02	11.03
Delta Creek at 96th Avenue	77.80	79.52	81.70	82.93	84.42	85.00	85.60

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

Capacity Assessment

Minor System

The minor trunk storm sewers were assessed to evaluate their ability to convey the minor flow, generated by the 10-year return period rainfall event. The following criteria were used to flag undersized pipes:

- Modelled 10-year instantaneous peak flow is larger than pipe capacity under free-flowing conditions; and
- Pipe surcharged for longer than 30 minutes.

Existing Land Use Conditions Minor System

Figure 3-1 schematically shows the pipes that exceeded the two criteria during the existing land use conditions 10-year event model runs. Table E-2 in Appendix E lists the pipes that exceeded the minor system criteria, listed above. Eleven out of 296 minor system pipes modelled exceeded the criteria and were flagged for consideration in the upgrade plan.

Future Land Use Conditions Minor System

An additional two pipes exceeded the criteria for the future land use scenario models. These additional pipes are adequately sized for the existing conditions but would need to be upgraded to accommodate the future conditions flows. The future conditions models did not account for potential detention that may be implemented as part of ongoing development in the watershed. These two pipes may not need replacing if detention is incorporated into future development plans.



Figure 3-1 schematically shows the pipes that exceeded the two criteria during the future land use conditions 10-year event model runs. Table E-3 in Appendix E lists the pipes that exceeded the minor system criteria, listed above.

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 at the end of their life cycle. Recommendations for upgrades and priorities are included in Section 4.

Major System

The major system is the conveyance system that carries large storms, greater than the 10-year event and up to the 100-year event. Road surfaces and day lighted sections of creeks make up the majority of the major system in this watershed.

The other elements that make up the major drainage system are storm sewers in private property without a safe overland flow path and all culverts. These elements were assessed.

Storm Mains

Storm sewers in private property were checked to determine if they had easements that would accommodate overland flow. It is standard industry practice to construct an overland swale that parallels the pipe in the easement, usually directly above the pipe. These swales should be part of the major system and their purpose is to prevent large flows from being directed towards adjacent lots. The existence of these swales was not verified, but they are assumed to be in place and to have adequate capacity in locations with easements.

For storm sewers in private property without an associated easement, the major flow must be conveyed in the storm sewer without an overland flow route. Three such locations were found. The three locations (7 pipes) are the only storm mains in the storm sewer system that were assessed as part of the major system.

A storm main assessment was performed to determine if any storm mains were undersized and required upgrading. The assessment criteria were:

- Modelled 100-year instantaneous peak flow is larger than pipe capacity under free-flowing conditions; and
- Upstream manhole flooded.

The results indicated that four pipes out of a total of seven would not meet the criteria for the existing land use flows. No additional culverts failed the criteria for the future flows. Figure 3-2 schematically shows these pipes. Refer to Table E-4 in Appendix E for the results pipes that exceeded the major system criteria, listed above.

Culverts

Additionally, all culverts have been designated as part of the major system when they are between daylighted sections of the creeks. This is to ensure that major flows from the daylighted sections have a major flow route and do not cause damage to neighbouring properties.

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



- Modelled 100-year instantaneous peak flow is larger than culvert capacity under free-flowing conditions; and
- Culvert surcharged for longer than 30 minutes.

The results indicated that five culverts out of a total of 15 modelled would not meet the criteria for the existing land use flows. No additional culverts failed the criteria for the future flows. Figure 3-2 schematically shows these culverts. Refer to Table E-5 in Appendix E for the culverts that exceeded the criteria, listed above.

A local deficiency is located at Russel Drive at Watson Drive. This deficiency was not modelled as it is not on the major drainage system, but has been identified by Delta staff.

3.3 Watershed Health Tracking System

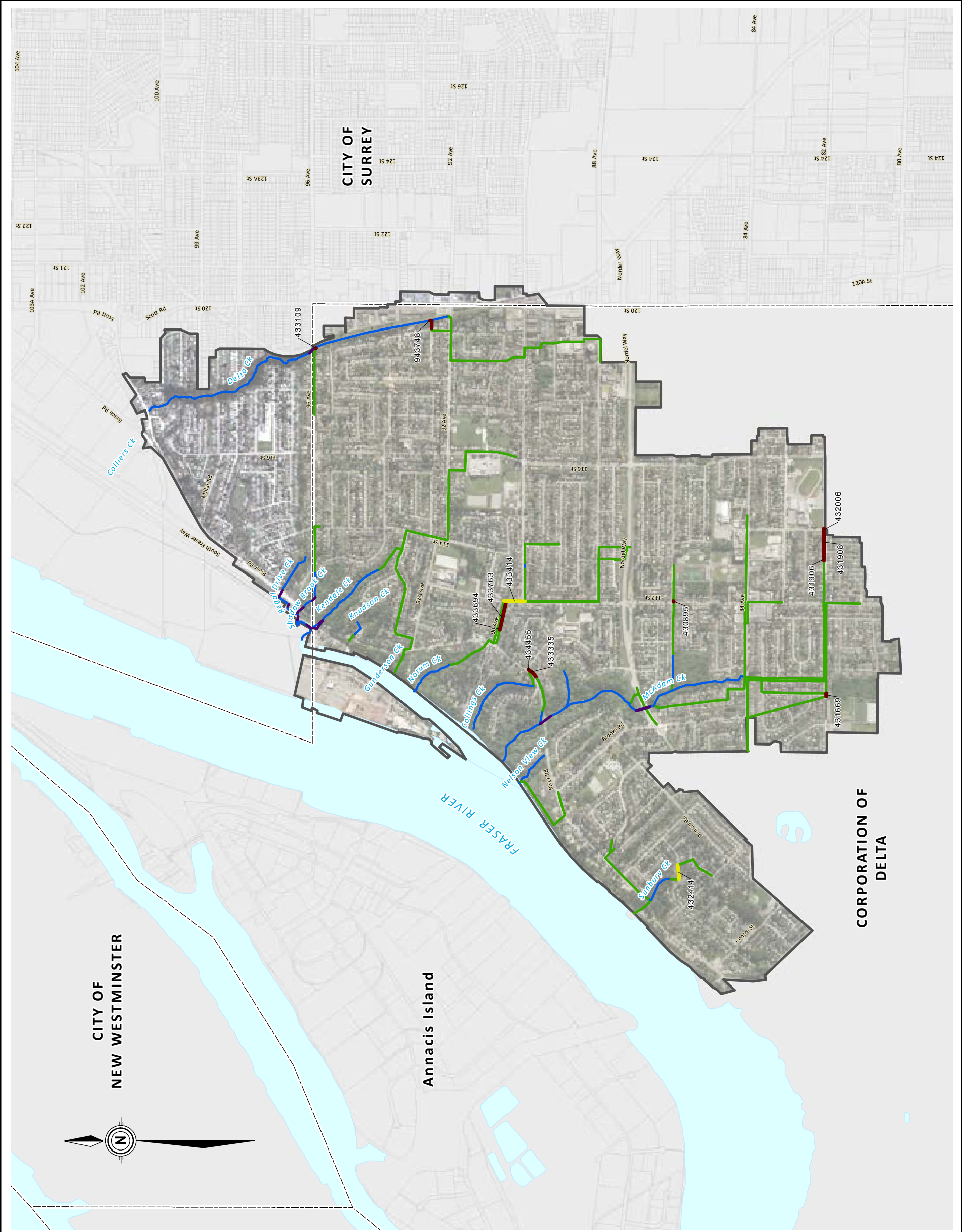
The watershed health was estimated using the Watershed Health Tracking System (WHTS) which uses the indicators of impervious percentage and riparian forest integrity to estimate the benthic index of biotic integrity (B-IBI) score. Figure 3-3 shows the WHTS graph for a number of locations in the study area. B-IBI sampling was only undertaken on McAdam Creek (see Figure 2-6 for sample locations).

The B-IBI samples collected, as discussed in Section 2.4, resulted in the scores shown in Table 3-6. There was general agreement between the measured score and that predicted by the WHTS from impervious area and riparian forest integrity.

Table 3-6: Measured and Predicted B-IBI Scores

Sampling Location	2013 B-IBI Score	
	Measured	WHTS Predicted
McAdam Creek	18	15
See Figure 2-6 for sampling locations.		

The land use analysis shows that imperviousness is predicted to increase by approximately 3%. Measures will be proposed to mitigate the watershed health impacts due to future land use changes and perhaps to improve stream health in certain areas.



**Corporation of Delta
North Delta Ravines
ISMP**

Legend

- Municipal Boundary
- Study Boundary
- Watercourse
- Modelled Culverts
- Modelled Conveyance System
- Modelled Creek / Ditch

Minor Storm Mains

- Pipes that Fail the 10-Year Existing Landuse Conditions
- Pipes that Fail the 10-Year Future Landuse Conditions

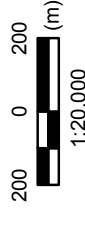
Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

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



KERR WOOD LEIDAL
consulting engineers

Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are authorized to use these materials for the purpose of conducting business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.









Project No.	Date
323-073	May 2014

**Minor System
Capacity Assessment**



Figure 3-1

Corporation of Delta
North Delta Ravines
ISMP

Legend

-  Municipal Boundary
-  Study Boundary
-  Watercourse
-  Modelled Culverts
-  Modelled Conveyance System
-  Modelled Creek / Ditch

Existing Landuse Flows

-  Culverts - That Fail the 100-Year Existing Land Use Conditions
-  Storm Mains - That Fail the 100-Year Existing Land Use Conditions

Note: No additional major system features failed during the future land use conditions.

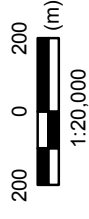
Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

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



KERR WOOD LEIDAL
consulting engineers

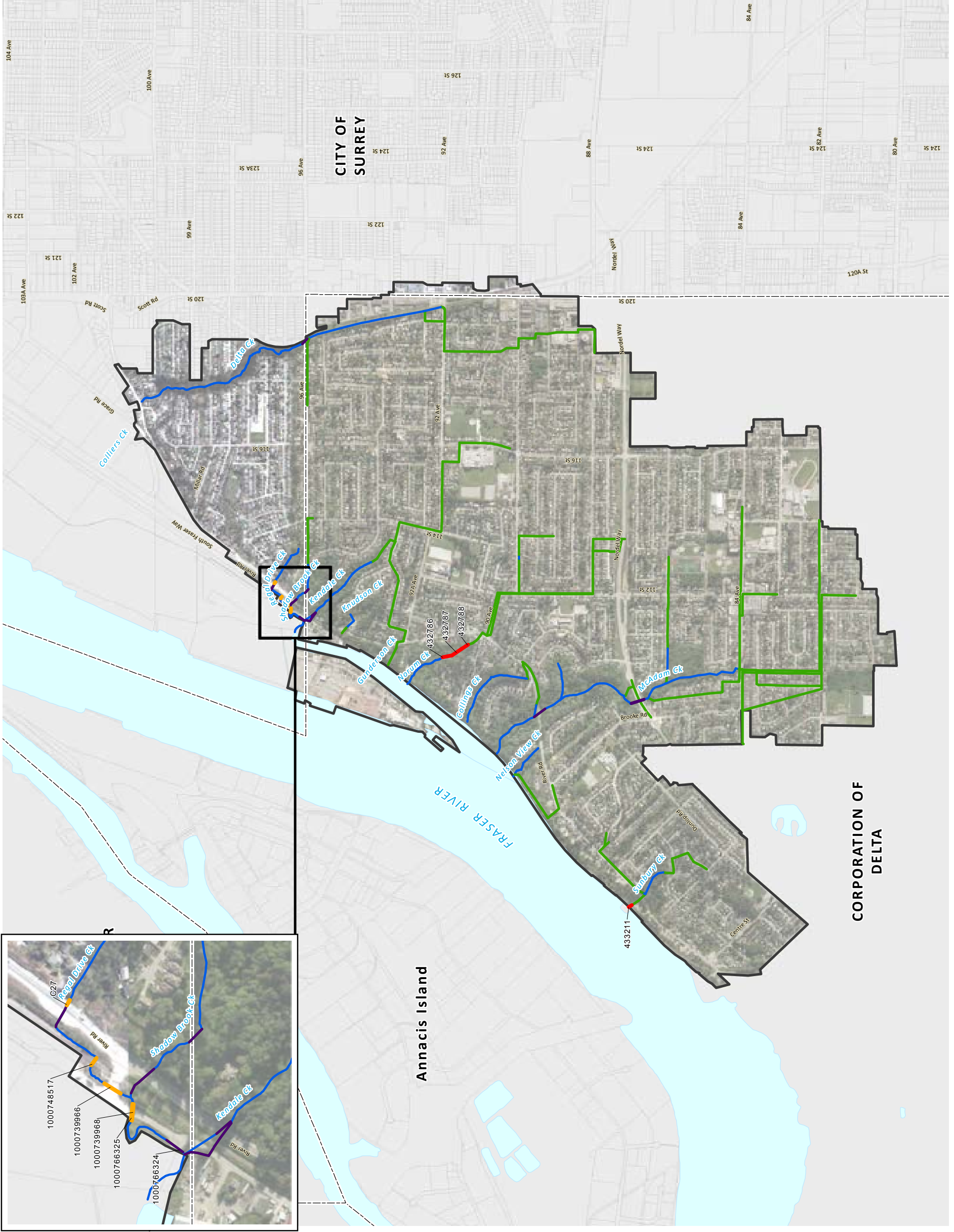
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are permitted to use these materials for the purpose of conducting business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073 Date May 2014

Major System
Capacity Assessment

Figure 3-2



Watershed Health Tracking System North Delta for Existing and Unmitigated Future Development

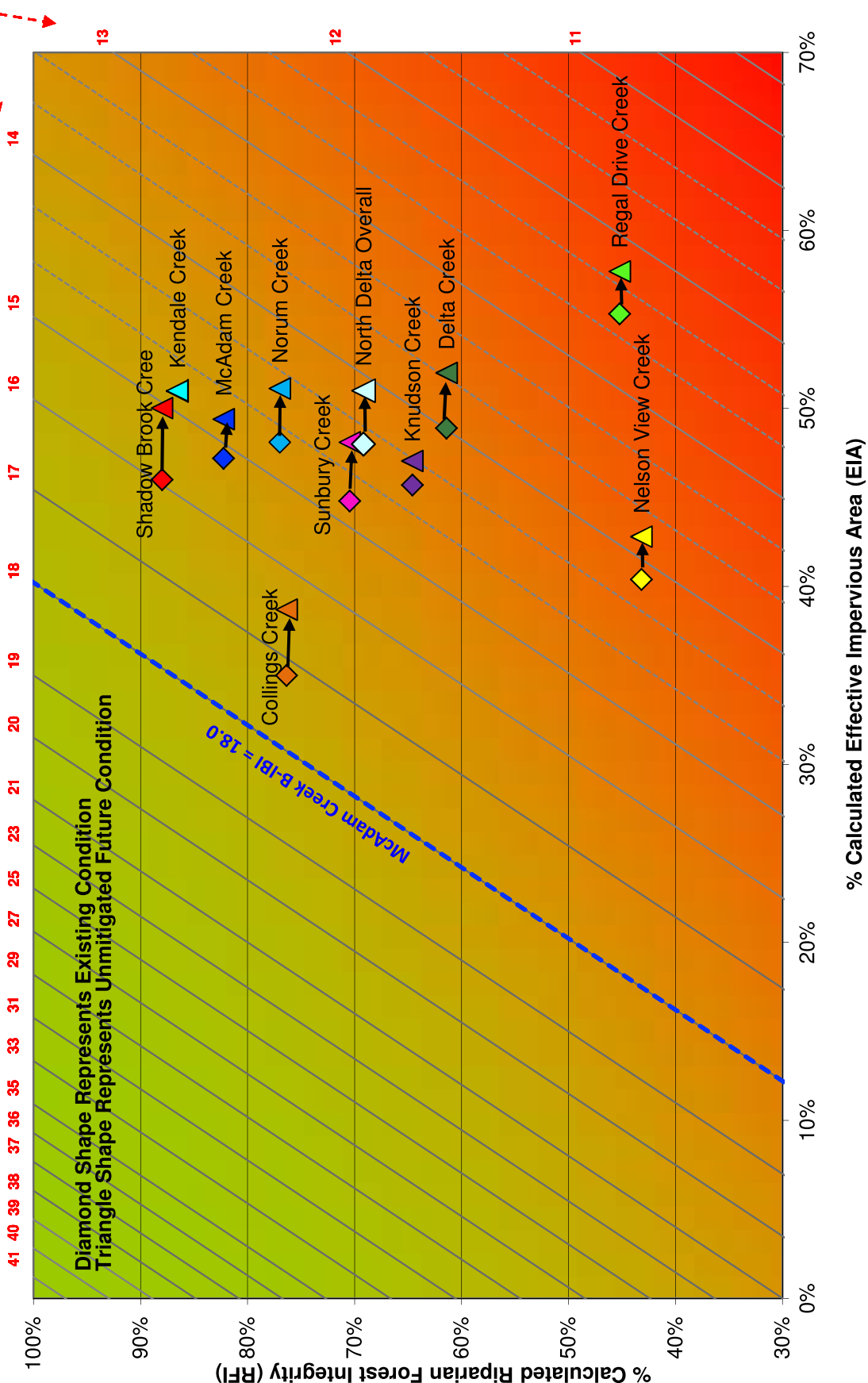


Figure 3-3

O:\0300-0399\323-073\400-Work\Analysis\WHTSWHTS_ExcelV2.xlsxFig_3-3



4. Mitigation Alternatives

4.1 Introduction

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

4.2 Required Hydrotechnical Upgrades

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

- Delta to conduct a detailed geotechnical investigation on Collings Creek to provide an analysis of the slope stability of the slide area (E11 and E12);
- Delta to remove blockages in Collings Creek;
- Delta to place erosion protection and slope stabilization measures at the outfall PVC pipe located within the sloughing fill on McAdam Creek (E4 to E10);
- Surrey to upgrade culvert 1000766325 on Shadow Brook Creek to 1500 mm diameter pipe;
- Surrey to upgrade culvert 1000739968 on Shadow Brook Creek to 1500 mm diameter pipe;
- Surrey to upgrade culvert 1000739966 on Regal Drive Creek to 1800 mm diameter pipe;
- BNR to upgrade culvert 1000748517 on Regal Drive Creek to 1650 mm diameter pipe;
- Surrey to upgrade culvert C27 on Regal Drive Creek to 1650 mm diameter pipe; and
- Delta to obtain ROW for pipes (See Table 4.1 for addresses).

The above list includes only high priority upgrades. Medium and low priority upgrades are listed in Table 4-1 and are shown on Figure 4-1. Low priority upgrade pipes should be replaced at the end of their design life or as DCC replacements as indicated in Table 4-1.

4.3 Mitigate Impacts of Future Development

To meet the no-net-loss requirement of an ISMP, future development impacts need to be mitigated. This mitigation can be performed at the source or with compensation works elsewhere in the watershed. The developable portions of the watershed are already largely developed and any future densification would be from re-development. Compensation works for redeveloping parcels are an option once the potential impacts can be quantified and projects from Section 4.4 could be used to offset redevelopment impacts. However, it is difficult to estimate how much of the area will redevelop and therefore difficult to



estimate the required amount of compensation works. Therefore, for the purpose of this ISMP, developers in both Surrey and Delta should apply the following source controls to allow development while not making conditions worse in the downstream creeks before considering compensation works (see Figure 4-2):

- Apply volume reduction source controls on all redevelopment areas including roadways for all areas draining to creeks (areas piped directly to Fraser River are excluded from this requirement). For redevelopment areas place 150 mm of amended topsoil in all pervious areas and disconnect roof leaders to maintain existing runoff volumes. For roadways, the types of source controls for volume reduction are discussed in Appendix F. Capture 6-month 24-hour storm (31 mm) to meet the DFO Guideline and avoid making creek erosion worse. Figure 4-3 shows the WHTS for the improvement alternatives. The line labeled “Redev. Source Controls” represents this item.
- Treat runoff from all new paved surfaces (draining to creeks or the Fraser River), including municipal roadways, resulting from a 6-month 24-hour storm (or 90% of annual flows) to remove pollutants. The types of source controls for water quality treatment are discussed in Appendix F. This level of treatment will meet the DFO Guideline.
- Restrict post-development flows to pre-development levels for all storms up to and including the 5-year storm on all new development and roadways and redevelopment draining to creeks (areas piped directly to Fraser River are excluded from this requirement) as per the Surrey Design Criteria Manual and the DFO Guidelines. The Delta Stormwater Management Design Manual requires a further detention of the 10-year return period flows for development in Delta.
- Protect riparian areas as per the existing bylaws, using the Riparian Areas Regulation (RAR) in Surrey and the Streamside Protection Regulation (SPR) in Delta.

4.4 Improve Watershed Health

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

Riparian Reforestation

Riparian forest integrity (RFI) is one of the major indicators of watershed health as shown on the WHTS discussed in Section 3.3. Approximately 68% (30.1 ha) of the riparian zones surrounding the North Delta study streams is currently forested. It varies from 41% along Regal Drive Creek to 82% along McAdam Creek. This is considered high for urban watersheds in Metro Vancouver.

Opportunities to improve riparian forest cover are limited because most of the ravine areas are forested, and other riparian areas are used for residential development or road corridors. Opportunities in parks and public lands which are often considered high priorities are almost non-existent in the study area. Redevelopment will provide opportunities to reduce encroachment into riparian areas and replant riparian forest. Specific riparian reforestation opportunities in the study area (shown in green on Figure 4-2) include the following:



- A. Encourage stewardship and riparian reforestation to increase riparian forest along lower Knudson Creek;
- B. Removing debris in McAdam Creek riparian zone associated with abandoned mink farm and restoring riparian conditions;
- C. Enhancing riparian forest along stream channels in rail and road corridor near Robson and Elevator roads (including possible road relocation or closures); and
- D. Restoring riparian forest along the lower section of Shadow Brook Creek upstream of River Road.

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

Water Quality Improvement

Water quality and sediment sampling did not identify any specific issues of concern in the North Delta study streams and water quality is considered to be similar to other moderately urbanized streams in Metro Vancouver. Further monitoring is required to more conclusively identify and quantify specific sources of pollutants, specifically during larger storms or during first-flush conditions. Further actions (shown in blue on Figure 4-2) include:

- A. Undertake additional water quality assessment and monitoring actions using Metro Vancouver’s regional strategy entitled: “ISMP Adaptive Management Framework”. This includes collecting data on general water quality parameters, nutrients, microbiological indicators, metals, and hydrocarbons and comparing to published thresholds and ranges.
- B. Consider policy to retrofit stormwater systems in residential paved areas (parking areas, roads, and driveways) to capture and trap fine sediment in rock pits, vegetated swales, oil-grit separators, chambers, or rain gardens to reduce the movement of contaminants into streams.
- C. Conduct further sampling of microbiological indicators (E. coli + fecal coliforms) during low flow conditions in August-September to identify cross-connections between sanitary and storm systems. A geometric mean of five samples in 30 days is needed to compare to BC Water Quality Guidelines.

Volumetric Reduction to Mitigate Existing Development Impacts

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

- A. Develop a policy to construct full volume reduction source controls during redevelopment/densification of single family lots to not only maintain EIA at existing values but reduce the EIA to 10% to reduce the overall study area EIA to less than existing (2013) values. The line labeled “Retrofit Lots” on Figure 4-3 represents this item.
- B. Develop a policy to encourage retrofit of institutional and municipal owned lots by directing pavement and roof runoff to rain gardens or other source controls (e.g. Schools). Retrofits would reduce EIA to 10% on these parcels. The line labeled “Inst. Source Controls” on Figure 4-3 represents this item.
- C. Evaluate program to help homeowners install rain barrels on existing single family development in Surrey to reduce potable water usage and increase rainfall capture.



- D. Explore options to allow disconnected roof runoff directed to landscaped areas in areas on existing single family development in Delta and initiate a program to help homeowners do so. This would reduce the EIA of approximately 428 ha of residential area by approximately 15%. The line labeled "Disconnect RL" on Figure 4-3 represents this item.
- E. Encourage homeowners to plant trees on their properties to increase evapotranspiration and reduce runoff volumes to creeks.
- F. Surrey and Delta could develop and implement policy to retrofit existing streets with roadside source controls in upland areas to reduce the EIA from 100% to 10% of approximately 204 ha of road right-of-way in the study area. The line labeled "Retrofit Roads" on Figure 4-3 represents this item.

Fish Habitat Improvements

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

- A. Increase habitat complexity in lower McAdam Creek using the addition of logs, boulders, and gravel-cobble weirs;
- B. Instream habitat complexing in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible road closure or relocation);
- C. Restore intertidal marsh habitat at mouth of Kendale Creek, including possible relocation or closure of Elevator Road; and
- D. Incorporate fish passage when upgrading the Sunbury Creek culvert under railway (see Table 4-1).

4.5 Evaluation of Potential Projects

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

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

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

Table 4-1: Issues and Improvement Alternatives

Category	Key Issue	Creek	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	Comment	Recommended (Y/N)	Identified By			
Erosion and Sedimentation (Requirement) - See Figure 4-1 for Locations														
Detailed Geotechnical Investigation	Remove Blockages	Collings Creek	Conduct a detailed geotechnical investigation of subsurface soils and groundwater conditions to provide a quantitative analysis of the slope stability in the slide area with a factor of safety for seismic and static conditions	Determine stability of slope failure area	\$ 20,000	Short Term	High	Delta		Y	exp			
			Remove blockages within ravine to prevent water build-up	Prevent destabilization of the toes of slopes that may allow more slides to occur	\$ 100,000	Short Term	High		Difficult due to access	Y	exp			
			Provide erosion protection and slope stabilization measures to slope below the outfall PVC pipe located within sloughing fill (8578 109B Street)	Prevent failure of the fill slope and pipe	\$ 70,000	Short Term	High	Delta	Difficult due to access	Y	exp			
Hydrotechnical Improvements (Requirement) - See Figure 4-1 for Locations														
Major System														
Culvert Capacity	C27 (Regal Drive Creek at River Road)	1000766325 (Shadow Brook Creek at Robson Road)	Replace existing 1200 mm culvert with 1800 mm culvert	Meet the Surrey capacity criteria.	\$ 33,000	Short Term	High	Surrey		Y	KWL			
			Replace existing 800 mm culvert with 1600 mm culvert	Meet the Surrey capacity criteria.	\$ 82,000	Short Term	High	Surrey		Y	KWL			
			Replace existing 800 mm culvert with 1600 mm culvert	Meet the Surrey capacity criteria.	\$ 81,000	Short Term	High	Surrey		Y	KWL			
			Replace existing 900 mm culvert with 1800 mm culvert	Meet the Surrey capacity criteria.	\$ 130,000	Short Term	High	Surrey		Y	KWL			
			Replace existing 900 mm culvert with 1800 mm culvert	Meet the BNR capacity criteria.	\$ 52,000	Short Term	High	BNR		Y	KWL			
			Obtain ROW for Pipe (GID 432786)	Provide safe flow route for major flows.	\$ 115,000	Long Term	Low	Delta	Does not take 100-year flow but no buildings are in the way	Y	KWL			
			Obtain ROW for Pipe (GID 432787)	Provide safe flow route for major flows.	\$ 138,000	Long Term	Low	Delta		Y	KWL			
			Obtain ROW for Pipe (GID 432788)	Provide safe flow route for major flows.	\$ 87,000	Long Term	Low	Delta		Y	KWL			
			Safe Major Flow Path	Sumbury Creek Outfall Pipe (Under Railway)		Replace existing 600 mm pipe with 900 mm pipe	Provide safe flow route for major flows.	\$ 26,000	Long Term	Low	Delta		Y	KWL

Table 4-1: Issues and Improvement Alternatives

Category	Key Issue	Creek	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	Comment	Recommended (Y/N)	Identified By
Hydrotechnical Improvements (Requirement) Continued - See Figure 4-1 for Locations											
1											
	Minor System										
		11202 86 Ave - 8589 112 St	Replace existing 300 mm Pipe with 675 mm pipe and upgrade 6 additional downstream pipes to 675 mm.	Meet the Delta capacity criteria.	\$ 251,000	Medium Term	Medium	Delta		Y	KWL
		11365 82 Ave- 11247 82 Ave	Replace existing 300 mm Pipe with 525 mm pipe and upgrade 3 additional downstream pipes to 525 mm.	Meet the Delta capacity criteria.	\$ 256,000	Medium Term	Medium	Delta		Y	KWL
		8979 Russell Dr- McAdam Creek	Replace existing 300 mm Pipe with 450 mm pipe and upgrade 6 additional downstream pipes to 450 mm.	Meet the Delta capacity criteria.	\$ 190,000	Medium Term	Medium	Delta		Y	KWL
		11375 82 Ave	Replace existing 250 mm Pipe with 450 mm pipe	Meet the Delta capacity criteria.	\$ 27,000	Medium Term	Medium	Delta		Y	KWL
		11132 90 Ave	Replace existing 300 mm Pipe with 600 mm pipe	Meet the Delta capacity criteria.	\$ 7,000	Medium Term	Medium	Delta		Y	KWL
		11132 90 Ave- 9044 112 St	Replace existing 300 mm Pipe with 600 mm pipe	Meet the Delta capacity criteria.	\$ 151,000	Medium Term	Medium	Delta		Y	KWL
		River Rd (Delwood Dr to Terrace Dr)	Replace existing 1050 mm Pipe with 1350 mm pipe	Meet the Delta capacity criteria.	\$ 141,000	Medium Term	Medium	Delta		Y	KWL
		8205 114 St- 11247 82 Ave	Replace existing 450 mm Pipe with 525 mm pipe and upgrade 4 additional downstream pipes to 525 mm.	Meet the Delta capacity criteria.	\$ 267,000	End of Life	Low	Delta		Y	KWL
		11269 82 Ave	Replace existing 450 mm Pipe with 525 mm pipe	Meet the Delta capacity criteria.	\$ 58,000	End of Life	Low	Delta		Y	KWL
		10956 82 Ave	Replace existing 300 mm Pipe with 375 mm pipe	Meet the Delta capacity criteria.	\$ 11,000	End of Life	Low	Delta		Y	KWL
		96 Ave outfall to Delta Creek	Replace existing 600 mm Pipe with 675 mm pipe	Meet the Delta capacity criteria.	\$ 3,000	End of Life	Low	Delta		Y	KWL
		10525 Main St- outfall to Sunbury Creek	Replace existing 375 mm Pipe with 525 mm pipe and upgrade 2 additional downstream pipes to 525 mm.	Meet the Delta capacity criteria.	Developer	At Time of Dev.	Low	Delta	Not needed if detention to predevelopment is provided	Y	KWL
		8984 112 St- 10986 River Rd.	Replace existing 600 mm Pipe with 900 mm pipe and upgrade 2 additional downstream pipes to 900 mm.	Meet the Delta capacity criteria.	Developer	At Time of Dev.	Low	Delta		Y	KWL
Hydrologic Mitigation of Future Development/Densification (Requirement)											
			Implement policy to apply volume reduction source controls on all new development / redevelopment including roadways to maintain existing EIA and catchment flow characteristics. Capture 6-month 24-hour storm (31 mm) to meet the DFO Guideline & mitigate creek erosion.	Restore pre-development hydrology on densifying parcels and roads to minimize EIA increase of additional impervious surfaces.	Developer	At Time of Dev.	High	Surrey Delta		Y	KWL
	Reduce Erosive Flows from Development	All Areas Draining to Creeks	Treat runoff from new paved surfaces, including municipal roadways to remove pollutants using biofiltration or manufactured systems (swales, rain gardens, oil/grit separators, etc.).	Remove pollutants from proposed additional travelled surfaces to meet DFO WQ Guideline.	Developer	At Time of Dev.	High	Surrey Delta	An option would be to construct regional WQ facilities but this would require land.	Y	KWL
	Treat Water Quality from Development	All	Detain post-development flows to pre-development levels for all storms up to and including the 5-year storm for all new development, new roadways, and redevelopment using onsite detention facilities. Additional 10-year detention required in Delta.	Maintain the peak flows at existing levels to meet the DFO, Delta, and Surrey requirements.	Developer	At Time of Dev.	High	Surrey Delta	An option would be to construct regional detention facilities.	Y	KWL
	Reduce Peak Flows from Development	All			Developer	At Time of Dev.	Ongoing	Surrey Delta	Existing bylaws/regulations in place	Y	KWL
	Riparian Protection	All Development Adjacent to Creeks	Protect riparian areas as per the RAR (Surrey) or SPR (Delta).	Meet Provincial and municipal riparian criteria.	Developer	At Time of Dev.	Ongoing	Surrey Delta		Y	KWL

Table 4-1: Issues and Improvement Alternatives

Category	Key Issue	Creek	Potential Project	Benefit	Capital Cost Estimate	Timeline	Priority	Action By	Comment	Recommended (Y/N)	Identified By
Watershed Health Improvement (Optional) - See Figure 4-2 for Locations											
Riparian Encroachment		Knudson	A. Encourage stewardship and riparian reforestation to increase riparian forest along lower Knudson Creek.	Improve stream health and increase riparian functions including wildlife habitat.	\$ 25,000	Medium Term	Medium	Delta		Y	Raincoast
		McAdam	B. Remove debris associated with mink farm from riparian zone; reforest disturbed areas.	Address possible impacts of contaminants (metals) on riparian habitat condition	\$ 75,000	Long Term	Low	Delta		Y	Raincoast
Water Quality Improvement		Shadow Brook and Regal Drive	C. and D. Riparian restoration and enhancement in lower sections of Shadow Brook and Regal Drive Creeks adjacent to railway and road corridor (including possible road closure or relocation).	Improve stream health and increase riparian functions including wildlife habitat.	\$ 50,000	Medium Term	High	Surrey BNR	does not include road related costs	Y	Raincoast
		Various Locations	E. Undertake additional water quality assessment and monitoring actions using Metro Vancouver's regional strategy.	Meet Metro Vancouver's ISMP Adaptive Management requirements.	\$ 10,000	Short Term	Medium	Surrey Delta		Y	Raincoast
			F. Consider policy to retrofit stormwater systems in residential paved areas (parking areas, roads, and driveways) to capture and trap fine sediment.	Capture and trap fine sediment to reduce the movement of contaminants into streams.	\$ -	Short Term	Medium	Surrey Delta		Y	Raincoast
			G. Conduct further sampling of microbiological indicators (E. coli + fecal coliforms) during low flow conditions in August-September.	Identify cross-connections between sanitary and storm systems.	\$ 10,000	Short Term	Medium	Surrey Delta		Surrey Delta	Delta is smoke testing already and CETU
3	Mitigate Existing Development through Volumetric Reduction	All	H. Develop policy to construct source controls during redevelopment to reduce EIA to less than existing values (e.g. during densification of 35% imp SFR area to 47%, reduce EIA to less than 35%).	Reduce overall EIA to less than 2013 value	Developer	Ongoing	High	Surrey Delta	Very long term strategy as lots are redeveloped. Consider incentives to maximize EIA reduction.	Y	KWL
		All	I. Develop program to encourage retrofit of institutional and municipal owned lots with 31 mm volume reduction source controls for pavement and roof runoff.	Reduce the EIA of the lots to 10%	\$ 24,235,300	Medium Term	Low	Surrey Delta		Y	KWL
		Surrey	J. Evaluate a program to help homeowners install rain barrels on existing single family development in Surrey.	Reduce potable water usage and increase rainfall capture	\$ -	Short Term	Medium	Surrey	Delta has a rain barrel program	Y	KWL
		Delta	K. Explore options to allow disconnected roof runoff directed to landscaped areas in areas on existing single family development in Delta and initiate a program to help homeowners do so.	reduce the EIA of approx. 428 ha of residential area by 15%	\$ -	Short Term	Medium	Delta	Surrey already has disconnected roof leaders policy.	Y	KWL
		All	L. Encourage homeowners to plant trees on their properties to increase evapotranspiration and reduce runoff volumes to creeks.	Increase evapotranspiration reducing volumes to creeks and erosion	\$ -	Short Term	Medium	Surrey Delta		Y	KWL
		All	M. Consider policy to retrofit existing streets with roadside source controls.	reduce EIA of 204 ha from 100% to 10%.	Developer	At Time of Dev.	High	Surrey Delta	Very long term strategy as roads are redeveloped.	Y	KWL
Instream Habitat		McAdam	N. Increase complexity using the addition of logs, boulders, and gravel cobble weirs in lower McAdam Creek ravine	Increase fish populations by improving habitat quantity and quality.	\$ 25,000	Medium Term	High	Delta	Undertake during mink farm debris removal	Y	Raincoast
		Shadow Brook and Regal Drive	O. Instream habitat complexing in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible road closure or relocation).	Increase fish populations by improving habitat quantity and quality.	\$ 75,000	Medium Term	High	Surrey BNR		Y	Raincoast
Estuarine Habitat		Kendale and tributaries	P. Restore intertidal marsh habitat at mouth of Kendale Creek including possible relocation or closure of Elevator Road.	Improve habitat quantity and quality for migrating juvenile salmonids from study area stream and Fraser River.	\$ 100,000	Long Term	High	Surrey		Y	Raincoast
Fish Passage		Sunbury	Q. Incorporate fish passage when upgrading the Sunbury Creek culvert under railway.	Provide access to additional fish habitat in Sunbury Creek, as well as reduce habitat isolation of Sunbury ravine	\$ 20,000	Long Term	Low	Delta		Y	Raincoast


**Corporation of Delta
North Delta Ravines
ISMP**

Legend


-  Municipal Boundary
-  Study Boundary
-  Modelled Culverts
-  Modelled Conveyance System
-  Modelled Creek / Ditch


Major Storm Mains

 Culvert Capacity Upgrades

 Pipe Capacity Upgrades

Minor Storm Mains

 Pipe Capacity Upgrades (Capital Plan)

 Pipe Capacity Upgrades (DCC)

Note:

No additional major system features failed the future landuse conditions.

