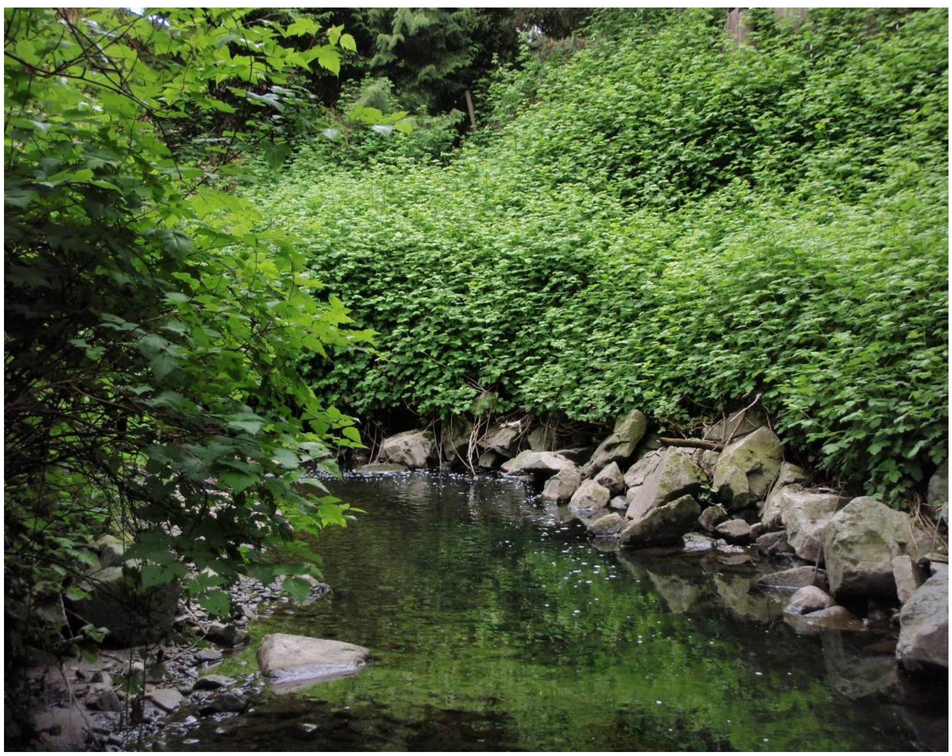
REPORT

City of Surrey

Cruikshank and Grenville
Integrated Stormwater
Management Plan



April 2014

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF

Signature

Date APRIL 8, 2014

Executive Summary

Associated Engineering was retained by the City of Surrey to complete an Integrated Stormwater Management Plan (ISMP) for the Cruikshank and Grenville watersheds in the City of Surrey. The objective of the ISMP as a whole is to develop and implement strategies and conceptual plans for managing stormwater to meet the planning objectives of the City of Surrey, adhere to the ISMP Terms of Reference Template prepared by Metro Vancouver, and meet the expectations of Metro Vancouver`s Integrated Liquid Waste and Resource Management Plan.

Summit Environmental (Summit), a subsidiary of Associated Engineering, developed the environmental components of the ISMP. Catherine Berris and Associates (CBA) assisted Associated Engineering with the planning, landscape architecture and public consultation components of this project.

1 STUDY AREA

The study location has a total area of approximately 1,380 hectares and contains the Cruikshank and Grenville watersheds. The watersheds generally slope from west to east with an average gradient of approximately 2.0 %. The area is mainly developed and includes single family residential developments, commercial “big box” store developments, small industrial developments, a BC Hydro site, BC Hydro high voltage transmission lines, Southern Railway of BC (SRBC) main track and industrial spurs, and the west portion of Bear Creek Park. The majority of the drainage area is located within the City of Surrey between 96 Avenue in the north, 120 Street (Scott Road) in the west, 74 Avenue in the south, and Bear Creek Park in the east. Refer to Map 2-1 for a map of the catchment boundaries and study area.

A small portion of the drainage area is located within the Corporation of Delta between 89A Avenue in the north, 118 Street in the west, 82 Avenue in the south, and 120 Street (Scott Road) in the east. We have accounted for the stormwater runoff from this catchment in this ISMP.

2 EVALUATION

2.1 FIELD RECONNAISSANCE AND ENVIRONMENTAL OVERVIEW

Associated Engineering and Summit Environmental staff conducted a field reconnaissance of the study area to assess environmental conditions, locate wildlife, observe drainage patterns, identify channel characteristics, and survey stormwater infrastructure. Staff noted and reported significant environmental, hydrologic, and hydraulic features within the watershed. This component of the ISMP is discussed in Section 3.

2.2 WATERSHED HEALTH ASSESSMENT

The Metro Vancouver template for Integrated Stormwater Management Planning provides guidance on preparing watershed health assessments using two physical characteristics: total impervious area and percent riparian integrity. Watershed health ratings are then calculated and compared to biological assessments obtained from measurements of benthic invertebrate communities. Existing watershed health was evaluated based on 2010 values. The watershed health assessment is discussed in Section 4 of the main report, and the relative health of the watersheds is indicated on Figure 4-1.

Overall the watersheds are indicated as being highly impacted, with a generally poor watershed health ranking.

2.3 DRAINAGE SYSTEM HYDRAULICS

In order to assess the current functionality of the drainage system in the study area and the potential impacts as a result of future changes in the study area, we developed a hydrologic and hydraulic model of the Cruikshank and Grenville watersheds using PC SWMM software. Both Base and Future hydrologic condition scenarios were developed and analyzed in the model.

To address the identified surcharging storm sewers within the Cruikshank and Grenville watersheds, approximately 10,115 m of storm sewers will need to be upgraded to service existing land use conditions and an additional 1,410 m of storm sewer will need to be upgraded to service future projected land use. Refer to Map 6-3A through Map 6-3F for the locations and Table 6-5 for a summary of the upgrade sizes and associated costs.

2.4 POLICY AND PLANNING CONTEXT

A number of Surrey's policy documents establish the context for stormwater management and environmental protection and enhancement. Two of these are particularly relevant, the City's Sustainability Charter, and the Official Community Plan.

Sustainability Charter

The City's Sustainability Charter sets high level and specific goals, as well as actions based on social, economic and environmental pillars of sustainability; the City's three spheres of influence are short, medium and long time frames. Supporting the implementation of the Sustainability Charter, the City generated 87 indicators and targets. The following are two specific targets relevant to this ISMP:

- 40% minimum tree canopy cover by 2058 to achieve a healthy urban forest, excluding ALR lands.
- 50% of total urban area with vegetative coverage by 2058 excluding the ALR.

Official Community Plan

The City of Surrey's Official Community Plan (OCP) is currently in the process of being updated with some key components being managing growth for compact communities and protecting natural areas. There are policies related to retaining significant trees, replacing trees based on the Tree Protection Bylaw, managing the quality and quantity of stormwater to help protect and enhance aquatic habitats, and protecting the quality and integrity of ecosystems.

Land Use Changes

The Cruikshank and Grenville watersheds are almost completely developed with the primary land uses being industrial and urban residential. Most of the urban residential areas, which are designated as “urban” OCP, are currently single family housing. There are two commercial areas (see Map 7-1) and several higher density residential developments. While official zoning of individual properties will likely remain unchanged, redevelopment activities will likely result in increased impervious coverage under pressures for increased utilization of lot area.

Surrey’s Ecosystem Management Study

Surrey’s Ecosystem Management Study (EMS) (HB Lanarc, 2011) provides an update to and an enrichment of the City's environmental areas mapping as currently identified in the Official Community Plan. The EMS is based on a City-wide Green Infrastructure Network (GIN) where all parts of the City have a role to play in the creation and enhancement of ecological processes. Phase 1 of the EMS includes the mapping, proposed ecosystem management strategies, and topics for policies and guidelines. Phase 2 of this project will identify the management strategies in more detail.

3 BEST MANAGEMENT STRATEGIES

In this section of the ISMP we discuss and outline stormwater management strategies that can be applied within the Cruikshank and Grenville watersheds. A combination of Best Management Practices and strategies will be needed to effectively manage stormwater at the site, sub-watershed, and watershed levels. Stormwater best management strategies are defined as approaches to land development or re-development that work to manage stormwater close to its source.

The majority of future development activity within these watersheds will consist of re-development and densification of already altered lands. The strategies described in this report can be applied to both new development and re-development projects. We present recommendations for privately owned urban residential lots, commercial, industrial, and multiple residential lots, publicly owned road rights-of-way, and other City owned property.

3.1 URBAN RESIDENTIAL LOTS

We recommend that the following source control measures be applied to urban (single family) residential lots at the time of re-development:

- Shrub Planting,
- Tree Planting,
- Increased Growing Medium Depth,
- Pervious Pavement, and,
- Minimum setbacks from EMS zones.

Overall, each redeveloped lot should be required to meet performance targets for control of runoff volumes and peak flow rates. These are discussed in Section 8, Table 8-1 of the main report.

3.2 INDUSTRIAL, COMMERCIAL AND MULTIPLE RESIDENTIAL LOTS

We recommend that the following source control measures be applied to commercial, industrial, and multiple residential lots at the time of development or re-development:

- Shrub planting,
- Tree planting,
- Pervious pavement,
- Green roof / detention Roof or other detention/retention systems,
- Enhanced growing medium depth,
- Bioswale / infiltration trench,
- Rain garden, and,
- Minimum setbacks from EMS zones.

The application of each source control on industrial lots are illustrated by Figure 8-7.

We developed source control performance targets that should be applied to commercial, industrial, and multi-family residential lots as listed in Table 8-3 of the main report. On-site detention storage requirements are summarized in Table 8-5.

3.3 LOCAL AND COLLECTOR ROAD RIGHTS-OF-WAY

We recommend that, where feasible, the following source control measures be applied to future local and collector road rights-of-way:

- Enhanced Growing Medium,
- Tree Planting,
- Shrub Planting,
- Pervious Parking Lanes, and
- Infiltration / Retention Systems.

The application of each source control on municipal road rights-of-way are described in detail in Section 8, and are illustrated in Figure 8-9 of the main report.

3.4 ARTERIAL ROAD RIGHTS-OF-WAY

We recommend that during future road improvement projects, the following source controls be incorporated into arterial road rights-of-way.

- Enhanced Growing Medium in Medians,

- Tree Planting in Medians and Boulevards,
- Enhanced Growing Medium in Boulevards,
- Shrub Planting in Medians and Boulevards, and
- Infiltration / Retention in Boulevards.

The application of each source controls on industrial lots are described in detail in Section 8 and illustrated by Figure 8-10 of the main report.

3.5 STORMWATER MANAGEMENT PONDS

Given the land constraints and the high runoff volumes from development in the study area, we recommend that the primary objectives of stormwater management ponds be to control runoff and provide extended detention to runoff from small frequently occurring rainfall events to provide relief to downstream stormwater infrastructure and watercourses.