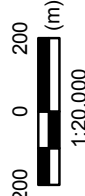
Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

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



KERR WOOD LEIDAL
consulting engineers

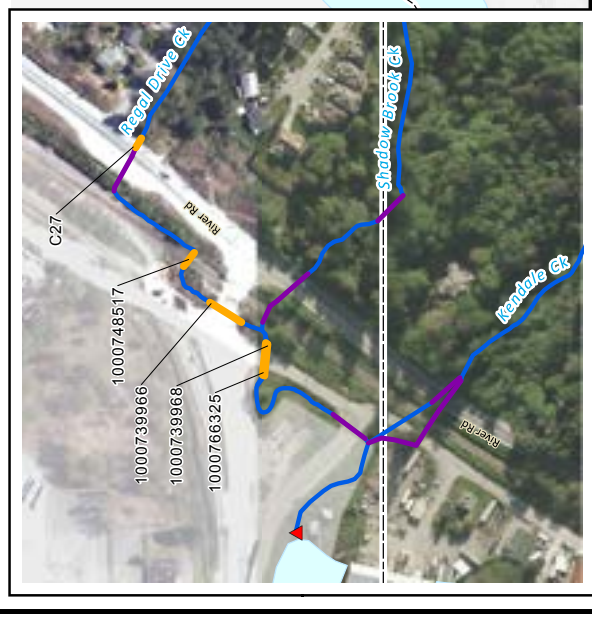
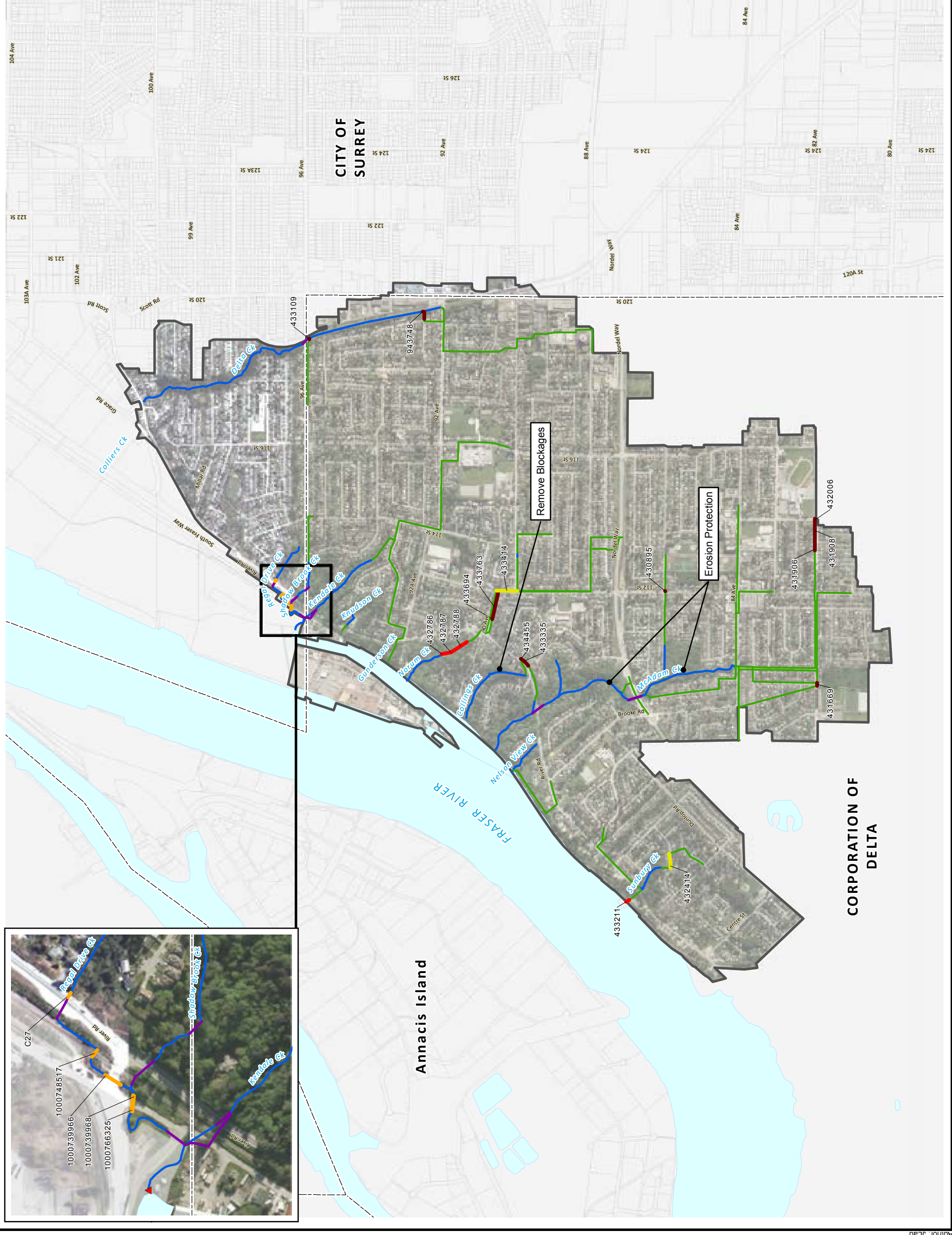
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are authorized to use these materials for the purposes of the study and to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073 Date May 2014

**Proposed
Mitigation of
Existing Deficiencies**

Figure 4-1



Future Redevelopment Requirements:
 Delta and Surrey to Set Policy to:

- Apply full volume reduction source controls (31 mm capture) for roadways.
- Apply 150 mm amended soil to all pervious areas on redeveloping lots and disconnect roof leaders to maintain existing runoff volumes.
- Treat water quality of pavement runoff for development/redevelopment including roadways.
- Protect riparian areas as per RAR or SPR.
- Detain peak flows from storms upto and including the 5-year return period to predevelopment rates for redevelopment including roadways. Additional 10-year detention is required in Delta.

Riparian Restoration:

- A. Encourage stewardship and riparian reforestation.
- B. Remove debris and restore riparian conditions.
- C. Enhance riparian forests along channels in rail and road corridor near Robson and Elevator Roads.
- D. Restore riparian forest.

Water Quality Improvement and Monitoring:

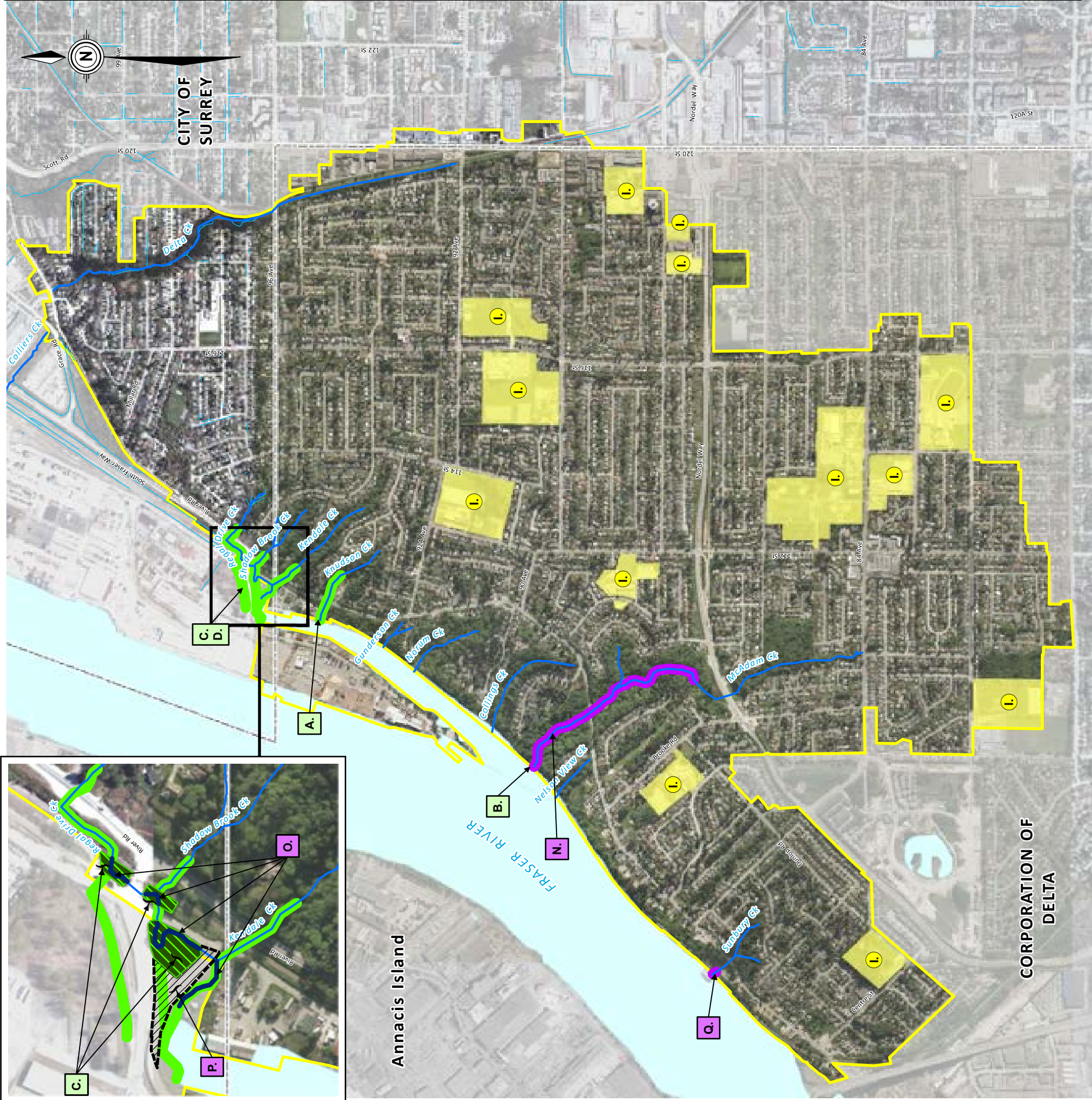
- E. Undertake additional water quality assessment and monitoring to comply with AMF.
- F. Consider policy to retrofit stormwater systems in residential areas to capture and trap fine sediments.
- G. Conduct further sampling of microbiological indicators during low flow to identify cross-connections between sanitary and storm system.

Volume Reduction:

- H. Develop policy to require reducing EIA to less than existing values on redeveloping lots.
- I. Develop policy to retrofit full volume reduction source controls with institutional and municipally-owned lots.
- J. Evaluate a program to install rain barrels on SFR lots in Surrey.
- K. Explore options to allow disconnected roofs leaders to lawn on SFR lots in Delta.
- L. Encourage residents to plant trees on their lots.
- M. Consider a policy to retrofit existing roads with source controls.

Fish Habitat Improvements:

- N. Increase habitat complexity using the addition of logs, boulders, and gravel cobble weirs.
- O. Instream habitat, complexing and road closure/relocation.
- P. Restore intertidal marsh habitat and possibly relocate or close Elevator Road.
- Q. Address large impassible culvert during site redevelopment.



**Corporation of Delta
 North Delta Ravines
 ISMP**

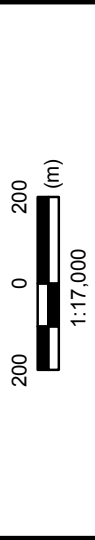
Legend

- Municipal Boundary
- Study Boundary
- Watercourse
- Habitat Complexing
- Riparian Reforestation
- Riparian Enhancement
- Intertidal Habitat Enhancement

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are permitted to use these materials for the purpose of conducting business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.

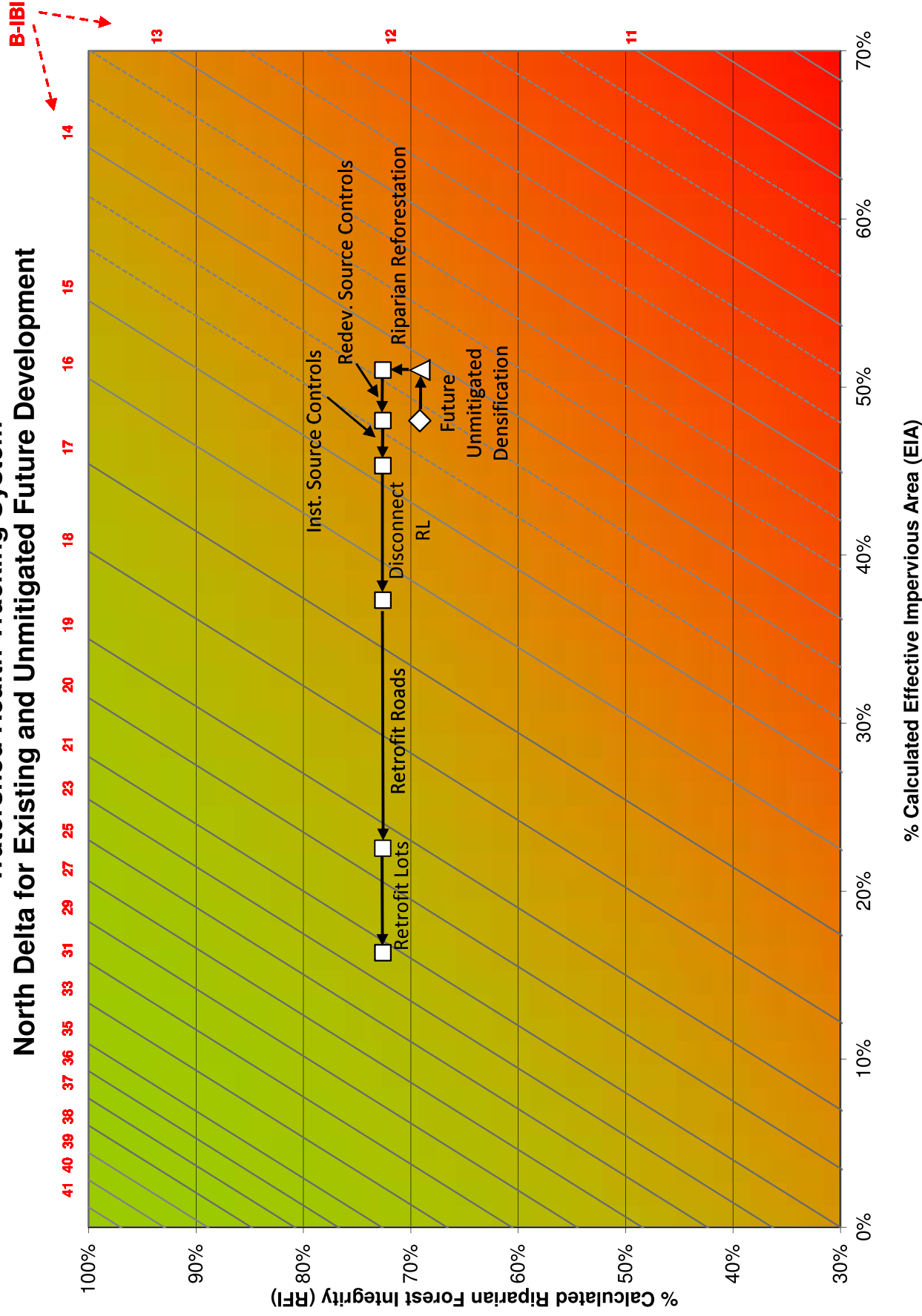


Project No. 323-073
 Date May 2014

**Watershed Health
 Improvement Alternatives**

Figure 4-2

Watershed Health Tracking System North Delta for Existing and Unmitigated Future Development





5. Proposed North Delta Ravines ISMP

5.1 Introduction

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

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

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

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

5.2 Required Hydrotechnical Improvements

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

Short Term Projects

The following short term projects are recommended as shown in pink on Figure 5-1:

1. Delta to conduct a detailed geotechnical investigation on Collings Creek to analyze the slope stability for seismic and static conditions (E11, E12). The slopes found in the ravine are considered to be marginally stable for the soil type, particularly where seepage and saturated soils are found. A significant slide area was found on the north slope and recently downed trees and soft saturated depositions indicate ongoing slope failures.
2. Delta to remove blockages from Collings Creek ravine as they occur to prevent water build up behind blockages that may destabilize slope (E11).
3. Delta to provide erosion protection and slope stabilization measures to the slope below the outfall PVC pipe (8578 109B Street).
- 4.-8. Surrey to replace culverts 1000766325 and 10000739968 with 1600 mm diameter pipes, culverts C27, and 1000739966 with 1800 mm pipes. BNR to replace culvert 1000748517 with 1800 mm pipe. Try to coordinate this project with the recommended environmental works in the area of the culvert replacements (Projects 38, 43, and 44 on Kendale and Shadow Brook Creeks). Surrey is completing an ISMP for the Manson Watershed and the recommendations in that report may supersede those recommended in this report.

Table 5-1: ISMP Class D Capital Cost Estimate

ISMP Component	Timeline	Class D Cost Estimates	
Hydrotechnical Improvements			
1. Conduct a detailed geotechnical investigation on Collings Creek	Short Term	\$20,000	Hydrotech. Subtotal
2. Remove blockages within ravine as they present to prevent water build up that may destabilize slope		\$100,000	
3. Provide erosion protection and slope stabilization measures to slope below the outfall PVC pipe (8578 109B Street)		\$70,000	
4. Replace existing 1200 mm culvert with 1800 mm culvert (C27 and 3DS)		\$352,300	
5. Replace existing 800 mm culvert with 1600 mm culvert (1000766325)		\$339,900	
6. Replace existing 800 mm culvert with 1600 mm culvert (1000739968)		\$339,900	
7. Replace existing 900 mm culvert with 1800 mm culvert (1000739966)		\$550,400	
8. Replace existing 900 mm culvert with 1800 mm culvert (1000748517)		\$324,500	
9. Replace existing 300 mm Pipe with 675 mm pipe and upgrade 6 additional downstream pipes to 675 mm (11202 86 Ave- 8589 112 St.)	Medium Term	\$373,200	
10. Replace existing 300 mm Pipe with 525 mm pipe and upgrade 3 additional downstream pipes to 525 mm (11365 82 Ave - 11247 82 Ave)		\$336,800	
11. Replace existing 300 mm Pipe with 450 mm pipe and upgrade 6 additional downstream pipes to 450 mm (8979 Russell Dr- McAdam Creek)		\$310,200	
12. Replace existing 250 mm Pipe with 450 mm pipe (11375 82 Ave)		\$53,600	
13. Replace existing 300 mm Pipe with 600 mm pipe (11132 90 Ave)		\$33,900	
14. Replace existing 300 mm Pipe with 600 mm pipe (11132 90 Ave-9044 112 St)		\$177,100	
15. Replace existing 1050 mm Pipe with 1350 mm pipe (River Rd (Delwood dr to Terrace Dr))	\$169,000		
16. Obtain ROW for Pipe (GID 432786)	Long Term	\$5,300	
17. Obtain ROW for Pipe (GID 432787)		\$6,400	
18. Obtain ROW for Pipe (GID 432788)		\$4,000	
19. Replace existing 600 mm pipe with 900 mm pipe (Sunbury Creek Outfall Pipe)		\$126,800	
20. Replace existing 450 mm Pipe with 525 mm pipe and upgrade 4 additional downstream pipes to 525 mm (8205 114 St-11247 82 Ave)		\$491,300	
21. Replace existing 450 mm Pipe with 525 mm pipe (11269 82 Ave)		\$84,800	
22. Replace existing 300 mm Pipe with 375 mm pipe (10956 82 Ave)		\$31,000	
23. Replace existing 600 mm Pipe with 675 mm pipe (96 Ave outfall to Delta Creek)		\$29,100	
24. Replace existing 375 mm Pipe with 525 mm pipe and upgrade 2 additional downstream pipes to 525 mm (10525 Main St- to Soutfall to Sunbury Creek)		By Developer	
25. Replace existing 600 mm Pipe with 900 mm pipe and upgrade 2 additional downstream pipes to 900 mm (8984 112 St- 10986 River Rd)		By Developer	
		\$4,329,500	
Water Quality Treatment			
26. Undertake additional water quality assessment and monitoring actions using Metro Vancouver's Adaptive Management Framework (see Section 5.8 for more detail).	Short Term	\$16,800	WQ Treat. Subtotal
27. Consider policy to retrofit stormwater systems in residential paved areas (parking areas, roads, and driveways) to capture and trap fine sediment.		By Municipality	
28. Conduct further sampling of microbiological indicators (E. coli + fecal coliforms) during low flow conditions in August-September.		\$16,800	
29. Treat runoff from new paved surfaces, including municipal roadways to remove pollutants using biofiltration or manufactured systems (swales, rain gardens, oil/grit separators, etc.).	At Time of Development and Ongoing	By Developer	
		\$33,600	
Volumetric Reduction to Mitigate Frequently Occurring Flows and Sustain Baseflows			
30. Evaluate a program to help homeowners install rain barrels on existing single family development in Surrey.	Short Term	By Municipality	Vol. Red. Subtotal
31. Explore options to allow disconnected roof runoff directed to landscaped areas in areas on existing single family development in Delta and initiate a program to help home owners do so.		By Municipality	
32. Encourage homeowners to plant trees on their properties to increase evapotranspiration and reduce runoff to creeks.		By Municipality	
33. Implement policy to apply volume reduction source controls on all new development / redevelopment including roadways to maintain existing EIA and catchment flow characteristics. Capture 6-month 24-hour storm (31 mm) to meet the DFO Guideline & mitigate creek erosion.	At Time of Development and Ongoing	By Developer	
34. Develop policy to construct source controls during redevelopment to reduce EIA to less than existing values (e.g. during densification of 35% imp SFR area to 47%, reduce EIA to less than 35%).		By Developer	
35. Consider policy to retrofit existing streets with roadside source controls.		By Municipality	
36. Develop program to encourage retrofit of institutional and municipal owned lots with 31 mm volume reduction source controls for pavement and roof runoff. (Cost reflect installation of rain gardens on these lots, not the cost associated with developing the program)	Medium Term	\$ 24,235,300	
		\$24,235,300	
Flow Rate Control to meet DFO Guidelines, and Surrey and Delta Bylaws			
37. Detain post-development flows to pre-development levels for all storms up to and including the 5-year storm for all new development, new roadways, and redevelopment using onsite detention facilities. Additional 10-year detention required in Delta.	At Time of Development	By Developer	
Riparian Protection and Enhancement			
38. Riparian restoration and enhance lower sections of Shadow Brook and Regal Drive Creeks adjacent to railway and road corridor (including possible road closure or relocation).	Short Term	\$84,000	Riparian Subtotal
39. Protect riparian areas as per the RAR (Surrey) or SPR (Delta).	At Time of Development and Ongoing	By Developer	
40. Encourage stewardship and riparian reforestation to increase riparian forest along lower Knudson Creek.	Medium Term	\$41,900	
41. Remove debris associated with mink farm from riparian zone on McAdam Creek; reforest disturbed areas.	Long Term	\$126,100	
		\$252,000	
Restoration and Enhancement for Fish			
42. Increase complexity using the addition of logs, boulders, and gravel cobble weirs in lower McAdam Creek ravine	Medium Term	\$42,000	Fish Habitat Subtotal
43. Instream habitat complexing in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible road closure or relocation).		\$126,000	
44. Restore intertidal marsh habitat at mouth of Kendale Creek including possible relocation or closure of Elevator Road.	Long Term	\$168,100	
45. Incorporate fish passage when upgrading the Sunbury Creek culvert under railway.		\$33,600	
		\$369,700	
TOTAL CAPITAL COST Excluding Developer Costs (Excluding HST)		\$29,220,100	
		Breakdown by Group	
Total Delta Cost		\$2,666,100	
Total Surrey Cost		\$1,750,600	
Total Delta/Surrey Cost		\$24,268,900	
Total BNR Cost		\$324,500	
Total BNR/Surrey Cost		\$210,000	
Total Developer Cost		not estimated	
		Breakdown by Timeline	
Total Short Term Cost		\$2,214,600	
Total Medium Term Cost		\$25,899,000	
Total Long Term Cost		\$1,106,500	



Medium Term Projects

The recommended medium term projects are shown in Table 5-2 and in pink on Figure 5-2.

Table 5-2: Medium Term Hydrotechnical Improvements

Project No.	Pipe ID	Approximate Location	Existing Size (mm)	Length (m)	Design Flow (m ³ /s)	Upgrade Size (mm)
9	430895	11202 86 Avenue - 8589 112 Street	300	3	0.60	675
	430882		600	52		675
	430887		600	93		675
	430890		600	4		675
	430891		525	20		675
	430995		525	38		675
	430996		300	21		675
10	431906	11365 82 Avenue - 11247 82 Avenue	300	91	0.48	525
	431884		450	85		525
	431900		450	63		525
	431892		450	66		525
11	434455	8979 Russell Drive - McAdam Creek	300	20	0.60	450
	433335		250	37		450
	434457		300	44		450
	434458		300	41		450
	433326		350	19		450
	433327		300	75		450
	433325		350	26		450
12	433335	11375 82 Avenue	250	37	0.60	450
13	433694	11132 90 Avenue	300	7	0.43	600
14	433763	11132 90 Avenue - 9044 112 Street	300	149	0.43	600
15	943748	River Road (Delwood Drive to Terrace Drive)	1,050	47	0.49	1,350



Long Term Projects

The long term/end-of-life replacement projects are shown in Table 5-3 and in pink on Figure 5-3.

Table 5-3: Long Term Hydrotechnical Improvements

Project No.	Pipe ID	Approximate Location	Existing Size (mm)	Length (m)	Design Flow (m ³ /s)	Upgrade Size (mm)
16	432786	11041-11031 River Road	900	53	5.36	Purchase ROW
17	432787	11031 River Road - 9150 Norum Road	900	63	5.36	Purchase ROW
18	432788	9150-9140 Norum Road	900	40	5.36	Purchase ROW
19	433211	Sunbury Creek Outfall	600	17	2.07	900
20	432006	8205 114 Street - 11247 82 Avenue	450	14	0.48	525
	431884		450	85		525
	431906		300	91		525
	431900		450	63		525
	431892		450	66		525
21	431908	11269 82 Avenue	450	69	0.48	525
22	431669	10956 82 Avenue	300	17	0.15	375
23	433109	96 Ave outfall to Delta Creek	600	2	0.85	675
24	432414	10525 Main St - outfall to Sunbury Creek	375	80	0.87	525
	432418		450	31		525
	432417		450	23		525
25	433414	8984 112 St - 10986 River Road	600	114	1.93	900
	433695		600	88		900
	433762		600	150		900

Shaded cells represent DCC projects

5.3 Water Quality Treatment

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

Short Term Projects

The following short term projects are recommended as shown in blue on Figure 5-1:

26. Delta to undertake additional water quality assessment and monitoring actions using Metro Vancouver's Adaptive Management Framework (see Section 5.8 for more detail). (No. 26)
27. Delta and Surrey to consider a policy to retrofit stormwater systems in residential paved areas to capture and trap fine sediments.
28. Delta to conduct further sampling of microbiological indicators (E.coli + fecal coliforms) during low flow conditions in August-September to identify cross-connections between sanitary and storm systems.



Developer, DCC, and Ongoing Projects

The following are recommended developer, DCC, and ongoing projects:

29. Delta and Surrey to require treatment from new paved surfaces, including municipal roadways, to remove pollutants using biofiltration or manufactured water quality treatment systems.

5.4 Volumetric Reduction to Mitigate Frequently Occurring Flows and Sustain Baseflows

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

Short Term Projects

The following short term projects are recommended as shown in **yellow** on Figure 5-1:

30. Delta to explore options to allow disconnected roof leaders directed to landscaped areas on existing single family development in Delta and initiate a program to help homeowners do so.
31. Surrey to evaluate a program to help homeowners install rain barrels on existing single family development.
32. Encourage homeowners to plant trees on their properties to increase evapotranspiration and reduce runoff volumes to creeks.

Developer, DCC, and Ongoing Projects

The following are recommended developer, DCC, and ongoing projects:

33. Both municipalities to implement a policy to apply volumetric reduction source controls on all new development / redevelopment including roadways to maintain existing EIA and catchment flow characteristics. Capture 6-month 24-hour storm (31 mm) to meet the DFO Guideline and mitigate creek erosion (see Appendix F for Typical BMPs).
34. Both municipalities to develop a policy to construct source controls during redevelopment to reduce EIA to less than existing values (e.g., during densification of 35% SFR area to 47%, reduce EIA to less than 35%).
35. Both municipalities to consider policy to retrofit existing streets with roadside source controls.

Medium Term Projects

The following medium term projects are recommended as shown in **yellow** on Figure 5-2:

36. Delta and Surrey to develop a program to encourage retrofit of institutional and municipal owned lots with volume reduction source controls to capture 31 mm of rain runoff from pavement and roof areas.



5.5 Flow Rate Control to Meet DFO Guidelines, and Delta and Surrey Bylaws

Flow rate control is the second step in addressing development impacts. The following flow rate control projects are proposed:

Developer, DCC, and Ongoing Projects

The following are developer, DCC, and ongoing projects:

37. Detain post-development flows to pre-development levels for all storms up to and including the 5-year storm for all new development, new roadways, and redevelopment using onsite detention facilities. Additional 10-year detention required in Delta.

5.6 Riparian Protection

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

Short Term Projects

The following short term projects are recommended as shown in **green** on Figure 5-1:

38. Surrey to complete riparian restoration on City property and BNR to complete riparian restoration on Railway property in the lower sections of Shadow Brook and Regal Drive creeks (including possible road closure or relocation) (to be completed in conjunction with instream enhancement works Project 43).

Developer, DCC, and Ongoing Projects

The following are recommended developer, DCC, and ongoing projects:

39. Protect riparian areas as per the Streamside Protection Enhancement Area By-Law in Delta and the Riparian Area Regulation in Surrey.

Medium Term Projects

The following medium term projects are recommended as shown in **green** on Figure 5-2:

40. Delta to encourage stewardship and riparian reforestation to increase riparian forest along lower Knudson Creek.

Long Term Projects

The following long term projects are recommended as shown in **green** on Figure 5-3:

41. Delta to remove debris associated with mink farm from riparian zone along McAdam Creek and reforest disturbed areas.



5.7 Restoration and Enhancement for Fish

Both fish-bearing and non-fish bearing streams are important to the sustainability of fish populations within watersheds and contribute to overall watershed health. There are a number of restoration and enhancement opportunities in the study area including the following:

Medium Term Projects

The following medium term projects are recommended as shown in purple on Figure 5-2:

42. Delta to increase complexity using the addition of logs, boulders, and gravel cobble weirs in lower McAdam Creek ravine.
43. Surrey to construct instream habitat complexing in lower sections of Shadow Brook and Regal Drive creeks adjacent to the BNR railway (no complexing on railway property) and road corridor (including possible road closure or relocation) (to be completed in conjunction with riparian reforestation Project 38).

Long Term Projects

The following long term projects are recommended as shown in purple on Figure 5-3:

44. Surrey to restore intertidal marsh habitat at the mouth of Kendale creek including possible closure or relocation of Elevator Road.
45. BNR to incorporate fish passage when upgrading the Sunbury Creek culvert under railway.

5.8 Public Access and Education

McAdam ravine is the only ravine in the study area that is potentially suitable for public access for recreational and education purposes but the steep side slopes of the ravine places very strict limits on this potential.

Increasing public access to the ravine would be difficult, potentially disruptive to habitat and would likely require physical structures such as stairs and viewing platforms, slope stabilization and other mitigation measures.

Although the potential to provide direct access to the ravine is very limited there is a range of other means to provide information and public education about the ravines and their ecological and stormwater function and to raise awareness of their importance and vulnerability, including signage, public information, outreach campaigns and public access.

Delta has a robust set of land use policies to protect ravines from development and permit them to perform their stormwater function. The ravines are designated "Development Permit" areas by the Official Community Plan and subject to Guidelines approved by Corporation Council. Delta's Planning regulations to protect the environmental quality and stormwater function of the ravines are comprehensive well co-ordinated and conform to the requirements of *the Local Government Act*. No additional Planning regulations are required.



5.9 Further Studies, Recommendations, and Monitoring Programs

Geotechnical Investigation

The geotechnical hazard assessment performed by exp identified the following recommended actions:

- Annual inspection of Shadow Brook creek at the area near the outfall to identify any acceleration of slope erosion. Measures such as rip rap may be appropriate if accelerated erosion is observed.
- Annual and post-storm inspection (after >5-year rain event) of slope conditions on Kendale Creek to confirm slope instabilities have not progressed up the slope, especially in the area 120 m west of the outfall at the east end of the ravine.
- Bi-annual review and further study of slope conditions on Collings Creek to assess the progress of slope movement.
- Annual review of McAdam Creek bank erosion and associated slopes to confirm that residential properties on the slope crest are not affected.

Hydrotechnical Investigation

A capacity study is recommended to determine the capacity and required upgrades for the local deficiency identified by Delta staff at Russel Drive at Watson Drive. This deficiency was not modelled as part of this study.

Ongoing Benthic, Water Quality and Sediment Sampling

To monitor the success of mitigation measures and measures to improve watershed health as outlined in the ISMP, ongoing benthic sampling of the same sites that were used in the ISMP is recommended. To establish trends over time, sites should be monitored approximately once every two years. At the time of the benthic sampling, water and sediment samples should be taken and analyzed to quantify long term trends of pollutants in the water and sediment. The cost of benthic, water and sediment sampling would be approximately \$33,600 per year for the 4 benthic and 6 water quality and sediment sampling locations used in this study.

Detailed Fish Presence and Fish Passage Investigations

Fish presence and distributions were derived from the detailed fisheries assessment completed previously by Coast River Environmental Services for the SFPR environmental impact assessment. Further fish sampling and a fish utilization study is recommended.

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

ISMP Performance Monitoring and Accountability of Plan

To measure and track the levels and changes in the health of a watershed, and to provide accountability to the ISMP, a suite of performance parameters has been developed that match the key issues identified above. Table 5-4 lists the parameters or 'indicators' that should be measured and tracked over time.



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

Table 5-4: North Delta Ravines Watershed Adaptive Management Indicators

Performance Indicator		Method of Analysis	2012	2017
1.	Total Impervious Area (% of Watershed Area)	GIS Analysis of Aerial Photos and Assessment Data	48%	Small increase expected due to development
2.	Effective Impervious Area (% of Watershed Area)	Estimated from surface cover type and source controls implemented	Flow monitoring required to quantify	decrease when source controls implemented
3.	Riparian Forrester Integrity (% of Riparian Area)	GIS Analysis of Aerial Photos	68%	Same or Increase
4.	Watershed Forest Cover (% of Watershed Area)	GIS Analysis of Aerial Photos	13%	Same or Increase
5.	Benthic Invertebrates	B-IBI scores based on methods used in this study	mean = 18.0	18
6.	Fish Populations	SFPR environmental impact assessment	7 of 11 streams support cutthroat Trout Three support coho Salmon	Confirm Data
7.	Fish Passage Barriers	SFPR environmental impact assessment	Full Barriers 5+ Partial Barriers 10	Several culverts need to be re-assessed Progressive Removal of non-natural Barriers
8.	Water Temperature (°C)	Field Measurement (during October)	Range: 9.9-14.1 Mean: 11.0	Same or Decrease
9.	Dissolved Oxygen (DO, mg/L)	Field Measurement (during October)	Range: 11.0-14.3 Mean: 12.8	Same or Increase
10.	Water pH	Field Measurement (during October)	Range: 7.05 – 8.08 Mean: 7.71	Same or Trend Toward Neutral
11.	Water Conductivity (µS)	Field Measurement (during October)	Range: 63 – 302 Mean: 192	Same or Decrease
12.	Turbidity (NTU)	Field Measurement (during October)	Range: 0.2-785.2 Mean: 51.0	Same or Decrease
13.	Water Quality Fecal Coliforms (MPN/100mL)	Field Measurement (during October)	Range: 57.2-108 Mean: 91.5	Same (< 200)
14.	Sediment Quality	Metals in sediment	See Section 2.4	Same or Decrease
15.	No. of Erosion Sites	Field Assessment and Designation as Low, Medium, or High Severity and Consequence	See Table 2-2	Same or Decrease



5.10 Stakeholder Feedback

Stakeholder engagement took place at a Public Open House on 11 March 2014. The stake holders were asked to identify any additional issues, rank the potential watershed improvement options, and provide comments on the project. The stakeholder feedback is summarized below.

Potential Watershed Improvement Rankings

Stakeholders were asked to rank the watershed improvement option projects from A to Q in order of most preferred to least preferred. Table 5-5 shows the projects as ranked by the stakeholders.