We identified five suitable locations for siting future stormwater management ponds. The City should secure these sites when the opportunity arises. In the main report, refer to Map 8-1 for the pond locations, Table 8-10 for a summary of the design information, and Appendix D for detailed cost estimates.

3.6 RIPARIAN AREAS

We recommend restoring riparian areas in the Cruikshank and Grenville watershed along the remaining natural or quasi-natural watercourses. This could be achieved as part of the re-development planning process for larger developments, but may not be feasible with single residential lots undergoing redevelopment. This will likely be an opportunity driven process, linked to re-development proposals.

Riparian areas can be associated with community amenity features, such as greenways, and, though DFO usually prefers that access to the creek itself be prevented, multi-use paths and pedestrian bridges will encourage the public to use riparian zones as recreational areas. Educational signage will inform users of the sensitive ecosystems within riparian zones and hopefully foster a sense of environmental stewardship.

4 IMPLEMENTATION STRATEGY

In this section of the report we discuss funding requirements and options for the design and construction of the stormwater best management practices previously discussed. We also introduce an enforcement strategy in which we provide suggestions that can be applied to checklists for development and re-development applications, develop incentive approaches to support compliance with the recommendations of the ISMP, and identify changes to City of Surrey By-Laws and documents that are impacted by the recommendations of the ISMP.

4.1 FUNDING SOURCES

Funding to implement, operate, and maintain the stormwater best management practices developed in the Cruikshank and Grenville ISMP will come from a variety of sources. These sources include:

City of Surrey Capital Construction Program

We note that development driven upgrades servicing catchments greater than 20 hectares are eligible to be funded from DCCs. Development driven upgrades for service areas smaller than 20 hectares must be directly funded by development proponents.

Land Owners and Developers

Development driven upgrades applied to City systems with service areas less than 20 hectares are generally required to be funded directly by the developer.

Federal Funding

The federal government provides funding for infrastructure and environmental projects primarily through Infrastructure Canada and Environment Canada. While these sources are not widely utilized for storm drainage related projects, on rare occasions they may provide useful funds for specific projects and should be considered when advancing projects. These programs are:

- Canada Building Fund
- Green Infrastructure Fund
- EcoAction Community Funding Program
- Green Municipal Fund

Provincial Funding

Currently, the only applicable funding source is the Infrastructure Planning Grant Program.

4.2 CHECKLISTS FOR DEVELOPMENT AND RE-DEVELOPMENT PROJECTS

We recommend that the City of Surrey develop a set of checklists to ensure that the recommended best management strategies developed in the ISMP are properly accounted for at every stage of the development process. Checklists can be incorporated into existing processes and will encourage proper implementation of the stormwater management recommendations promoting improved long term health of the watershed.

4.3 INCENTIVES

Compliance with the recommendations of the Cruikshank and Grenville ISMP may be more readily achieved if land owners and developers are offered incentives for implementing, operating, and monitoring stormwater best management strategies. Possible incentives include:

- One Time Rebates
- Adjustments to Stormwater Utility Fees
- Publicity Achievement Recognition Program for Compliant Businesses

4.4 RECOMMENDED CHANGES TO CITY OF SURREY BY-LAWS AND DOCUMENTS

The City of Surrey has By-Laws in place to regulate and enforce practices within the City. We identified five (5) By-Laws that will be impacted by the best management strategies recommended in the ISMP. We recommend that each By-Law be amended accordingly to ensure the implementation of best management strategies. Changes are recommended to the following By-Laws and documents:

- City of Surrey Zoning By-Law, 1993, No. 12000
- City of Surrey Drainage Parcel Tax By-Law, 2001, No. 14593
- City of Surrey Stormwater Drainage Regulation and Charges By-Law, 2008, No. 16610
- City of Surrey Erosion and Sediment Control By-Law, 2006, No. 16138
- City of Surrey Supplementary Master Municipal Construction Documents, 2004

5 RECOMMENDATIONS

The context for the following recommendations is provided by the assessment of the watersheds and general goals and objective discussed in earlier sections.

As discussed in Section 3, the Cruikshank and Grenville watersheds retain significant and important functionality as fish habitat. A majority of the surviving watercourses have documented fish presence or have a supporting role in providing food and nutrients (Refer to Map 3-5). Preservation of the remaining habitat value is important and suitable measures are required to prevent further degradation and to provide opportunities for improvement. This provides a primary motivation for ensuring that sufficient measures are implemented to prevent further degradation of the watersheds, and preferably, provides for an improvement in watershed health.

Modelling of development impacts (refer to Section 6) indicated that there was an 8% increase in mean annual runoff volumes if no measures were implemented to address the changes in watershed hydrology. This increase implies a further degradation of the watercourses in the study area due to increased erosion and disruption of fish habitat. Mitigation of runoff volumes is primarily accomplished by the application of source controls, which form an important part of the recommendations of this ISMP.

The following vision statement guides the recommendations of this Cruikshank and Grenville ISMP:

"The vision for the Cruikshank and Grenville ISMP is to achieve a significant improvement in watershed health and the aesthetic and community values in the watershed. This ISMP will present a strategy for the successful implementation of stormwater best management practices that balance economic activities in the watershed with preserving and enhancing natural features, environmental health and engaging the public."

Below, we summarize the recommendations made throughout the Cruikshank and Grenville ISMP including environmental enhancements, stormwater management measures, and implementation and enforcement strategies. Each recommendation is classified as either short term (10-year horizon or less) or long term

(10 to 20-year horizon). Short term recommendations should be included in the City of Surrey's 10-year Servicing Plan. Long term recommendations should be implemented when either an opportunity arises, or during the 10 to 20-year horizon. If necessary, some programs initiated under the immediate 10-year plan can be extended through to the later period to control expenditures, and address opportunities as they arise.

5.1 SHORT TERM (10-YEAR PLAN) RECOMMENDATIONS

All short term recommendations are listed in Table ES-1 and discussed in detail in Section 10 of the main body of this ISMP.

Table ES-1
10-Year Plan Actions

No.	Recommendations	Location	Unit Cost	Qty.	Sub-Total Cost
Environmental Enhancements/Actions – Locations Indicated on Figure 10-1					
E.1	Remove Log Jams and Debris within Watercourses, place LWD along banks	Bear, Cruikshank, and King Creek	$30,000/ea	5	$150,000
E.2	Remediate High Risk Erosion Sites	Bear Creek	$100,000/ea	4	$400,000
E.3	Improve In-Stream Habitat and Channel Complexity	Healy Creek	$100,000		$100,000
E.4	Improve Fish Passage at Vertical Drop Structures	Cruikshank Creek	$100,000		$100,000
E.5	Re-Vegetate Bare Earth and Exposed Soils	Riparian Corridors	$500,000		$500,000
E.6	Enhancement of Flooded Field Adjacent to Bear Creek to a more Permanent "Wetland" Feature	Adjacent to Bear Creek, east of railway	$1,900,000		$1,900,000
E.7	Place Interpretive Signage along Trail Systems	Bear, Quibble, Healy, & Queen Mary Creek	$20,000		$20,000

No.	Recommendations	Location	Unit Cost	Qty.	Sub-Total Cost
E.8	Soil Evaluation Test Pitting Program	Vacant land	$50,000		$50,000
E.9	Infiltration Testing Pilot Program	Lots adjacent to watercourses	$50,000		$50,000
E.10	Restrictive Covenant Fencing for Future Development	Riparian Corridors	varies		varies
E.11	Remove Invasive and Nuisance Weed Species and Re-Vegetate Weed Control Areas	Adjacent to Cruikshank, Quibble, Bear, Healy, & Queen Mary Creek	$100,000		$100,000
E.12	Native Vegetation Planted Adjacent to EMS Zones	Development Adjacent to EMS Zones	varies		varies
Stormwater Management Infrastructure					
S.1	Construct Stormwater Management Ponds • assumes half of capital work undertaken in short term, half in long-term	Shown on Map 10-2	$11,775,000		$11,775,000
S.2	Implement Pipe System Upgrades: • assumes half of upgrades undertaken in short term, half in long-term • cost assumes source controls and BMPs fully implemented	Throughout Study Area – Refer to Maps 6-3A to 6-3F, and Table D-1, Appendix D, for details.	$5,340,000		$5,340,000
S.3	Future Urban Residential Source Controls	Future Development	varies		varies
S.4	Future Commercial, Industrial, and Multiple Residential Source Controls	Future Development	varies		varies

No.	Recommendations	Location	Unit Cost	Qty.	Sub-Total Cost
S.5	Sub-Surface Detention and Retention Storage	Future Development	varies		varies
S.6	Future Right-of-Way Source Controls	Road Improvements	varies		
Implementation and Enforcement Strategies					
I.1	Update Land Development and Building Permit Application Forms and Checklists	N/A	$25,000		$25,000
I.2	Stormwater Management Rebate Program	N/A	$200,000		$200,000
I.3	Revise the Drainage Utility Rate Structure	N/A	$50,000		$50,000
I.4	Update City of Surrey By-Laws	N/A	$50,000		$50,000

Overall, the 10-Year Plan recommended actions have an estimated cost of approximately $18,910,000 over the 10-year span, or approximately $1,890,000 per year.

5.2 LONG TERM (10-20 YEAR PLAN) RECOMMENDATIONS

All long term or on-going recommendations are listed in Table ES-2 and discussed in detail in Section 10 of the main report.

Table ES-2
Long Term (On-Going) Recommendations

No.	Recommendations	Location	Cost
Stormwater Management Measures			
S.1	Construct Stormwater Management Ponds assumes half of capital work undertaken in short term, half in long-term	Shown on Map 10-2	$11,775,000
S.2	Implement Pipe System Upgrades: • assumes half of upgrades undertaken in short term, half in long-term • cost assumes source controls and BMPs fully implemented	Throughout Study Area – Refer to Maps 6-3A to 6-3F, and Table D-1, Appendix D, for details	$5,340,000

The long term (10 to 20 Year Plan) recommended actions have an estimated capital cost of approximately $17,120,000 over the 10-year period, or approximately $1,710,000 per year.

5.3 ONGOING MANAGEMENT EFFORTS

Ongoing management efforts related to this ISMP, including operations and maintenance related to specific ISMP recommendations are listed in Table ES-3 and described in Section 10 of the main report.

Table ES-3
Ongoing Management Efforts

No.	Recommendations	Location	Cost
Operations and Maintenance (Annual)			
O.1	Regular Maintenance of Culverts and Removal of Debris	Bear, Cruikshank, and King Creek	$10,000
O.2	Annual Maintenance and Upkeep of Setback Fencing within Bear Creek Park	Bear Creek Park	$5,000
O.3	Remove Garbage	Riparian Corridors	$10,000

No.	Recommendations	Location	Cost
O.4	Annual Pruning and Maintenance of Himalayan Blackberry	Riparian Corridors	$25,000
O.5	Undertake a bird and bat-box program	Riparian Corridors	$5,000
Management Activities (Annual)			
M.1	Enforcement Monitoring of Implemented Urban Residential Source Controls	Future Development	$25,000
M.2	Enforcement Monitoring of Future Commercial, Industrial, and Multiple Residential Source Controls	Future Development	$25,000
Implementation and Enforcement Strategies (Annual)			
I.5	Inspection Services	Future Development	varies
I.6	Publicity Achievement Recognition Program for Compliant Businesses	Future Development	$10,000

If all required monitoring and maintenance activities are implemented they represent a budget requirement of approximately $115,000 per annum. This amount does not include the monitoring of performance indicators discussed in Section 11 of the main report.

Table of Contents

1 Introduction

Associated Engineering was retained by the City of Surrey to complete an Integrated Stormwater Management Plan (ISMP) for the Cruikshank and Grenville watersheds in the City of Surrey. The objective of the ISMP as a whole is to develop and implement strategies and conceptual plans for managing stormwater to meet the planning objectives of the City of Surrey, adhere to the ISMP Terms of Reference Template prepared by Metro Vancouver, and meet the expectations of Metro Vancouver`s Integrated Liquid Waste and Resource Management Plan.

Summit Environmental (Summit), a subsidiary of Associated Engineering developed the environmental components of the ISMP. Summit completed aquatic, terrestrial, groundwater, and hydro-geological assessments to gain information pertaining to fish and wildlife values, examine soil conditions, and identify general areas that may allow for small, medium, and large scale infiltration practices within the study area. Field information was collected to determine fish distribution, assess the quality and quantity of fish and wildlife habitat present, provide information on potentially sensitive habitat areas, and assess erosion or sedimentation concerns within the watershed.

Catherine Berris and Associates (CBA) assisted Associated Engineering with the planning and public consultation components of this project. CBA evaluated land planning and policy considerations which were used to identify stormwater best management strategies that could be effectively implemented. CBA also helped facilitate a workshop that was held with City of Surrey staff through which we gained valuable input regarding the City's preferred stormwater management strategies.

We worked with the City of Surrey to develop Stages 1 through 4 of the ISMP. In Stage 1 we collected, compiled, and reviewed background information and completed field reconnaissance to inventory the environmental and drainage features of the two watersheds. In Stage 2 we outlined a vision for future development within the watershed and determined opportunities and constraints for habitat enhancement, protection and future land use. In Stage 3 we developed an implementation plan, funding strategy, and enforcement strategy intended to bridge the gap between recommending a stormwater management approach and putting it into practice. In Stage 4 we created a monitoring and assessment plan to establish a framework for the ongoing evolution of the ISMP during implementation in response to performance goals.

Key team members from Associated Engineering were:

- Michael MacLatchy, Ph.D., P.Eng., Project Manager, Technical Leader
- John van der Eerden, M.Eng., P.Eng., Technical Reviewer and QA/QC Reviewer
- Joanne Slazyk, P.Eng., Lead Water Resource Engineer
- Andrew Wiens, P.Eng., Water Resource Engineer
- Aaron Deane, G.I.S.(PG), GIS/Asset Management Technician

Key team members from Summit Environmental were:

- Brent Phillips, M.Sc., R.P.Bio., Senior Environmental Reviewer
- Lyndsey Johnson, R.P.Bio., Aquatic Biologist
- Alexandra de Jong Westman, CEP, R.P.Bio., Terrestrial Biologist
- Joe Alcock, M.Sc., P.Geo., Geoscientist
- Dan Austin, M.G.I.S., GISP, GIS/Environmental Analyst

Key team members from Catherine Berris and Associates were:

- Catherine Berris, BLA, MLA, FCSLA, MCIP, Planner
- William Gushue, B.Sc., GIS Analyst

City of Surrey staff involved over the course of the project included:

- David Hislop, City's Project Manager
- Carrie Baron, Manager Drainage and Environment
- Don Luymes, Manager Community Planning
- Steve Whitton, Manager Trees and Landscaping
- Stephen Godwin, Environmental Coordinator
- Liana Ayach, Drainage and Environment
- Dan Chow, Planning and Development
- Mary Beth Rondeau, Planning and Development
- Doug Merry, Parks Planning
- Kristen Tiede, Roads and Transportation

We gratefully acknowledge the contribution of community stakeholders who provided insightful discussion and knowledge of the local concerns within the Cruikshank and Grenville watersheds.

2 Study Area

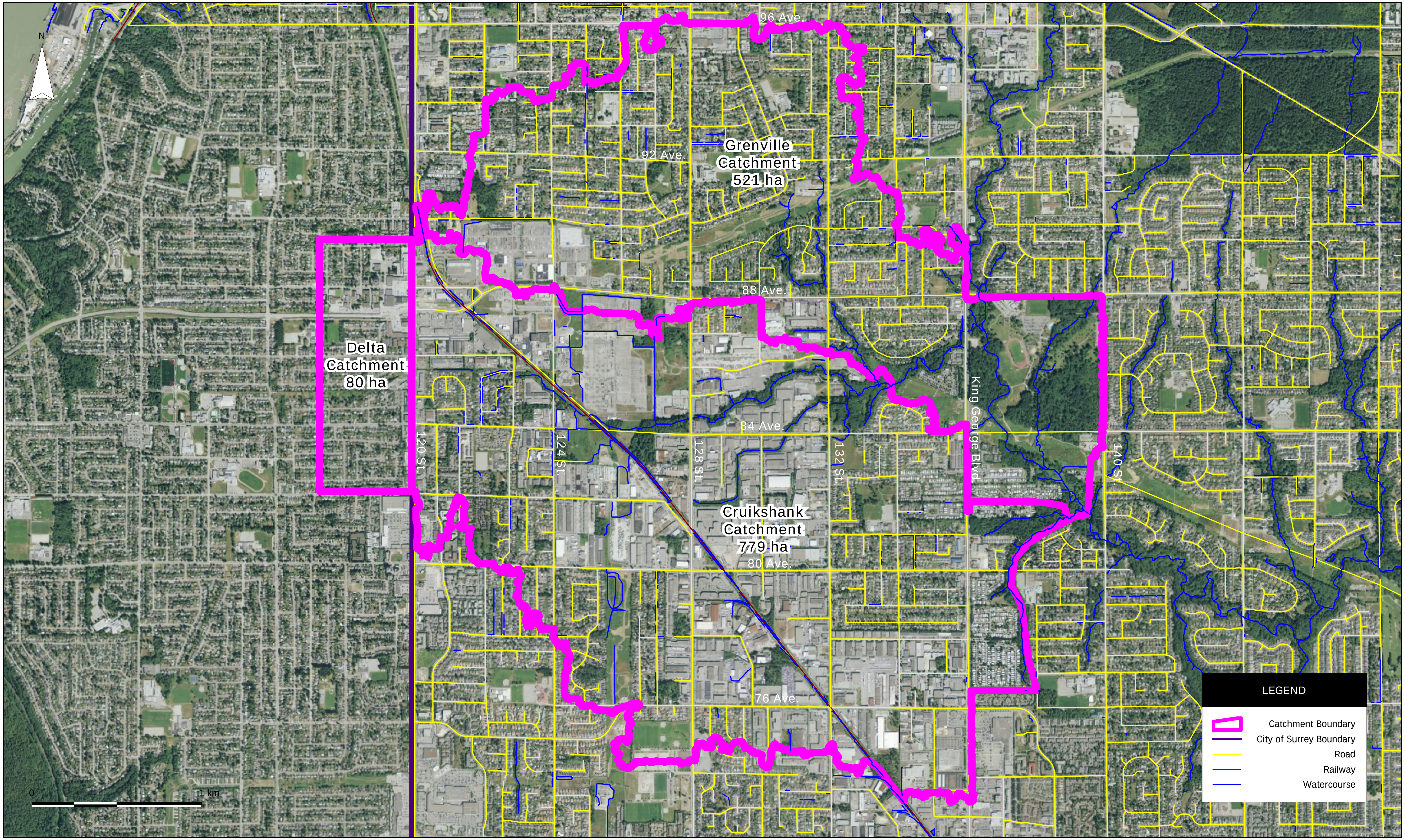
The study location has a total area of approximately 1,380 hectares and contains the Cruikshank and Grenville watersheds. The watersheds generally slope from west to east with an average gradient of approximately 2.0 %. The area is mainly developed and includes single family residential developments, commercial "big box" store developments, small industrial developments, a BC Hydro site, BC Hydro high voltage transmission lines, Southern Railway of BC (SRBC) main track and industrial spurs, and the west portion of Bear Creek Park. The majority of the drainage area is located within the City of Surrey between 96 Avenue in the north, 120 Street (Scott Road) in the west, 74 Avenue in the south, and Bear Creek Park in the east.

A small portion (80 ha) of the drainage area is located within the Corporation of Delta between 89A Avenue in the north, 118 Street in the west, 82 Avenue in the south, and 120 Street (Scott Road) in the east. The drainage area outside of the City of Surrey boundary may potentially impact property within the limits of the City. We have accounted for the stormwater runoff from this catchment in our report, but have not conducted detailed investigations of this drainage area.

For the purpose of this report, we have divided the study area into three overall drainage catchments; the portion of the Cruikshank watershed located within the Corporation of Delta (Delta), the portion of the Cruikshank watershed located within the City of Surrey (Cruikshank), and the Grenville watershed (Grenville). The overall catchment areas thus reflect the drainage areas determined during watershed delineation as described in Section 5, and are as follows:

- Delta, 80 ha
- Cruikshank, 779 ha
- Grenville, 521 ha

Refer to Map 2-1 for a map of the catchment boundaries and study area.



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No.	REVISION	DATE

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CITY OF SURREY — the future lives here.

Project No.: 20112781

Date: December 2012

Scale: 1:20,000

City of Surrey
Cruikshank and Grenville ISMP

Map 2-1: General Watershed Plan

3 Field Reconnaissance and Environmental Overview

Associated Engineering and Summit Environmental staff conducted field reconnaissance of the study area to assess environmental conditions, locate wildlife, observe drainage patterns, identify channel characteristics, and survey stormwater infrastructure. Staff noted and reported significant environmental, hydrologic, and hydraulic features within the watershed.

3.1 HYDRAULIC INVENTORY

We completed a hydraulic inventory of the study area to identify existing major drainage structures including culverts, bridges, and outfalls, to determine the approximate dimensions of channels and ditches, and to identify erosion and debris blockage sites. For the purpose of organizing the hydraulic inventory, we divided the study area into the Delta, Cruikshank, and Grenville catchments as shown on Map 2-1. A field inventory was not completed for the Delta catchment as it is located outside of the City of Surrey and is not being modelled in detail. Refer to Map 3-1A and Map 3-1B for a map of the inventoried infrastructure. The inventory data is contained in Appendix A.