Table 5-5: Watershed Improvement Options as Ranked by Stakeholders

H. Develop policy to construct source controls during redevelopment to reduce EIA to less than existing values (e.g., during densification of 35% imp SFR area to 47%, reduce EIA to less than 35%).
I. Develop program to encourage retrofit of institutional and municipal owned lots with 31 mm volume reduction source controls for pavement and roof runoff.
K. Explore options to allow disconnected roof runoff directed to landscaped areas in areas on existing single family development in Delta and initiate volunteer program to help home owners do so.
L. Encourage homeowners to plant trees on their properties.
M. Consider policy to retrofit existing streets with roadside source controls.
Q. Address large impassable culvert in lower reaches during site redevelopment or upgrading.
P. Restore intertidal marsh habitat at mouth of Kendale Creek including possible relocation or closure of Elevator Road.
N. Instream habitat complexing in lower McAdam Creek ravine
O. Instream habitat complexing in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible relocation).
C. and D. Riparian and instream restoration in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible road closure or relocation).
A. Encourage stewardship and riparian reforestation to increase riparian forest along lower Knudson Creek.
B. Remove debris associated mink farm from riparian zone; reforest disturbed areas.
E. Undertake additional water quality assessment and monitoring actions using Metro Vancouver's regional strategy.
F. Retrofit stormwater systems in residential paved areas (parking areas, roads, and driveways) to capture and trap fine sediment.
G. Conduct further sampling of microbiological indicators (E. coli + fecal coliforms) during low flow conditions in August-September.
J. Evaluate a volunteer program to help homeowners install rain barrels on existing single family development in Surrey.

In general the stakeholders identified that the preferred options would be ranked in the following order:

1. Source controls / stormwater infiltration;
2. More tree cover in all areas;



3. Riparian / instream improvements; and
4. Monitoring / testing.

Several stakeholders expressed that not enough information was presented to allow ranking of the options.

Issues/Projects as Identified by Stakeholders

Stakeholders were asked to list any key issues in the watershed that should be addressed by the ISMP. The issues/projects identified by the stakeholders are listed below. The issues/projects have been separated into two lists: Addressed in ISMP Alternatives and Additional Issues.

Addressed in ISMP Alternatives

46. All developments and redevelopment, including single family residential, required to install source controls for stormwater management.
47. Improve Kendale Creek, allow more fish access and remove culverts in lower reaches and restore channel.
48. Construct rain gardens, retention ponds, and porous asphalt.
49. Make source controls compulsory in new developments.
50. Encourage disconnected roof leaders.

Additional Issues

51. Habitat fragmentation: develop a plan based on site visits to determine where tree planting and wildlife corridor creation could be located.
52. Improve fish access along Norum Creek (railway culverts) to bring back historical salmon runs.
53. Remove or improve piped sections of Norum Creek, restore channel and add complexing.
54. Remove piped sections of Kendale Creek, restore channel and add complexing.
55. Add baffles to culvert under Nordel Way on McAdam Creek.
56. Construct fish ladder on Colliers/Delta Creek to get fish into the 96th Avenue culvert.
57. Disallow infilling of ditches.
58. Require developers to contribute to the restoration of Creeks as part of approvals process.
59. Create a greenway for wildlife that connects with Burns Bog, the North Delta Ravines, and the Fraser River.
60. Governmental (municipal, provincial or federal) purchase of all stream courses and riparian buffer.
61. Strive for more than just slightly improve watershed health.



5.11 Capital Cost Estimates and Funding

Capital Cost Estimate

The sizing of facilities in the ISMP is conceptual in nature and should be thoroughly assessed during pre-design. The capital cost estimates of the overall proposed works in the ISMP are summarized in Table 5-1. The detailed cost estimates are included in Appendix G.

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

Class 'D' Cost Estimate and Assumptions

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

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

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

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

GST has not been included in the estimated project costs. The unit prices reflect KWL's recent experience with similar work, and therefore represent the best prediction of actual (2014) costs as of the date prepared. Actual tendered costs would depend on such things as market conditions generally, remoteness factor, the time of year, contractors' workloads, any perceived risk exposure associated with the work, and unknown conditions.

Funding Strategies

Funding opportunities from senior governments should be pursued for some of the items for example:

- Fish barrier removals and habitat improvements – Wildlife Habitat Canada Conservation Grant;
- Riparian enhancement and conservation areas – Environment Canada Habitat Stewardship Program; and
- Conveyance upgrades – Infrastructure grant programs.

Possible Short Term Water Quality Improvement and Monitoring Projects:

No. 26 Undertake additional water quality assessment and monitoring to comply with AMF.

No. 27 Consider policy to retrofit stormwater systems in residential areas to capture and trap fine sediments.

No. 28 Conduct further sampling of microbiological indicators during low flow to identify cross-connections between sanitary and storm system.

Possible Short Term Volume Reduction:

No. 30 Evaluate a program to install rain barrels on SFR lots in Surrey.

No. 31 Explore options to allow disconnected roofs leaders to lawn on SFR lots in Delta.

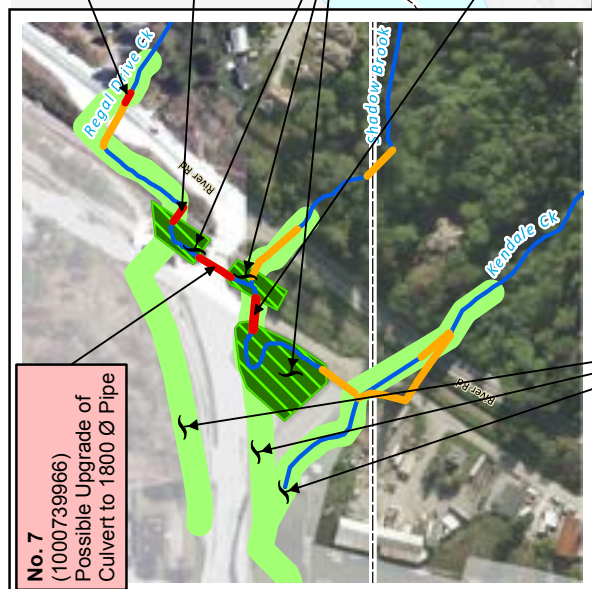
No. 32 Encourage residents to plant trees on their lots.

No. 4 (C27)
Possible Upgrade of Culvert to 1800 Ø Pipe

No. 8 (1000748517)
Possible Upgrade of Culvert to 1800 Ø Pipe

No. 38
Enhance Riparian Forest Along Channels in Rail and Road Corridor near Robson and Elevator Roads

No. 5/6 (1000739968, 1000766325)
Possible Upgrade of Culverts to 2 x 1600 Ø Pipe



**Corporation of Delta
North Delta Ravines
ISMP**

Legend

- Municipal Boundary
- Study Boundary
- Culverts
- Modelled Conveyance System
- Modelled Creek / Ditch
- Pipes to be Upgraded
- Riparian Reforestation
- Riparian Enhancement

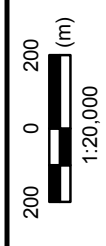
Note:
No additional major system features failed the future landuse conditions.

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

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



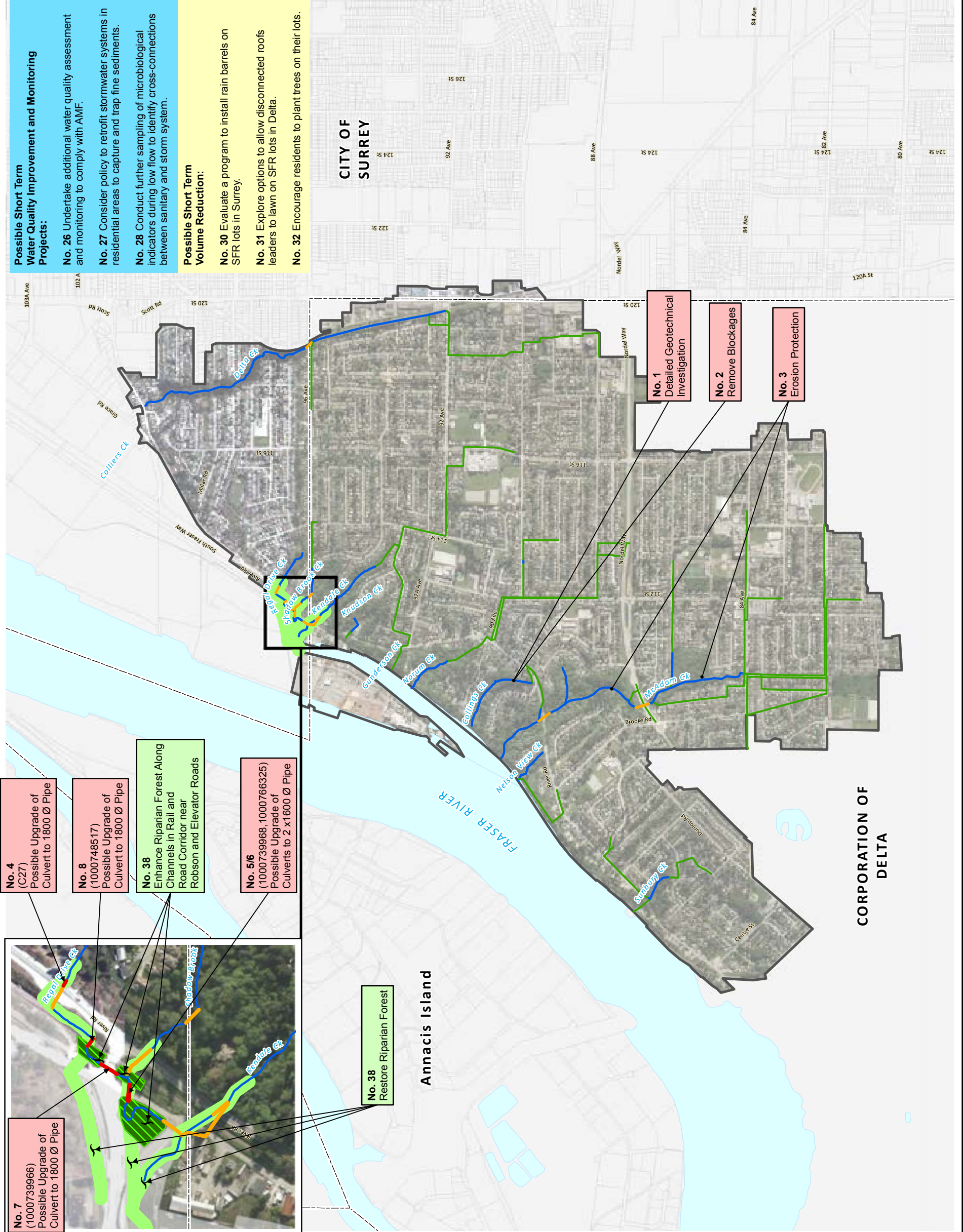
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey. No part of these materials may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or by any information storage and retrieval system, without the prior written permission of Kerr Wood Leidal Associates Ltd. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073
Date May 2014









**Proposed
Short Term Projects**

Figure 5-1



**Corporation of Delta
North Delta Ravines
ISMP**

Legend

-  Municipal Boundary
-  Study Boundary
-  Culverts
-  Modelled Conveyance System
-  Modelled Creek / Ditch
-  Pipes to be Upgraded
-  Riparian Reforestation
-  Fish Habitat Improvements

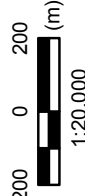
Note:
No additional major system features failed the future landuse conditions.

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

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



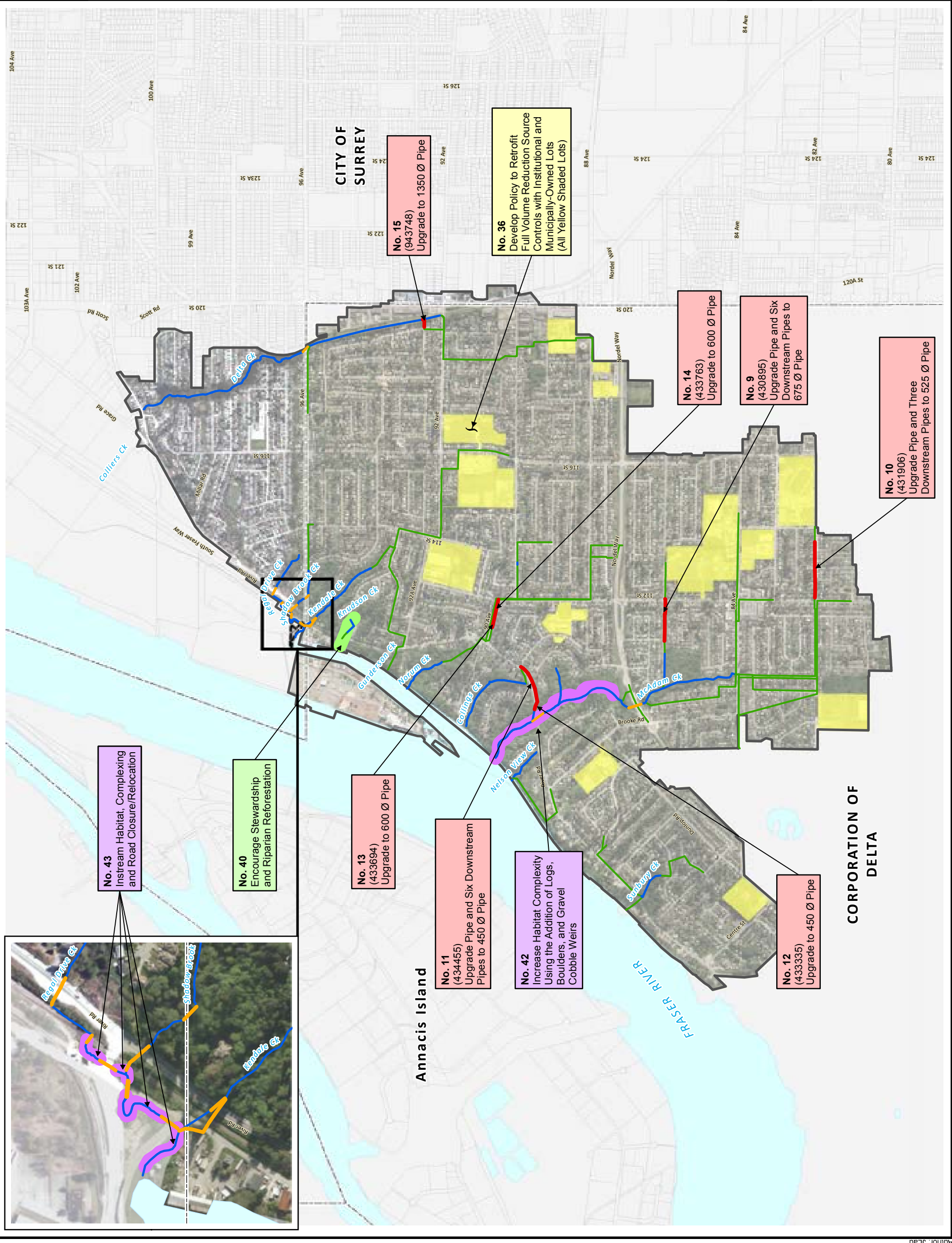
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey are authorized to use these materials for the purpose of conducting business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073
Date May 2014










**Proposed
Medium Term Projects**

Figure 5-2



**Corporation of Delta
North Delta Ravines
ISMP**

Legend

-  Municipal Boundary
-  Study Boundary
-  Culverts
-  Modelled Conveyance System
-  Modelled Creek / Ditch
-  Pipes to be Upgraded
-  Riparian Reforestation
-  Fish Habitat Improvements
-  Intertidal Habitat Enhancement

Note:
No additional major system features failed the future landuse conditions.

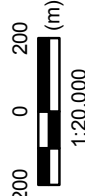
Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

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



KERR WOOD LEIDAL
consulting engineers

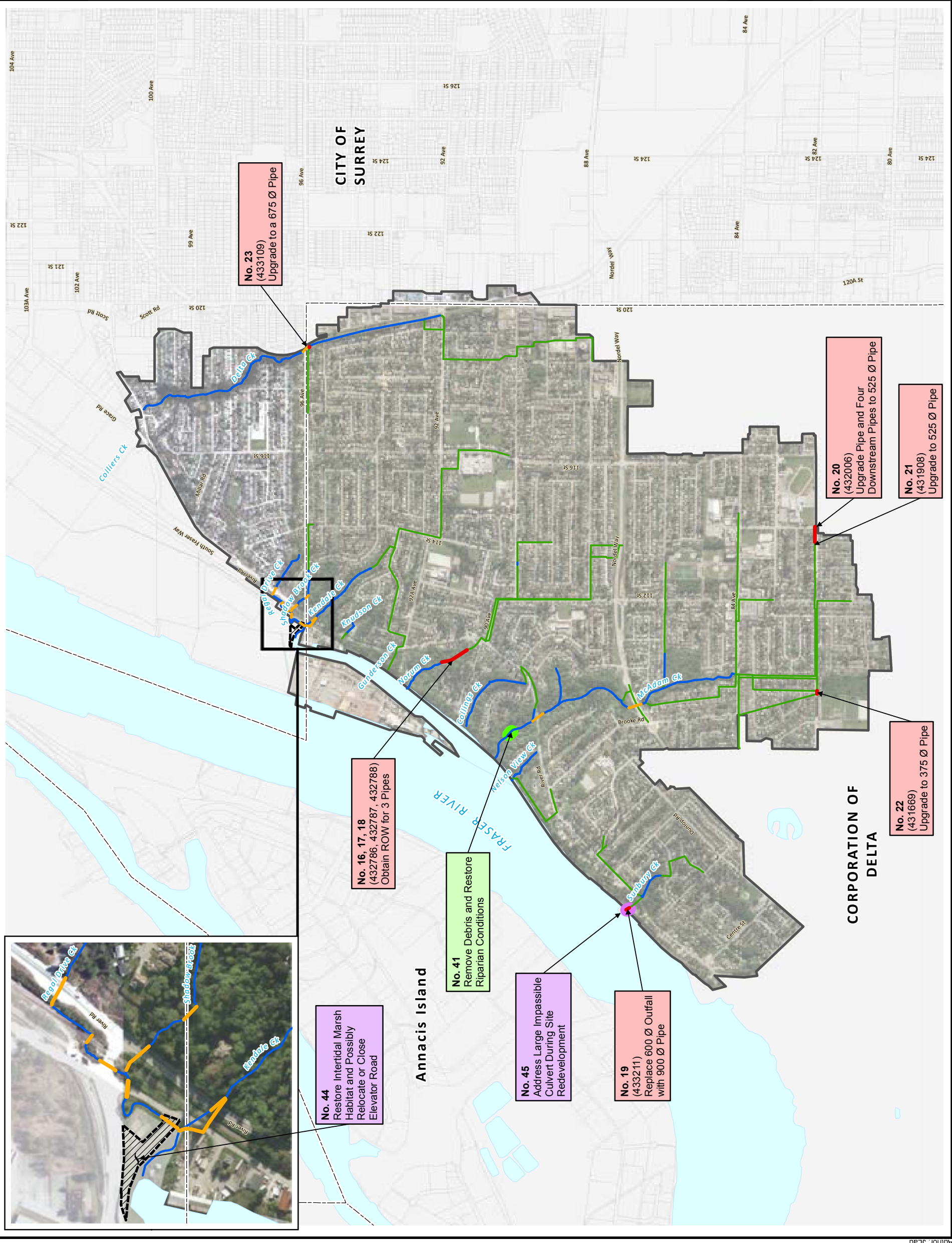
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta and the City of Surrey. No part of these materials may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or by any information storage and retrieval system, without the written permission of KWL. All rights reserved.



Project No. 323-073 Date May 2014

**Proposed
Long Term Projects**

Figure 5-3





6. Summary and Recommendations

6.1 Summary

Introduction

- The North Delta Ravines ISMP employed a multi-disciplinary approach including stormwater engineering and environmental protection.
- The study included consultation with the municipalities and the public.
- Two main watershed goals directed the ISMP: Protect aquatic ecosystems and water resources and minimize the risk to life and property associated with flooding and erosion.
- Key issues include existing erosion and environmental issues such as fish passage barriers.
- Applicable stormwater criteria included Delta and Surrey 10-year minor and 100-year major conveyance standards and detention criteria, DFO Guidelines for 6-month volume reduction, 6-month to 5-year detention, and water quality treatment of 90% of annual runoff, and the Riparian Area Regulation (Surrey) and Streamside Protection Regulation (Delta) for riparian protection.

North Delta Ravines Watershed

Drainage Inventory

- The North Delta Ravines watershed is 802 ha and drains to the north to the Fraser River. There are 11 significant watercourses in the watershed: Sunbury Creek, Nelson View Creek, McAdam Creek, Collings Creek, Norum Creek, Gunderson Creek, Knudson Creek, Kendale Creek, Shadow Brook Creek, Regal Drive Creek, and Delta/Colliers Creek.
- There is existing erosion, slope failures, slide scarps and slide areas in McAdam Creek, Kendale Creek, Knudson Creek, Collings Creek, and Nelson View Creek.
- A drainage inventory included investigations on Creek crossings, channel cross-sections, erosion, deposition, obstructions, and a condition assessment of hydraulic structures.

Land Use Assessment

- The existing and future land uses were summarized. The existing land use is largely developed in both Delta (696 ha at 47% impervious area) and Surrey (106 ha at 52 % impervious). The future land use has minor zoning changes and mainly includes redevelopment at higher impervious percentages (Delta 50% impervious and Surrey 55% impervious).

Environmental Inventory and Assessment

- A total of 87.5 ha (13%) of the study area and approximately 30.1 ha of the riparian zone (68%) was forested (based on 2012 aerial photos). Riparian forestation varied from 41% along Regal Drive Creek to 82% along McAdam Creek. Total forestation has declined by approximately 10.8 ha (1.3%) and riparian forestation has declined by approximately 1.8 ha (4%) over the past 17 years.
- Water quality sampling shows Sunbury and Knudson Creeks have higher specific conductivity, higher turbidity, and lower Oxygen Reduction Potential. Levels of total copper were marginally



higher than BCWQ in Sunbury and McAdam creeks and levels of antimony were elevated in samples from McAdam. Fecal coliforms were lower than the BCWQ guideline for primary contact recreation.

- Sediment sampling from four streams (Sunbury, Collings, Knudson and Kendale Creeks) had concentrations of total nickel above the BCSQGs. Total arsenic from in Knudson creek was also above BCSQG.
- The biological condition of the watershed has been heavily impacted by human disturbances in the watershed as reflected in the 2012 B-IBI score of 18.0 and a mean taxa richness of 13.3. These results are not unexpected given the high levels of urbanization and total impervious area within the watershed.
- Fish presence was derived from the detailed fisheries assessment completed previously for the SFPR environmental impact assessment. Six of the ten streams support resident or searun cutthroat trout populations, and two (McAdam and Regal Drive creeks) support coho salmon. Additional streams may support coho or chum salmon but presence was not confirmed.
- Stream channel substrate is predominantly cobble and gravel with lesser amounts of boulder and fine sediment. Large instream wood is widely distributed in the study areas, but rarely abundant. Twenty pools deeper than 40 cm were recorded; all were found in McAdam Creek.
- Culverts restrict fish access into Sunbury, Nelson View, Knudson, Kendale, Shadow Brook and Regal Drive Creeks.

Geotechnical Assessment

- The assessment revealed cross bedded sands with silt and gravel lenses, cross bedded sand to gravel and inter bedded fine sand to clayey silt in the watershed. Groundwater was not typically encountered along the ravine banks except in localized seepage areas.
- The granular nature of the soils encountered within the ravines were typically considered to be susceptible to erosion, with the exception of McAdam and Nelson View Creeks in which clayey soils were encountered which would be more resistant to erosion.
- Erosion within the ravines was generally limited to localized areas.

Watershed Analysis

Hydrologic and Hydraulic Modelling

- A PCSWMM model was developed for trunk storm sewers in the watershed.
- The design storms were created from the IDF curve for the GVRD DT34 rain gauge and the 1-, 2-, 6-, 12-, and 24-hours storms for the 2-, 5-, 10-, 25-, 50-, and 100-year return periods. These were used for the storm sewer and culvert capacity assessments.
- Peak flows and water levels for design events were estimated at strategic locations within the watershed.
- The future land use, if left unmitigated, would increase 2-year to 100-year peak flows by approximately 1% to 73% and increase water levels by less than 1%.



- A minor trunk sewer capacity assessment was performed. Pipes were checked using the 10-year peak flow limiting the surcharge time to 30 minutes. Eleven out of 296 minor pipes exceed criteria in the existing land use and an additional two pipes exceeded criteria in the future land use.
- A major system capacity assessment was performed. Pipes were checked to determine if they had easements that would accommodate the 100-year peak overland flow safely. Seven pipes were identified as failing the criteria, however they were considered low-risk failures as the pipes are located in the ravines away from structures.
- A culvert capacity assessment was performed. Culverts were checked using the 100-year instantaneous peak flow limiting the surcharge time to 30 minutes. Five out of 15 culverts exceed the criteria in the existing land use case and no additional culverts exceeded it under future land use.
- A local deficiency located at Russel Drive at Watson Drive was identified by Delta staff. This deficiency was not modelled as it is not on the major drainage system.

Watershed Health Tracking System

- The Watershed Health Tracking System shows general agreement between the measured score (18) and the score predicted from impervious area and riparian forest integrity (15) for McAdam Creek. The watershed health is as would be expected for a watershed with this level of development and would benefit from improvement.

Mitigation Alternatives

- Alternatives were developed and explored with Delta and Surrey to address the existing issues and mitigate the potential impacts of future development.
- Hydrotechnical upgrades to protect property and infrastructure were identified.
- To meet the no-net-loss requirements of an ISMP, future development impacts need to be mitigated. Developers in both Delta and Surrey should apply source controls to allow development while not making conditions worse in the downstream creeks and ravines.
- To go beyond the no-net-loss requirement of an ISMP and in fact improve the watershed, a number of existing issues could be addressed. Four categories of alternatives are identified:
 - **Riparian reforestation** to improve and reduce the losses in the riparian area.
 - **Water quality improvements** to identify pollutants and treat water quality of outflows to the creek.
 - **Volumetric reduction alternatives** to reduce existing development flows.
 - **Fish habitat improvement** to improve instream habitat, estuarine habitat and improve fish access to creeks.
- The potential projects were discussed with Delta and Surrey and evaluated based on cost and qualitative benefit. The projects were assigned a timeline and importance which results in a prioritization. The majority of the options were selected to be incorporated into the ISMP.
- Stakeholder engagement took place at a Public Open House on 11 March 2014. The stakeholders were asked to identify any additional issues, rank the potential watershed improvement options and provide comments on the project.



Proposed North Delta ISMP

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

- **Required Hydrotechnical Improvements** include eight short term projects (\$2,097,000), seven medium term projects (\$1,453,800), and eight long term projects (\$778,000).
- **Water quality treatment** to improve instream conditions for fish includes three short term projects (\$33,600) and one ongoing project (\$0).
- **Volumetric reduction** for environmental protection includes three short term projects (\$0), three ongoing projects (\$0), and one medium term project (\$24,235,300).
- **Flow rate control** to meet bylaws and guidelines includes one ongoing project (\$0).
- **Riparian protection and enhancement** for improving watershed health includes one short term project (\$84,000), one ongoing project (\$0), one medium term project (\$41,900), and one long term project (\$126,100).
- **Restoration and enhancement for fish** includes two medium term projects (\$168,000) and two long term projects (\$328,500).
- Further studies and monitoring are recommended for the North Delta Ravines study area to investigate the geotechnical hazards in Shadow Brook, Kendale, Collings, and McAdam Creeks, to continue benthic and water quality sampling, to document fish presence and fish passage through culverts, and to measure the performance of the ISMP.
- The total capital cost of the ISMP projects is up to \$29,346,900 million of which \$27 to \$39 M is attributable to Delta projects and \$2 to \$14 M to Surrey projects. Short term costs projects are valued at \$2,214,600, medium term projects at \$25,899,000, and long term projects at \$1,233,300. Funding opportunities from senior governments may be pursued for some of these projects.

6.2 Recommendations

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

- Adopt the goal of net gain of ecological health for the North Delta Ravines watershed as a whole.
- Initiate a monitoring program to collect benthic samples, water quality samples, and sediment samples. Undertake further fish presence and fish passage investigations. Track the performance of the ISMP by comparing trends in indicators as shown in Table 5-4.
- Implement the proposed short term projects and improvements first, followed in turn by the medium and long term projects and improvements.
- Develop and implement policy requiring volume reduction source controls on all new development and redevelopment.
- Develop a policy to retrofit existing streets with roadside source controls BMPs.
- Review implications of a roof leader disconnection program that directs roof runoff to landscaped areas and encourage home owners to do so.
- Encourage homeowners to plant trees on their properties.



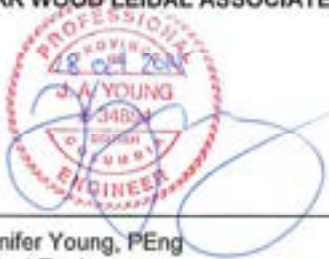
- Initiate a detailed geotechnical investigation on Collings Creek to analyse the slope stability for seismic and static conditions.
- Regularly review Shadow Brook, Kendale, Collings and McAdam Creek ravines to monitor progression of existing slope movement and/or erosion of creek banks.
- Construct erosion protection for areas within McAdam Creek ravine.
- Confirm that setbacks for homes adjacent to Gunderson Creek ravine are sufficient through a detailed location survey.
- Perform capacity study for the local deficiency identified by Delta staff at Russel Drive at Watson Drive.



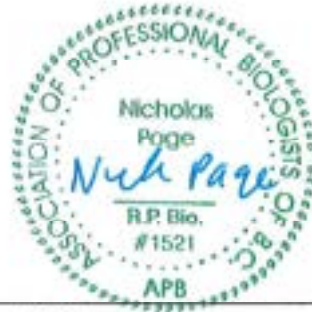
7. Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.



Jennifer Young, PEng
Project Engineer



Nick Page, RPBio
Senior Biologist – Raincoast Applied Ecology

Reviewed by:



David Zabil, PEng
Project Manager



Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the Corporation of Delta for the North Delta Ravines 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.

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

Copyright Notice

These materials (text, tables, figures and drawings included herein) are copyright of Kerr Wood Leidal Associates Ltd. (KWL). The Corporation of Delta is permitted to reproduce the materials for archiving and for distribution to third parties only as required to conduct business specifically relating to the North Delta Ravines Integrated Stormwater Management Plan. Any other use of these materials without the written permission of KWL is prohibited.

Revision History

Revision #	Date	Status	Revision	Author



KERR WOOD LEIDAL
consulting engineers

Appendix A

Drainage Inventory



Appendix A – Engineering Field Inventory

Contents

1. Engineering Field Inventory.....1

Figures

Figure A-1: Culvert, Outfall and Obstruction Inventory 3
Figure A-2: Field Inventory - Erosion Inventory..... 4
Figure A-3: Photo Overview - Main Issues Identified 5

Tables

Table A-1: Field Inventory - Observed Obstruction Sites 6
Table A-2: Field Inventory - Observed Culvert Inlet Sites..... 7
Table A-3: Field Inventory - Observed Culvert Outlet Sites 8
Table A-4: Field Inventory - Observed Outfall Sites 9
Table A-5: Field Inventory - Observed Erosion Sites 10



Appendix A – Engineering Field Inventory

1. Engineering Field Inventory

KWL undertook drainage inventory survey activities in November of 2012. The scope of work covered the North Delta Ravines area.

The purpose of the survey was to supplement the Corporation of Delta’s existing CAD database by locating, photographing and assessing the following features along each major tributary:

- Hydraulic structures and stormwater outfalls; 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.

A geotechnical inventory survey of the nine ravines in North Delta was completed by exp Services Inc. The purpose of the survey was to locate erosion sites along the creeks.

Equipment

Features and observations were positioned and recorded using the Rino 520-530HCx mapping grade GPS.

All inventory features were photographed at 1,600 x 1,200 pixel resolution using a digital camera.

Coordinate System

The coordinate system used for this survey is Universal Transverse Mercator (UTM) Zone 10 North, North American Datum of 1983. Raw GPS positions were differentially corrected against reference data measured at base stations in Chilliwack, Vancouver, and Bellingham. The data collected was converted to Delta mappings co-ordinate system.

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 Inlet

Diameter	(mm)
Material	(CMP, concrete, PVC, etc.)
Condition	(good, fair, damaged)
Headwall	(type)
Barrier/Trash rack	(yes/no)
Overflow Height	(from invert of culvert up to road surface)
Sediment Depth	(from invert of culvert up to creek bed)
Comment	(additional notes or comments)
Photo Numbers	



Appendix A – Engineering Field Inventory

Culvert Outlet and Storm Water Outfall

Diameter	(mm)
Material	(CMP, concrete, PVC, etc.)
Condition	(good, fair, damaged)
Headwall	(type)
Energy Dissipation	(type)
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)
Photo Numbers	

Channel Obstruction

Cause	(natural, anthropogenic)
Risk	(low, medium, high)
Comment	(additional notes or comments)
Photo Numbers	

Observed Sites

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

The CAD data was converted into an ESRI shape file format.

GIS layers were created for obstruction, culverts and outlets observed during the field inspection.

The culverts, outfalls, obstructions and erosion site GIS layers contain the location and comments on the features. These are summarized in Figure A-1 and A-2 and Tables A-1 through A-5.

Corporation of Delta
North Delta Ravines
ISMP

Legend

- Municipal Boundary
- Study Boundary
- Watercourse
- Culvert
- Storm Main

Field Inventory

★ Obstruction - Low Risk

Outfall

- Good
- Fair
- Poor

Culvert

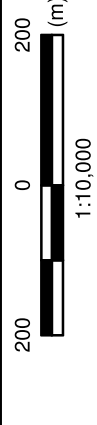
- Good
- Fair
- Poor

Inventory ID

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



© 2013 Kerr Wood Leidal Associates Ltd.
Copyright Notice: These materials are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Corporation of Delta is permitted to reproduce the materials for archiving and for distribution to third parties only as required to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073
Date March 2013








Culvert, Outfall and
Obstruction Inventory

Figure A-1



Corporation of Delta
North Delta Ravines
ISMP

Legend

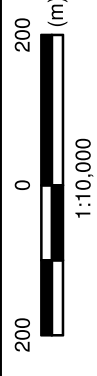
-  Municipal Boundary
-  Study Boundary
-  Watercourse
-  Culvert
-  Storm Main
-  Observed Erosion Site
-  Erosion ID

Inventory ID

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.



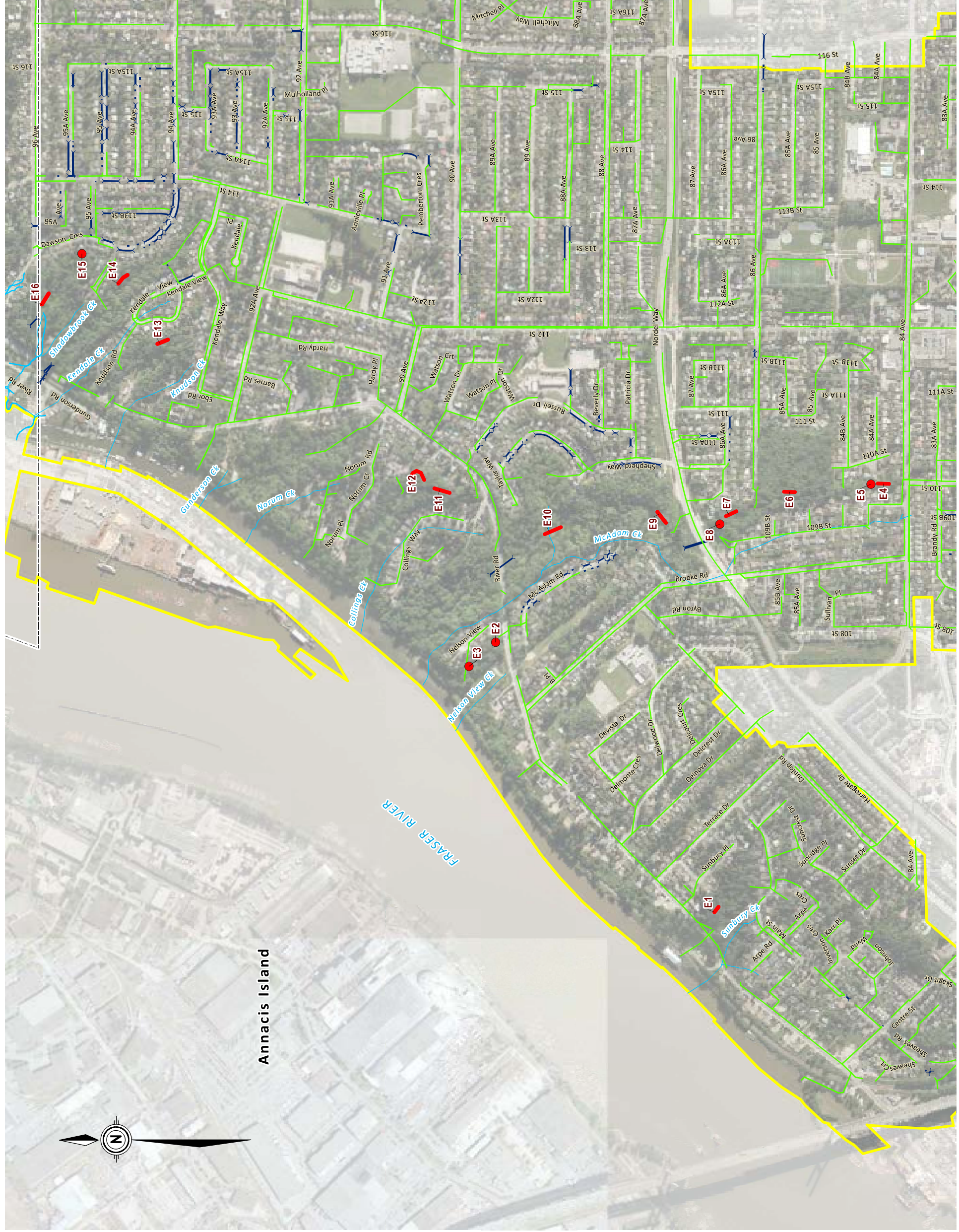
© 2013 Kerr Wood Leidal Associates Ltd.
Kerr Wood Leidal Associates Ltd. (KWLA), Corporation of Delta is permitted to reproduce the materials for archiving and for distribution to third parties only as required to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWLA is prohibited.