Associated Engineering staff conducted the field investigation with the aid of a mobile Global Positioning System (GPS) unit. Mobile GPS integrates Global Navigation Satellite Systems (GNSS), rugged handheld computers, and Geographic Information System (GIS) software. The mobile GPS unit contained existing mapping of open channels provided by the City of Surrey. Field staff walked the majority of the watercourses and surveyed channel cross sections, culverts, bridges, outfalls, erosion sites, and debris blockages as they were encountered. Special attention was paid to potential crossing locations to ensure that each major culvert and bridge was assessed. At each point, staff recorded the dimensions, material, and configuration of the hydraulic feature and assessed its risk level. Staff also measured and noted features of channel cross sections including right and left bank height, side slopes, low flow channel width, depth, and roughness. Each surveyed hydraulic feature was documented with photographs.

Information collected during the hydraulic inventory was added to the GIS database of the study area. The database includes all surveyed hydraulic features and all applicable hydraulic features provided by City of Surrey mapping. A picture of each surveyed hydraulic feature has been linked to its respective point within the database.

Associated Engineering field staff ensured that all significant hydraulic features within the study area were inventoried but it was not practical to assess all of the lesser hydraulic features. All primary watercourses crossed by major roads and railways were inventoried, as were the majority of driveway culverts and roadside ditches to obtain their general dimensions, material, and condition. Culvert and ditches not inventoried are assigned the dimensions and characteristics consistent with their location and role in the drainage system.

A detailed inventory and photographs of the surveyed hydraulic features can be found in Appendix A.

As a matter of observation, it is certain that the hydrology of the watersheds has been significantly altered over those that existed for pre-development conditions by the wide spread development of the watersheds. Experience in other watersheds throughout Metro Vancouver (and worldwide) has shown that removal of forest cover and introduction of significant impervious coverage will cause an increase in total runoff and peak flow rates. These changes generally have a detrimental impact on natural watercourses by increasing erosion activity, disturbance of aquatic and riparian habitat and reduced base flows to support fish populations.

During the hydraulic inventory, our staff came across several erosion and debris sites. Our staff noted each erosion and debris site and ranked each according to the apparent degree of activity or vulnerability, or potential damage to public or private property. Erosion and debris sites are noted in the hydraulic inventory contained in Appendix A, and shown on Map 3-2.

3.2 GENERAL DRAINAGE CHARACTERISTICS

As part of the field investigation, Associated Engineering staff became familiar with the topography and hydraulic and hydrologic features of the study area. Flow routes including watercourses, ditches, culverts, and gravity storm sewers were identified with GIS analysis and verified in the field, where appropriate. Refer to Map 3-3 for a map of the open channel flow routes and Map 3-4 for a map of the piped systems in the study area.

Approximately 13.9 km of Bear Creek and its tributaries are located within the study area. No major watercourses are located within the 80 hectare Delta catchment. Within the upper portion of the 520 hectare Grenville catchment, approximately 2.4 km of Healy Creek, Queen Mary Creek, and Grenville Creek generally flow southeast. Within the upper reaches of the 779 hectare Cruikshank catchment, approximately 5.4 km of Bear (Bear) Creek and Cruikshank Creek generally flow east and north. The two systems combine approximately 310 m east of 132 Street and 280 m north of 84 Avenue to form Bear Creek. After the confluence of the two systems, Bear Creek continues northeast then southeast for a distance of approximately 2.4 km through the Grenville catchment before exiting the catchment approximately 105 m west of 140 Street and 335 m north of 80 Avenue. Approximately 1.9 km of Hunt Creek, 1.5 km of King Creek, and 0.3 km of Quibble Creek also pass through the study area and combine with Bear Creek within Bear Creek Park upstream of the watershed boundary.

Roadside ditches are located discontinuously throughout the study area interspersed with sections of the piped stormwater network. The majority of residential ditches connect into the piped drainage system. Ditches are located along both sides of the SRBC line that traverses the Cruikshank catchment from northwest to southeast. Railway ditches are relatively continuous from the upstream extents of the catchment to the point at which they join Bear Creek at the southwest corner of the BC Hydro site approximately 200 m east of 124 Street and 735 m south of 88 Avenue. Other ditch systems are located within industrial developments, the BC Hydro site, and along pedestrian walkways that pass through the BC Hydro transmission line rights-of-way.

There are approximately 108.2 km of storm drainage pipes ranging in diameter from 200 mm to 1800 mm throughout the study area. This includes approximately 20 culverts. The majority of the study area is serviced by piped systems where runoff is intercepted by catch basins. Several urban residential areas are serviced by ditch systems that capture runoff and convey it to downstream piped systems. The piped systems discharge to watercourses via one of the approximately 45 outfalls in the study area.

3.3 AQUATIC ECOSYSTEM ASSESSMENT

The majority of open channels within the study area, including the main stems and tributaries, are designated as Class A watercourses (i.e. inhabited by salmonids) in the City of Surrey's Watercourse Classification Map; reaches of Class A (O) and Class B also exist. Some watercourses, including Cruickshank Creek and Healy Creek, have been substantially altered as a result of local development. Other watercourses, including Bear Creek within Bear Creek Park and outside the park, remain in a natural or near-natural state, providing good habitat for salmonid rearing and migration. Within the study area (mainly within Bear Creek Park) several existing restoration and enhancement projects have taken place and are currently being maintained, including those run by the Salmon Habitat Restoration Program (SHaRP) and Surrey's Natural Areas Partnership (SNAP) Programs. Conceptual plans for the Bear Creek Salmon Interpretive Park have been developed and will be implemented as funding becomes available.

3.3.1 Fish Species

Several creeks within the study area have been stocked since the 1980s and, more recently, the Serpentine Enhancement Society and Nicomekl Enhancement Society have stocked Bear Creek annually. There are additional fish releases upstream of Bear Creek that are undertaken by other ecological non-profit organizations. A numbers of ponds and pools within the study area offer excellent rearing habitat for salmonids. Fish species listed on the provincial HabitatWizard[1] as present in the study area are listed in Table 3-1. During the field assessment, salmonids were observed only in Bear Creek. Bear Creek provides good fish habitat as it has deep pools, in-stream cover, including coarse woody debris and overhanging vegetation. Healy Creek and Cruikshank Creek would be considered poor to moderate fish habitat as they lack sufficient habitat features, such as water depth and appropriate shade, and/or may have barriers to fish migration during low flows. Detailed stream habitat features were documented during the field assessment and are provided in Appendix B.

[1] BC Ministry of Environment. HabitatWizard. Available at: http://www.env.gov.bc.ca/habwiz/

Table 3-1
Documented Fish Presence in Cruikshank and Grenville Watersheds

Watercourse	Fish Species Present
Bear Creek	Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), cutthroat trout (*O. clarkii*), rainbow trout (*O. mykiss*), peamouth chub (*Mylcheilus caurinus*), prickly sculpin (*Cottus* sp.), redside shiner (*Richardsonius balteatus*), threespine stickleback (*Gasterosteus aculeatus*), western brook lamprey (*Lampetra planeri*), dolly varden (*Salvelinus malma malma*), catfish.
Cruikshank Creek	Coho salmon
Healy Creek	Coho salmon, cutthroat trout, rainbow trout, steelhead (*O. mykiss*), sculpin, threespine stickleback
Quibble Creek	Chinook salmon, coho salmon, chum salmon, pink salmon, sockeye salmon, cutthroat trout, rainbow trout, Dolly varden, kokanee, steelhead.

3.3.2 Stream Classifications

The City of Surrey's online watercourse mapping (COSMOS[2]) and the City of Surrey's Fish Classification Map[3] provide watercourse classification for watercourses and tributaries in the study area (Map 3-5). Watercourses are divided into four classifications which are based on fish presence, duration and source of water, and surrounding vegetation potential. Table 3-2 summarizes the stream classifications used by the City of Surrey.

[2] City of Surrey, COSMOS, available at http://www.surrey.ca/city-services/665.aspx
[3] City of Surrey, Fish Classification, available at http://www.surrey.ca/files/ENG-FishClass.pdf

Table 3-2
Stream Classification System, City of Surrey

Classification	Map Symbol	Description
Class A	Solid red line	Inhabited by or potentially inhabited by salmonids year round.
Class A (O)	Dashed red line	Inhabited by or potentially inhabited by salmonids primarily during the over-wintering period.
Class B	Solid yellow line	Significant food and/or nutrient value, no fish present
Class C	Solid green line	Insignificant food and/or nutrient value or road-side ditches

Within the study area, the major watercourses are classified as summarized in Table 3-3.

Table 3-3
Generalized Stream Classifications for Cruikshank-Grenville Watersheds

Watercourse	Classification
Bear Creek	Class A
Cruikshank Creek	Class B
Queen Mary Creek	Class A (Class B at headwaters)
Healy Creek	Class A (Class B at headwaters)
Grenville Creek	Class A
Unnamed tributary to Bear Creek 1	Class A (Class B at headwaters)
Quibble Creek	Class A
Unnamed tributary to Bear Creek 2	Class A (unknown classification north of 84 Avenue)
King Creek	Class A
Hunt Brook	Class A

Note: Refer to Map 3-5 for detailed illustration of stream classifications in the study area.

3.3.3 Stream Habitat Assessment

The aquatic habitat assessment was conducted by a Summit aquatic biologist on June 3 and 10, 2011 in order to assess the current aquatic habitat and to identify specific issues related to erosion, bank instability and barriers to fish movement. Points of interest were geo-referenced in the field using GPS and are indicated on Map 3-6; details are provided in Appendix B (Note that most points on Map 3-6 are related to the hydrogeology/geomorphic assessment and do not have stream habitat information, which is discussed later in this section, with data presented in Appendix C). Attributes of the open channel were characterized for specific stream reaches. Delineation of stream reaches was based on gradient breaks, shifts in substrate composition or other hydrological or morphological features, such as points of erosion or channel barriers.

Field assessments were conducted at each reach following the protocols provided by the Resources Inventory Committee for Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures[4]. Ground photographs were taken during the field assessment to document specific observations. Stream reaches were assessed on foot and detailed information was collected, including:

- Channel morphology,
- Wetted width and depth,
- Bank width and depth,
- Substrate composition,
- Habitat values and problems,
- Fish presence and barriers to fish movement,
- Riparian characteristics,
- Habitat enhancement opportunities, and
- Water quality.

Point attributes such as water quality, erosion point, location of fish barriers and ground photographs are identified by GPS number and position. Line attributes such as channel widths, substrate characteristics and in-stream cover pertain to the reach segments.

On Cruikshank Creek upstream of 84 Street (Station ID 45 and 46), there are concrete drop structures spaced at approximately 100 m intervals which may act as barriers to fish passage. Additionally, several log jams were identified during the field assessment including Bear Creek, upstream of 128 Street (Station ID 60), Cruikshank Creek, downstream of 132 Street (Station ID 49), King Creek (Station 42). These log jams could be considered barriers to fish migration during low flows; however they may also provide refuge and cover to fish during higher flows. The watercourses assessed were of low gradient (less than 5 %), and therefore are not steep enough to create a velocity barrier to fish migration (greater than 20 %, based on the Forest Practices Code).

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[4] Resources Inventory Committee. Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures. Available at: http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/recon/recce2c.pdf

3.3.4 Water Quality

In-Situ Water Characteristics

Watercourses in urban and residential areas are often impacted by stormwater runoff and human activities which can degrade the quality of water. Given the amount of residential and urban activity within the watershed, water quality could be an issue without proper mitigation. Limited water quality sampling and analyses were undertaken as part of this ISMP and provided a “snap shot” of existing conditions. Sampling and laboratory analysis for specific contaminants was not undertaken. A long term water quality sampling program within the study area to assess impacts to the health and survival of salmonids is desirable. Contaminant analyses should include metals, coliforms, anions and hydrocarbons, and samples should be collected during both low flows and high flows.

During the June 2011 field assessment water quality was assessed in situ and included temperature, pH, conductivity, TDS and salinity, as described in Table 3-4. Water quality results were within the range of the Ambient Water Quality Objectives for Boundary Bay and its Tributaries Fraser-Delta Area (Ministry of Environment, 1988) for pH (6.5-8.5) with the exception of the pH of Station 71 which was slightly above the water quality objective. Temperatures measured at water quality stations met the BC Ministry of Environment Environmental Protection Division Water Quality Guidelines for Temperature (2001) for streams with unknown fish distributions (mean weekly maximum temperature of 18ºC) and for rearing of cutthroat trout (7.0-16.0ºC), Chinook salmon (10.0-15.5ºC) Coho salmon (9.0-16.0ºC) and Chum salmon (12.0-14.0ºC).

Table 3-4
In situ Water Quality Measurements, June 3 and 10, 2011

Station ID	Temperature (ºC)	pH	Conductivity (µS/cm)	TDS (ppm)	Salinity (ppm)
1	12.5	7.99	144.7	102	68
45	13.4	8.17	153.7	109	72
46	13.3	8.10	148.7	105	69
48	13.5	8.21	158.2	122	74
49	13.1	8.08	159.7	113	74
50	13.3	8.25	139.8	99	65
51	13.3	8.36	139.7	98	65
52	13.8	8.32	202.0	144	94

Station ID	Temperature (ºC)	pH	Conductivity (µS/cm)	TDS (ppm)	Salinity (ppm)
53	13.6	8.20	230.0	168	110
54	14.0	8.20	201.0	143	94
55	13.6	8.03	221.0	158	104
56	14.0	8.32	236.0	167	109
58	14.0	8.28	202.0	161	106
71	12.8	8.77	252.0	180	117
72	13.0	8.43	237.0	174	110

Benthic Invertebrates

Benthic invertebrate communities are often used as ecological indicators of stream health, because they integrate water quality and reflect site-specific environmental conditions. Accordingly, benthic invertebrates are identify by the ISMP template (Metro Vancouver, 2005) and GVRD Benthic Invertebrate Index of Biotic Integrity (B-IBI) guide (EVS 2003) for evaluation as part of an ISMP's development. Benthic surveys provide a biologically based performance measure of the effectiveness of watershed planning and implementation processes because these organism, which inhabit the cobble and gravel substrates of the stream, experience the ambient conditions and stressors of the watershed (e.g., changes in flow regime and in-stream habitat, sediment and toxic substances that enter through storm drains and other runoff).

The B-IBI assessment incorporates environmental and community characteristics (taxon richness and composition, pollution tolerance vs. sensitivity, feeding ecology, population structure) and index scores have been shown to correlate with TIA and RFI (Metro Vancouver 2005). Values range from 10 (very poor) to 50 (excellent), although a maximum of 40 has been observed for pristine streams within Metro Vancouver (Metro Vancouver 2005).

As part of the ISMP process, the City of Surrey began monitoring benthic invertebrate communities in 1999. In 2009, the sampling program included 29 stations within 19 streams and rivers. Although this Project Background report does not include benthic invertebrate sampling, data from three sample locations within the City's sampling program are applicable to the Project area: Bear 1-1, Bear 1-2, and Bear 1-3. Bear 1-2 and Bear 1-3 are directly within the Project area, and Bear 1-1 is located on an adjacent creek near the Project area.

In the spring and fall of 2009, the mean benthic index of biological integrity (B-IBI; a metric that summarizes taxa richness and community structure) was 14 for all sites in Bear Creek [5]. B-IBI values range from 40 (good conditions) to 10 (poor conditions). The low B-IBI value suggests that Bear Creek is in poor condition, based on benthic invertebrate communities. In the City's overall study area, B-IBI values ranged between 14 to 28 in the spring, and 14 to 22 in the fall of 2009. According to the B-IBI index, all streams sampled in the City of Surrey are indicated to be significantly impacted. Bear Creek has one of the lowest B-IBI values (14); however, this B-IBI value is the same for King, Quibble, Delta, and McLellan creeks in the spring and fall, and Cougar, Enver, Erickson, Fergus, Hyland, and Latimer creeks in the spring.

The spring and fall 2009 Bear Creek samples were dominated by Chironomidae (nonbiting midges that are ubiquitous to aquatic habitats), Oligochaeta (aquatic worms), and Baetidae species (a family of mayflies). Taxa richness values for the Bear Creek sites were low (between 5 and 7). These values were lower than all other sample locations, except McLellan Creek. Environmental stresses tend to reduce the number of species that can exist, and systems that have a high abundance of organisms belonging to a few taxa are often more stressed than those with a more even community distribution.

It is important to note that data from Bear Creek was only available from 2009. The 2003-2005 [6] and 2006 [7] sampling reports did not include Bear Creek as a sample site. While benthic invertebrates provide an integrative view of water quality conditions, it is difficult to ascertain trends in water quality conditions from one (1) year of data. For comparison, B-IBI values calculated for Enver Creek (a nearby location) from 2003 to 2009 show an observable decreasing trend in B-IBI values in the spring, yet no observable decreasing trend in B-IBI values in the fall (a Seasonal Kendall test showed no significant trends in the data $p = 0.968$).

3.3.5 Fish Habitat Compensation, Restoration, and Management

To improve aquatic habitat within the Cruikshank and Grenville watersheds, we identified the following actions:

1. Remove log jams and debris within watercourses to promote seasonal fish movement. Replace with appropriately placed and anchored large-woody debris to create fish habitat (Figure 3-6, Points 48, 57, 71, 72).
2. Continue regular maintenance of culverts by clearing debris in Bear Creek (upstream of 128 Street), Cruikshank Creek (downstream of 132 Street) and King Creek in order to promote fish passage and improve culvert integrity and safety.
3. Continue requirements to install restrictive covenant fencing for any future development (Map 3-6, Points 1 & 45, and generally along all Class A and A (O) watercourses).
4. Within Bear Creek Park, Bear Creek has several existing restoration and enhancement projects including in-stream installation of root wads and large-woody debris with adequate setback fencing

[5] 2009 City of Surrey Benthic Invertebrate Sampling Program: Methods and Results. July 2010. Prepared by Raincoast Applied Ecology. 13 pp.
[6] Surrey Benthic Invertebrate Sampling Program 2003-2005 Summary Report. January 2007. Prepared by Dillon Consulting Limited. 89 pp.
[7] Surrey Benthic Invertebrate Sampling Program 2006 Summary Report. June 2008. Prepared by Dillon Consulting Limited. 52 pp.

and signage to deter pedestrian traffic within the riparian corridors. Continue maintenance and upkeep of setback fencing as well as adequate vegetation in order to maintain fish habitat within Bear Creek Park.

5. Monitor and remediate erosion sites within Bear Creek that have resulted in bank instability which may contribute to downstream sedimentation and decrease available habitat for juvenile salmonids and benthic invertebrates (Map 3-6, Points 48 & 54).
6. Improve in-stream habitat and channel complexity as well as riparian vegetation within Healy Creek and the unnamed tributary to Healy Creek upstream of 88 Avenue. The lack of in-stream habitat is limiting the capacity to support juvenile fish and poor in-stream complexity reduces the amount of available aquatic habitat for rearing or migration of salmonids (Map 3-6, Points 55, 56, 57).
7. Vertical drop structures within Cruickshank Creek are currently barriers to fish migration and should be made passable by creation of fish ladders or weir structures, or removal or reducing the height of the centre portion of the vertical drop structure, as well as enhancing in-stream fish habitat (such as creation of deep pools, installation of coarse woody debris, etc.)

3.4 TERRESTRIAL ECOSYSTEM ASSESSMENT

A terrestrial field assessment was conducted by Summit on June 3, 2011. The assessment focused on the riparian habitats along the creek corridors, noting habitat features (e.g. ponds, flooded fields, cavity nests), local ecology and plant communities, and areas for potential restoration (quality of existing habitats). Through this collection of data, we quantified the environmental sensitivity of the study area by developing a correlation matrix, considering existing ecology, wildlife and their habitats particularly those at-risk [8] within the province, and the quality of the natural environment. These “environmentally sensitive areas” (ESAs), are ranked based on sensitivity of the environment, conservation value and level of disturbance criteria provided by the City of Surrey (Refer to Section 3.4.3 for criteria and methodology).

The study area is located within the Coastal Western Hemlock biogeoclimatic zone, dry maritime subzone (CWHdm1) within the City of Surrey[9]. The CWHdm1 occurs at low to middle elevations mostly west of the coastal mountains, along the entire British Columbia coast. The CWHdm1 occupies elevations from sea level to 900 m on windward slopes in the south and mid-coast (1050 m on leeward slopes), and to 300 m in the north. The CWHdm1 is, on average, the rainiest biogeoclimatic zone in British Columbia, experiencing cool summers and mild winters[10]. While the study area has little native, contiguous vegetation remaining, the potential growing conditions remain the same.

3.4.1 Plants and Riparian Ecology

Riparian ecosystems are constrained by urban development including road infrastructure, industrial areas, and housing developments. Minimum vegetation buffers along the creeks have been retained; however,

[8] Species and ecosystems within the province are ranked as either red-listed (populations or ranges are extirpated, endangered or threatened by development) or blue-listed (populations or ranges are considered of special concern due to threat of development). Ministry of Forests, Lands and Natural Resource Operations. 2010. Online at: http://www.env.gov.bc.ca/atrisk/red-blue.html

[9] Ministry of Forest and Range. 2008. Biogeoclimatic Ecosystem Classification Subzone/Variant Map for the Chilliwack Forest District, Coast Forest Region. Government of BC. Kamloops, B.C.

[10] Meidinger D and J Pojar. 1991. Ecosystems of British Columbia. Ministry of Forest Research Branch. Victoria, B.C.

areas in close proximity to development have infestations of horticultural plants, and nuisance and noxious weed species. Weed species such as Himalayan blackberry (Rubus armeniacus), English ivy, false lamium (Lamiastrum galeob) and English holly (Ilex aquifolium) are the most common invasive plants within the study area.