Project No. 323-073
Date March 2013

Erosion Inventory

Figure A-2





Appendix A – Engineering Field Inventory

Figure A-3: Photo Overview - Main Issues Identified

ID 214 – Culvert Railway Crossing	ID 249 – Creek Culvert Eroded	ID 200 – Projecting Outfall
		
ID 230 – Projecting Outfall	ID 259 – Projecting Outfall	MacAdam Creek: Undermining of fence
		
MacAdam Creek: Failing Slope	Norum Creek: Abandoned House near Creek	Norum Creek: Shed near Creek
		

Corporation of Delta

Table A-1: Field Inventory - Observed Obstruction Sites			
Obstruction Observations			
SiteID	CAUSE	RISK	COMMENT
193	Natural	Low	Fallen log and debris build up. (Note: A lot of erosion at property line)
202	Natural	Low	Debris in creek
212	Natural	Low	Debris build up in creek
214	Natural	Low	Debris, Fallen logs, Shopping cart
215	Natural	Low	Debris build up, Low Priority
216	Natural	Low	Deposition behind debris build up of fallen logs, Low Priority
218	Natural	Low	Wood debris and logs, Medium Priority
223	Natural	Low	Fallen logs, seems to be a barrier for sprat fish
224	Natural	Low	Log debris, blocking flow, 1m drop,
226	Natural	Low	Fallen Log
228	Natural	Low	Log debris in creek
230	Natural	Low	Fallen Log
232	Natural	Low	Fallen Log
261	Natural	Low	Fallen Log
262	Natural	Low	Log debris in creek
263	Natural	Low	Fallen Log
264	Natural	Low	Fallen Log
265	Natural	Low	Log debris in creek

Corporation of Delta

Table A-2: Field Inventory - Observed Culvert Inlet Sites

Culvert Inlet Points										
SITE ID	DIAMETER (m)	BARRELS	MATERIAL	CONDITN	HEADWALL	BARRIER	OVRFL_HT (m)	SED_DPTH (m)	COMMENT	PHOTO_NO
208	1.5	2	CSP	Good	Concrete	No	20	0	Right hand side culverts invert is .5m above the invert of other culvert on the left	324
221	1.8 x 1.4 : Square	1	Concrete	Good	Concrete	Large Concrete Pillars	20	0	Log stuck behind large concrete pillars, fish steps in culvert	348-352
225	1.3m	2	Concrete	Good	Concrete	Trash Rack	2	0	Culvert newly installed below new road works, 2nd culverts invert raised .8m above the main culvert to the left, 2nd culvert has a 1m dia and no trash rack	370-375
238	.9	1	Concrete	Fair	Concrete	No	15	0	Some debris and fallen logs around inlet but not hindering inlet capacity	97,99-100
242	.6	1	Concrete	Good	None	No	1	0	Vegetation overgrown at inlet, 600mm, beneath railway track	114
243	1.8	1	Concrete	Good	Rock Stack and Allan Blocks	No	3	0	Flows are tidal, Culvert runs below temporary construction road and railway	115-116
245	.5	1	CSP	Poor	None	Straw Bales	1	0	Culvert below railway track. In very poor condition - cracked and broken.	118-119
246	.3	1	PVC	Good	None	No	1	0	Culvert below railway track.	120
247	?	1	CSP	Good	Manhole	No	3	0	Culvert runs under railway, Flows drop roughly 2m to reach inlet	121
249	?	1	CSP	Poor	Rock Stack	No	?	0	Fallen tree above inlet, The bottom of the culvert has eroded away	129-131
251	.9	1	Concrete	Good	Concrete	Trash Rack	4	0	Newly Constructed	135-137
252	.75	1	CSP	Fair	Not Visible	No	1	0	Vegetation overgrown at inlet	138
253	1.3 x .9 : Elliptical	1	CSP	Fair	Rock Stack	No	1	0.2	Runs below railway tracks	141
253	1.3 x .9 : Elliptical	1	CSP	Fair	None	No	1.5	0	Runs below access road	142144
256	1.2	1	Concrete	Good	Rock stack	No	3	0	Culverts outfall on other side of railway tracks not visible due to vegetation	152-154
257	1.2	1	PVC	Good	None	No	1.5	0	Culvert runs under construction access road	155-156

Corporation of Delta

Table A-3: Field Inventory - Observed Culvert Outlet Sites

Culvert Outlet Points										
SITE ID	DIAMETER (m)	BARRELS	MATERIAL	CONDITN	HEADWALL	ENERGY DISIPATION	SED_DPTH	BARRIER	COMMENT	PHOTO_NO
211	1.8	2	CSP	Good	Concrete	Rock Satcks	0	No	No visible erosion of banks	331-333
222	1.8 x 1.4 : Square	1	Concrete	Good	Concrete	Sediment Bay and Rock Stacks	0	No	Fish Ladder to right of outlet, No visible erosion of banks	355-359
239	0.6	1	Concrete	Good	Rock stack	Not Visible	0	No	Outfall to the Fraiser River	104
244	1.8	1	Concrete	Good	Rock Stack	Not Visible	0	No	Outfall to Frasier River	117
253	1.3	1	Concrete	Good	Manhole	None	0	No	Newly Installed	139-140
253	1.3 x .9 : Elliptical	1	CSP	Fair	None	None	0	No	Runs below railway tracks	143
256	1.2	1	PVC	Good	None	None	0	No	Maybe temporarily installed, No access for close inspection, Directs flow to culvert under the railway	150-151

Corporation of Delta

Table A-4: Field Inventory - Observed Outfall Sites

Storm Outfalls											
Site_ID	BANK	DIAMETER	MATERIAL	CONDITN	ENRG_DIS	HEADWALL	OUT_DROP	SED_DPTH	EROSION	COMMENT	PHOTO_NO
192	Left	1.05	Steel	Good	None	Concrete	None	None	0	The source of MacAdam Creek, Half submerged below the water line, Pipe extruding from large concrete chamber (flowsplit chamber?)	294-296
200	Right	0.15	PVC	Poor	None	None - Projecting	1.5	None	0	Projecting from bank	307-309
201	Left	0.75	Concrete	Good	Yes	Concrete	None	None	0	Energy disipation Chamber, 3m by 1.5m with 2x100 mm outlets with overflow ridge	310-315
207	Left	0.9	Concrete	Good	Yes	Concrete	None	None	0	Some debris (shopping cart) in energy disipation bay, Overflow onto rock stack	318-323
210	Center	0.75	PVC	Good	Yes	Concrete	None	None	0		329-330
229	Left	0.3	PVC	Good	None	Concrete	None	None	0		379-381
230	Right	0.25	CSP	Poor	Yes	None - Projecting	0.5	None	0	Built on what looks like a DIY support brace	386
235	Center	1.05	CSP	Good	Yes	Gabion Baskets	none	None	0.3	Outlet source of Kendall Creek, sedient bay built of gabion baskets	394-401
237	Center	0.4	PVC	Good	Yes	None - Projecting	0.2	None	0	Looks newly installed, 400mm PVC with HDPE cover	94-96
238	Left	0.6	Concrete	Good	Yes	Concrete	None	None	0	Outflow onto energy disipation blocks and rock stack	98,101-103
240	Center	0.6	Concrete	NA	NA	NA	NA	NA	NA	No outfall visible, maybe buried beneath rock armor on bank, seepage and small stream visible, stream starts below rock stack and pile of tires tires, remove and clean outfall, Creek appears to be a low flow creek compared to the others	105-106
241	Right	0.3	PVC	Good	None	Concrete	None	None	0	Outfall replaces old outfall - relocated due to road construction	107-109,-112-113
241	Left	0.75	NA	NA	Yes	Concrete	None	None	0	Only headwall and energy disipation bloacks installed at time of inspection	110-11
246	Center	0.3	PVC	Fair	None	None - Projecting	None	Yes	0	Outfall into flows into ditch along railway, straw bales surrounding outfall, flow directed towards railway bank. Erosion of railway bank may be an issue in long term?	120
247	Center	0.3	HDPE	Good	None	None	2	None	0	300mm HDPE pipe laid down bank and into drop manhole (2m drop). Flow then runs through a culvert below railway. This culvert also receives flow from the ditch. Flow in the 300mm was quite high, 2 x 150mm pipes flowed into the drop manhole also, The structure appears to be a temporary solution.	121-125
250	Center	0.9	CSP	Fair	Yes	None	None	None	0	Outflow into energy disipation bay constructed from logs and rock stacks located at the bottom of the energy disipation bay's overflow	132-134
254	Center	0.3	PVC	Good	None	None	None	None	0	Newly installed, No flow visible at time of inspection	145
255	Center	0.75	CSP	Good	Yes	Rock Stack	2	None	0	Outfall into Fraiser. 2m drop onto rock stacks	146-149
259	Center	0.4	CSP	Poor	None	None	0.5	Yes	0	.5m drop to bank. Outfalls flow is causing erosion of bank. A 300mm white PVC stump has been placed into the mouth of the outfall in an attempt to carry flows out over the bank into the fraiser but the flow is leaking around the 300mm pipe.	162-168

Corporation of Delta

Table A-5: Field Inventory - Observed Erosion Sites		
Erosion Observations		
SiteID	COMMENT	CREEK
E1	Slide Scarp	Main
E2	Constructed Tire and Rock Slope	Nelson
E3	Wood Crib Retaining Wall	Nelson
E4	Undermined Fence and Trees	MacAdam
E5	Approximate Location Gabion Blocks	MacAdam
E6	Slope Failures Right Bank	MacAdam
E7	Sloughing Both Banks	MacAdam
E8	Sloughing Laminated Silty Clay	MacAdam
E9	Right Bank - Historical Scarp / Left Bank - Slough	MacAdam
E10	Riprap Bottom and Sides	MacAdam
E11	Approximate Location Undulating Topography and Slide Scarps	Collings
E12	Approximate Location Slide Area	Collings
E13	Approximate Location Slide Area	Knudson
E14	Slide Scarp	Kendale
E15	Bank Eorsion (Both Banks)	Shadowbrook
E16	Approximate Location Lock Block Wall	Shadowbrook



KERR WOOD LEIDAL
consulting engineers

Appendix B

Land Use

DATE October 29, 2014**REFERENCE No.** 1214410157-003-TM-Rev0**TO** David Zabil
KWL Engineering**FROM** Aaron Licker,
Don Crockett**EMAIL** Aaron_Licker@golder.com,
Don_Crockett@golder.com**NORTH DELTA RAVINES INTEGRATED STORMWATER MANAGEMENT PLAN**

Golder Associates Ltd., (Golder) as part of the consulting team, conducted a review of the North Delta project area in order to estimate existing and potential development impacts to the hydrological functioning of ravines and related stormwater management protocols. The project area was assessed in terms of existing and future land use, impervious area coverage, and stormwater management plans and policies in both Delta and Surrey. The study area includes a large portion of North Delta and a small portion of Surrey as outlined in Figure 1 (Appendix A).

1.0 EXISTING AND FUTURE LAND USE

Existing land use, historical development trends, and future land use plans have been reviewed by Golder GIS analysts to assess the current and future state of development in the study area. Through interviews with city staff, review of development trends (building permit, demolition, and subdivision statistics), zoning bylaws, Official Community Plans (OCPs) and Area Plans, existing and future land use was assessed in both Delta and Surrey to estimate the average rate of change, average lot coverage, and projected increase to total impervious areas.

1.1 Delta: Anticipated Growth and Development

Largely developed in the 1960's and 70's, aging buildings and infrastructure in the North Delta area are reaching the point where replacement or redevelopment of some areas may be attractive to the development industry. Past trends have shown piecemeal infill development as older single family lots are replaced with larger homes or subdivided into multiple lots. This type of gradual infill is expected to continue although new development and higher densities are increasingly being guided into comprehensive developments located in nodes along major transportation corridors such as Scott Road and Nordel Way¹. The following nodes have been identified in Delta's OCP for increased density²:

¹ Rukowski, M. (2013, January 16). Senior Planner, Community Planning and Development, Corporation of Delta. (L. Cowan, interviewer).

² Corporation of Delta. 1985. Official Community Plan Bylaw No. 3950, Schedule C.1 North Delta Area Plan. Retrieved January 16, 2013 from <https://delta.civicweb.net/Documents/DocumentList.aspx?Id=37999>.



- **Richardson Node** (80th Avenue and Scott Road) - high intensity, mixed-use development proposed, not in study area (application under review, 3rd reading)
- **Kennedy Node** (88th Avenue and Scott Road) - high intensity mixed-use development proposed, just outside study area
- **84th Avenue Node** (84th Avenue and Scott Road) – low intensity, mixed-use development proposed, just outside study area
- **Townline Node** (92nd Avenue to 96th Avenue along Scott Road) – redevelopment and revitalization including a wide range of residential, commercial, institutional, and light industrial.
- **Delsom Estates/Sunstone Community Node** (84th Avenue and Nordel Way – just outside study area boundary) – low intensity, mixed-use development proposed (approved, in progress).

Residential

North Delta is largely made up of low density single family residential lots with a variety of higher density duplexes, row or townhomes, strata houses, multi-family apartments, and mixed-use residential/commercial developments throughout the area. Aside from the higher density growth nodes listed above, residential development is expected to continue gradually through subdivision and infill based on historical trends and existing land use policy. The North Delta Area Plan (currently under review) contained in Delta’s OCP encourages the retention of single family homes. Current zoning bylaws³ regulate the size and dimensions of housing on subdivided lots to reduce the impact to neighbouring single family areas.

As per communication with Corporation staff, the following demolition, subdivision and infill rates were identified and projected into the future.

Table 1: North Delta Single Family Residential Land Use Change

8 Year Averages	Parcels Per Annum	Notes
Building Permit Rate	71	Standard of deviation = 25.8
Subdivision Rate	15	Each Subdivision Yields 2.4 Parcels on Average
Demolition Rate	35	Demolition rate is based on total demolitions in all zones (42) multiplied by the ratio of SF parcels to total parcels resulting in 35 parcels per annum.

Commercial

The majority of commercial properties are located along the Scott Road corridor with a small commercial node at 84th Avenue and 112th Street and select neighbourhood commercial spread throughout the remainder of the study area. Similar to residential, commercial growth is expected to occur mainly in the identified nodes (either as sole commercial properties or mixed-use developments) with limited infill development occurring gradually throughout adjacent neighbourhoods and along the Scott Road Corridor.

³ Corporation of Delta. 1977. Delta Zoning Bylaw No. 2750. Retrieved December 17, 2012 from <https://delta.civicweb.net/Documents/DocumentList.aspx?ID=38103>.

Industrial

Industrial lands in North Delta are located mainly along the Fraser River on the western side of the study area and along Scott Road on the eastern side. The addition of some light industrial land use has been proposed for the Townline Node (92nd Avenue to 96th Avenue along Scott Road) and the development of the South Fraser Perimeter Road is also expected to impact industrial land use to some degree⁴.

Infrastructure

In addition to land use changes, the North Delta Area Plan has proposed improvements and upgrades to its transportation and utility networks. The development of pedestrian and cyclist routes have been proposed for numerous neighbourhood streets throughout the study area, many of which would connect the area's existing parks and green spaces. Road improvements are suggested for several major corridors including Scott Road, Nordel Way, and 86th Avenue, as well as a possible new 2-lane waterfront arterial road. Water supply system, storm sewer system, and sanitary sewer system improvements are also proposed in select locations to ensure adequate service for future growth and development.

Parks, Natural Green Spaces, and Recreation

Green spaces in the study area are made up of neighbourhood parks, community and school playing fields (two of which are synthetic turf), pedestrian trails, and riparian corridors surrounding the numerous ravines emptying into the Fraser River.

Delta's OCP aims to increase parks, open spaces, and recreation facilities to accommodate the existing population's needs and meet the needs of future growth and development. Specific objectives include acquiring more open spaces to achieve a standard of 2.4 hectares per 1,000 people, developing a riverfront recreational trail system, creating pedestrian and cyclist trail networks, working with schools to upgrade existing playing fields, and encouraging new developments to include indoor and/or outdoor recreation amenities.

Additional objectives in Delta's OCP related to the health of natural ecosystems include protecting natural systems, improving public awareness of environmentally sensitive areas, conducting impact studies on sensitive areas where development is being considered, preserving Burns Bog and its wildlife habitat, and preserving ravines as natural areas.

1.2 Surrey: Anticipated Growth and Development

The small portion of Surrey lands within the study area boundary is quite comparable with Delta in its existing land use, future plans, and rate of change⁵.

The Surrey portion of the site (north of 96th Avenue) is zoned primarily as low density single family with various higher density housing types spread throughout residential neighbourhoods. Concentrations of commercial, higher density residential and mixed-use developments are found along the Scott Road corridor. Future development is expected to occur mainly within these growth nodes along Scott Road with gradual residential infill and subdivision throughout residential neighbourhoods. It is not expected that growth along the Scott Road nodes will significantly alter the imperviousness of the area.

⁴ Rukowski, M. (2013, January 16). Senior Planner, Community Planning and Development, Corporation of Delta. (L. Cowan, interviewer).

⁵ COSMOS. City of Surrey Mapping Online System, Version 1.0.2.1. Retrieved January 16, 2013 from <http://cosmos.surrey.ca/external/>.

Additionally, much like the single family areas in North Delta, it is anticipated that infill and redevelopment will occur at a slow pace resulting in the gradual replacement of 1970s single family stock with newer single family dwellings.

Several ecological corridors run through the northern portion of the study area as well as a number of greenbelts, neighbourhood parks, and riparian areas. As these areas are protected by both local and provincial law, it is not anticipated that any development will occur which will impact the imperviousness of the area.

2.0 IMPERVIOUS AREAS

To estimate the Total Impervious Area for the study area, A GIS technique called supervised classification of aerial imagery was performed using ESRI ArcMap and its Spatial Analysis extension. In this process, discreet representative features from the source imagery were manually identified using polygonal selections. The spectral signatures from these areas were inputted into the software as 'training samples' which are then used to classify the remainder of the image.

Specific features were selected and assigned a binary code with two criteria in mind: impervious structures (0) and permeable features (1). For instance, rooftops of various colours, asphalt lots and road sections as well as some concrete structures were selected as impervious. Trees, shrub and open field of various hues, chroma, and values were selected as permeable. Care was taken during this process to represent unique (discreet) features only once for each image and to avoid ambiguous features such as green rooftops. In order to quantitatively minimize redundancy, histograms of related training samples were compared in the three colour bands of each image (Red, Green and Blue). Histograms show the pixel value and count (per value as well as total) for each selection.

In total, there were 12 high-resolution images for the study area: 10 for Delta at 10cm resolution and 2 for Surrey at 40cm resolution. Approximately 15 to 20 training samples were used for each image. The result of this process was a new raster for each image showing the same extent classified according to the training samples. Each resulting raster was then reclassified according to the original binary assignment of 0 or 1, impervious or permeable. This reclassified data was then combined into a single surface covering the study area (Figure 2). This was overlaid by relevant parcel boundaries for Delta and Surrey and through an intersection process this data was combined, allowing for the calculation of an imperviousness 'index', which is a ratio between the total area of a parcel and the area represented by pixels classified as impervious.

Future impervious surface coverage was estimated by understanding where change would occur in the study using extrapolated current and historical building trends for single family areas and the location of known development nodes for along Scott Road/120th. Assignment of a "change-value" to single family parcels that could experience intensification through demolition and rebuilding was completed by randomly selecting 86 Parcels a year (71 from Delta, 15 proportionately from Surrey) and applying the average total impervious area of infill residential (47%) which is reflective of that type of development in the North Delta context. Additionally, there were nine (9) parcels in the North Delta Mixed Use and Commercial zones that are expected to be redeveloped to the highest possible site coverage Accordingly these nine parcels received a future TIA of 79%. Table 2 below outlines in increased detail current and future impervious areas.

Table 2: Anticipated Future Impervious Surface Coverage

OCP Designation	Average Coverage (existing - 2012)	Average Coverage (future - 2035)	Count of Parcels
Rights of way	80%	80%	1
Special Development Area	79%	79%	174
Low-Rise Residential	77%	77%	90
Neighbourhood Commercial	73%	73%	1
Road	68%	68%	9
Townhouse Residential	63%	63%	117
Split	61%	61%	108
Commercial (North Delta)	57%	64%	23
Mixed-Use (North Delta) 4	56%	68%	5
Stratahouse Residential	54%	54%	167
Institutional	51%	51%	30
Mixed-Use (North Delta) 2	50%	50%	2
Infill Single-Family Residential	47%	47%	72
Industrial	47%	47%	20
Residential Ground-Oriented	45%	45%	1
Medium Density Residential	41%	41%	63
Mixed-Use (North Delta) 1	39%	39%	110
Single Family Residential	35%	40%	5,491
Medium Density Ground Oriented Residential	26%	26%	52
Major Parks & Recreational Areas	26%	26%	34
Environmentally Sensitive Area 2	7%	7%	19

Figures 2, 3, and 4 in the appendix illustrate classified impervious areas, existing impervious areas by parcel, and anticipated future impervious areas by parcel.

3.0 RAVINES AND STORMWATER MANAGEMENT

The study area boundary includes nine ravines in total; seven of which fall in the North Delta area and two within the Surrey area boundary.

The seven ravines in the North Delta portion are classified as environmentally sensitive and make up part of the Metro Vancouver Regional Green Zone⁶. The surrounding area has been identified as sensitive in terms of archaeological potential as well as potential geotechnical hazards due to steep slopes leading down to the Fraser River. While some residential and industrial land use is located nearby, large riparian buffers surround the mouths of these ravines and future development is restricted to low intensity residential clustered on portions of sites with low environmental sensitivity.

⁶ Corporation of Delta. 1985. Official Community Plan Bylaw No. 3950, Schedule C.1 North Delta Area Plan. Retrieved January 16, 2013 from <https://delta.civicweb.net/Documents/DocumentList.aspx?Id=37999>.

The two ravines in the Surrey area of the study boundary are designated as potential ecological corridors and support year round presence of salmonids⁷. The smaller ravine on the eastern edge of the Surrey area is protected by a riparian buffer surrounded by small lot single family residential. The ravine running through the northeastern portion of the Surrey area is largely surrounded by the city-owned Tom Hopkins Ravine Park with low density residential adjacent⁸.

3.1 Delta: Stormwater Policies and Practices

Policies and regulations related to stormwater management were identified in Delta's OCP and Zoning Bylaw. Zoning regulations require minimum permeable lot coverage (as described in Section 2.0) as well as landscaping on all portions of a lot that are not utilized by structures, parking/access, or outdoor storage. Development Permit Areas (DPAs) are identified for zones within 30 meters of the top bank of any watercourse (whether usually containing water or not) that is integral to a stream and provides fish habitat. Specific requirements and recommendations are made within these DPAs with regards to landscaping, tree retention, sediment management, alterations to natural drainage, and restrictive covenants in order to protect and enhance watercourses and riparian areas adjacent to development. Additional bylaws include waterways protection, soil removal and deposit guidelines, and tree cutting regulations.

OCP objectives directly related to ravines include: preserving ravines as environmentally sensitive areas and permitting only low intensity residential nearby, avoiding impact to ravines in road development, and working with other agencies to manage/monitor point and non-point source pollution of waterways. Objectives related to stormwater management that will indirectly affect ravines include: developing Integrated Stormwater Management Plans (ISMPs), conducting impact studies on sensitive areas being considered for development, enhancing the natural environment and minimizing damage through appropriate planning/construction measures, working with other agencies to protect/enhance shoreline habitat during coastal development, considering Fraser River Estuary Management Program (FREMP) Area Designations in land use decisions, requiring development applications in foreshore areas to be reviewed by FREMP, maintaining groundwater/aquifer water quality, and upgrading water, storm, and sanitary sewer systems.

3.2 Surrey: Stormwater Policies and Practices

In addition to policies and regulations for construction and development in Surrey's OCP, the city has also developed numerous resources to support and guide stormwater management⁹ including:

- Master Drainage Plans, detention ponds, driveway culverts, flows and flow monitoring data, and sustainable drainage best management practices. Also, the integration of stormwater or drainage considerations into area servicing studies, preliminary design assessments, development application plans, neighbourhood concept plans, functional feasibility plans, and infrastructure management plans. In addition, ISMPs have been or will be completed for the 39 different watershed drainage areas located within the City.

⁷ HB Lanarc Consultants Ltd. and Raincoast Applied Ecology (2011, April). City of Surrey Ecosystem Management Study. Retrieved February 8, 2013 from <http://www.surrey.ca/plans-strategies/1332.aspx>.

⁸ COSMOS. City of Surrey Mapping Online System, Version 1.0.2.1. Retrieved January 16, 2013 from <http://cosmos.surrey.ca/external/>.

⁹ City of Surrey. 2012. Stormwater. Retrieved December 17, 2012 from <http://www.surrey.ca/city-services/4706.aspx>.

4.0 CONCLUSIONS

Although the North Delta Study area is quite mature in terms of build out, it is not expected that significant amounts of change will occur with respect to future total impervious areas. There are only two land use zones in the City that have been identified as undergoing intensification that may result in an increase in total impervious area. These are single family residential zones where the average TIA will increase from 35% to 40% and the North Delta Commercial and Mixed-Use zones, which will see an increase in TIA from 57% to 64% and 56% to 68% respectively. Average total impervious area for the entire study area will increase from 38% to 42% and the average area-weighted total impervious areas will increase from 48% to 50%. Based on interviews within City staff and an analysis of existing planning documents, no additional changes are expected to occur in other land use zones.

5.0 CLOSURE

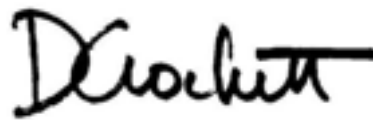
We trust the information contained in this technical memorandum is sufficient for your present needs. Should you have any additional questions regarding the project, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.



Aaron Licker, B.A., Adv. Dipl. Tech. GIS
GIS Programmer/Analyst

AL/DC/asd



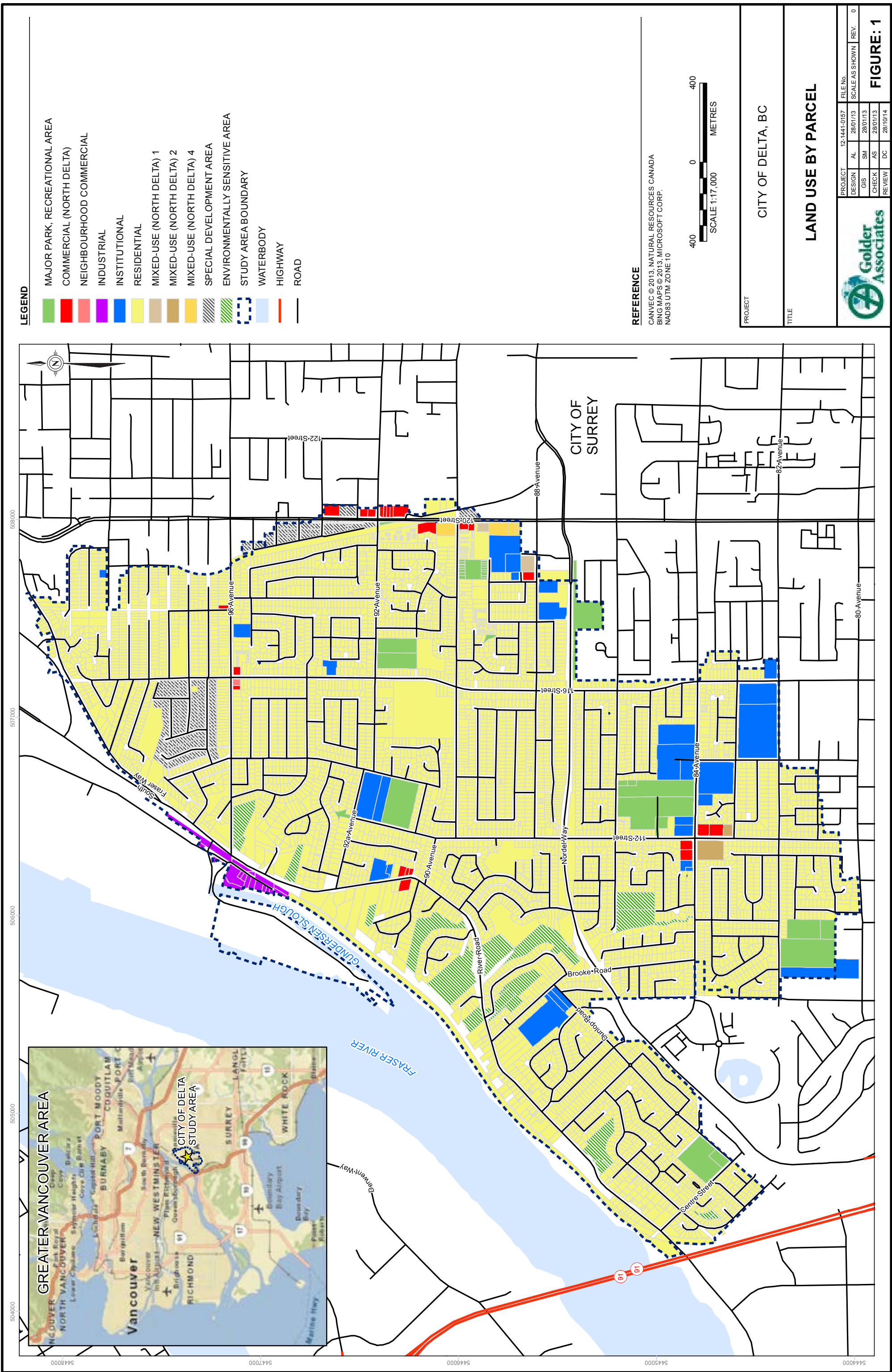
Don Crockett, B.E.S., M.L.Arch., BCSLA, CSLA
Principal, Landscape Architect

Attachment: Appendix A – Study Area Figures

\\golder.gds\gal\vancouver\final\2012\12-1441-0157\1214410157-003-tm-rev0\1214410157-003-tm-rev0-north delta ravines 29oct_14.docx

APPENDIX A

Study Area Figures

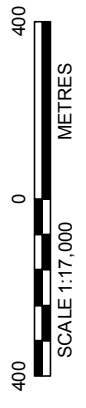


LEGEND

- MAJOR PARK, RECREATIONAL AREA
- COMMERCIAL (NORTH DELTA)
- NEIGHBOURHOOD COMMERCIAL
- INDUSTRIAL
- INSTITUTIONAL
- RESIDENTIAL
- MIXED-USE (NORTH DELTA) 1
- MIXED-USE (NORTH DELTA) 2
- MIXED-USE (NORTH DELTA) 4
- SPECIAL DEVELOPMENT AREA
- ENVIRONMENTALLY SENSITIVE AREA
- STUDY AREA BOUNDARY
- WATERBODY
- HIGHWAY
- ROAD