Bear Creek Ecology

The natural riparian ecosystems are largely dominated by red alder – vine maple/salmonberry – common horsetail (Alnus rubra – Acer circinatum/Rubus spectabilis – Equisitem arvense), with some areas of standing water conditions, where skunk cabbage (Lysichiton americanus) becomes the dominant forb over horsetail. In the mature riparian forests of Bear Creek the dominant tree species is black cottonwood (Populus balsamifera tricocarpa), with minimal recruitment of cottonwoods in the understory. In the fringe areas, adjacent to development, the riparian communities were dominated by an understory of Himalayan blackberry or English ivy, preventing native shrubs and forbs from establishing. Table 3-6, with reference to Map 3-7, provides a detailed account of the ecology of Bear Creek.

Table 3-6
Ecology of Bear (Bear) Creek

Point #	Ecology	Comments
Bear Creek	• Western red cedar/alder – vine maple/salmon berry – false lily of the valley/horsetail (*Thuja plicata/Alnus rubra – Acer circinatum – Maianthemum bifolium/Equisitem arvense*)	
Be2	• Flooded field under power line	
Be3	• Stormwater drainage with thick orchard grass and Himalayan blackberry • Native ecological community: black cottonwood – paper birch – willow – orchard grass (*Populous balsamifera tricocarpa – Betula papyrifera – Salix sp. – Dactylis glomerata*)	
Be4	• Cattail marsh with red alder – willow/red osier dogwood – thimbleberry riparian (*Alnus rubra – Salix sp./Cornus stolonifera – Rubous parviflorous*)	
Be5	• Red alder – salmonberry – skunk cabbage (*A. rubra – Rubus spectabilis – Lysichiton americanus*)	

Point #	Ecology	Comments
Be6	• Red alder/hemlock – salmonberry/vinemaple – sword fern (*R. alnus/Tsuga heterophylla – R. spectabilis/Acer circinatum – Polystichum munitem*)	• False lamium (*Lamiastrum galeob*) from "Hook and Ladder" village pub
Be7	• Coastal western hemlock – salmonberry/red osier dogwood – horsetail (*T. heterophylla – R. spectabilis/C. stolonifera – E. arvense*)	
Be8	• Red alder/black cottonwood – black hawthorn – purple spirea/thimbleberry (*A. rubra/P. balsamifera tricocarpa – Crataegus douglasii – Spirea douglasii/R. parviflorous*)	
Be9	• Red alder – coastal western hemlock – salmonberry/thimbleberry – foamflower (*A. rubra – T. heterophylla – R. spectabilis/R. parviflorous – Tiarella trifoliate*)	
Be10	• Red alder – vine maple – salmonberry – bracken fern (*A. rubra – A. circinatum – R. spectabilis – Pteridium aquillinum*)	
Be11	• Red alder – vine maple/salmonberry – sword fern (*A. rubra – A. circinatum/R. spectabilis – P. munitem*)	

Cruikshank Creek Ecology

Cruikshank Creek has been altered by the installation of weirs that have influenced both the stream morphology and the riparian vegetation. The extent and continuity of riparian habitats is limited, as much of the historic development has encroached within the current minimum setbacks for riparian corridors. This encroachment has also resulted in patches of extensive weed infestations, primarily of Himalayan blackberry, English ivy and scotch broom. Table 3-7, with reference to Map 3-7, provides a detailed account of the ecology of Cruikshank Creek.

Table 3-7
Ecology of Cruikshank Creek

Point #	Ecology	Comments
Cruikshank	• Red alder – Himalayan blackberry (*A. rubra – R. armeniacus*)	• Box culvert, chainlink fence within mini-mall
Cru2	• Red alder – hazelnut – salmonberry (*A. rubra* - *Corylus avellana* – *R. spectabilis*)	• Thick understory • Gated at intersection of 84 and 132 Avenue
Cru3	• Black cottonwood – black hawthorn – mallow ninebark – moss (*P. balsamifera tricocarpa – C. douglasii – Physocarpus malvaceus*)	• Scotch broom (*Cytisus scoparius*) and Himalayan blackberry inundate the native riparian understory
Cru4	• Red alder – salmonberry – trailing blackberry (*A. rubra – R. spectabilis – R. ursinus*)	• Understory and edges of riparian inundated with Himalayan blackberry and English ivy • Young broadleaf maple (*Acer macrophyllum*) saplings
Cru5	• Red alder – salmonberry – English ivy (*A. rubra – R. spectabilis – H. helix*)	• No emergent vegetation in creek, flow controlled by steppe weirs
Cru6	• Red alder – broadleaf maple – salmonberry – horsetail (*A. rubra – A. macrophyllum – R. spectabilis – E. arvense*)	• Some red osier dogwood and scotch broom in the understory
Cru7	• Red alder – salmonberry (*A. rubra – R. spectabilis*)	• Broadleaf maple saplings in understory
Cru8	• Red alder – willow sp. – thimbleberry – horsetail (*A. rubra – Salix sp. R. parviflorous – E. arvense*)	• Understory also inundated in patches with Himalayan blackberry
Cru9	• Red alder – vine maple – bracken fern/horsetail (*R. rubra – A. circinatum – P. aquillinum/E. arvense*	• Mature forest with large seepage zones with dense skunk cabbage
Cru10	• Red alder – salmonberry – buttercup/horsetail (*A. rubra – R. spectabilis - Ranunculus acris/E. arvense*)	• Patches of thick ivy and morning glory (*Lpomoea purpurea*)

Quibble Creek Ecology

Quibble Creek and its ecology were assessed approximately 50 m upstream of the confluence with Bear Creek. The dominant ecological community consists of red alder – vine maple/salmonberry – Pacific bleeding heart (A. rubra – A. circinatum/R. spectabilis – Dicentra formosa). Quibble Creek is within Bear Creek Park and the riparian vegetation is slightly more intact than on Cruikshank Creek or Healy Creek. Human and pet foot traffic in the park has degraded the understory, leaving the area susceptible to weed invasion. Opportunities for restoration and compensation are discussed further in this report.

Healy Creek and Queen Mary Creek Ecology

Healy Creek and Queen Mary Creek are flanked on all sides by residential subdivisions, constraining the extent and contiguous nature of the riparian vegetation. Table 3-8, with reference to Map 3-7, provides a detailed account of the ecology of both Healy Creek and Queen Mary Creek.

Table 3-8
Ecology of Healy Creek and Queen Mary Creek

Point #	Ecology	Comments
Healy	• Coastal Douglas fir – red alder – Himalayan blackberry – common horsetail (*Pseudostuga menzesii – A. rubra – R. armeniacus – E. arvense*)	• Disturbed riparian vegetation between residential subdivisions and 88 Avenue • Understory is mostly weedy, with evidence of some attempts of restoration
He2	• Western red cedar – red alder – skunk cabbage – common horsetail (*T. plicata – A. rubra – L. americanus – E. arvense*)	• Sandy braided flood zone allows for pockets of standing water, this hygric climate allows for dense large skunk cabbage to establish
He3	• Red alder/coastal Douglas fir – Himalayan blackberry (*A. rubra – P. menzesii – R. armeniacus*)	• Understory is dominated by invasive blackberry, weedy buttercups and thick orchard grass
He4	• Red alder/broadleaf maple – salmonberry – bracken fern (*A. rubra/A. macrophyllum – R. spectabilis – P. aquillinum*)	
He5	• Sitka willow – Himalayan blackberry – baldhip rose – orchard grass (*Salix sitchensis – R. armeniacus – Rosa gymnocarpa – D. glomerata*)	• Tall shrub ecosystem, managed corridor beneath power lines
He6	• Red alder – broadleaf maple – salmonberry – bracken fern (*A. rubra – A. macrophyllum – R. spectabilis – P. aquillinum*)	• Lack of recruitment of native trees and shrubs has allowed an understory of dandelions, bluebells, ivy and buttercups to establish

3.4.2 Wildlife and Wildlife Habitats

The riparian habitats along the various creeks are suitable for numerous wildlife species, both common and at-risk. Mature forests with the standing snags, backwater or pooling streams, and flooded fields are found in pockets throughout the study area. These provide a diversity of habitat types for a variety of wildlife species. Areas of dense vegetative cover along watercourses and an abundance of fish and benthic invertebrates provide high-value habitat for water birds such as the green heron (Butorides virescens; provincially blue-listed) and black-crowned night heron (Nycticorax nycticorax; provincially red-listed). Areas of mixed woodland and mature deciduous riparian forests provide ample canopy and habitat for the provincially blue-listed olive-sided flycatcher (Contropus cooperi).

Backwater areas and flooded fields within the study area contained tadpoles of both the Pacific chorus frog (Pseudacris regilla) and the red-legged frog (Rana aurora), a provincially blue-listed and federal species of special concern. Mature black cottonwood riparian areas are also suitable for the provincially blue-listed and federal species of special concern, a western screech owl kennicottii subspecies (Megascops kennicottii kennicottii).

Wildlife and Wildlife Habitats of Bear Creek

Bear (Bear) Creek in its entirety is a mixture of natural riparian forest, ditched drainage courses and underground pipes. As a result, the wildlife habitats occur in patches with little connectivity between them. Areas of natural treed vegetation provide potential for wildlife movement corridors for smaller urbanized mammals, such as coyotes, racoons and skunks. Because the habitat patches to which these riparian corridors connect are not large enough to sustain larger mammals, use as corridors will be limited. The natural sections of Bear Creek offer habitats for amphibians, songbirds and small to medium-sized urban-adapted mammals (Table 3-9).

Table 3-9
Wildlife Habitats of Bear Creek and Tributaries

Point #	Wildlife Habitat Values	Comments
Bear Creek	• Riffle morphology of the creek provides suitable habitat for Coastal tailed frog (*Ascaphus truei*) and red-legged frog (*Rana aurora*)[11] • Extensive human-developed trail network likely used by urbane mammals such as coyotes (*Canis latrans*), racoons (*Procyon lotor*) and striped skunks (*Mephitis mephitis*)	• Birds included American robin (*Turdus migratorius*), dark-eyed junco (*Junco hyemalis*) and house sparrow (*Passer domesticus*)

[11] The northern red-legged frog (*Rana aurora*) is currently provincially blue-listed and is listed as a species of Special Concern by the federal *Species at Risk Act*.