REFERENCE

CANVEC © 2013, NATURAL RESOURCES CANADA
 BING MAPS © 2013, MICROSOFT CORP.
 NAD83 UTM ZONE 10



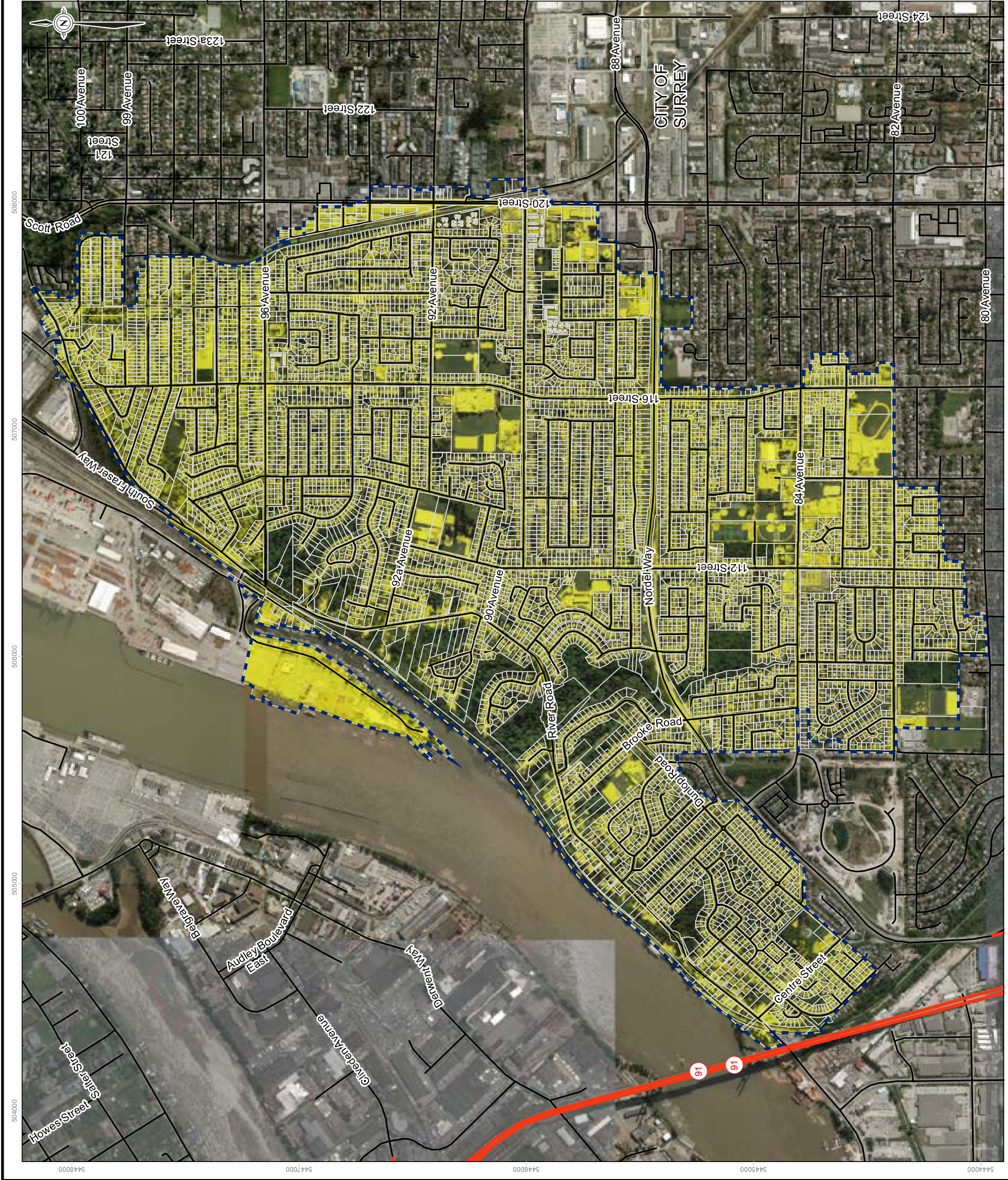
PROJECT CITY OF DELTA, BC

LAND USE BY PARCEL

PROJECT	12-1441-0157	FILE NO.
DESIGN	AL	28/01/13
GIS	SM	28/01/13
CHECK	AS	28/01/13
REVIEW	DC	28/10/14



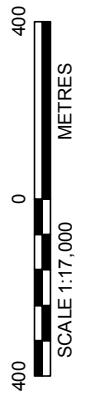
FIGURE: 1



LEGEND

- CLASSIFIED IMPERVIOUS AREA
- STUDY AREA BOUNDARY
- PARCEL BOUNDARIES
- HIGHWAY
- ROAD

REFERENCE
 CANVEC © 2013, NATURAL RESOURCES CANADA
 BING MAPS © 2013, MICROSOFT
 NAD83 UTM ZONE 10



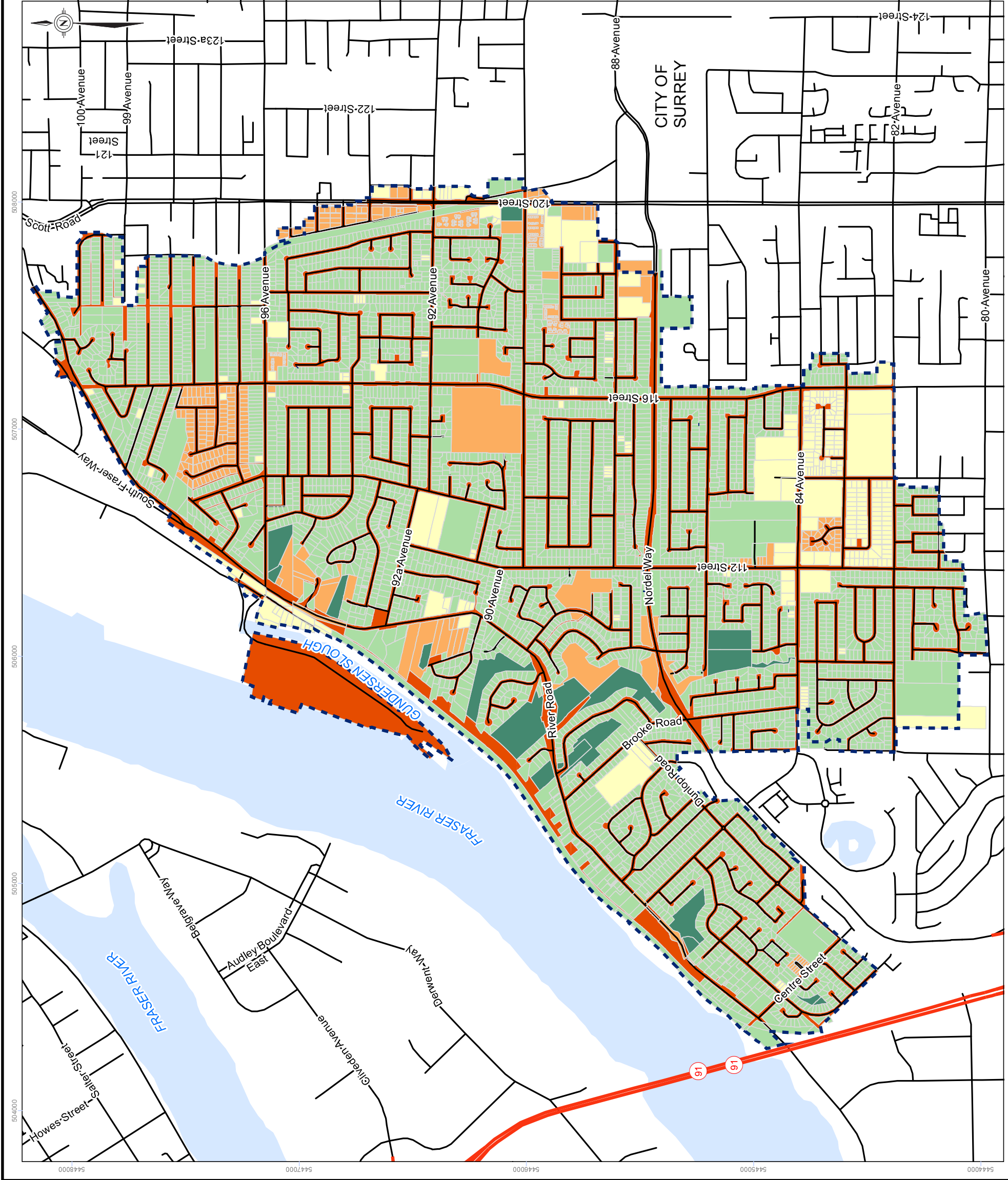
PROJECT: CITY OF DELTA, BC

TITLE: **CLASSIFIED IMPERVIOUS AREA BY ANALYSIS GRID**



PROJECT	FILE No.	SCALE AS SHOWN	REV.	0
DESIGN	AL	28/01/13		
GIS	SM	07/02/13		
CHECK	AS	28/01/13		
REVIEW	DC	28/10/14		

FIGURE: 2



LEGEND

PERCENT IMPERVIOUS AREA

- 0 - 19.9%
- 20 - 39.9%
- 40 - 59.9%
- 60 - 79.9%
- 80 - 100%

STUDY AREA BOUNDARY

PARCEL BOUNDARY

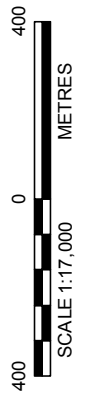
WATERBODY

HIGHWAY

ROAD

REFERENCE

CANVEC © 2013, NATURAL RESOURCES CANADA
 BING MAPS © 2013, MICROSOFT
 NAD83 UTM ZONE 10



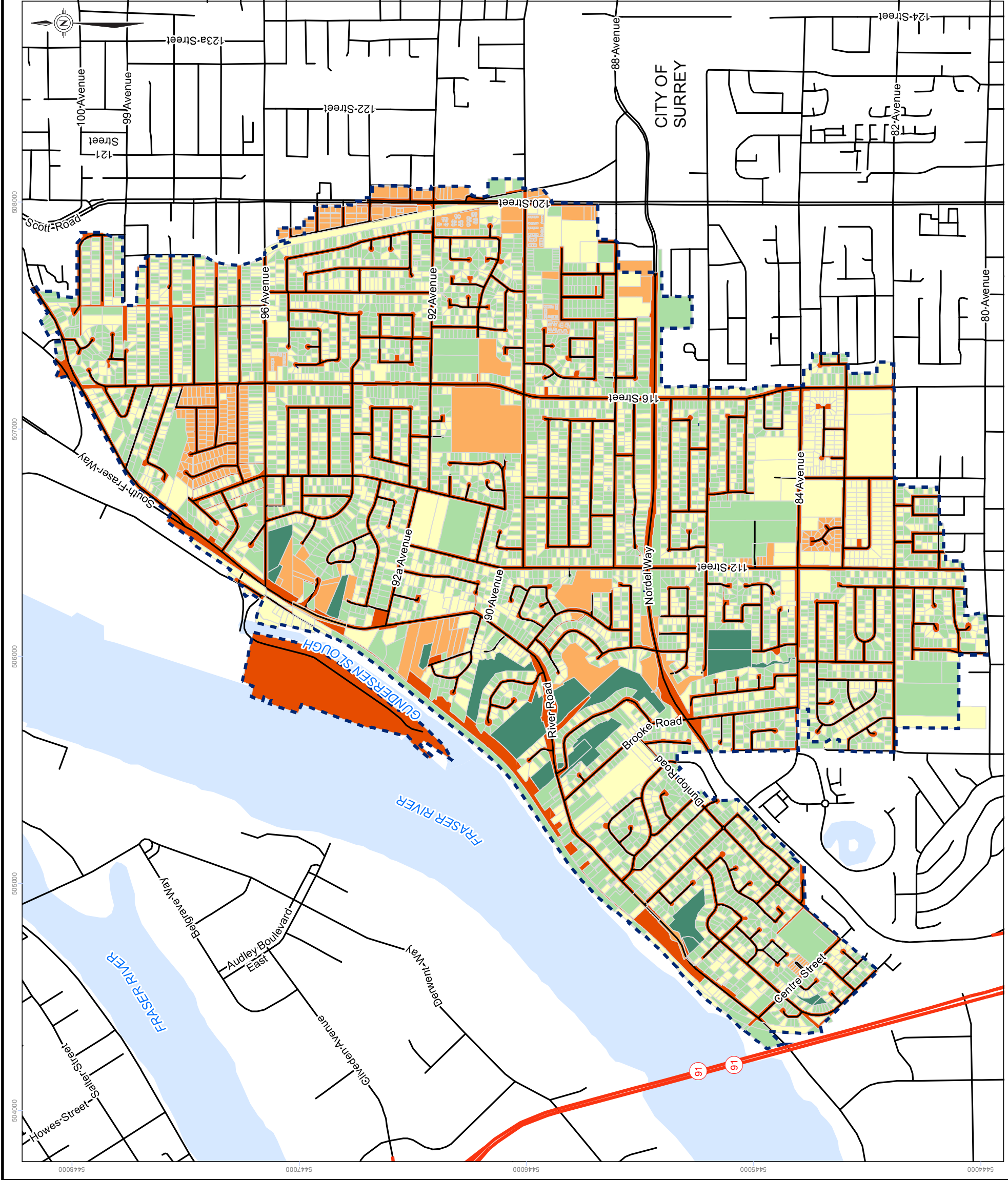
PROJECT CITY OF DELTA, BC

TITLE **PRESENT IMPERVIOUS AREA BY PARCEL**



PROJECT	FILE No.	SCALE AS SHOWN	REV.	0
DESIGN	AL	28/01/13	07/02/13	
GIS	SM	28/01/13	28/01/13	
CHECK	AS	28/01/13	28/01/13	
REVIEW	DC	28/10/14	28/10/14	

FIGURE: 3



LEGEND

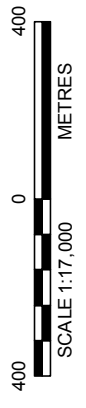
PERCENT IMPERVIOUS AREA

- 0 - 19.9%
- 20 - 39.9%
- 40 - 59.9%
- 60 - 79.9%
- 80 - 100%

STUDY AREA BOUNDARY

- Parcel Boundary
- Waterbody
- HIGHWAY
- ROAD

REFERENCE
 CANVEC © 2013, NATURAL RESOURCES CANADA
 BING MAPS © 2013, MICROSOFT
 NAD83 UTM ZONE 10

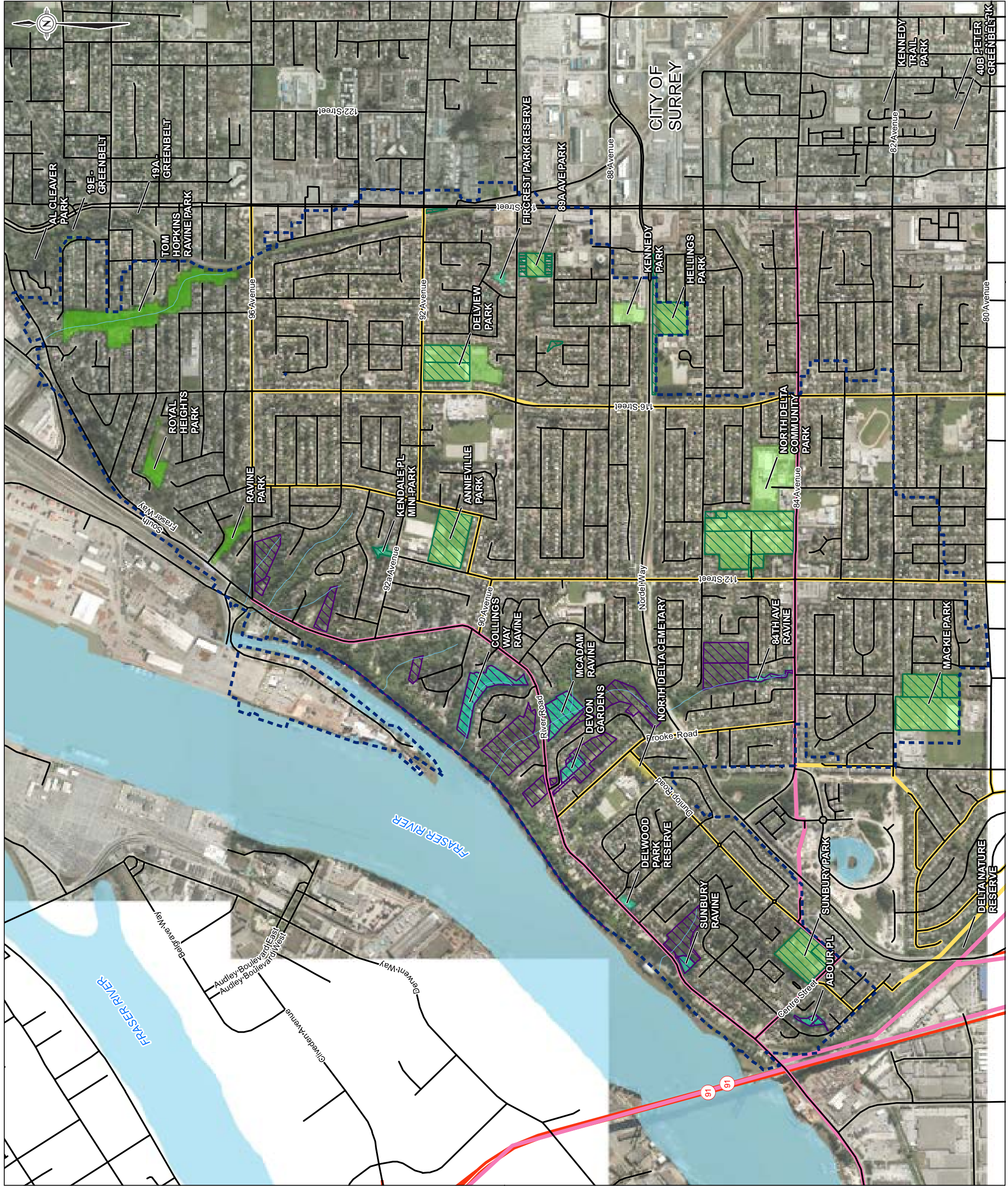


PROJECT CITY OF DELTA, BC

TITLE **FUTURE IMPERVIOUS AREA BY PARCEL**



PROJECT		FILE No.	SCALE AS SHOWN	REV.	FIGURE: 4
DESIGN	AL	28/01/13		0	
GIS	SM	07/02/13			
CHECK	AS	28/01/13			
REVIEW	DC	28/10/14			

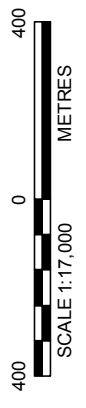


LEGEND

- STUDY AREA BOUNDARY
- DELTA DEVELOPED PARK
- DELTA RESERVE
- DELTA CEMETARY
- SURREY PARKS AND NATURAL AREAS
- Trail
- MAJOR PARK, RECREATIONAL AREA (DELTA OCP)
- ENVIRONMENTALLY SENSITIVE AREA (DELTA OCP)
- WATERBODY
- COMMUNITY ALTERNATIVE TRANSPORTATION ROUTE
- REGIONAL ALTERNATIVE TRANSPORTATION ROUTE
- HIGHWAY
- ROAD
- WATERCOURSE
- SCHOOL

REFERENCE

CANVEC © 2013. NATURAL RESOURCES CANADA
 BASE IMAGES FROM CORPORATION OF DELTA, CITY OF SURREY AND ESRI.
 NAD83 UTM ZONE 10



PROJECT CITY OF DELTA, BC

TITLE
PARKS AND NATURAL AREAS



PROJECT	12-1441-0157	FILE NO.	
DESIGN	AL	19/07/13	SCALE AS SHOWN
GIS	DL	19/07/13	REV. 0
CHECK	AS	19/07/13	
REVIEW	DC	28/10/14	

FIGURE: 5



KERR WOOD LEIDAL
consulting engineers

Appendix C

Environmental Inventory and Assessment



Appendix C – Environmental Inventory and Assessment

Contents

C.1	Introduction and Purpose	1
C.2	Watershed and Riparian Forest Cover	1
C.3	Water and Sediment Quality	5
	General Water Quality Survey	7
	Detailed Water Quality Survey	8
	Sediment Quality Sampling	8
C.4	Benthic Invertebrates	9
C.5	Fish Community	9
C.6	Instream Habitat	11
C.7	Barriers to Fish Passage	15
C.8	SFPR Construction.....	17
C.9	Environmental Enhancement and Restoration Opportunities.....	17
	Watershed and Landscape-scale Actions	18
	Riparian Corridor Actions	18
	Instream Habitat Actions.....	18
	Fish Passage Improvements	18

Figures

Figure C-1: Watershed forest cover in 2012 (dark green) and losses since 1995 (light purple) in the North Delta watershed	3
Figure C-2: Riparian forest cover (%RFI) in the North Delta watershed. 2012 riparian forest cover shown in light green and 1995 riparian forest cover is light purple. Recent losses associated with construction of the SFPR are visible along the Fraser River	4
Figure C-3: The McAdam Creek ravine supports the largest concentration of forest in the study area. An 11 ha forest patch (shown in red) is found in the central ravine between River Road and Nordel Way.....	5
Figure C-4: Location of water and sediment quality sampling sites in the North Delta watershed study area	6
Figure C-5: 30 cm spawning sea-run coastal cutthroat trout found dead in McAdam Creek in March 2012.....	11
Figure C-6: Location of instream habitat sampling sites in North Delta watershed	12
Figure C-7: Distribution of instream large wood (pink dots: larger than 2 m long and 10 cm in diameter) and pools >40 cm deep (blue dots) in the watercourses in the North Delta study area in March 2013.....	14
Figure C-8: Important fish passage barriers in the North Delta watershed	16



Appendix C – Environmental Inventory and Assessment

Tables

Table C-1: Riparian Forest Cover Summary.....	2
Table C-2: General Water Quality Conditions Summary (October 2012)	7
Table C-3: Fish Presence Summary	10
Table C-4: Fish Passage Issues Summary.....	15
Table C-5: Impact of SFPR Construction on North Delta Watercourses	17
Table C-6: Summary of Channel Measurements	19
Table C-7: General Water Quality Measurements (October 3, 2012)	20
Table C-8: Metal Concentrations in Sediment Samples.....	21
Table C-9: Total Metals, Fecal Coliforms, and Nutrients	22
Table C-10: Benthic Index of Biological Integrity Values for McAdam Creek	23



Appendix C – Environmental Inventory and Assessment

C.1 Introduction and Purpose

An environmental inventory of watercourses and riparian areas in the North Delta watershed was undertaken to summarize information on watershed and riparian forest cover, water and sediment quality, benthic invertebrate communities, fish and fish habitat, and instream habitat. In addition, habitat restoration sites and enhancement strategies focusing on instream and riparian areas were also identified. The inventory focused on ten streams that are within the Corporation of Delta's boundaries.

There is relatively little specific information on fish and fish habitat, water quality, and other components of the ecological health of the study area streams. Stream inventories were undertaken by Coast River Environmental Services to characterize fish use and habitat conditions as part of the planning and design of the South Fraser Perimeter Road (SFPR)¹. Additional information from the SFPR construction phase was also incorporated when available.

C.2 Watershed and Riparian Forest Cover

Forest vegetation and forest soils regulate many important watershed processes, such as the movement and provision of water, sediment, nutrients, organic matter, and wood. Within watersheds, forests are important regulators of streamflow through rainfall interception, capture, and evapotranspiration, and forest soils infiltrate, store, and transport water. Forests within the riparian area, the interface zone between the water and land, also protect streams by providing cooling shade and stabilizing banks, as well as supplying food, nutrients, organic matter, and instream wood debris that are important components of aquatic ecosystems and fish habitat. Both watershed and riparian forest cover decline with increasing urbanization. Watershed forest cover may also be a useful indicator of the increasing intensity of urban land use in situations where imperviousness remains relatively stable.

Watershed and riparian forest cover was mapped using 2012 (rectified Google imagery) and 1995 orthophotos in GIS based on visual interpretation of forest cover. It included large forest patches as well as smaller patches distributed within urban areas and parks. The assessment area was expanded to include Delta Creek and the Colliers Creek watersheds to the north of the main study area.

Riparian forest cover mapping followed methods followed those used by Page and Johnston (2006). A standard 30 m buffer on either side of the centerline of permanent stream channels (60 m total width) was used to assess riparian forest integrity (RFI) across the watershed. RFI has been used as an indicator of riparian function in urbanizing watersheds in Metro Vancouver as part of ISMP planning².

Figures C-1 and C-2 provide a graphical summary of watershed and riparian forest cover mapping. Key findings of the analysis were:

- A total of 87.5 ha (13%) of the 802.4 ha study area was forested in 2012. Concentrations of forest were found in the stream ravines and along the Fraser River escarpment. The largest area of forest was the central unit of the McAdam Creek ravine at 11.1 ha (see Figure C-1).

¹ Coast River Environmental Services Ltd. 2006. South Fraser Perimeter Road Fish Habitat Assessment: Technical Volume 9 of the Environmental Assessment Application. Prepared for Ministry of Transportation. 140 pp + appendices.

² Greater Vancouver Regional District. 2005. Template for Integrated Stormwater Management Planning 2005. Draft report produced by Kerr Wood Leidal Associates for Greater Vancouver Regional District, December 2005.



Appendix C – Environmental Inventory and Assessment

- Approximately 10.8 ha (1.3%) of forest cover have been lost in the past 17 years based on 98.3 ha (12%) of watershed forest cover in 1995. The largest losses have occurred recently during construction of the South Fraser Perimeter Road.
- Approximately 68% (30.1 ha) of the combined riparian zones surrounding the study streams is currently forested (Table C-1). It varies from 41% surrounding Regal Drive Creek to 82% around McAdam Creek. Most of the riparian area is vegetated with deciduous forest (red alder and black cottonwood).
- Riparian forest cover has declined 1.8 ha (4%) over the past 17 years (30.1 ha (68%) in 2012 and 31.9 ha (72%) in 1995) (see Table C-1). The difficulty in developing on steep ravine slopes and the regulation of development in riparian areas has limited riparian forest loss. However, recent losses have occurred because of construction of the SFPR.

Table C-1: Riparian Forest Cover Summary

No.	Name	Length (m)	Riparian Area	Rip Forest 1995 (ha)	Rip Forest 2012 (ha)	% Rip Forest 1995	% Rip Forest 2012
1	Sunbury Creek	393	2.44	1.95	1.72	80%	70%
2	Nelson View Creek	205	1.36	0.84	0.58	62%	43%
3	McAdam Creek	1,817	10.74	9.17	8.83	85%	82%
4	Collings Creek	506	3.15	2.60	2.41	83%	76%
5	Norum Creek	320	2.07	1.92	1.59	93%	77%
6	Gunderson Creek	205	1.12	0.86	0.67	77%	60%
7	Knudson Creek	387	2.50	1.68	1.62	67%	65%
8	Kendale Creek	566	3.65	2.61	2.61	72%	72%
9	Shadow Brook Creek	584	3.53	2.29	2.24	65%	63%
10	Regal Drive Creek	424	2.76	1.15	1.14	41%	41%
11	Delta Creek	1,781	10.92	6.84	6.71	63%	61%
	Total	7,188	44.24	31.90	30.11	72%	68%



Appendix C – Environmental Inventory and Assessment



Figure C-1: Watershed forest cover in 2012 (dark green) and losses since 1995 (light purple) in the North Delta watershed



Appendix C – Environmental Inventory and Assessment

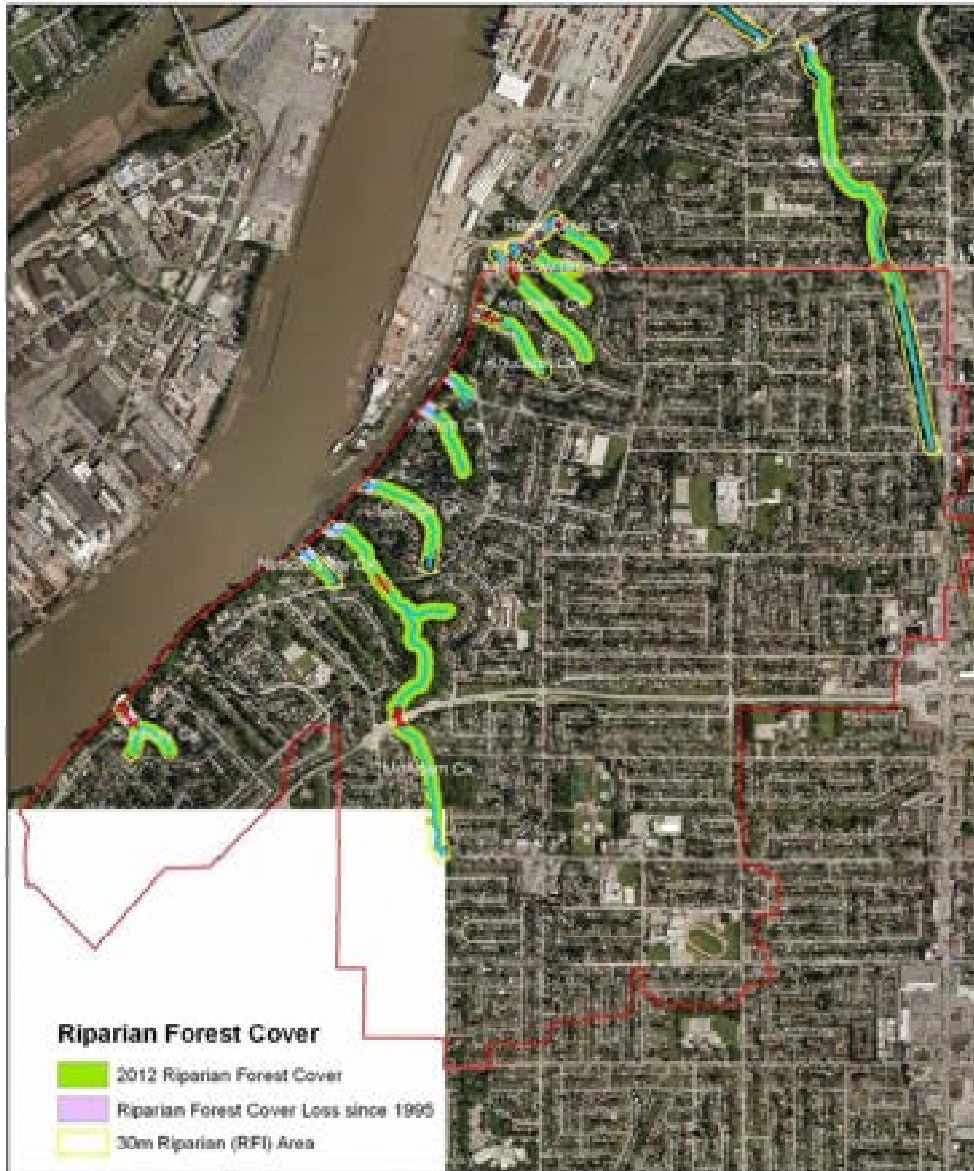


Figure C-2: Riparian forest cover (%RFI) in the North Delta watershed. 2012 riparian forest cover shown in light green and 1995 riparian forest cover is light purple. Recent losses associated with construction of the SFPR are visible along the Fraser River

Appendix C – Environmental Inventory and Assessment



Figure C-3: The McAdam Creek ravine supports the largest concentration of forest in the study area. An 11 ha forest patch (shown in red) is found in the central ravine between River Road and Nordel Way

C.3 Water and Sediment Quality

Water quality refers to the chemical, physical and biological conditions of water and the degree to which it is impaired or degraded by natural or anthropogenic factors. Water quality in streams is vital to the protection of ecosystem functioning and aquatic life, such as fish, as well as human uses for drinking water and recreation, and aesthetics. None of the streams in the study area are used for drinking water. Comparisons to BC Water Quality Guidelines (BCWQGs) and the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) can help to assess whether current stormwater management is adequately protecting these values.

No existing information on water and sediment quality in the study streams was available except for City of Surrey's biannual (spring and fall) sampling of general patterns in Delta Creek as part of their benthic invertebrate sampling program.

Appendix C – Environmental Inventory and Assessment

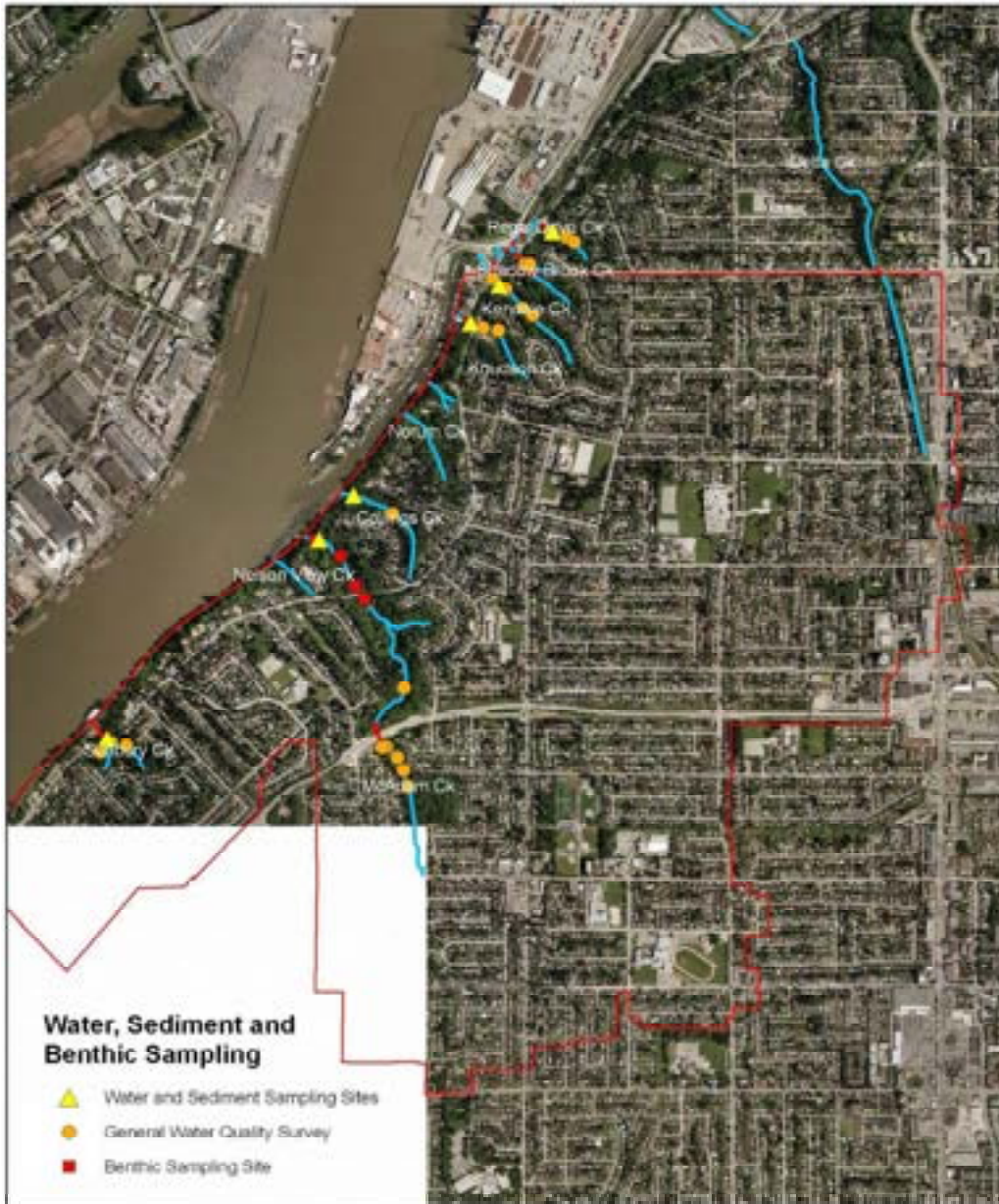


Figure C-4: Location of water and sediment quality sampling sites in the North Delta watershed study area



Appendix C – Environmental Inventory and Assessment

Three methods were used to assess water and sediment quality in streams in the study area:

1. A survey of general water quality parameters (e.g., temperature, pH) in seven of the study streams on October 3, 2012 using a multi-parameter (YSI 6920) probe;
2. Lab-based measurement of total metals, nutrients, and fecal coliforms was completed at six streams on November 12, 2012; and
3. Concentrations of total metals were also measured in streambed sediments from six streams in the study area (Sunbury, McAdam, Collings, Knudson, Kendale, and Shadow Brook) on November 12, 2012.

Sites sampled are illustrated on Figure C-4 and general water quality data is summarized in Table C-2. Raw data for each component is presented in Tables C-5 to C-9.

Table C-2: General Water Quality Conditions Summary (October 2012)

Parameter	Units	Parameter Values		
		Minimum	Maximum	Mean
Water Temperature	°C	9.9	14.1	11.0
Dissolved Oxygen	mg/L	11.0	14.3	12.8
Dissolved Oxygen	% Sat	101.8	130.4	116.4
Specific Conductivity	µS/cm	63	302	192
pH	pH units	7.05	8.08	7.71
Turbidity	NTU	0.2	785.2	51.0
Oxygen Reduction potential (ORP)	mV	-58.4	51.4	3.36

General Water Quality Survey

Key results of the general water quality survey were:

- The survey did not find any specific sites or stream sections with elevated or unusual water quality characteristics which would indicate specific sources of contaminations (e.g., “hot spots”). Measurements of general water quality parameters were consistent with regional observations in urban streams. The study streams have similar water quality characteristics although Sunbury and Knudson creeks had higher specific conductivity, higher turbidity, and lower ORP which may indicate more urban influences.
- Specific conductivity was elevated (mean of 192 µS/cm) relative to undisturbed streams (typically <20 µS/cm in Metro Vancouver), however, it was lower than many heavily urbanized streams such as Still Creek in Vancouver, Quibble Creek in Surrey, and Wagg Creek in North Vancouver (typically these streams have specific conductivity values over 300 µS/cm).
- All streams had dissolved oxygen levels were above 11 mg/L which is suitable for salmonid spawning and rearing.



Appendix C – Environmental Inventory and Assessment

- pH ranged from 5.47 to 8.29 (mean of 7.67) which is more variable than some watersheds but still within expected ranges.
- Mean turbidity was elevated above background levels (51.0 NTU compared to <5 NTU in reference streams) but this was influenced by the measurement of 785.2 NTU in one the tributaries to Sunbury Creek). If this measurement was removed, the mean turbidity was 14.3 NTU.

Detailed Water Quality Survey

Key results were:

- Generally, the sampling showed that study area streams had total metals concentrations below BCWQ guidelines. Total copper was marginally higher than the BCWQ guideline in Sunbury and McAdam creeks, and total antimony was elevated in the sample from McAdam Creek. These results are not a concern for aquatic life or other values.
- Fecal coliforms were lower than the BCWQ guideline for primary contact recreation (200 MPN/100 ml). Mean value was 91.5 (range of 57.2 to 108).
- Nutrients concentrations were similar to moderately urbanized streams in Metro Vancouver. The mean concentration of total nitrate was 1.14 mg/L which is slightly higher than expected based on land use (no agricultural activity) but less than the 2.95 mg/L recommended by the CCME guidelines. There were no signs of eutrophication such as excessive algae growth observed in the streams.

Sediment Quality Sampling

Stream sediments accumulate metals and other contaminants from a variety of sources in developed watersheds, and provide a complimentary assessment of environmental chemistry when combined with water quality. They are also useful for long-term monitoring of stream condition because they are much less variable than water quality measurements. Concentrations of total metals in stream sediments can be compared to BC Working Sediment Quality Guidelines (BCSQGs) and regional studies.

A single sediment samples were collected on November 12, 2012 from the lower reach of six of the study streams. The sample was composite of surface and shallow sub-surface fine sediment collected from 10-15 sites from within the active stream channel. The sampling location is shown in Figure C-4. The sample was analyzed for total metals using BC CSR standard methods.

Key results were:

- Total metals in streams sediments were similar to other moderately urbanized watersheds in Metro Vancouver.
- Samples from four streams (Sunbury, Collings, Knudson, and Kendale creeks) had concentrations of total nickel above the BC Working Sediment Quality Guidelines (BCSQGs), and the other two samples were near the guideline. The similar pattern across these streams and the lack of shared land use sources suggests nickel may be naturally elevated because of geological sources.
- Total arsenic in the sample from Knudson Creek was also above BCSQG. It is not considered unusual for urban streams in Metro Vancouver.

Full sediment quality sampling data can be found in Tables C-5 to C-9.



Appendix C – Environmental Inventory and Assessment

C.4 Benthic Invertebrates

Benthic (streambed) invertebrates are useful indicators of the biological condition of the stream or watershed and can be monitored over time to track changes in stream or watershed health. B-IBI (Benthic Index of Biotic Integrity) is a common method for summarizing benthic invertebrate data using metrics of community structure and composition. B-IBI is an effective tool for measuring the biological condition of small streams in Metro Vancouver and is recommended as part of Integrated Stormwater Management Plan (ISMP) projects.

Samples are collected from the lower 500 m of McAdam Creek using a field sampling protocol developed for streams in Metro Vancouver. McAdam Creek was selected both as an indicator of the typical land use conditions in the North Delta watershed, and also as the stream with the highest ecological values.

Four composited samples are collected from segments within a 500 m sampling reach using a 500 micron Surber sampler on October 11, 2013. Composite samples are collected from three placements in riffle habitats using 3 minutes of substrate disturbance. Sample processing, subsampling, taxonomic identification, and B-IBI scoring (used as an index of watershed health) was completed by Rhithron Associates (Missoula, MT).