Point #	Wildlife Habitat Values	Comments
Be2	• Red-legged frog and pacific chorus frog (*Pseudacris regilla*) tadpoles about Gosner stage 30-33[12] indicates a productive wetland. Long-term monitoring would determine the viability of an amphibian population in an urban environment. • Thick Himalayan blackberry provides nesting habitat for small songbirds using the wetland and riparian for foraging habitat • Wetland with grass fields provides herons and other raptors (hawks and harriers) with high-value foraging and hunting habitats for amphibians, small mammals and songbirds	
Be3	• Stormwater drainage with thick Himalayan blackberry and tall orchard grass provide suitable nesting habitat for songbirds, such as the American robin (*Turdus migratorius*) and song sparrow (*Melospiza melodia*) observed in the thickets	• Nesting house finch (*Carpodacus mexicanus*), American robin and song sparrow (*Melospiza melodia*) in blackberry thickets
Be4	• Cattail marsh with some young deciduous vegetation providing habitat for red-winged blackbirds (*Agelaius phoeniceus*), tree swallows (*Tachycineta* [redacted]	• Marsh observed providing habitat for red-winged blackbirds (*Agelaius phoeniceus*), tree swallows (*Tachycineta bicolour*) and song sparrows
	...se deciduous forest with limited	

Point #	Wildlife Habitat Values	Comments
Be7	• Mature cedar within riparian provides habitat for many forest passerines and raptors, such as bard owl (*Strix varia*) and great-horned owl (*Bubo virginianus*)	• Songbirds observed included black-capped chickadee (*Poecile atricapillus*) and crow
Be8	• Deciduous riparian forests provide suitable habitat for specialist birds such as Wilson's warbler (*Wilsonia pusilla*) and yellow warbler (*Dendroica petechia*)	
Be9	• Permanent and large streams provide year-round abundant prey for all wildlife, particularly those who rely on benthic invertebrates, winged insects and ground-dwelling beetles	• Birds observed include: American robin, Wilson's warbler, mallards, Swainson's thrush (*Catharus ustulatus*) and yellow warbler
Be10	• Structural diversity with mature trees and a well-developed understory allows for higher biodiversity as the ecosystem provides diverse habitat types and food types	

Wildlife and Wildlife Habitats of Cruikshank Creek

The riparian vegetation of Cruikshank Creek is greatly constrained by industrial and commercial development on either side of the creek. The structural simplicity of the riparian corridor does not provide a diversity of habitats which would in-turn allow for a diversity of wildlife to use the area. Broad-niche generalists such as black-capped chickadees, dark-eyed juncos, American robins and European starlings (Sturnus vulgaris) are adaptable to these degraded habitats. Birds and other wildlife found in developed habitats rely on food from humans, as the natural ecosystem cannot support them.

Where the riparian and creeks are less channelized with weirs and constrained by development, mature alders provide an open understory with diverse shrubs and ground covers (Cru9; Map 3-7). This more structurally-complex and natural ecology allows for wildlife to persist and take up residence.

Wildlife and Wildlife Habitats of Quibble Creek

The Quibble Creek corridor within the Bear Creek Park provides connectivity for songbirds between riparian and edge habitats. However, the narrow riparian corridor does not allow for sufficient continuous habitat to support larger taxa. Bird species observed in larger numbers include cedar waxwing (Bombycilla cedrorum), yellow warbler, Swainson's thrush, American robin, northern pintail (Anas acuta), mallards and American dipper (Cinclus mexicanus).

Wildlife and Wildlife Habitats of Healy Creek and Queen Mary Creek

Healy Creek and Queen Mary Creek are constrained on all sides by residential developments, limiting the width of the riparian habitat and the connectivity between natural areas. As with Cruikshank Creek, the structural simplicity of the riparian corridor results in low biodiversity of the understory and limiting habitats for wildlife. Broad-niche generalist bird species observed included black-capped chickadee, Wilson's warbler, song sparrow, house finch and spotted towhee. The occasional mature conifer, dense thickets of Himalayan blackberry and baldhip rose provides nesting habitat for these generalist species, protecting them from predation by household cats.

The powerline corridor, from which Healy Creek and Queen Mary Creek drain, provides some potential for urban wildlife movement. Local trail users reported frequent sightings of both striped skunk and coyote in the area. Skunks are frequent backyard visitors, adapting to urban diets of garbage cans, gardens and compost piles. Coyotes are well known to feed on small dogs and/or cats in addition to their natural prey, voles, squirrels and mice.

3.4.3 Environmentally Sensitive Areas

To complete the matrix for the ESA designation (as described below), we considered the habitat requirements for a variety of provincial species-at-risk as "indicator" species, as their habitat requirements are often more specific and of greater provincial management concern than those considered to have broader ecological niches.

ESAs are determined by:

1. Uniqueness to not only the property, but also the surrounding area.
2. Presence of wildlife movement corridors.
3. Presence of provincially-designated at-risk ecological communities or habitats suitable for species at risk; residence features such as wildlife trees, rock outcroppings, and dens.
4. Presence or potential for heritage or archaeological features.
5. The level of disturbance including the presence and abundance of invasive and non-native species, connectivity to contiguous habitats and proximity to urban development.

This ranking system is based on methods adopted by the City of Surrey (1996) and used to classify sensitive areas in this report. The four-classes in the ESA ranking system are defined as:

ESA – 1 contains significant vegetation and wildlife characteristics representing a diverse range of sensitive habitat. These features contribute significantly to the overall connectivity of the habitat and ecosystems. Avoidance and conservation of ESA-1 designations should be the primary objective. If development should occur within these areas (Only after it proves impossible or impractical to maintain the same level of ecological function) compensation will promote no net loss to the habitat (typically with a 3:1 replacement of equivalent functioning habitat).

ESA – 2 or moderate significance, contributes toward the overall diversity and contiguous nature of the surrounding natural features. If development is pursued in these areas, portions of the habitat should be retained and integrated to maintain the contiguous nature of the landscape. Some loss to these ESAs can be offset by habitat improvements to the remaining natural areas found on the property.

ESA – 3 or low significance, represents disturbed habitats or fragmented features. These areas contribute to the diversity to the landscape, although based on the condition and adjacency of each habitat, the significant function within the landscape is limited. If development is pursued in these areas the impacts should be offset by habitat improvements in other more sensitive natural areas found on the property.

ESA – 4 contributes little or no value to the overall diversity or vegetation, soils, terrain and wildlife characteristics of the area. Development is encouraged to be focused on these sites before consideration developing higher rated sites in the area. These areas shall not be considered as areas for restoration and enhancement in offsetting development in other areas.

To establish preliminary ESA ratings (1 = high sensitivity; 4 = no sensitivity), the property and the Sensitive Ecosystem Inventory (SEI) data was analyzed through the following stages:

1. Estimate size of habitat polygon based on continuous habitat.
2. Identify land designation and use (i.e. urban, commercial, agricultural etc.).
3. Determine the dominant vegetation type, primary and secondary ecological community within the habitat polygon and apply a quality rating based on level of existing disturbance or degree of continuity.
4. Determine provincial status of each ecological community. Communities are identified on either the BC red-list (considered endangered or threatened in the province, based on extent and degree of threat), or the BC blue-list (considered of special concern based on extent or degree of threat).
5. Determine the wildlife habitat value affiliated with each polygon and assign a numerical value (0 = no habitat, 6 = high value habitat) based on BC wildlife habitat ratings (MOE).
6. Combine ecosystem sensitivity and wildlife habitat value into one unit (2 x ecosystem value + wildlife habitat rating).
7. Determine ranges of values to group the ecosystem sensitivity into four ESA classes through an analysis matrix (i.e. if the primary ecological community is red listed and the secondary ecological community is red listed, and the wildlife habitat rating is considered high, then the area is designated as ESA 1).
8. Provide an illustrative description of the ESA ratings throughout the property (Map 3-8).

Table 3-10
ESA Designation Criteria Summary

ESA Rank	Ecological Community Rarity	Ecosystem/Community Quality	Wildlife Habitat Rating	Field Observations and Verification
ESA 1	1. community is red-listed **and** 2. community is red-listed OR 1. community is red-listed **and** 2. is blue-listed	1	WHR is **high**	Specific features such as wildlife trees, rock crevices appropriate for den or hibernation sites etc. are prevalent. Area is identified as primary wildlife movement corridor.
ESA 2	1. community is red-listed **and** 2. is blue-listed OR 1. community is blue-listed and 2. is **either** red- or blue-listed OR 1. community is red-listed **and** 2. is not listed OR The ecosystem is dominated by mature native trees with structurally diverse understory	0.8	WHR is **moderate**	Few specific features providing high-value habitat to less than half of identified species or fragmented by previous disturbance. Wildlife movement corridor, providing unobstructed access between or within habitat types.
ESA 3	1. community is blue-listed **and** 2. is not listed OR 1. community is not listed **and** 2. is blue-listed OR	0.5	WHR is **low**	Typically young forests or disturbed areas constrained by development. Few to no features essential for living qualifications of any of the identified species.

ESA Rank	Ecological Community Rarity	Ecosystem/Community Quality	Wildlife Habitat Rating	Field Observations and Verification
	The ecosystem is comprised of mature native trees but the understory has some weed infestation			
ESA 4	No native vegetation or natural channel exists	0.1	WHR is **low**	Areas are paved or barren ground, with significant disturbance or invasion by weedy plant species.

The creeks and riparian corridors of Bear Creek, Quibble Creek, Healy Creek and Queen Mary Creek are designated as ESA 2 (moderate environmental sensitivity; Map 3-8). The riparian corridors of these creeks are dominated by stands of native vegetation, and include sites providing wildlife habitat, such as cattail marshes, flooded fields, or standing snags with excavated cavities.

Cruikshank Creek has diminished environmental value and sensitivity due to historic encroachment by commercial and industrial development and the altered morphology of the creek. The lack of a sufficient buffer from the otherwise sensitive riparian habitats prevents the green space from being utilized as a corridor by larger mammals for access to other habitats. Further, the infestation of ivy and lack of a natural understory prevents the establishment of native vegetation that would otherwise increase the relative environmental value of the corridor.

3.4.4 Terrestrial Ecosystem Restoration, and Management

Riparian areas are the interface areas bordering streams, lakes, and wetlands that link aquatic and terrestrial habitat. The blend of streambed, water, trees, shrubs and grasses provides both fish and wildlife habitat. Achieving high standards of environmental stewardship requires effective protection of riparian habitat, while facilitating urban development. While much of the development within the study area is complete, there remains the potential for restoration and enhancement of the riparian corridors to increase the biological functioning of the areas despite not increasing the geographical extents of the riparian habitats. This section discusses preliminary restoration opportunities identified through both the terrestrial and aquatic assessments.

Currently the riparian corridors within the project area are less than those required under the DFO Land Development Guidelines for the Protection of Aquatic Habitat, which Surrey currently abides by. Moving forward, new development or significant re-development activity will require a Registered Professional Biologist to conduct a watercourse assessment to determine the appropriate setback in order to provide adequate riparian protection. Currently the width of the riparian corridors are limited and not protected against further degradation due to urban encroachment. Below are suggested actions for general restoration of riparian systems within the project area; restoration will generally be limited to City owned property, rather than privately held properties, unless the restoration activity is linked to significant re-development applications.