Key results of the benthic invertebrate sampling were:

- Mean B-IBI for McAdam Creek was 18.0 which is consistent with the level of urbanization in the watershed. B-IBI ranges from 10 to 50 and a mean score of 18.0 indicates McAdam Creek is transitional between fair and poor condition³.
- Mean taxa richness for all samples was 13.3 (range of 9 to 19). Mean EPT taxa richness (stoneflies, mayflies, caddisflies) was 4.5 (range of 3 to 7). Similar to B-IBI, both metrics indicate the stream is transitional between conditions typical of moderate urbanization and more urban land use which leads to a more substantial decline in benthic invertebrate taxa richness.
- The most abundant taxa in McAdam Creek were a larval midges (Chironomids; identified only to family: 43% of individuals sampled), Oligochaete worms (25%), and the pollution-tolerant stonefly *Baetis tricaudatus* (14%).

Full taxonomic data and individual B-IBI scores are available in Tables C-5 to C-9.

C.5 Fish Community

Information on fish presence was derived from the detailed fisheries assessment completed by Coast River Environmental Services for the SFPR environmental impact assessment⁴. No new fish sampling was used to confirm or update information on the fish community. Sampling to confirm this information was not part of the scope of this project. Existing fisheries information on each watercourse is summarized in Table C-3 based on the Coast River SFPR report.

³ See Puget Sound Benthos for more information on B-IBI score. [Available here](#).

⁴ Coast River Environmental Services Ltd. 2006. South Fraser Perimeter Road Fish Habitat Assessment: Technical Volume 9 of the Environmental Assessment Application. Prepared for Ministry of Transportation. 140 pp + appendices.



Appendix C – Environmental Inventory and Assessment

Seven of the eleven streams support resident cutthroat trout populations, and three (McAdam, Delta and Regal Drive Creek) support coho salmon. Additional streams may support coho salmon or chum salmon but presence is not confirmed.

Table C-3: Fish Presence Summary

Stream	Fish Presence	Watercourse Coding ¹
Sunbury Creek	Cutthroat trout occur upstream of River Road	Red
Nelson View Creek	No fish present; dry during summer	Yellow
McAdam Creek	Cutthroat trout, coho salmon, sculpins; searun cutthroat trout observed March 2013 (see Figure E-5)	Red
Collings Creek	Cutthroat trout and coho salmon suspected but not confirmed	Red
Norum Creek	Cutthroat trout confirmed; coho and chum salmon possible	Red
Gunderson Creek	No fish present; dry during summer	Yellow
Knudson Creek	No fish present	Yellow
Kendale Creek	Cutthroat trout, rainbow trout, sculpin species, threespine stickleback	Red
Shadow Brook Creek	Cutthroat trout; coho salmon possible but not confirmed	Red
Regal Drive Creek	Coho salmon, cutthroat trout	Red
Delta Creek	Cutthroat trout, rainbow trout, coho salmon	Red

¹ Red coded = Inhabited by salmonids year round or potentially inhabited year round.
 Yellow coded = Significant food/nutrient value. No fish present.

Appendix C – Environmental Inventory and Assessment



Figure C-5: 30 cm spawning sea-run coastal cutthroat trout found dead in McAdam Creek in March 2012

C.6 Instream Habitat

Instream habitat characteristics (channel dimensions, substrate, channel complexity, etc.) were assessed during field visits in February and March 2013. To understand the distribution of different habitat types, channel dimensions and substrate conditions were measured at 41 points at intervals along the study area streams (see Figure C-6 for locations). Bankfull width, wetted width, substrate composition (visual estimate of % boulder, cobble, large gravel, small gravel, silt/sand), and substrate embeddedness were recorded. These measurements provide quantitative information on channel conditions as well as providing data that can be monitored over time.

In addition, pieces of large wood (greater than 10 cm in diameter and 2 m long) and pools >40 cm deep were mapped as indicators of fish habitat value. Large wood and deep pools are important for sustaining salmon and trout populations, particularly juvenile coho salmon and cutthroat. Large wood is an important structural feature in small coastal streams which is reduced or eliminated by urbanization.



Appendix C – Environmental Inventory and Assessment

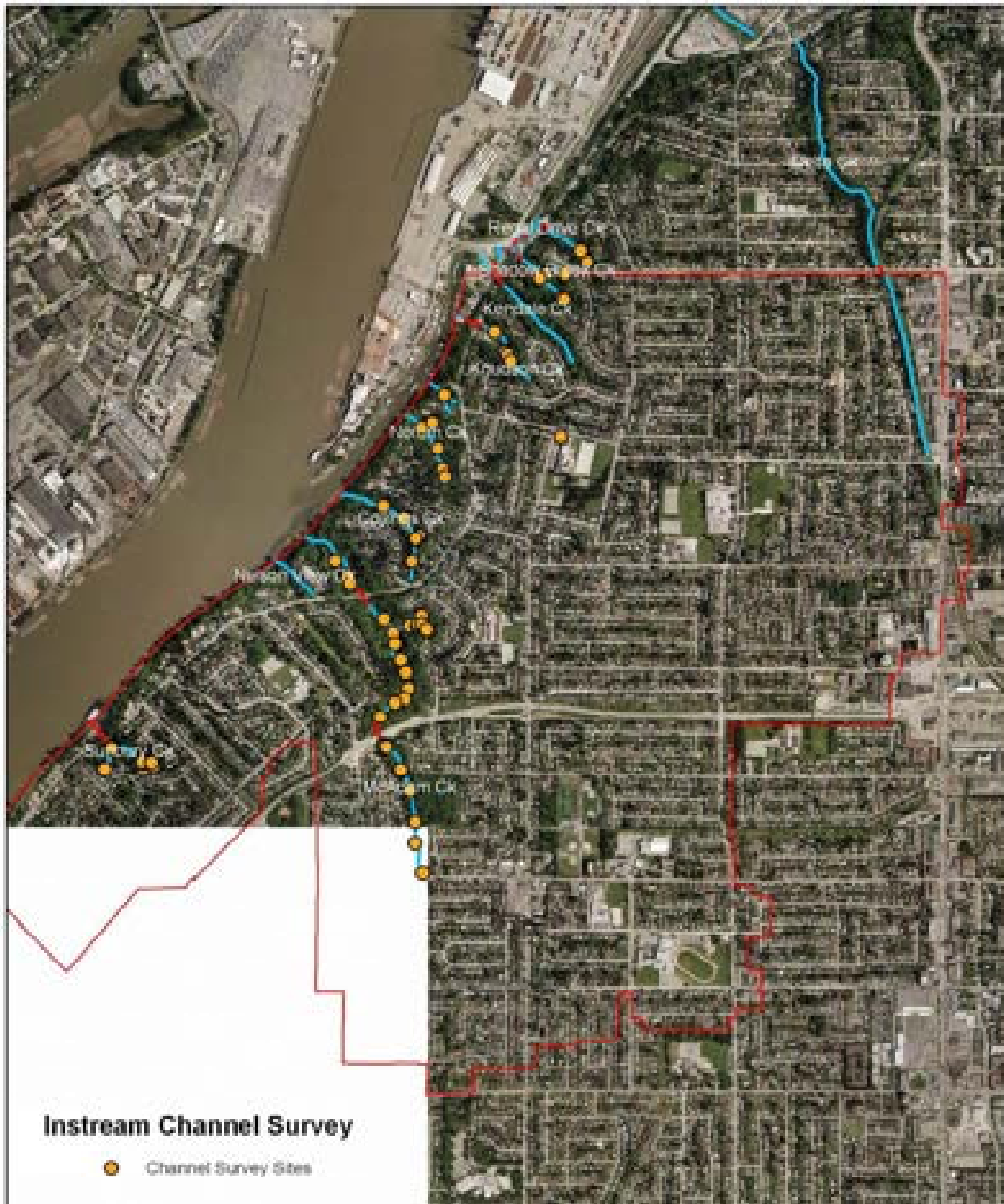


Figure C-6: Location of instream habitat sampling sites in North Delta watershed



Appendix C – Environmental Inventory and Assessment

Key results of the instream habitat survey were:

- Mean bankfull width in the study streams ranged from 0.6 m in Kendale Creek to 2.2 m in McAdam Creek with an overall mean of 1.6 m. Wetted width during the survey ranged from 0.4 m in Kendale Creek to 1.4 m in McAdam Creek (overall mean of 1.0 m). Channel dimensions are characteristic of small first or second-order streams.
- Stream channel substrate is predominantly cobble and gravel with lesser amounts of boulder and fine sediment (sand and silt). Mean substrate was approximately 10% boulder, 26% cobble, 34% large gravel, 20% small gravel, and 10% fines.
- Embeddedness, a measure of the sedimentation of substrate, was 21% (meaning about 1/5 of a typical piece of cobble is embedded in the stream bed). Embeddedness increases with urbanization because of the increase in fine sediment.
- Large instream wood (“large wood debris (LWD)”) is widely distributed in the study area streams but rarely abundant compared to undisturbed streams (see Figure C-7). A total of 381 pieces were recorded with an average length of 4.4 m, diameter of 27 cm and volume of 0.45 m³. Wood pieces were not differentiated by species or age/condition.
- The density of large instream wood was 5.3 pieces per 100 m of stream channel. Natural streams typically have been 10 and 20 pieces per 100 m and wood volume is often much higher. Overall, the survey indicates that the study streams have less than half the large instream wood compared to natural streams. Large wood is concentrated in the upper ravine areas rather than the higher productivity fish habitat in the lower reaches.
- Twenty pools deeper than 40 cm deep were recorded in March 2013 (see Figure C-7). All were found in McAdam Creek. Mean depth was 47 cm (range of 40 to 70 cm). There was no clear pattern or concentration of pool development related to channel dimensions or other factors.

Appendix C – Environmental Inventory and Assessment



Figure C-7: Distribution of instream large wood (pink dots: larger than 2 m long and 10 cm in diameter) and pools >40 cm deep (blue dots) in the watercourses in the North Delta study area in March 2013



Appendix C – Environmental Inventory and Assessment

C.7 Barriers to Fish Passage

Fish passage barriers restrict fish access from the Fraser River in to most streams in the North Delta watershed. Steep channel gradient and historical railway development along the Fraser River have combined to create impassable barriers or seasonal obstructions. Table C-4 summarizes available information on fish passage based on the Coast River SFPR report and field surveys and Figure C-8 shows their location.

Table C-4: Fish Passage Issues Summary.

Stream	Fish Passage Issue
Sunbury Creek	13 m long culvert at stream mouth (railway crossing and light industrial site) precludes anadromous fish access from Fraser River; culvert is located near archaeological site; River Road culvert has a 60 cm drop from accumulated debris lodged at inlet; resident cutthroat trout population above River Road
Nelson View Creek	Railway culvert (approx. 22 m long) likely precludes fish access from Fraser River; small stream size and seasonal flow also limit fish use
McAdam Creek	Fish passable culvert (25 m) under railway; new bridges for SFPR; fishway allows adult salmonid access at River Road; Nordel Way culvert allows limited passage (at high flows fish can approach up riprap cascade enter back flooded culvert)
Collings Creek	Passable to fish at Fraser River (marsh area); no open channel above River Road
Norum Creek	40 m long culvert at railway crossing; potential fish access under some flow levels; no open channel above River Road
Gunderson Creek	No fish access; vertical riser pipe at railway culvert precludes access
Knudson Creek	Multiple fish passage barriers including culverts beneath industrial site at mouth (40 m), under railway crossing, and River Road (grated vertical riser pipe); no fish access
Kendale Creek	River Road culvert likely prevents upstream fish access because of internal velocity; culvert under railway tracks; 29 m long culvert at mouth (downstream of Gunderson Road)
Shadow Brook Creek	River Road culvert is likely a barrier to anadromous fish based on sampling results
Regal Drive Creek	40 m culvert under River Road precludes fish access; steep channel and cascade combined with 70 cm drop at culvert outlet 100 m east of River Road is also a passage barrier
Delta Creek	Fish passage not assessed



Appendix C – Environmental Inventory and Assessment



Figure C-8: Important fish passage barriers in the North Delta watershed



Appendix C – Environmental Inventory and Assessment

C.8 SFPR Construction

Recent construction of the South Fraser Perimeter Road (SFPR) has affected watercourses in the North Delta study area including riparian clearing and changes to culverts. Impacts have been closely scrutinized and mitigation measures to maintain or improve fish and riparian habitat have been implemented. Table C-5 summarizes riparian and stream changes associated with the SFPR.

Table C-5: Impact of SFPR Construction on North Delta Watercourses

Watercourse	Fish	SFPR Works
Sunbury Creek	CT upstream of River Road	Culvert replacement but no upgrading to fish passage because extensive culverting of lower section
Nelson View Creek	No Fish	Headwalls installed
McAdam Creek	CT, CO, etc.	Headwalls installed; bridge crossing; riparian clearing (50 m x 30 m)
Collings Creek	CO, CT suspected	Lock-blocks to minimize disturbance; riparian clearing (53 m x 30 m)
Norum Creek	CO, CT, CH, confirmed or suspected	Installation of temporary culvert (40 m long) and restoration at later date; riparian clearing (40 m x 30 m).
Gunderson Creek	No fish (access barrier at railway)	Installation of 30 m pipe arch
Knudson Creek	Fish to River Road (steep above)	Culvert extension on north and south sides of River Road; no change to fish access but loss of habitat on north side
Kendale Creek	CO, CT in lower section; CT in ravine	Two culverts: one for fish and water flow (1200 mm) and the other for wildlife (1050 mm); riparian clearing: 50 by 30 m work area on the east bank and a 30 x 30 m ² work area on the west bank

C.9 Environmental Enhancement and Restoration Opportunities

Restoration and enhancement opportunities were identified at four scales:

1. Landscape-level connections including forest protection or restoration that support the broader ecological network in the watershed as well as watershed-scale functions;
2. Riparian restoration and management that focuses on increasing the amount and ecological function of riparian forest;
3. Instream habitat restoration to enhance fish populations; and
4. Fish passage improvements to restore access to habitat.



Appendix C – Environmental Inventory and Assessment

Watershed and Landscape-scale Actions

- The streams and forested ravines of the North Delta watershed should be recognized as a critical component of the ecological network of north Delta and the adjacent portion of Surrey. The McAdam Ravine forests are the central unit in this network.
- Construction of the SFPR has increased habitat fragmentation and options for increasing connectivity between the ravine areas through adjacent residential areas should be reviewed (e.g., providing lateral connections between the ravines outside of the SFPR corridor).
- Watershed-scale tree planting should be undertaken on public lands (parks and school sites), and encouraged on private lands.

Riparian Corridor Actions

- There are limited opportunities to increase riparian forest cover mainly because the existing riparian ravines are forested and surrounded by existing residential land use or roads. Opportunities for additional riparian protection may occur during redevelopment. Some private land use occurs in ravine areas and landowners should be encouraged to minimize forest loss.
- Removal of the debris associated with the abandoned milk farm in the lower portion of the McAdam Creek ravine should be undertaken.

Instream Habitat Actions

- Given the limited access into ravine areas, enhancement of instream habitat is not recommended as a mitigation strategy.
- Some opportunity exists for instream habitat complexing in McAdam Creek combined with the riparian restoration efforts described above.

Fish Passage Improvements

- Fish passage in to Knudson Creek, Kendale Creek, Shadow Brook, and Regal Drive Creek should be restored by addressing culvert barriers.

Table C-6: Summary of channel measurements in North Delta watershed study streams

Stream	X	Y	BW	WW	Habitat	BW Depth	WW Depth	%Boulder	%Cobble	%Lggravel	%Smgravel	%Fines	%Embed
Colliers	506590	5447232	1.2	0.9	P	28	4	2	40	20	8	20	10
Colliers	506513	5446513	2.7	0.8	R	48	10	1	25	45	20	9	20
Collings	505952	5446120	1.5	0.9	R	21	5	5	30	35	25	4	50
Collings	505829	5446246	1.8	0.6	P	45	9	0	3	40	30	27	15
Collings	505908	5446198	1.9	0.9	R	20	6	5	5	53	25	12	35
Collings	505939	5446031	2.1	0.7	R	34	7	20	10	50	20	0	10
Gunderson	506066	5446673	1.1	0.7	R	15	4	0	15	35	30	15	20
Kendale	506308	5446832	1.4	1.0	R	7	3	0	30	40	25	5	30
Kendale	506262	5446920	1.6	1.1	R	22	10	15	2	13	7	65	50
Knudson	506057	5446386	1.5	0.8	R	11	5	0	20	40	30	10	50
Knudson	506018	5446565	2.3	1.8	R	40	12	2	40	40	15	3	30
Knudson	505979	5446548	2.9	1.6	R	45	15	0	25	35	25	5	5
Knudson	506040	5446465	3.2	2.0	R	53	15	5	45	30	20	10	35
McAdam	505929	5445782	1.2	0.9	R	3	5	0	50	35	5	10	15
McAdam	505951	5444940	1.7	1.3	R	34	11	0	10	15	40	35	20
McAdam	505960	5445787	1.8	0.3	R	20	4	0	25	60	10	5	25
McAdam	505951	5445020	1.9	1.2	R	29	11	10	25	25	15	5	0
McAdam	505979	5445788	2.1	1.1	R	35	10	0	60	30	5	5	10
McAdam	505840	5445313	2.6	2.2	R	27	10	3	15	50	30	2	10
McAdam	505896	5445224	3.2	1.1	P	41	7	1	25	50	20	4	5
McAdam	505642	5446033	3.3	2.8	P	64	23	1	34	30	30	5	45
McAdam	505831	5445317	3.5	0.5	P	53	7	90	2	4	3	1	5
McAdam	505932	5445144	3.6	2.1	R	18	9	2	13	30	20	10	10
McAdam	505830	5445323	3.8	2.5	R	42	15	10	35	45	10	0	20
McAdam	505831	5445806	4.5	3.0	R	45	11	2	45	30	20	3	30
McAdam	505896	5445651	4.5	2.7	R	52	25	15	35	30	15	5	10
McAdam	505701	5445944	5.1	4.1	R	32	11	0	25	40	30	5	25
McAdam	505873	5445482	5.4	3.8	R	45	17	15	35	35	13	2	18
McAdam	505874	5445713	5.6	2.6	P	46	19	1	52	35	10	2	15
McAdam	505816	5445428	5.6	4.8	P	42	13	85	3	5	5	2	30
McAdam	505925	5445540	5.7	4.5	R	57	15	20	35	35	10	0	10
Shadow Brook	506432	5447126	2.0	1.4	R	22	5	1	14	30	40	5	30
Shadow Brook	506456	5447142	2.4	1.4	R	32	9	4	82	5	6	3	10
Shadow Brook	506519	5447047	2.4	1.2	P	28	5	0	45	40	12	3	5
Sunbury	504777	5445306	0.6	0.4	R	18	5	0	10	15	35	40	50
Sunbury	504898	5445255	0.9	0.5	R	13	2	1	9	15	50	25	40
Sunbury	504888	5445253	1.4	0.6	R	42	13	1	19	50	25	5	20
Sunbury	504903	5445248	1.7	0.5	R	50	10	5	25	35	25	5	0
Sunbury	504742	5445225	2.3	0.6	P	35	10	0	25	25	5	5	0
Sunbury	504786	5445317	2.4	1.0	R	33	8	35	25	15	5	20	30
Sunbury	504785	5445303	3.6	2.6	R	24	6	0	5	25	60	10	30

Table C-7: General water quality measurements in streams in the North Delta watershed (October 3, 2012)

Name	Location		Temp oC	Sp Cond uS/cm	DO% % sat	DO mg/L	pH pH units	ORP mV	Turbidity NTU
	X	Y							
Sunbury	504778	5445328	12.1	0.064	102.7	11.03	7.69	-11.4	182.9
Sunbury	504837	5445314	12.23	0.115	105.7	11.2	7.69	-17	9.4
Sunbury	504738	5445291	10.01	0.192	106.1	11.96	7.43	-6.6	785.2
McAdam	505929	5445156	11.39	0.068	107.9	11.79	7.34	29.4	3.8
McAdam	505912	5445219	10.55	0.066	105.8	11.71	7.05	48.2	3.1
McAdam	505888	5445269	10.65	0.072	101.8	11.26	7.13	42.1	2.2
McAdam	505845	5445310	10.19	0.073	107.4	11.98	7.22	35.7	8.4
McAdam	505828	5445306	11.67	0.063	109.4	11.87	7.5	36.6	0.2
McAdam	505915	5445538	9.91	0.075	114.1	12.76	7.21	51.4	0.8
Regal Dr	506480	5447304	11.3	0.275	118	12.81	7.99	-25.7	2.4
Regal Dr	506544	5447282	11.31	0.276	122.4	13.29	7.84	-8.8	19.3
Regal Dr	506575	5447266	11.21	0.279	123.3	13.37	7.93	-1.2	2.2
Shadow Brook	506383	5447180	14.15	0.238	125.5	13.79	8.01	18.8	1.2
Shadow Brook	506402	5447180	10.68	0.277	126.7	13.76	7.98	-3.3	1.3
Kendale	506308	5447081	10.55	0.274	127.5	14.06	8.08	5.4	2.3
Kendale	506376	5447011	10.37	0.276	123.4	13.74	8.03	12.6	1.7
Kendale	506413	5446981	10.31	0.28	123.4	13.67	7.96	11.6	3.4
Kendale	506258	5447123	10.97	0.252	112.1	12.28	7.83	-32.8	0.8
Knudson	506220	5446933	10.62	0.292	121.8	13.52	8.05	-33.6	26.8
Knudson	506279	5446924	10.6	0.302	130	14.28	7.98	-58.4	10.9
Collings	505870	5446212	11.24	0.233	130.4	14.15	8	-22.3	3.6

Table C-8: Metal concentrations in sediment samples from streams in the North Delta watershed

RESULTS OF ANALYSIS

Sample ID Date Sampled	Units	Detection Limits	Sunbury Ck 08-NOV-12	McAdam Ck 08-NOV-12	Collings Ck 08-NOV-12	Kundson Ck 08-NOV-12	Kendale Ck 08-NOV-12	Shadow Brk 08-NOV-12	BC Working Sediment Quality Guidelines - Freshwater (August 2006)	CCME Sediment Quality Guidelines - Freshwater (Update 2002)	Other Comparative Values	
Metals			ISGQ BC 2006	PEL BC 2006	ISGQ CCME 2002 (Aquatic Life)	PEL CCME 2002 (Aquatic Life)	ISGQ CCME 2002 (Aquatic Life)	ISGQ CCME 2002 (Aquatic Life)	Still Creek Subbasin 1995 (median)	Brunette Rv. Subbasin 1995 (median)	Oh (2003) thesis Table 2-3	
Aluminum (Al)	mg/kg	50	8760	9090	7780	9690	6490	7370	5.9	17	141	
Antimony (Sb)	mg/kg	0.10	0.15	0.23	0.12	0.33	0.14	0.16				
Arsenic (As)	mg/kg	0.050	2.87	3.13	1.98	7.52	2.74	4.17		5.9		
Barium (Ba)	mg/kg	0.50	43.7	46.1	39.9	53.3	31.4	36.8				
Beryllium (Be)	mg/kg	0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20				
Bismuth (Bi)	mg/kg	0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20				
Cadmium (Cd)	mg/kg	0.050	0.087	0.131	0.090	0.109	0.078	0.083	0.6	3.5	103	
Calcium (Ca)	mg/kg	50	2660	2770	2480	3180	2900	3240				
Chromium (Cr)	mg/kg	0.50	19.3	17.8	19.8	17.6	19.5	18.0	37.3	90		
Cobalt (Co)	mg/kg	0.10	5.53	5.26	4.37	7.18	4.32	4.13				18
Copper (Cu)	mg/kg	0.50	10.9	12.6	7.04	11.0	9.07	10.3	35.7	197	130	33-210
Iron (Fe)	mg/kg	50	14700	14500	11600	15200	12100	11800	21200	43766	2.10%	4.00%
Lead (Pb)	mg/kg	0.50	4.90	7.18	4.90	7.74	5.82	23.0	35	91	130	10-223
Lithium (Li)	mg/kg	5.0	8.8	6.3	7.5	7.6	<5.0	6.7				
Magnesium (Mg)	mg/kg	20	4230	3950	3540	4220	4220	4130				
Manganese (Mn)	mg/kg	1.0	312	292	252	767	230	427			576	807
Molybdenum (Mo)	mg/kg	0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50				
Nickel (Ni)	mg/kg	0.50	20.3	15.0	16.0	16.2	16.9	12.1	16	75	17	32-340
Phosphorus (P)	mg/kg	50	273	403	195	326	336	272				
Potassium (K)	mg/kg	100	440	440	330	420	390	370				
Selenium (Se)	mg/kg	0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	2			
Silver (Ag)	mg/kg	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.5			
Sodium (Na)	mg/kg	100	110	160	110	150	180	170				
Strontium (Sr)	mg/kg	0.50	16.5	15.7	16.6	19.1	16.0	16.9				
Thallium (Tl)	mg/kg	0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050				
Tin (Sn)	mg/kg	2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0				
Titanium (Ti)	mg/kg	1.0	559	622	582	609	446	549				
Uranium (U)	mg/kg	0.050	0.264	0.210	0.226	0.279	0.204	0.273				
Vanadium (V)	mg/kg	0.20	29.1	33.1	31.2	35.2	30.4	28.2				
Zinc (Zn)	mg/kg	1.0	58.4	76.4	46.0	46.7	40.0	45.0	123	315	251	159-983
Physical Tests												
pH	pH	0.10	7.42	6.80	7.57	7.92	7.90	7.87				

Table C-9: Total metals, fecal coliforms, and nutrients in streams in the North Delta watershed

RESULTS OF ANALYSIS

Sample ID Date Sampled	Detection Limits		BC Water Quality Guidelines (A - Jan 2010, W - Aug 2006) BCWQ 2010						CCME Protection of Aquatic Life (December 2007) CCME 2011	
	Units		Sunbury Ck 08-NOV-12	McAdam Ck 08-NOV-12	Collings Ck 08-NOV-12	Kundson Ck 08-NOV-12	Kendale Ck 08-NOV-12	Shadow Brk 08-NOV-12		
Total Metals										
Aluminum (Al)-Total	mg/L	0.0050	0.223	0.0425	0.0481	0.0373	0.0721	0.0349	0.005 @ pH<6.5; 0.1 @ pH>6.5	
Antimony (Sb)-Total	mg/L	0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.02** (W)	
Arsenic (As)-Total	mg/L	0.00050	0.00082	0.00088	0.00253	0.00399	0.00268	0.00268	0.005 (A)	0.005
Barium (Ba)-Total	mg/L	0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	5 (max); 1 (30-d avg) (W)	
Beryllium (Be)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0053 (chronic criterion) (W)	
Boron (B)-Total	mg/L	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	1.2 (A)	
Cadmium (Cd)-Total	mg/L	0.000017	<0.000017	0.000018	<0.000017	<0.000017	<0.000017	<0.000017	(=10 exp (0.86[log(hardness)]-3.2)/1000) (W)	29 (short-term exp.); 1.5 (long-term exp.) (=10 exp (0.86[log(hardness)]-3.2)/1000)
Calcium (Ca)-Total	mg/L	0.10	16.3	19.7	33.2	29.3	30.0	30.0	0.001 Cr(VI) (max); 0.0089 Cr(III) (max) (W)	0.001 Cr(VI); 0.0089 Cr(III)
Chromium (Cr)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.110 (max); 0.004 (30-d avg) (A)	
Cobalt (Co)-Total	mg/L	0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	(0.094*(hardness+2)/1000 (max); 0.002 @ CaCO3 ≤ 50 mg/L, 0.00004 @ CaCO3 > 50 mg/L (30-d avg) (A)	(e ^{0.8545 ln(hardness)-1.465})*200 (or 0.002)
Copper (Cu)-Total	mg/L	0.0010	0.0022	0.0027	<0.0010	0.0015	0.0014	0.0014	0.003 @ CaCO3 ≤ 8 mg/L, (e ^{1.273 ln(hardness)-1.460})/1000 @ CaCO3 > 8 mg/L (max); (3.31 + e ^{1.273 ln(hardness)-4.704})/1000 @ CaCO3 > 8 mg/L (30-d avg) (A)	(e ^{1.273 ln(hardness)-4.705})*1000 (or 0.001)
Iron (Fe)-Total	mg/L	0.030	0.342	0.157	0.137	0.084	0.107	0.107	0.014 (secondary chronic); 0.096 (final chronic); 0.870 (aquatic max) (W)	0.3
Lead (Pb)-Total	mg/L	0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.8-1.1 @ CaCO3 = 25-50 mg/L (max); 0.7-0.8 @ CaCO3 = 25-50 mg/L (30-d avg) (A)	
Lithium (Li)-Total	mg/L	0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0001 (max); 0.00002 or less (30-d avg) (A)	
Magnesium (Mg)-Total	mg/L	0.10	4.03	3.96	11.3	7.05	8.13	8.13	0.0001 (max); 0.00002 or less (30-d avg) (A)	
Manganese (Mn)-Total	mg/L	0.00030	0.0181	0.0174	0.0358	0.0133	0.0204	0.0204	0.0001 (max); 0.00002 or less (30-d avg) (A)	
Mercury (Hg)-Total	mg/L	0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	2 (max); 1 (30-d avg) (A)	0.073
Molybdenum (Mo)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	373-432 (W)	
Nickel (Ni)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.002 (mean) (A)	0.001
Potassium (K)-Total	mg/L	2.0	<2.0	<2.0	2.7	2.5	2.3	2.3	0.0001 @ CaCO3 < 100 mg/L (max); 0.00005 @ CaCO3 < 100 mg/L (30-d avg) (A)	0.0001
Selenium (Se)-Total	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010		
Silver (Ag)-Total	mg/L	0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020		
Sodium (Na)-Total	mg/L	2.0	9.8	10.2	9.2	10.2	10.9	10.9		
Thallium (Tl)-Total	mg/L	0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020		
Tin (Sn)-Total	mg/L	0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Titanium (Ti)-Total	mg/L	0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	0.3 (max); 0.5*** (W)	0.033 (short-term exp.); 0.015 (long-term exp.)
Uranium (U)-Total	mg/L	0.00020	<0.00020	<0.00020	0.00042	0.00055	0.00055	0.00055	0.3 (max); 0.5*** (W)	0.033 (short-term exp.); 0.015 (long-term exp.)
Vanadium (V)-Total	mg/L	0.0010	<0.0010	0.0011	0.0014	0.0019	0.0021	0.0021	0.006***; 0.020 (secondary chronic) (W)	
Zinc (Zn)-Total	mg/L	0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	(33+0.75*(hardness-90))/1000 (max); 7.5+0.75*(hardness-90)/1000 (30-d avg) (A)	0.03
Bacteriological Tests										
Coliform Bacteria - Fecal	MPN/100mL	2	57.2	65.6	85.8	130	102	108	200	
Coliform Bacteria - Total	MPN/100mL	2	12.4	3.1	3.8	<3.0	7.1	5.8		
Anions and Nutrients										
Alkalinity, Total (as CaCO3)	mg/L	2.0	44.9	58.3	74.2	133	95.8	94.4	20.0 (at pH 7, T=13.0°C) (A)	5.74 (at pH 7, T=15.0°C)
Ammonia as N	mg/L	0.0050	0.0055	0.0092	<0.0050	0.0167	0.0085	<0.0050	31.3 (max); 3.0 (30-d avg) (A)	2.935 (interim)
Nitrate (as N)	mg/L	0.0050	2.13	2.16	1.13	0.493	1.15	0.998		
Orthophosphate-Dissolved as P	mg/L	0.0010	0.0079	0.0123	0.0202	0.0369	0.0633	0.0319		
Physical Tests										
Hardness (as CaCO3)	mg/L	0.50	57.2	65.6	85.8	130	102	108		
Total Suspended Solids	mg/L	3.0	12.4	3.1	3.8	<3.0	7.1	5.8	25 (24 h change); 5 (30 day change) (A)	

Table C-10: Benthic index of biological integrity scoring and summary values for McAdam Creek (North Delta watershed)

	McAdam Ck				Mean
	C-1	C-2	C-3	C-4	
METRIC VALUES					
Taxa richness	15	9	10	19	13.25
E richness	1	2	1	3	1.75
P richness	1	1	0	1	0.75
T richness	3	0	2	3	2
INTOLERANT taxa richness	1	0	0	2	0.75
Clinger richness	6	2	4	7	4.75
LL richness	3	1	3	4	2.75
% tolerant	0.9	4.4	0.2	3.0	2.2
% predator	3.8	0.0	2.8	2.5	2.3
% dominance (3)	79.3	79.6	95.5	76.8	82.8
METRIC SCORES					
Taxa richness	3	1	1	3	
E richness	1	1	1	1	
P richness	1	1	1	1	
T richness	1	1	1	1	
INTOLERANT taxa richness	1	1	1	1	
Clinger richness	1	1	1	1	
LL richness	3	1	3	3	
% tolerant	5	5	5	5	
% predator	1	1	1	1	
% dominance (3)	3	3	1	3	
					Mean
SAMPLE SCORE	20	16	16	20	
Mean B-IBI Score					18.0



KERR WOOD LEIDAL
consulting engineers

Appendix D

Geotechnical Report



August 29, 2014

Reference: VAN-00209598-A0

Kerr Wood Leidal Associates Ltd.
200-4185A Still Creek Road
Burnaby, BC V5C 6G9

Email: dzabil@kwl.ca

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

**Re: North Delta Ravines, Delta, BC
Geotechnical Review, Rev. 1**

Dear Mr. Zabil:

1.0 INTRODUCTION

As requested, **exp** Services Inc. (**exp**) has completed a geotechnical review of North Delta Ravines and adjacent slopes as part of an Integrated Stormwater Management Plan (ISMP). Ravines included in the ISMP listed from north to south include:

- Shadowbrook
- Kendale
- Knudson
- Gunderson
- Norum
- Collings
- MacAdam
- Nelson View
- Main

The ravine locations are shown on attached Map 2. The purpose of our review was to characterize the subject sites with regards to slope stability, stream erosion and soil types and present mitigative options where appropriate.

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

Our characterization is based on the following information:

- Published surficial geology information from GSC Map 1484A (1:50,000);

- Aerial photographs of the general area dated from 1949 to 2004;
- Regional topographic contour plan provide by Kerr Wood Leidal Associates Ltd.;
- Plan map of existing culverts and storm water pipes in the area provided by Kerr Wood Leidal Associates Ltd.
- Information from previous **exp** projects in the general vicinity of the subject sites;
- Site reconnaissance of each ravine, with the exception of Gunderson for reasons stated below.

A geotechnical field reconnaissance of Gunderson was not conducted as water in the ravine has been directed into a culvert, mitigating erosion of slopes, and the lack of development and infrastructure along the ravine slopes.

2.0 SITE DESCRIPTIONS

In general, the ravines included in this review contain watercourses, or previously contained watercourses, which flow/flowed from east to west outletting into the Fraser River. A brief description of each ravine is provided below.

The study area lies within an area of Pre-Vashon Drift deposits consisting of fluvial, glacio-fluvial and marine deposits. Soils deposited in such environments would generally consist of crossbedded sands with silt and gravel lenses, crossbedded sand to gravel and interbedded fine sand to clayey silt.

A railway track is located parallel to the Fraser River near the mouths of the ravines. The railway track is generally located in areas where the ravines broaden and slope heights are minimal.

2.1 Shadowbrook Ravine

Shadowbrook Ravine is located near the northern boundary of North Delta and contained an open creek which flows east to west. The ravine was bordered by residential development to the north, east and along the southeast portion (see Map 3). In addition, a single family residential dwelling had been constructed on the south side of Shadowbrook Ravine, on a ridge between Shadowbrook and Kendale Ravines, near River Road.

The ravine was about 290m long and up to approximately 100m wide. The open creek had a length of approximately 215m and entered the ravine through a culvert located about 70m east of Dawson Crescent. The culvert is located about 2m below the crest of the slope at the eastern end of the ravine. Water flowing out of the culvert dropped about 2.5m then flowed along a riprap surface generally comprised of sub-angular boulders with a diameter of about 600mm. The creek had a width of up to about 2m and was incised up to about 1m. The creek ends at a culvert intake located about 70m west of River Road.

The ravine slopes were generally gently to moderately inclined (as steep as 2H:1V (horizontal:vertical)) with heights up to about 15m. Adjacent to the creek some near vertical eroded banks were noted. However, only one area was noted as experiencing significant erosion with a bank height of about 2.5m. Significant erosion was also noted on both sides of the ravine near the culvert outfall at the east end of the ravine, particularly the north bank. Exposed bank material generally consisted of sand and gravel.

A lock-block wall about 2.25m in height (3 rows) was noted on the right bank of the ravine near the

midway point of the creek. The purpose of the lock-block wall was unknown; however, it appeared to be in generally good condition with some movement of a top block at the wall end.

Vegetation within the ravine generally consisted of thick underbrush with widely spaced deciduous trees and some coniferous trees.

2.2 Kendale Ravine

Kendale Ravine was located about 200m south of Shadowbrook Ravine and contained an open creek which flowed east to west. The ravine was about 700m long with a width up to about 100m. The ravine was bordered by residential development to the northeast, southeast and at the east end. A single residential dwelling was located at the western end of the ravine between Shadowbrook and Kendale ravines.

The creek had a length of about 430m and entered the ravine at a culvert outfall located about 250m northeast of the intersection of 114 Street and Kendale Way and flows for about 440m before entering a culvert intake to flow under River Road and outlet to the Fraser River. The creek generally has a width of about 1m and was incised into the subgrade up to about 0.5m. An additional outfall is located about 200m west of the culvert outfall at the east end of the ravine with a two tier lock block wall located above. Placed rip rap was noted on the creek bottom upstream of the culvert inlet.

The ravine slopes were generally inclined at about 1.3H:1V with slope heights ranging from approximately 15m to 20m, increasing in height from the east end to about 100m east of the west culvert intake. Slopes adjacent to the creek were generally gently inclined steepening away from the creek. Erosion of the creek banks had resulted in some near vertical slopes, up to about 3.5m in height, particularly near the culvert inlet at the west end of the ravine. A slide scarp approximately 20m in length and up to about 6m in height was noted on the right bank about 120m downstream of the culvert outlet. Also, in the general vicinity of the slide scarp, the left bank was noted to have undulating topography with leaning trees, often indicative of surficial soil movement. Isolated areas of sloughing of soil slopes were noted (both banks), often associated with seepage zones in the creek banks and/or fallen trees.

Exposed soils within the ravine generally consisted of sand to silty sand with trace to some gravel. The density of the exposed soils ranged from compact in near vertical eroded banks to loose and saturated in areas where sloughing and/or seepage was noted.

Vegetation within the ravine generally consisted of thick underbrush with deciduous trees in the ravine bottom and evergreen trees on the ravine slopes.

2.3 Knudson Ravine

Knudson Ravine was located south of Knudson Road and contained an open creek which flows east to west. The ravine was about 280m in length with a width of up to about 120m. The ravine was bordered by residential developments to the north, southeast and along the east end. Immediately adjacent to the south bank of the creek at the west end, structures (sheds, farm vehicle storage) had been constructed.

The open creek had a length of about 280m and originated at the east end of the ravine on a natural slope. The creek had a width of about 1m incised into the subgrade up to about 0.75m at the west end

diminishing to very limited flow upstream.

The ravine slopes were generally inclined flatter than 2H:1V with slope heights ranging from about 15m to 20m. The area south of the creek, in the western portion of the ravine, was flat lying and thus conducive to allowing the building of the structures mentioned above. A slide scarp about 20m long and 3m high was noted on the north slope in the eastern portion of the ravine. In some locations, fallen trees were noted, generally in clusters.

Exposed soils within the ravine generally consisted of compact sand with some gravel.

Vegetation consisted of thick underbrush with deciduous trees in the ravine bottom with evergreens generally located on the ravine slopes.

2.4 Gunderson Ravine

Our description of Gunderson Ravine was based on a review of a plan map showing culverts, air photos and the topographic contour plan.

Gunderson Ravine was located between River Road and the railway track and was immediately north of 92A Avenue with an approximate length of 120m. There was no open creek in the ravine as the water flows through a pipe outletting into the Fraser River. The ravine was bordered by a single residence in the northeast corner and two residences on the south side. Based on our review of air photos, it appeared that the original ravine was significantly infilled during placement of the pipe, resulting in moderated slope inclinations and lower slope heights.

The ravine slopes had a maximum height of about 15m and were inclined at about 2.4H:1V on the north side with localized slopes as steep as 1.6H:1V on the south slope.

Vegetation within the ravine consisted of thick underbrush with deciduous trees and evergreen trees on the upper slopes.

2.5 Norum Ravine

Norum Ravine was located west of River Road originating at the intersection of Norum Road and River Road and contained an open creek which flows east to west. The ravine was about 380m long with a width up to about 160m. The ravine was bordered by residential development to the south and in the northeast corner, a single residence located on the northwest corner of the ravine. An abandoned home was located immediately south of the creek near the western end of the ravine.

The open creek had length of about 230m and originated at an outfall located approximately 200m northwest of the intersection of Norum Road and River Road. Immediately below the outfall were a series of concrete weirs. The creek had a maximum width of up to about 6m, though generally in the order of 1m to 2m, incised into the subgrade up to about 1m and outlets into the Fraser River. A small watercourse flowed from the top of the ravine into the creek originating from the culvert outfall. A small creek was also noted to be flowing into the main creek from the north slope about 280m from River Road. A review of historical records indicates that this small creek was formerly part of a larger ravine which joined into Norum Ravine and was largely infilled during development.

The ravine slopes were generally inclined at about 2.5H:1V; however, localized steeper slopes up to about 1.5H:1V were noted particularly in the upper portions of the slopes. Maximum slope heights ranged from about 30m on the north slope to about 25m on the south slope. Localized bank erosion noted and was generally less than 1m in height; however, on the outside of a creek bend, an eroded bank up to about 3.5m in height was noted.

Exposed soils within the ravine generally consisted of compact silty sand with trace to some gravel.

Vegetation within the ravine consisted of heavy underbrush with deciduous trees in the bottom area with coniferous trees on the slopes.

2.6 Collings Ravine

Collings Ravine was located between Norum Crescent to the north and Collings Way to the south and contained an open creek which flows east to west. The ravine was about 500m long with a width of up to about 80m with a significant curve bowing out to the north. An area about 150m west of the east end of the ravine widened to about 100m for a distance of approximately 50m due to a curvature in the crest of the south slope. The ravine was bordered by residential development to the north and south and River Road to the east.

The open creek also had a length of about 500m entering the ravine at the east end via a culvert outfall. The creek generally had a width of about 1m and was incised into the subgrade about 1m; however, little flow was noted in approximately the eastern 100m of the ravine.

Ravine slopes were generally inclined at about 1.8H:1V with maximum slope heights of about 25m on the south slope and 20m on the north slope. Localized slide scarps with lengths up to about 10m and heights of about 2m along with undulating topography were noted on both the north and south slopes. In addition, an area on the south slope where numerous trees had recently fallen and significant deposition of soft soils was noted coincided with the area of ravine widening noted above. A small gully with some seepage was noted on the north slope about 100m west of the east end of the gully.

Exposed soils within the ravine generally consisted of compact to dense gravelly sand with some silt, except in the area of tree fall and soil deposition noted above, where the soils were saturated and soft/loose.

Vegetation within the ravine generally consisted of thick underbrush with sparse coniferous trees. In localized areas, some trees on the ravine slopes exhibited curved trunks.

2.7 MacAdam Ravine

MacAdam Ravine was located north of 84 Avenue and contained an open creek which flows under Nordel Way and River Road via culverts. The ravine was bordered by residential development along the crests of the slopes on both sides of the ravine with the exception of an undeveloped area between 84B Avenue and 86 Avenue, west of 111 Street. The ravine was oriented in a north-south direction south of Nordel Way and in a northwest-southeast direction north of Nordel Way.

The ravine had a total length of about 1500m with approximately 300m west of River Road, 600m between River Road and Nordel Way and 550m south of Nordel Way. The maximum width of the ravine was about 180m with the exception of an area about 350m west of Nordel Way where a tributary

flows into the creek from the northeast and the ravine is about 300m wide. The tributary, which was less than 1m in width and incised about 0.5m, flowed into the creek between Nordel Way and River Road. The ravine containing the tributary was about 150m long and approximately 110m wide. South of Nordel Way MacAdam Ravine was generally narrow (less than 20m) and had slope heights in the order of about 10m. The creek starts at the south end of the ravine at a culvert outfall located immediately north of 84 Avenue. The creek ranges from about 1m in width at the southeast end to about 3.5m at the west end, incised a maximum of about 1.5m into the subgrade.

As mentioned above MacAdam Ravine south of Nordel Way had a maximum slope height in the order of 10m; however, it was noted that the creek banks were often steeply inclined as a result of erosion of the banks. The ravine increases in depth and width to the north. Undermining of trees was noted in several locations in this portion of the ravine. In addition, a private fence located along the crest of the west bank of the creek near the south end of the ravine was severely undermined and had been constructed within the creek to the north. A gabion wall had been constructed along the east bank immediately north of the above described fence. The gabion wall was about 1m in height and appeared to be in generally good condition. An outfall for a PVC pipe was noted downstream of a water main crossing. Sloughing of the fill surrounding the PVC pipe resulted in a very steep bank with minimal vegetation. No flow from the pipe was observed at the time of our field review. A concrete outfall with a concrete apron was noted on the east bank downstream of the PVC pipe. Approximately 20m upstream of the watermain, several slope failures were noted on the east side of the creek. These slope failures ranged from about 5m to 9m and 10m to 20m in height and length respectively. Undulating slopes and smaller slide scarps were common in this portion of the ravine. The creek flows through a culvert intake at a large fill slope stabilized with a bin wall to cross Nordel Way.

North of Nordel Way the creek turned to the northwest about 220m north of the culvert outfall. The ravine bottom widened; however, the ravine slopes increased in height to a maximum of about 30m with slope inclinations ranging from approximately 2H:1V on the northeast slope to 1H:1V on the southwest slope. Near vertical eroded banks up to about 1.5m height were noted along both banks of the creek with some localized undermining of trees and slope crests. The creek flowed into a culvert intake located at the base of a high fill slope retained by a bin wall to cross River Road.

The slopes for the tributary had a maximum height of about 25m and were inclined as steep as 0.8H:1V in the localized upper portions of the slopes; however, were generally inclined at about 1.5H:1V. Seepage at the upper end of the ravine containing the tributary was noted on the north slope with some associated sloughing.

Slopes within the ravine to the north of River Road had a maximum height of about 25m and were generally inclined at about 2.3H:1V. A gabion wall was located on the south bank immediately below the culvert outfall. The wall was about 2.5m in height and appeared to be in generally good condition.

Soils exposed along the creek banks and in the creek bottom consisted of clayey silt, particularly in the upstream portions and in areas where slope failures were noted. Other soils consisted of fine sand with some silt and gravelly sand with some silt. Rip rap had been placed in areas near culvert intakes and outfalls.

Vegetation consisted of heavy underbrush, particularly south of Nordel Way and deciduous trees with coniferous trees on the ravine slopes. Several areas of trees downed across the creek and tributary were noted, often the result of bank erosion.

2.8 Nelson View Ravine

Nelson View Ravine was located south of Nelson View and west of River Road and contained an open creek which flowed east to west. The ravine was about 200m long with a width up to about 50m. The ravine was bordered by residential development to the north and a single residence to the south.

The open creek had a length of about 200m and entered the ravine via a culvert outfall above a constructed slope with a blast rock and tire surface. The creek is about 1m wide and incised about 0.5m. Minimal flow was noted in the upper portions of the creek.

The ravine slopes were inclined at about 2H:1V with a maximum height of about 15m. Significant amounts of garden refuse were noted along the ravine slopes. Eroded banks with a height of up to about 1.2m were noted in localized areas with some undermining of trees. A minor slope failure about 10m long with a 2m high scarp was also noted on the north slope in the upper portion of the ravine. A wood crib retaining wall was noted on the south slope about 100m west of River Road.

Exposed soils generally consisted of soft clayey silt overlying dense granular soil.

Vegetation generally consisted of thick underbrush with sparse coniferous and deciduous trees.

2.9 Main Ravine

Main Ravine is located between Sunbury Place and Arpe Road, west of Main Street and east of River Road. The ravine contained an open creek which flowed from east to west. The ravine was about 220m long and up to about 130m wide. The ravine was bordered by residential development to the north and along the east end with undeveloped land to the south.

The open creek was about 180m long and entered the ravine via two outfalls at the east end. The creek entered a culvert intake to cross River Road. The creek generally had a width of about 1m and was incised from about 0.5m to 2m.

The ravine slopes were generally inclined at about 3H:1V with some localized steeper areas. Maximum slope heights were about 15m. Near vertical creek banks up to about 2.5m height were noted. A gully, with minor flow and some erosion at the top, leading into the creek from the north slope was noted in the east portion of the ravine. Another gully was noted on the north slope with a residence at the crest about 140 m west of Main Street. A cased pipe outfall on the north slope was noted to be outletting onto a rip rap covered slope below a residential development. A minor vegetated slide scarp was noted on the north slope in the mid-portion of the ravine.

Exposed soils within the ravine generally consisted of dense silty sand with some gravel and firm to stiff clayey silt.

Vegetation within the ravine generally consisted of some underbrush with coniferous sparse tree cover. Some trees were noted to have curved trunks and others had fallen due to erosion undermining the trees.

3.0 DISCUSSION

A brief discussion regarding identified potential naturally occurring geologic hazards (slope instabilities, erosion, etc.) is provided for each ravine below. Included in the discussion are:

- Potential blockages from tree fall which could result in sudden releases during periods of high water flow which, in turn, could block culvert intakes downstream.
- Slope failures in the form of slides or sloughing can deposit materials in the creeks also resulting in potential blockages with similar consequences.
- Slope failures near the crest of slopes in close proximity to residences may undermine structure foundations damaging the building.
- Erosion along creek banks may undermine slopes resulting in unstable slopes, sloughing and/or slope failures.

3.1 Shadowbrook Ravine

The creek banks were generally comprised of sand and gravel which would typically be susceptible to erosion; however, relatively limited flow of the creek combined with a rip rap bottom for a substantial portion of the creek has limited the bank erosion to localized areas. As a result, undermining of trees along the banks is minimal and few blockages were noted in this ravine. The most significant erosion was noted near the culvert outfall at the east end of the ravine and was not considered to be likely to result in unstable slopes that would affect private property.

The slopes were considered to be inclined at a relatively stable angle (2H:1V) and large scale global slope failures are not expected. However, some sloughing may occur, particularly in the area near the outfall.

3.2 Kendale Ravine

The creek banks appeared to be generally comprised of compact sand to silty sand with some gravel which is typically susceptible to erosion; however, the small size of the creek (about 1m wide and 0.5m deep) has limited erosion along the creek banks. Areas of loose saturated soils were also noted in areas of seepage. Erosion was noted on the slopes above the creek in localized steep areas where flowing water would have concentrated, including at the outfall of a residential drain. The erosion on the slope was undermining some trees away from the creek and there is a possibility such trees would fall into the creek creating potential blockages.

The slopes were generally steeply inclined (up to 1.3H:1V) resulting in sloughing and slope failures. The slope failures appeared to be localized with the most significant one occurring about 120m west of the outfall at the east end of the ravine. This slope failure scarp was near the crest of the slope with exposed soils and a residence nearby. Sloughing of slopes within the ravine appeared to be generally associated with seepage zones. Due to the apparent relationship between groundwater and unstable slopes it is considered that periods of high precipitation or groundwater tables may result in increased sloughing and mobilization of existing slope failures.

Some trees had fallen across the creek resulting in potential blockages; however, the small size of the creek will likely mitigate the effects of such blockages.

A PVC pipe outfall onto the slope at the east end of the ravine did not appear to be creating significant erosion as soils were identified as being dense to very dense silty sand which typically has good resistance to erosion.

3.3 Knudson Ravine

The creek banks appeared to generally consist of compact sand and gravel which is typically susceptible to erosion. However, the creek had minimal flow with a maximum width of about 1m and incised about 0.75m and no significant erosion was noted.

The slopes were generally inclined less steeply than 2H: 1V which would be considered a stable inclination for the soil type encountered. A localized slide scarp about 20m long was noted near the toe of the north slope in the eastern portion of the ravine. It is considered unlikely that the observed slide area would affect residences setback from the crest of the slope.

Two significant creek blockages in the form of downed trees were noted along the creek. However, due to the limited creek flow in the areas of the blockages, significant ponding behind the blockage is considered unlikely. Buildings located in close proximity to the south bank of the creek and limited elevation difference between the creek and the buildings make these buildings susceptible to even limited flooding resulting from a breach of a blockage.

3.4 Gunderson Ravine

The lack of an open creek within the Gunderson Ravine makes undermining of slopes by erosion unlikely. It appears that during installation of a pipe in the ravine, substantial fill was placed in the ravine lessening slope heights and increasing stability of those slopes though the south slopes are inclined at a steep angle of about 1.6H:1V. The residences in the vicinity of Gunderson Ravine were setback about 10m from the slope crests resulting in an approximate maximum gradient of less than about 2H:1V from toe of slope to building foundation which would generally be considered stable in granular soils.

3.5 Norum Ravine

The creek banks within Norum Ravine generally consisted of silty sand with trace to some gravel which would typically be susceptible to erosion. Erosion of the creek banks was noted in several locations with one area located on the outside of a bend in the creek having a near vertical inclination and a height of about 3.5m. Due to relatively moderately inclined slopes (2.5H:1V), particularly in the lower portions of the slopes erosion of the slopes is not expected to destabilize slopes to the extent where infrastructure at the slope crests would be affected.

The ravine which connected to Norum Ravine on the north side appears to have been largely filled during development in the area contained a small creek during our reconnaissance. This infilled ravine provides a buttress for the former slopes in the area and likely increases slope stabilities in the area.

No significant blockages or slope instabilities were noted along the creek banks.

3.6 Collings Ravine

The creek banks within Collings Ravine were generally comprised of compact to dense gravelly sand with some silt with the exception of a slide area where exposed soils were saturated and soft/loose. Limited erosion of the banks was observed during field reconnaissance; however, some areas with near vertical eroded banks up to about 2m in height were observed.

The slide area coincided with a localized widening of the ravine indicating that soil movement has likely been occurring in this area for some time. No residential development is located at the crest of the slope in this area. Numerous fallen trees were associated with the slide area and a significant blockage of the creek was noted.

Slopes within the ravine were inclined at about 1.8H:1V and several areas of undulating topography and curved trees were noted which is typically indicative of surficial soil movement. In addition, localized slide scarps were observed near the slope toes. Based on our observations, it appears that there are localized areas of unstable or marginally stable slopes with the ravine where erosion of the creek banks may further destabilize slopes particularly in the western portion of the ravine where creek flows were noted to be higher.

3.7 MacAdam Ravine

The creek banks within MacAdam Ravine north of Nordel Way generally consisted of granular soils overlying stiff silty clay/ clayey silt which would typically be resistant to erosion. North of Nordel Way exposed soils generally consisted of fine sand with some silt to gravelly sand with some silt which would typically be relatively susceptible to erosion. Erosion of the creek banks was noted in numerous locations along the creek, particularly in the east end of the ravine where fences and trees had been undermined as the granular soils were eroded and a bottom of stiff silty clay/clayey silt has formed. Erosion of the creek banks was also noted in the area between Nordel Way and River Road with near vertical banks up to about 1.5m height. Minimal erosion was noted along the tributary.

Slopes within the portion of the ravine south of Nordel Way were generally of lower height (5m to 10m). The higher slopes frequently had areas of bare ground exposed by slope failures and undulating topography. Soils exposed by slope failures generally consisted of silty clay/clayey silt indicating a lower friction angle for these soils; hence, less stable slopes when the slope geometry is similar to those comprised of granular soils. Between Nordel Way and River Road slopes were generally higher (25m to 30m) and localized sloughing and slide scarps were noted, particularly in areas where significant bank erosion was noted. These features are indicative of marginally stable slopes being destabilized by erosion at the slope toes. The ravine below River Road consisted of slopes with inclinations in the order of 2.3H:1V, which would generally be considered to be a stable slope angle for granular soils.

Potential creek blockages were noted in several locations both due to fallen trees and anthropogenic sources (i.e., fences). Due to limited water flow in the creek, the potential for significant sudden release following the collapse of a blockage are considered to be a low risk.

An outfall PVC pipe outletting onto a fill slope is likely the cause of the sloughing as it erodes the surface of the slope and introduces water into the placed fill.

3.8 Nelson View Ravine

Creek banks within Nelson View Ravine generally consisted of soft to firm clayey silt overlying dense granular soils. These soils would typically be relatively resistant to erosion and minimal erosion was observed along the creek banks; however, some localized erosion of the creek banks was noted.

Slopes within the ravine were inclined at about 2H:1V with a slide scarp about 10m in length and 2m in height noted on the north slope near the east end of the ravine. As the slopes are relatively moderately inclined and limited slope instabilities were identified, it is considered unlikely erosion of the slope toes by the creek would affect residential lots at the crest of the slope.

No significant blockages were noted along the creek.

3.9 Main Ravine

Creek banks within Main Ravine generally consisted of dense silty sand with some gravel and firm to stiff clayey silt. The silty sand would typically be relatively susceptible to erosion and eroded banks up to about 2.5m in height were noted. In addition, erosion of the clayey silt was also noted in localized areas, due to higher flows as water was directed against creek banks.

Slopes within the ravine were gently inclined (3H:1V) at what would typically be considered a stable slope angle. Minor indications of previous slope movement were noted (curved tree trunks, small slide scarps); however, these instabilities are limited in extent and are unlikely to be significantly affected by toe erosion along the creek banks.

The outfall observed to be outletting water onto a rip rap slope appeared to have sufficient erosion protection.

Fallen trees within the ravine across the creek were not considered to present a significant risk of blockage due to the limited nature of their presence and the ability of water to flow under the trees.

4.0 RECOMMENDATIONS

Recommendations for mitigation of the effects of erosion of creek banks by streams and creeks within the ravines and slope instabilities along ravine slopes are provided below for each ravine where appropriate.

4.1 Shadowbrook Ravine

Slopes within Shadowbrook Ravine were generally inclined at about 2H:1V, which would typically be considered a stable slope for the soils identified along the creek banks (sand and gravel). Minimal erosion of the creek banks was noted and only the area in the vicinity of the eastern outfall was noted to be experiencing significant issues. Regular reviews (annual) of the area near the outfall should be conducted to identify any acceleration of the slope erosion which could affect residences at the slope crest. Rip rap protection may be appropriate of accelerated erosion were to be observed.

4.2 Kendale Ravine

Slopes within Kendale Ravine may be as steep as 1.3H:1V which would not generally be considered to be slope with a satisfactory factor of safety for slope stability. This opinion is further confirmed by observations of surficial movement and ongoing slope failures within the ravine. However, the majority of the slope instabilities and steeper slopes were located in the eastern portion of the ravine where the creek flow was lower and erosion of the slope toes less evident. Regular reviews (annual) of the slope conditions should be conducted to confirm slope instabilities have not progressed up the slope so as not to affect residential development at the slope crest particularly in the area about 120m west of the outfall at the east end of the ravine. Such reviews should also be conducted following unusually heavy precipitation (1 in 5 year event).

The residential outfall identified at the east end of the ravine does not appear to be having a significant effect on the slope.

4.3 Knudson Ravine

Slopes within Knudson Ravine were generally inclined at less than 2H:1V which would typically be considered a stable slope for the sand and gravel soils encountered in the ravine. A localized indication of unstable slope (slide scarp about 20m long) is not considered likely to affect residences at the slope crest.

Potential blockages of the creek were noted; however, the low flow of the creek limits the anticipated significance of such blockages.

4.4 Gunderson Ravine

Gunderson Ravine has had significant infilling, reducing the height of the ravine slopes and providing additional stabilization to those slopes. Steep slopes (1.6H:1V) were noted on the south slopes; however the residential structures appear to be setback from the slope crest. Confirmation of sufficient setback should be confirmed and is beyond the scope of this report.

4.5 Norum Ravine

The north slope of Norum Ravine has been substantially infilled during development reducing slope heights in this area. The remaining slopes are generally moderately inclined (2.5H:1V) and would typically be considered to be stable with the soil types encountered in the ravine.

No significant blockages or slope instabilities were noted during the field reconnaissance.

4.6 Collings Ravine

Slopes within Collings Ravine were inclined as steep as 1.8H:1V with localized steeper slopes. Slopes with these inclinations would typically be considered to be marginally stable for the soil types encountered, particularly where seepage and saturated soils are found. A significant slide area was identified on the north slope where the gully widens indicating long term slope recession. The presence of relatively recent downed trees and soft saturated depositions indicate ongoing slope failure. Other areas were noted to have numerous indicators of slope movement (curved trees,

undulating topography, etc.). In order to provide a quantitative analysis of the slope stability in the slide area, a geotechnical review is required.

Blockages within this ravine should be removed as they present an opportunity for water build-up which may destabilize the toes of the slopes by increasing pore pressures and reducing the friction angle of the soils.

Regular reviews (6 month intervals) of the conditions of slopes in this ravine should be conducted to assess the progress of slope movement, if any.

4.7 MacAdam Ravine

Slopes within MacAdam Ravine range from about 1H:1V on the south slope between Nordel Way and River Road to about 2.3H:1V west of River Road.

Sloughing and slope failures were noted in the portion of the ravine south of Nordel Way. Due to limited slope heights in this area, slope instabilities are not expected to affect residential development at the crests of the ravine slopes.

Sloughing and slope instabilities between Nordel Way and River Road were frequently associated with erosion along the creek banks at the slope toes. Regular reviews of bank erosion and the associated slopes should be conducted to confirm that the residential properties at the slope crests are not affected.

No slope instabilities were noted west of River Road.

Several blockages along the creek were noted; however, the minimal flow of the creek and ability of water to flow under/around the potential blockages limited the significance of such blockages.

Slopes within the tributary generally appeared to be stable with the exception of areas of seepage where sloughing was noted. Due to the limited extent of these seepage zones, and as they generally occurred in areas of less steep inclinations, the slope instabilities associated with them are not considered to likely affect the residential developments at the slope crests.

The slope below the outfall PVC pipe located within sloughing fill should be provided with erosion protection and possibly slope stabilization measures (i.e., berms, erosion mats, etc.) in order to prevent failure of the fill slope and pipe.

4.8 Nelson View

Slopes within Nelson View Ravine are generally inclined at about 2H:1V which would typically be considered a stable slope for granular and cohesive firm soils. Softer soils encountered within the ravine are likely indicative of surficial conditions and hence would not affect the overall slope stability.

With the exception of a single slide scarp, which is not expected to affect residential development at the slope crest, no significant indications of slope instabilities or erosion were encountered.

No significant blockages were encountered during the field reconnaissance.

4.9 Main

Slopes within Main Ravine were generally inclined at about 3H: 1V which would typically be considered a stable slope for the soil conditions encountered in the ravine (firm to stiff silty clay). Some indications of surficial slope movement were noted (curved trunks, small slide scarps); however, the global stability of the slopes appeared to be adequate and unlikely to be affected by erosion at the slope toes.

Downed trees creating potential blockages within the creek were considered minor and unlikely to provide sudden releases of water.

5.0 CLOSURE

As no geotechnical subsurface exploration was conducted, we have provided a qualitative review of the existing slope stability based on our visual characterization of the subject sites including identified recent and historical slope failures. Our characterization of the subject sites is based on site reconnaissance, topographic plan maps, surficial geology maps and exp's experience with similar sites throughout British Columbia.

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

Sincerely,

exp Services Inc.

Evan Sykes, P.Eng.
Senior Engineer

Reviewed by:


For Ben Weiss, P.Eng.
Senior Engineer

Enclosures: Interpretation & Use of Study and Report
Location Plan (Map 1)
Overall Site Plan (Map 2)
Site Plan – Shadowbrook, Kendale, Knudson (Map 3)
Site Plan – Gunderson, Norum, Collings (Map 4)
Site Plan – MacAdam, Nelson View, Main (Map 5)
Photos

ES/es



INTERPRETATION & USE OF STUDY AND REPORT

1. STANDARD OF CARE

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

2. COMPLETE REPORT

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

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

3. BASIS OF THE REPORT

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

4. USE OF THE REPORT

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

5. INTERPRETATION OF THE REPORT

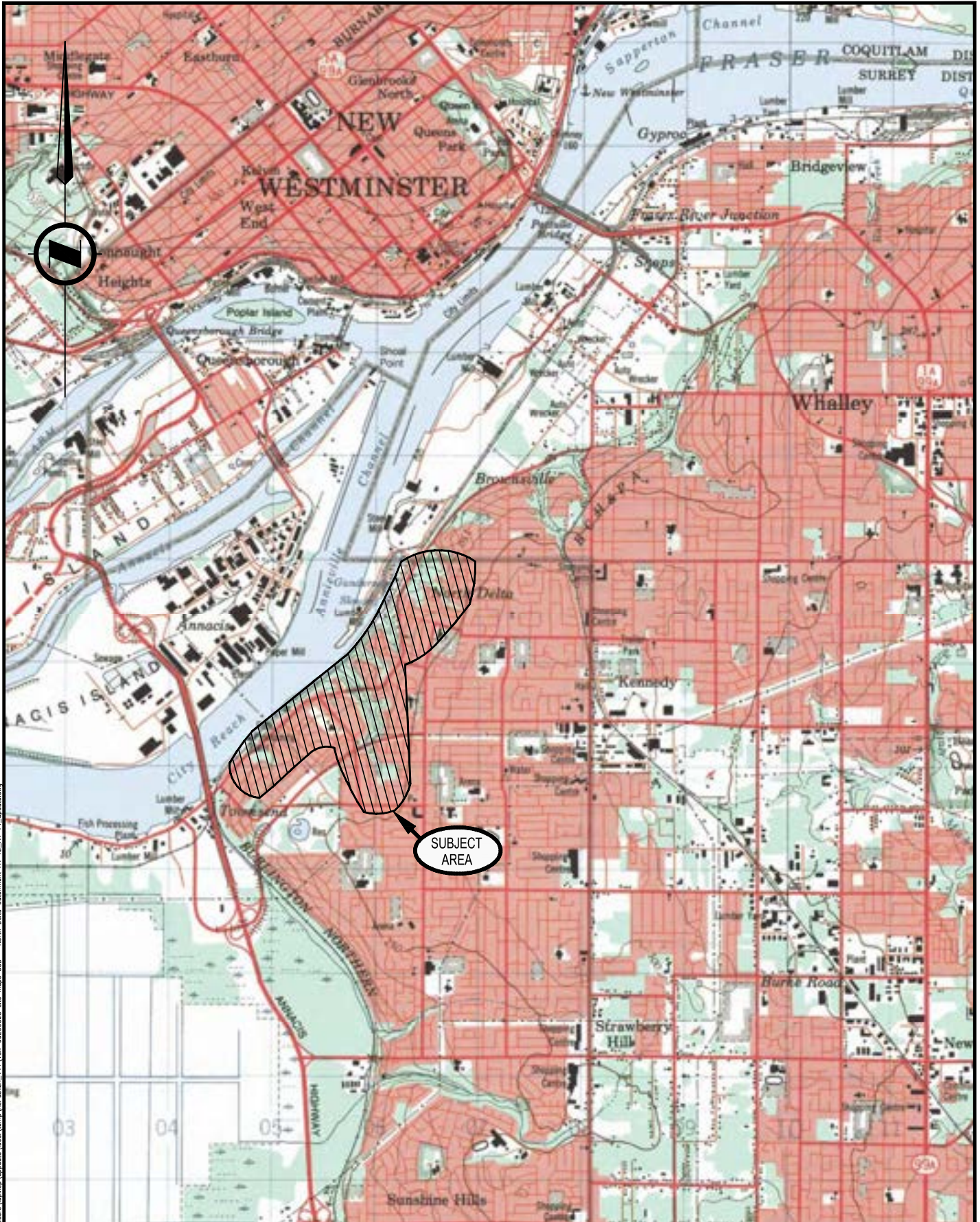
- a. Nature and Exactness of Descriptions: Classification and identification of soils, rocks, geological units, contaminant materials, building envelope assessments, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations, or building envelope descriptions, utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b. Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.
- c. To avoid misunderstandings, **exp** Services Inc. (**exp**) should be retained to work with the other design professionals to explain relevant engineering findings and to review their plans, drawings, and specifications relative to engineering issues pertaining to consulting services provided by **exp**. Further, **exp** should be retained to provide field reviews during the construction, consistent with building codes guidelines and generally accepted practices. Where applicable, the field services recommended for the project are the minimum necessary to ascertain that the Contractor's work is being carried out in general conformity with **exp's** recommendations. Any reduction from the level of services normally recommended will result in **exp** providing qualified opinions regarding adequacy of the work.

6.0 ALTERNATE REPORT FORMAT

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

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

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



Jan 21, 2013 - 11:46am
 C:\Users\Nepinep\AppData\Local\Temp\AschPublish_144\Van-00209598 site maps COO - North Delta Catchment FA-12_FA-14_update.dwg



CLIENT				Kerr Wood Leidel Associates Inc.		TITLE:		LOCATION PLAN	
PROJECT				North Delta Ravine ISMP Study				NTS MAP 92G02	
PROJECT NO.				DFTR.	DSGN.	CHK.	DATE	SCALE:	DWG NO.
VAN-00209598-0A				PDL		EGS	2013-01-17	N.T.S.	MAP 1



REFERENCE:
 KERR WOOD LEIDEL DRAWING: COD - North
 Delta Catchment FA-12_FA-14_update.dwg
 ORTHO IMAGE GOOGLE EARTH 2008-08-04

exp Services Inc. 275-3001 Wayburne Drive Burnaby, British Columbia V5G 4W3 Telephone: 604-874-1245 Fax: 604-874-2358 exp.com		exp	
DTTR: PDL DSGN: CHK: EGS	REVISIONS No. DESCRIPTION 	CLIENT Kerr Wood Leidel Associates Inc. PROJECT North Delta Ravine ISMP Study North Delta, BC PROJECT NO. VAN-00209598-A0	TITLE: OVERVIEW SITE PLAN
DATE 	DATE 2013-01-17	SCALE: 1:10,000	DWG NO. MAP 2



REFERENCE:
 KERR WOOD LEIDEL DRAWING: COD - North
 Delta Catchment FA-12_FA-14_update.dwg
 ORTHO IMAGE GOOGLE EARTH 2008-08-04

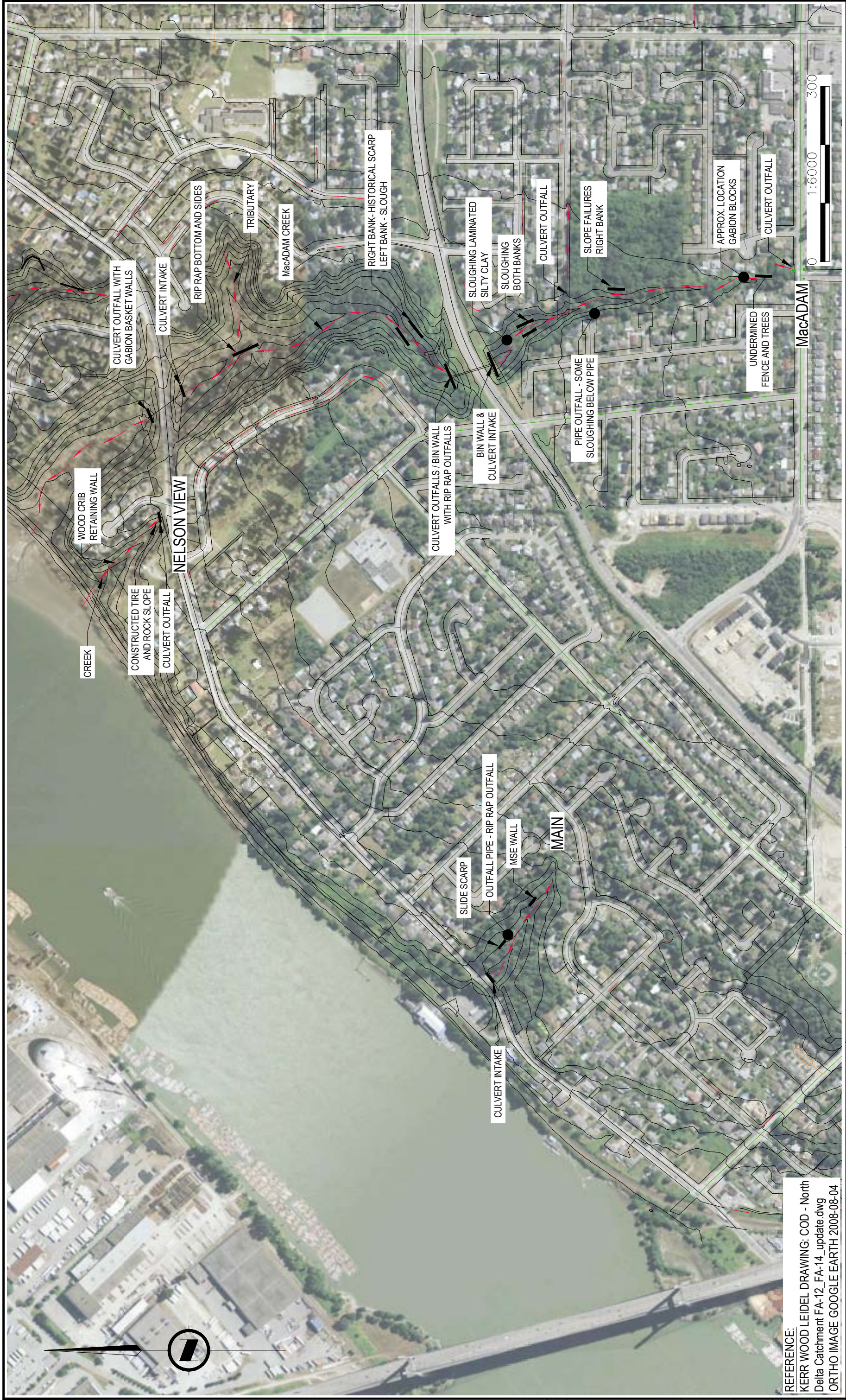


exp Services Inc.
 275-3001 Wayburne Drive
 Burnaby, British Columbia V5G 4W3
 Telephone: 604-874-1245
 Fax: 604-874-2358
 exp.com

DTTR.	PDL	REVISIONS
DSGN.	CHK.	DESCRIPTION
	EGS	

CLIENT	PROJECT	DATE
Kerr Wood Leidel Associates Inc.	North Delta Ravine ISMP Study North Delta, BC	

TITLE:	DATE	SCALE:	DWG NO.
GUNDERSON, NORUM & COLLINGS SITE PLAN	2013-01-17	1:4000	MAP 4



exp exp Services Inc. 275-3001 Wayburne Drive Burnaby, British Columbia V5G 4W3 Telephone: 604-874-1245 Fax: 604-874-2358 exp.com		exp exp Services Inc. 275-3001 Wayburne Drive Burnaby, British Columbia V5G 4W3 Telephone: 604-874-1245 Fax: 604-874-2358 exp.com	
DTR: PDL DSGN: CHK: EGS	REVISIONS No. DESCRIPTION DATE	CLIENT: Kerr Wood Leidel Associates Inc. PROJECT: North Delta Ravine ISMP Study North Delta, BC PROJECT NO.: VAN-00209598-A0	TITLE: MacADAM, NELSON VIEW & MAIN SITE PLAN
		DATE: 2013-01-17 SCALE: 1:6000 DWG NO.: MAP 5	

SHADOWBROOK RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 1 – Culvert intake east of River Road



PHOTO 2 - Steep right bank with minor erosion



PHOTO 3 – Lock-block wall

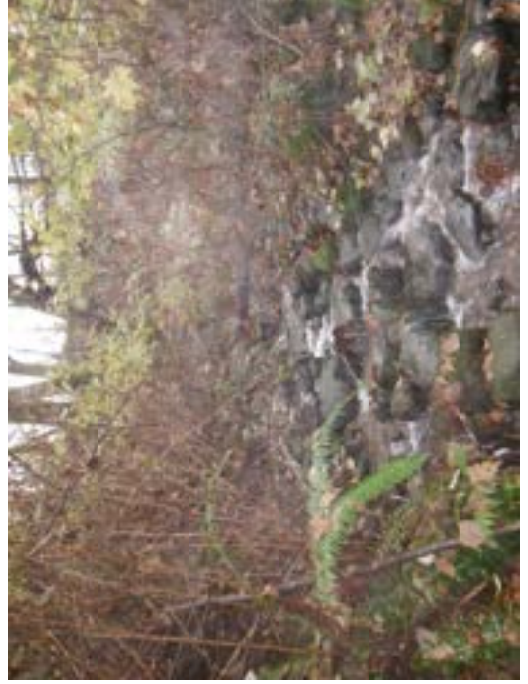


PHOTO 4 - Rip Rap bottom below outfall

SHADOWBROOK RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 5 – Outfall east end of ravine, eroded left bank



PHOTO 6 - Eroded right bank near outfall

KENDALE RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 1 – Culvert inlet at River Road



PHOTO 2 – Looking upstream from River Road culvert



PHOTO 3 – Rip rap placed near west end creek



PHOTO 4 – Outfall part way up creek

KENDALE RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 5 – Lock-block wall



PHOTO 6 – Slope erosion above creek



PHOTO 7 – Bank erosion undermined tree



PHOTO 8 – Active slide area north slope



PHOTO 9 – Undermined trees



PHOTO 10 – Rip rap on creek bottom, near east end creek



PHOTO 11 – Eroded soil slope exposing sand



PHOTO 12 – Outfall with gabion walls

KENDALE RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 13 – Pipe leading to outfall east end creek



PHOTO 14 – Residential drainage pipe outletting onto slope

KNUDSON RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 1 – Building near creek, west end ravine



PHOTO 2 – Looking upstream from buildings



PHOTO 3 – Shed near creek, west end ravine



PHOTO 4 – Creek bottom, west end

KNUDSON RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 5 – East end ravine



PHOTO 6 – Slide area



PHOTO 7 – Trees down creating blockage



PHOTO 8 – Downstream of trees down creating blockage

NORUM RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 1 - Outfall



PHOTO 2 – Heavily vegetated slopes near outfall



PHOTO 3 – Bank erosion exposing Sand with some Gravel



PHOTO 4 – Eroded bank on outside of creek bend

NORUM RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 5 – Overall photo of creek, near west end



PHOTO 6 – Abandoned residence, near west end creek

COLLINGS RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 1 – Gully leading into Collings Ravine



PHOTO 2 – Steep slopes top of ravine



PHOTO 3 – Ivy-covered fallen tree, bank erosion both banks



PHOTO 4 – Eroded bank exposing Gravelly Sand with some Silt

COLLINGS RAVINE



PHOTO 5 –
Undulating
slope
with slide
scarps



PHOTO 6 –
Gully
north bank
with
seepage



PHOTO 7 – Slide scarp at slope toe north bank



PHOTO 8 – Fallen trees creating blockage

COLLINGS RAVINE



PHOTO 9 – Trees down as a result of slide, soft soils encountered



PHOTO 10 – Gully from north slope near slide area (Photo 9)



PHOTO 11 – Multiple trees down creating potential blockage



PHOTO 12 – Minor scarps near slope toe

COLLINGS RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 13 – Looking upstream, narrow ravine near east end



PHOTO 14 – Outfall upstream, end of creek



PHOTO 1 – Undermined fence south bank



PHOTO 2 – Constructed bench (1.5m wide)



PHOTO 3 – Fence in water, potential blockage



PHOTO 4 – Undermined tree



PHOTO 5 – Gabion wall, north bank



PHOTO 6 - Failing north bank



PHOTO 7 – Eroded bank exposing dense Silty Clay



PHOTO 8 – Eroding north bank



PHOTO 9 – Outfall pipe with sloughing fill



PHOTO 10 – Concrete outfall with concrete apron



PHOTO 11 – Undulating north slope



PHOTO 12 – Failing slope exposing laminated Silty Clay



PHOTO 13 – Bin wall at Nordel Way



PHOTO 14 – Rip rap above culvert inlet at Nordel Way



PHOTO 15 – Ridge below Nordel Way



PHOTO 16 – Exposed dry laminated Silty Clay on ridge



PHOTO 17 – Bin wall downslope side Nordel Way



PHOTO 18 – Ridge by bin wall below Nordel Way



PHOTO 19 – Eroded bank



PHOTO 20 – Slough about 4m high, 20m long



PHOTO 21 – Vertical banks exposing stiff Silty Clay



PHOTO 22 – Steep bank undermining crest



PHOTO 23 - Creek incised about 1.2m



PHOTO 24 – Seepage at gully base south slope

MacADAM RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 25 – Fallen trees, potential blockage



PHOTO 26 – Sloughing along tributary

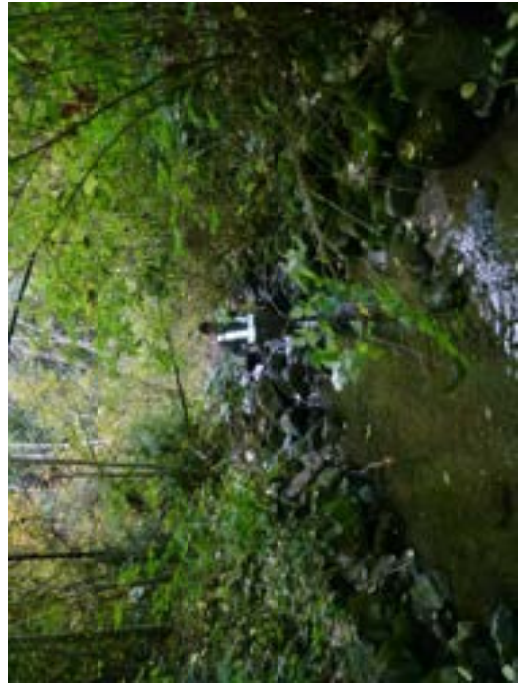


PHOTO 27 – Rip rap bottom and bank near River Road



PHOTO 28 – Culvert inlet River Road

MacADAM RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 29 – Culvert Outfall River Road, gabion walls



PHOTO 30 – Gabion walls below outfall

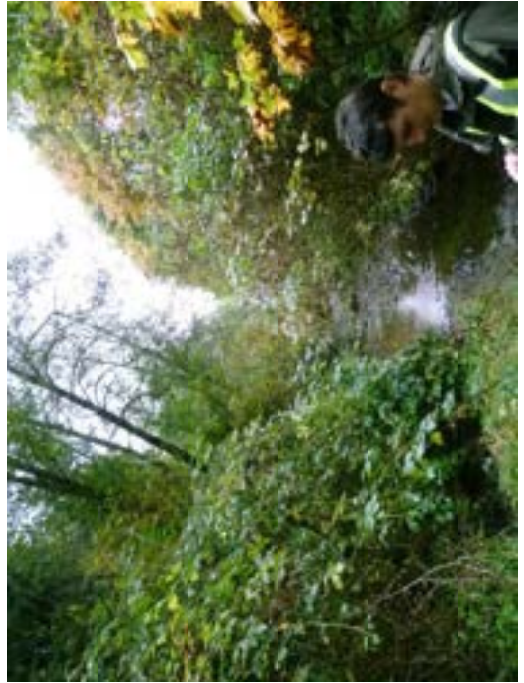


PHOTO 31 – Looking downstream near west end ravine



PHOTO 1 – Looking downstream from east end creek



PHOTO 2 – Garden refuse slope crest



PHOTO 3 – South Fraser Perimeter Road construction

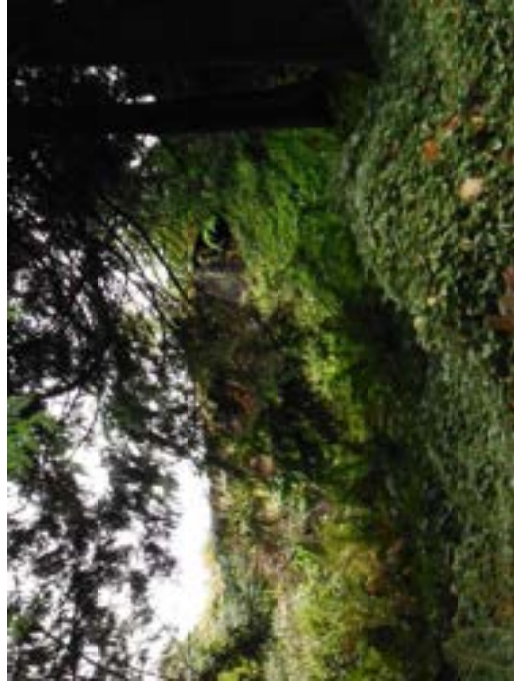


PHOTO 4 – Wood cribbing retaining wall

NELSON VIEW RAVINE

North Delta Ravines, Delta, BC, Geotechnical Review
exp File: VAN-00209598-A0, Date: January 22, 2013



PHOTO 5 – Rip rap below River Road



PHOTO 6 – Tire and rock constructed slope,
downslope River Road

MAIN RAVINE



PHOTO 1 – Outfall into east end ravine



PHOTO 2 – Another outfall, east end ravine



PHOTO 3 –
Small creek
flowing into
main creek



PHOTO 4 - Eroded banks exposing dense Silty Sand with some Gravel

MAIN RAVINE



PHOTO 5 – Gully eroding at crest



PHOTO 6 - Erosion of creek bank exposing Sand



PHOTO 7 – Stump in creek, potential blockage



PHOTO 8 – Trees with curved trunks

MAIN RAVINE



PHOTO 9 – Historic slide scarp near slope crest with residence nearby



PHOTO 10 – Outfall flowing onto rip rap slope



PHOTO 11 – Near vertical bank



PHOTO 12 – Gully on north slope

MAIN RAVINE

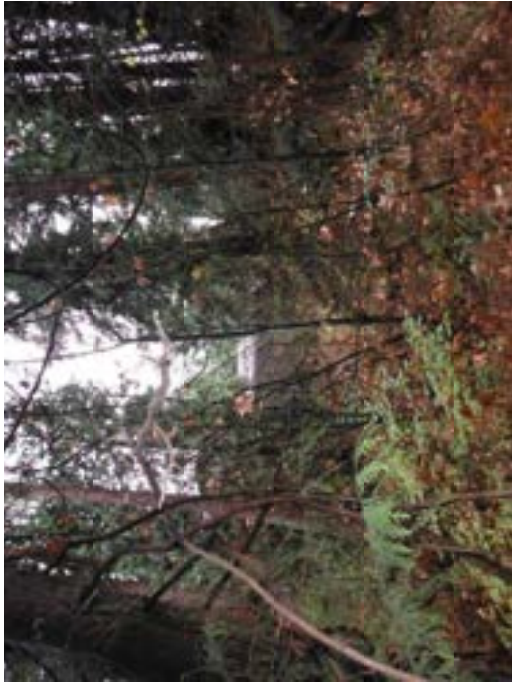


PHOTO 13 – MSE Wall – residential lot



PHOTO 14 - Seepage



PHOTO 15 – Tree down in creek, potential blockage



PHOTO 16 – Rip rap slope below Main Street

MAIN RAVINE



PHOTO 17 - Creek from River Road



KERR WOOD LEIDAL
consulting engineers

Appendix E

Modelling and Assessment



Appendix E – Hydrologic/Hydraulic Modelling

Contents

E.	Hydrologic and Hydraulic Modelling	1
E.1	Introduction	1
E.2	PC SWMM Model Development	1
E.3	PC SWMM Overview.....	1
E.4	Boundary Conditions.....	2
E.5	Results Analysis.....	3

Tables

Table E-1: Total Precipitation Amounts for Climate Station DT34.....	2
Table E-2: Minor Pipe Assessment - 10 Year Storm Event - Pipes Failed Assessment Criteria for Existing Land Use Flows.....	4
Table E-3: Minor Pipe Assessment - 10 Year Storm Event - Pipes Failed Assessment Criteria for Future Land Use Flows.....	4
Table E-4: Major Pipe Assessment - 100 Year Storm Event - Pipes Failed Assessment Criteria for Existing Land Use Flows.....	4
Table E-5: Culvert Assessment - 100 Year Storm Event - Culverts Failed Assessment Criteria for Existing Land Use Flows.....	5

Figures

Figure E-1: Catchments and Model Schematic.....	6
---	---



Appendix E – Hydrologic/Hydraulic Modelling

E. Hydrologic and Hydraulic Modelling

E.1 Introduction

This appendix outlines the development of the detailed hydrologic and hydraulic model of the North Delta Drainage Basin.

E.2 PC SWMM Model Development

The drainage system is shown in Figure E-1 and includes portions of both Delta and Surrey.

One model was developed for the watershed. PC SWMM was used for both the hydrology and hydraulics. The hydrology portion of PC SWMM uses inputs such as rainfall and catchment characteristics (area, slope, soil type, etc.) to estimate catchment flows. The hydraulic portion of PC SWMM use hydraulic system inputs (culvert/pipe/channel characteristics) to simulate flow routing, water levels.

E.3 PC SWMM Overview

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

Model Catchments

The watershed was discretized into major sub-catchments using contours, field watercourse information, and existing drainage information. The major sub-catchments for the study area are shown on Figure E-1.

In total, 146 catchments were created and imported into the PC SWMM model. Catchments were assigned the following attributes:

- areas;
- slopes, using contour information;
- impervious percentage values; and
- Infiltration and groundwater parameters.

Impervious Percentage

Existing land use impervious percentages were estimated based on the land use type visible in the aerial photography and typical impervious percentage values. For more details, see Appendix B.

The future land use impervious percentages were derived using the OCP zoning information combined with typical impervious percentage values. For more details, see Appendix B.

Soil Parameters

The groundwater portion of PC SWMM was used to estimate the groundwater and interflow portions of the runoff hydrograph. Figure 2-7 shows the surficial geology that was used to determine soil



Appendix E – Hydrologic/Hydraulic Modelling

parameters. The majority of the watershed is silt-clay soils and till, with some sand, steep land sediments and sand and silt soils.

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

Hydraulic Model

The model incorporates the study areas storm trunk network of drainage pipes, manholes, ditches, creeks and culverts as provided by the Corporation in their GIS databases. Each culvert was assigned a unique identifier. Creek and ditch cross-sections were obtained from the DEM (Digital Elevation Model). Nodes in the model consist of manholes, catch basins, cleanouts, intakes, outfalls and junctions. Missing or inaccurate information in the database was corrected with the use of available as-built drawings.

Channel roughness values were assigned based on typical values for the various conduit materials.

The drainage system includes:

- 16 km of pipes;
- 247 manholes; and
- 6 km of creeks and ditches.

E.4 Boundary Conditions

Rainfall Input

The design storms used in the analysis were generated from the IDF curve for the GVRD DT34 rain gauge. The rain gauge is located in North Delta at 8544-116th Street. The 1, 2, 6, 12 and 24-hour design storms were used for the conduit and culvert capacity assessments.

Table E-1 shows precipitation totals for all events.

Table E-1: Total Precipitation Amounts for Climate Station DT34

Duration	Total Rainfall (mm)					
	2-year	5-year	10-year	25-year	50-year	100-year
1-hour	9.5	12.6	14.6	17.3	19.2	21.1
2-hour	11	14.4	16.7	19.5	21.6	23.7
6-hour	23.4	31.7	37.1	44.0	49.1	54.2
12-hour	31.9	43.8	51.8	61.8	69.2	76.6
24-hour	42.5	62.2	75.2	91.7	103.9	116.1

Water Level Boundaries

The outlets of each of the creeks were modelled with a fixed high tide water level elevation of 2.4 m. This water elevation was taken as an average of the maximum water elevation recorded at Deas Island Tunnel (downstream of the study area) and Port Mann Pump Station (upstream of the study area) in 2012.



Appendix E – Hydrologic/Hydraulic Modelling

E.5 Results Analysis

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

Capacity Assessment

Assessments were performed for the modelled conduits and culverts in the study area to determine if any were undersized and required upgrading. Tables E-2 to E-5 show the pipes and culverts that are flagged for upgrading based on this analysis.

There are 11 pipes that exceeded the minor system criteria during existing land use conditions and an additional two pipes that exceeded the criteria for the future land use conditions.

Four pipes did not meet the major system criteria for the existing land use conditions and no additional pipes failed the criteria for the future land use conditions.

Five culverts did not meet the major system criteria for the existing land use conditions and no additional culverts failed the criteria for the future land use conditions.

Table E-2 : Minor Pipe Assessment - 10 Year Storm Event - Pipes Failed Assessment Criteria For Existing Land Use Flows

Conduit ID	Existing Landuse Peak Flow (m3/s)	Future Landuse Peak Flow (m3/s)	Existing Landuse Q / Qcap (Fraction)	Future Landuse Q / Qcap (Fraction)	Existing Landuse Upstream Node Total Surge Time (hr)	Future Landuse Upstream Node Total Surge Time (hr)	KWL Comments
430895	0.578	0.599	8.29	8.59	5.81	5.76	Length increased to 10m for model stability
431906	0.48	0.483	3.59	3.61	3.38	3.38	None
432006	0.48	0.482	1.47	1.48	2.51	2.51	None
431908	0.48	0.483	1.05	1.05	2.62	2.63	None
431669	0.149	0.149	1.52	1.52	3.17	3.2	None
434455	0.586	0.602	1.86	1.91	0.76	0.85	None
433335	0.586	0.602	3.5	3.6	2.69	2.7	None
433694	0.412	0.427	3.35	3.47	22.25	22.31	Length increased to 10m for model stability
433763	0.412	0.427	1.45	1.5	15.7	15.82	Assumed Upstream Invert
943748	0.478	0.49	6.83	7	1.13	1.27	Assumed Upstream Invert
433109	0.865	0.85	1.09	1.07	3.36	3.38	Length increased to 10m for model stability

Table E-3 : Minor Pipe Assessment - 10 Year Storm Event - Pipes Failed Assessment Criteria For Future Landuse Flows

Conduit ID	Existing Landuse Peak Flow (m3/s)	Future Landuse Peak Flow (m3/s)	Existing Landuse Q / Qcap (Fraction)	Future Landuse Q / Qcap (Fraction)	Existing Landuse Upstream Node Total Surge Time (hr)	Future Landuse Upstream Node Total Surge Time (hr)	KWL Comments
432414	0.832	0.868	1.98	2.06	0.5	0.53	None
433414	1.931	1.933	1.99	1.99	0.5	0.53	None

Table E-4 : Major Pipe Assessment - 100 Year Storm Event - Pipes Failed Assessment Criteria For Existing Land Use Flows









Conduit ID	Existing Landuse Peak Flow (m3/s)	Future Landuse Peak Flow (m3/s)	Existing Landuse Q / Qcap (Fraction)	Future Landuse Q / Qcap (Fraction)	Existing Landuse Upstream Node Total Surge Time (hr)	Future Landuse Upstream Node Total Surge Time (hr)	KWL Comments
432786	5.19	5.364	1.5	1.55	0.01	0.01	Assumed Upstream Invert
432788	5.19	5.364	1.32	1.37	0.13	0.15	None
432787	5.19	5.364	1.5	1.55	0.15	0.16	None
433211	2.052	2.07	2.26	2.28	10.66	10.8	None

Table E-5 : Culvert Assessment - 100 Year Storm Event - Culverts Failed Assessment Criteria For Existing Land Use Flows

Conduit ID	Shape	Diameter / Width (m)	Existing Landuse Peak Flow (m3/s)	Future Landuse Peak Flow (m3/s)	Overflow Elevation (m)	Existing Landuse Peak HGL (m)	Future Landuse Peak HGL (m)	Existing Landuse Upstream Node Total Surcharge Time (hr)	Future Landuse Upstream Node Total Surcharge Time (hr)	KWL Comments
1000766325	CIRCULAR	0.80	1.56	1.57	3.0	6.6	6.68	51.42	51.4	None
1000739968	CIRCULAR	0.80	1.57	1.58	2.9	11.42	10.54	50.02	50.02	None
1000739966	CIRCULAR	0.90	2.09	2.10	2.5	8.85	9.22	14.97	14.99	None
1000748517	CIRCULAR	0.90	2.09	2.10	4.7	12.09	10.52	2.58	2.58	Assumed Inverts
C27	CIRCULAR	1.20	2.15	2.15	8.0	9.21	9.3	0.67	0.7	None

**Corporation of Delta
North Delta Ravines
ISMP**

Legend

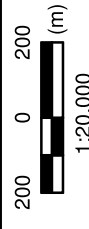
-  Municipal Boundary
-  Study Boundary
-  Watercourse
-  Modelled Outfalls
-  Modelled Culverts
-  Modelled Conveyance System
-  Modelled Creek / Ditch
-  Modelled Catchments

Reference: 2010 Orthophoto from the Corporation of Delta. Topographic, cadastral and utility data from the Corporation of Delta and the City of Surrey.

Surficial Geology Information: Natural Resource Canada and the Geological Survey of Canada
This information is not warranted as to its accuracy by Kerr Wood Leidal Associates and is provided for illustrative purposes only.



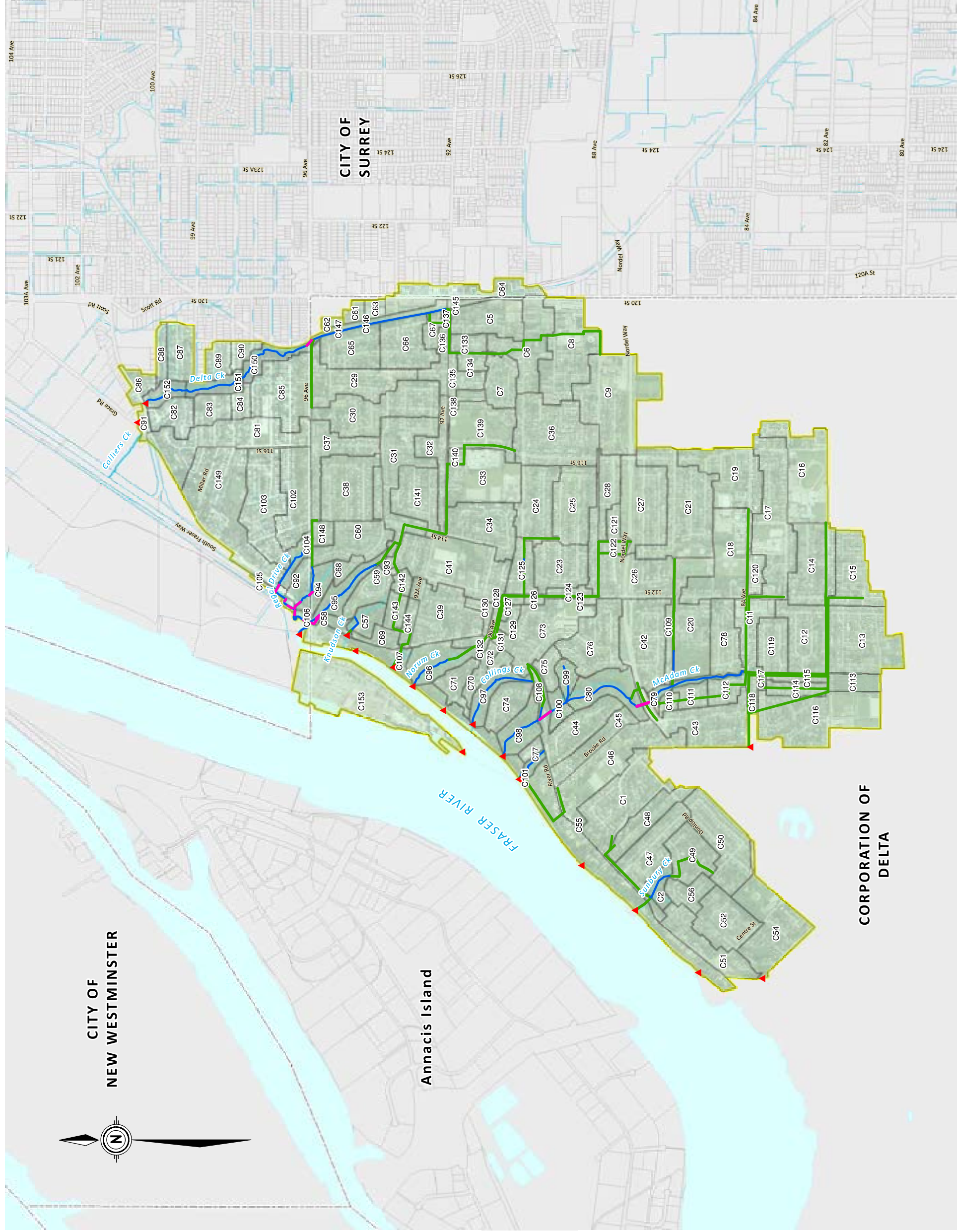
© 2013 Kerr Wood Leidal Associates Ltd.
Kerr Wood Leidal Associates Ltd. (KWL), a Corporation of Delta, is permitted to reproduce the materials for archiving and for distribution to third parties only as required to conduct business specifically relating to the Corporation of Delta North Delta Ravines ISMP. Any other use of these materials without the written permission of KWL is prohibited.



Project No. 323-073 Date May 2013

**Catchments and
Modelling Schematic**

Figure E-1





KERR WOOD LEIDAL
consulting engineers

Appendix F

Measures to Mitigate Environmental Hydrologic Impacts of Development



Appendix F – Mitigation Measures

Measures to Mitigate Environmental Hydrologic Impacts of Development

Contents

1.	Low Impact Development Practices.....	1
2.	Stormwater Source Control Technologies	2
3.	Stormwater Detention Systems	10
4.	Infiltration Systems.....	10



Appendix F – Mitigation Measures

1. Low Impact Development Practices

Introduction

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

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

Reduced Road Widths

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

Reduced Building Footprints

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

Reduced Parking Standards

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

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



Appendix F – Mitigation Measures

Limiting Surface Parking

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

Pervious Parking Surfaces

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



Reinforced Clean Crushed Gravel



Pavers

Building Compact Communities

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

Preserving Naturally Significant Features

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

2. Stormwater Source Control Technologies

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



Appendix F – Mitigation Measures

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

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

Absorbent Landscaping

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

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

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

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



Absorbent Landscaping



Absorbent Landscaping

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



Appendix F – Mitigation Measures

Surface Infiltration Facilities

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

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

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

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



Surface Infiltration Swale

Bio-Retention Facilities

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

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



Appendix F – Mitigation Measures



Bio-Retention Swale



Bio-Retention Swale

Sub-surface Infiltration Facilities

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

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



Sub-Surface Infiltration



Appendix F – Mitigation Measures

Green Roofs

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

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

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



Green Roof



Green Roof

Rainwater Re-use

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

Appendix F – Mitigation Measures



Re-Use Tank



Re-Use Rain Barrel

Water Quality Best Management Practices

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

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

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

Water Quality Best Practical Technologies

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

Biofilters

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



Appendix F – Mitigation Measures

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

Urban Forests and Leave Strips

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

Infiltration Systems

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

Constructed Wetlands

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



Small Wetland



Wetland

Wet Detention Ponds

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



Appendix F – Mitigation Measures

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



Wet Detention Pond



Wet Detention Pond

Oil and Grit Separators

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



Oil Grit Separator



Oil Grit Separator

Construction Best Practices

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



Appendix F – Mitigation Measures

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

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

3. Stormwater Detention Systems

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

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

4. Infiltration Systems

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

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

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



KERR WOOD LEIDAL
consulting engineers

Appendix G

Capital Cost Estimates

Table G-1: Storm Sewer and Culvert Upgrade Cost Estimate

Project No.	Link Name	Approximate Location	Existing Size (mm)	Priority	Length (m)	Upgrade Material	Upgrade Size (mm)	Number of Manhole Upgrades	Number of Days for Culvert Replacement	Storm Pipe Cost	Manhole Cost	Culvert Crew Cost	Culvert Material Cost	Culvert Crane Cost	Culvert Pumping Cost	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. GST)
1	C27		1,200	1	16	CMP	1,800		12			\$ 103,560	\$ 78,160	\$ 6,000	\$ 22,000	\$ 209,720	\$ 352,330
2	1000766325		800	1	22	CMP	1,600		10			\$ 86,300	\$ 88,000	\$ 6,000	\$ 22,000	\$ 202,300	\$ 339,864
3	1000739968		800	1	22	CMP	1,600		10			\$ 86,300	\$ 88,000	\$ 6,000	\$ 22,000	\$ 202,300	\$ 339,864
4	1000739966		900	1	26	CMP	1,800		20			\$ 172,600	\$ 127,010	\$ 6,000	\$ 22,000	\$ 327,610	\$ 550,385
5	1000748517		900	1	12	CMP	1,800		12			\$ 103,560	\$ 58,620	\$ 18,000	\$ 13,000	\$ 193,180	\$ 324,542
6	432786	11041 River Rd. 11031 River Rd.	900	1	53	CMP	3 m ROW									\$ 3,180	\$ 5,342
7	432787	11031 River Rd. 9150 Norum Rd.	900	1	63	CMP	3 m ROW									\$ 3,780	\$ 6,350
8	432788	9150 Norum Rd. 9140 Norum Rd.	900	1	40	CMP	3 m ROW									\$ 2,400	\$ 4,032
9	433211	Sunbury Creek Outfall Pipe (Under Railway)	600	1	17	CO	900*	2		\$ 59,500	\$ 16,000					\$ 75,500	\$ 126,840
10	430895		300	2	3	CO	675			\$ 1,950							
	430882		600	2	52	CO	675			\$ 33,800							
	430887		600	2	93	CO	675			\$ 60,450							
	430890	11202 86 Ave - 8589 112 St	600	2	4	CO	675	9		\$ 2,600						\$ 222,150	\$ 373,212
	430891		525	2	20	CO	675			\$ 13,000							
	430995		525	2	38	CO	675			\$ 24,700							
	430996		300	2	21	CO	675			\$ 13,650	\$ 72,000						
	431906		300	2	91	PVC	525			\$ 45,500							
	431884	11365 82 Ave - 11247 82 Ave	450	2	85	PVC	525	6		\$ 42,500						\$ 200,500	\$ 336,840
431900		450	2	63	PVC	525			\$ 31,500	\$ 48,000							
431892		450	2	66	PVC	525			\$ 33,000								
434455		300	2	20	PVC	450			\$ 8,600								
433335		250	2	37	PVC	450			\$ 15,910								
434457		300	2	44	PVC	450			\$ 18,920								
434458	8979 Russell Dr - McAdam Creek	300	2	41	PVC	450	9		\$ 17,630						\$ 184,660	\$ 310,229	
433326		350	2	19	PVC	450			\$ 8,170								
433327		300	2	75	PVC	450			\$ 32,250								
433325		350	2	26	PVC	450			\$ 11,180	\$ 72,000							
433335	11375 82 Ave	250	2	37	PVC	450	2		\$ 15,910	\$ 16,000					\$ 31,910	\$ 53,609	
433694	11132 90 Ave	300	2	7	CO	600	2		\$ 4,200	\$ 16,000					\$ 20,200	\$ 33,936	
433763	11132 90 Ave - 9044 112 St	300	2	149	CO	600	2		\$ 89,400	\$ 16,000					\$ 105,400	\$ 177,072	
943748	River Rd (Delwood Dr to Terrace Dr)	1,050	2	47	CO	1,350	2		\$ 84,600	\$ 16,000					\$ 100,600	\$ 169,008	
432006		450	3	14	PVC	525			\$ 7,000								
431884		450	2	85	PVC	525			\$ 42,500								
431906	8205 114 St - 11247 82 Ave	300	2	91	PVC	525	7		\$ 45,500						\$ 215,500	\$ 491,340	
431900		450	2	63	PVC	525			\$ 31,500								
431892		450	2	66	PVC	525			\$ 33,000	\$ 56,000							
431908	11269 82 Ave	450	3	69	PVC	525	2		\$ 34,500	\$ 16,000					\$ 50,500	\$ 84,840	
431669	10956 82 Ave	300	3	17	PVC	375	2		\$ 6,460	\$ 12,000					\$ 18,460	\$ 31,013	
433109	96 Ave outfall to Delta Creek	600	3	2	CO	675	2		\$ 1,300	\$ 16,000					\$ 17,300	\$ 29,064	
432414	10525 Main St - outfall to Sunbury Creek	375	4	80	PVC	525	5		\$ 40,000						\$ 107,000	DCC	
432418		450	4	31	PVC	525			\$ 15,500								
432417		450	4	23	PVC	525			\$ 11,500	\$ 40,000							
433414	8984 112 St - 10986 River Rd.	600	4	114	CO	900	5		\$ 102,600						\$ 356,800	DCC	
433695		600	4	88	CO	900			\$ 79,200								
433762		600	4	150	CO	900			\$ 135,000	\$ 40,000							
TOTAL																\$ 2,851,000	\$ 4,140,000

*Sunbury outfall must be jacked in place under the railway and industrial area.

**North Delta Ravines ISMP
Final Report
October 2014**

Corporation of Delta/City of Surrey

Table G-2: Environmental Improvement Cost Estimate

Project	Approximate Location	Project Description	Total Cost	Total Cost with Mobilization, Engineering & Contingency (excl. GST)
E.	Various	Undertake additional water quality assessment and monitoring actions using Metro Vancouver's regional strategy.	\$ 10,000	\$ 16,800
F.	Various	Retrofit stormwater systems in residential paved areas (parking areas, roads, and driveways) to capture and trap fine sediment.	\$ -	\$ -
G.	Various	Conduct further sampling of microbiological indicators (E. coli + fecal coliforms) during low flow conditions in August-September.	\$ 10,000	\$ 16,800
J.	Surrey	Evaluate a program to help homeowners install rain barrels on existing single family development in Surrey.	\$ -	\$ -
K.	Delta	Explore options to allow disconnected roof runoff directed to landscaped areas in areas on existing single family development in Delta and initiate a program to help home owners do so.	\$ -	\$ -
L.	All	Encourage homeowners to plant trees on their properties to increase evapotranspiration and reduce runoff to creeks.	\$ -	\$ -
I.	Delta	Develop program to encourage retrofit of institutional and municipal owned lots with 31 mm volume reduction source controls for pavement and roof runoff.	\$ 14,425,792	\$ 24,235,330
C. D.	Shadow Brook and Regal Drive	Riparian restoration and enhancement in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible road closure or relocation).	\$ 50,010	\$ 84,017
A.	Knudson	Encourage stewardship and riparian reforestation to increase riparian forest along lower Knudson Creek.	\$ 24,990	\$ 41,983
B.	McAdam	Remove debris associated with milk farm from riparian zone; reforest disturbed areas.	\$ 75,080	\$ 126,134
N.	McAdam	Increase complexity using the addition of logs, boulders, and gravel cobble weirs in lower McAdam Creek ravine	\$ 25,000	\$ 42,000
O.	Shadow Brook and Regal Drive	Instream habitat complexing in lower sections of Shadow Brook and Regal Drive creeks adjacent to railway and road corridor (including possible road closure or relocation).	\$ 75,000	\$ 126,000
P.	Kendale	Restore intertidal marsh habitat at mouth of Kendale Creek including possible relocation or closure of Elevator Road.	\$ 100,006	\$ 168,010
Q.	Sunbury	Incorporate fish passage when upgrading the Sunbury Creek culvert under railway.	\$ 20,000	\$ 33,600
Total Costs for Environmental Improvements			\$ 14,816,000	\$ 24,891,000