1. Hand and/or spray removal of invasive and nuisance weed species, including: English ivy, Scotch broom, false lamium and morning glory to allow native vegetation to return to disturbed areas.
2. Immediate re-vegetation of weed control areas with native plants such as red alder, willow, red-osier dogwood, thimbleberry, trailing blackberry and salmonberry. Planting with shrubs or persistent ground covers will prevent weed species from reintroducing into these areas and increase nesting habitat for forest passerines.
3. Re-vegetation of bare earth or disturbed soils not resulting from weed control should be implemented immediately to reduce the potential for further weed invasions.
4. Removal of garbage in and about streams within the project area, and implementation of regular monitoring of garbage accumulation and other disturbances will assist in long-term maintenance of healthy ecosystems.
5. Removal of invasive (i.e. non-native/cultivated/landscaping) grasses as found beneath power lines adjacent to Bear Creek, Healy Creek and Queen Mary Creek and replacement with native shrubs such as red alder and black cottonwood trees, willows, more baldhip rose, salmonberry bushes and native grasses. Horticultural and cultivated grasses choke out native wild flowers and shrubs and offer no habitat value for wildlife.

Maintenance management of existing areas is as essential as restoration. While most of the streams in the project area are ranked as ESA 2, having moderate environmental sensitivity, these areas have the potential to degrade quickly due to future development and further encroachment. Therefore, we recommend the following protection and management measures as described below and summarized in Table 3-11.

1. Install wildlife friendly fencing along the edges of riparian corridors to deter human and pet access, but not limit wildlife access to the riparian and aquatic habitats. Existing chain link fencing prevents wildlife access, forcing animals onto busy roads and parking lots. Natural materials will also increase the aesthetics of these areas, encouraging protection by trail users and business owners, and minimizing further degradation of the vegetation.
2. Implement annual pruning and maintenance (between October and March) of Himalayan blackberry patches to discourage further expansion of these patches. This will also promote growth of native shrubs, while maintaining the valuable nesting habitat that blackberry species provides.
3. Provide enhancement and fencing of the flooded field adjacent to Bear Creek (Be2; Map 3-7) to develop a more permanent "wetland" feature and encourage further use by native amphibians.
4. Install interpretive signage along the trail systems of Bear Creek, Quibble Creek, Healy Creek and Queen Mary Creek to highlight the uniqueness and values of the riparian ecosystems. In addition the restoration and management activities in progress or completed in the areas can be recognized through signage. Collaboration with local businesses, school and community groups will not only

decrease the cost to the City but also increase pride and accountability of environmental stewardship in the community.

5. Develop a bird and bat-box program including installation of nest boxes within the riparian areas and collaborate with schools and community groups for long-term monitoring and maintenance. Bird nest boxes should range from housing songbirds as small as chickadees to larger birds such as woodpeckers and owls. Bat boxes are a standard size, sufficient to house a small colony of bats. Including an interpretive aspect to these programs will serve to highlight the value of these species in insect control and general ecosystem health. Monitoring should occur a minimum of three visits during the active wildlife season (March to October) to observe nesting, breeding and fledging of the box inhabitants.
6. Development of a "bio-blitz" program and continuation of "stream-keepers" programs to encourage community involvement in environmental stewardship throughout the City. Collaboration with other nature and environmental groups will promote the programs as well as increase exposure and support within the City.

Table 3-11
Summary of Recommended Terrestrial Ecosystem Upgrades

No.	Recommendation	Approximate Location	Total Estimated Cost ($)
1	Remove invasive and nuisance weed species	Cruikshank Creek and Quibble Creek	$50,000
2	Re-vegetate weed control areas	Cruikshank Creek and Quibble Creek	$50,000
3	Re-vegetate bare earth and exposed soils	Riparian corridors	$25,000
4	Remove garbage	Riparian corridors	$10,000
5	Remove introduced grasses	Beneath power lines adjacent to Bear Creek, Healy Creek, and Queen Mary Creek	$25,000
6	Install split-rail fencing	Riparian corridors	$100,000
7	Annual pruning and maintenance of Himalayan Blackberry	Riparian corridors	$25,000
8	Enhancement of flooded field to a more permanent "wetland" feature	Adjacent to Bear Creek east of railway	$1,900,000 (includes land acquisition)

No.	Recommendation	Approximate Location	Total Estimated Cost ($)
9	Place interpretive signage along trail systems	Bear Creek, Quibble Creek, Healy Creek, Queen Mary Creek	$5,000
10	Develop a bird and bat-box program	Riparian corridors	$5,000
			$2,195,000

3.5 HYDROGEOLOGICAL REVIEW

We completed desktop research, literature reviews and a field assessment of the study area to determine the hydrogeologic conditions of the watersheds. The results will allow planning of future assessment phases of the suitability and effectiveness of infiltration-based stormwater management techniques, including best management practices for stormwater and low impact development.

3.5.1 Site Conditions

The Cruikshank and Grenville watersheds are part of the Fraser Lowland (Holland 1976), and generally consists of a concave, gently-sloped upland surface draining to the southeast. The elevation ranges from approximately 105 m geodetic in the western portions of the study area to approximately 20 m geodetic at the eastern boundary. The watersheds are gently sloped and arbitrarily defined in places, with some boundaries located along roads and beside creeks.

The Cruickshank and Grenville watersheds have a warm, moist to wet maritime climate, with significant rainfall generally between November and April, and light rainfall over summer often leading to moisture deficit conditions (Environment Canada 2011). The closest long term Environment Canada climate stations are Kwantlen Park, just outside the watershed to the north, and Newton, just outside the watershed to the south. The City of Surrey also operates a rainfall gauge at Kwantlen Park. Refer to Map 3-9 for their locations.

Table 3-12 summarizes the 1971 to 2000 climatic normal data available for precipitation and temperature at the Environment Canada stations. Table 3-13 summarizes the 1997 to 2012 climatic normal data available for rainfall at the City of Surrey Kwantlen Park Station. The largest annual precipitation events are associated with the passage of cyclonic frontal systems, with heavy rainfall over one to three days, typically during November to January. On occasion these rainfall events are compounded with the melting of snow accumulations, which increases total runoff.

3.5.2 Field Assessment

We conducted hydrogeology field assessments on June 3, 4 and 30, 2011. Refer to Map 3-6 for a map of the observation sites, with details provided in Appendix C. We noted the following:

- Estimation of water table elevations,
- Observations at exposures of thick surficial deposits in stream gullies,
- Determination of areas with groundwater discharge,
- Observations of near surface groundwater conditions from vegetation patterns, soil weathering and gleying (the process of waterlogging and reduction of iron in soils to a water soluble form. The removal of iron leaves the soil a grey or bluish colour) and areas of seasonal surface ponding,
- Mapping areas of hydrophyllic vegetation and surface organic deposits indicative of shallow groundwater flow, and
- Assessment of locations with more pervious soils where stormwater infiltration may be possible.

The inspection of watercourses included recording stream channel conditions, noting surficial geological and soil units exposed, searching for groundwater seepage, and hand testing for grain size and soil moisture conditions. Evidence of previous stream floods or bank instabilities, erosion and deposition points, and unstable sediment wedges in channels were recorded and photographed.

As most of the watershed is developed for residential and industrial/commercial land uses, there are few places other than stream ravines where the natural surficial geological and soil units are exposed or accessible. A number of temporary, small shovel test pits were completed in low-use areas of parks, road rights-of-way and other City land. These ranged up to approximately 0.50 m in depth. Tree and plant roots are common in the top 0.30 m, and evidence of a seasonal water table was often only 0.30 m to 0.50 m below the surface. The field review was conducted within a few days of rainfall, during a wet cool spring and early summer, which aided with locating groundwater discharge areas.

3.5.3 Surficial Geology Background

The locations of surficial geological observation sites are presented in Map 3-10 and the site information and photographs are located in Appendix C.

Three main surficial units underlie the Cruikshank and Grenville watersheds:

- Weathered to fresh, glaciomarine stony silts and sands (Capilano Sediments) in places naturally cemented (possibly by iron) or compacted by glacier ice overriding,
- Oxidized, pebbly to cobbly sand littoral deposits lying unconformably on top of the glaciomarine deposits, often in the topographic highs (Salish Sediments), and
- Modern alluvial gravels, cobbles and sands along streams.

Some minor areas of colluvium on stream ravine slopes were noted. On top of the surficial deposits is the weathered soil horizon, which ranges from approximately 0.20 m to 0.70 m thick.

Table 3-12
Environment Canada Climatic Normals, Kwantlen Park and Newton Stations, 1971-2000

Kwantlen Park	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Rain (mm)	179.4	147.3	143.2	116.2	92.3	73.6	52.9	50.7	71.7	152.3	235.5	212.7	1527.9
Snow (mm snow water equivalent)	22.7	11.2	3.1	0.1	0	0	0	0	0	0.2	4.4	16.3	58.1
Precipitation. (mm)	202.2	158.5	146.3	116.4	92.3	73.6	52.9	50.7	71.7	152.5	239.9	228.9	1585.9
Newton	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Year**
Average Temperature (°C)	3.1	4.8	7	9.6	12.6	15.2	17.6	17.7	15.1	10.3	5.7	3.3	10.2
Rain (mm)	166	126.4	126.2	100.3	81.6	68	50	48.7	64.2	131.1	209.1	187	1358.5
Snow (mm snow water equivalent)	19.7	9.7	2.5	0.2	0	0	0	0	0	0.3	3.2	15.1	50.7
Precipitation. (mm)	185.7	136.1	128.7	100.5	81.6	68	50	48.7	64.2	131.4	212.3	202.1	1409.2

Source: Environment Canada 2011: Climatic Normals 1971-2000

Table 3-13
City of Surrey Climatic Normals, Kwantlen Park, 1997-2012

Kwantlen Park	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Rain (mm)	235.2	119.4	155.8	104.7	86.4	73.3	44.8	44.4	75.8	180.1	239.6	192.3	1551.8

Source: City of Surrey Rainfall Data

Armstrong and Hicock (1980) prepared surficial geological mapping for the Lower Fraser Valley including the Cruikshank and Grenville watersheds. Their mapping indicates that the entire study area is underlain by Capilano Sediments. The Capilano Sediments unit includes:

- Sand, silt and clay sediment deposited from the sediment-rich base of the ice sheet during melting and settled onto the sea bed,
- Glacially shaped and rounded pebbles, cobbles and boulders which melted out and dropped into the soft sediment below, and
- Glacial sediments which melted out from grounded glacier ice sitting on the substrate.

The Capilano Sediments grade from marine to glaciomarine stony to stoneless silt loam to clay loam, with minor sand and silt, and may contain marine shells. Borehole records from within the watershed indicate it varies from 3 to 30 m thick or more, overlying earlier deposits of till or outwash (Ministry of Environment 2011a).

There are small areas of wave-washed or littoral sand and gravel sediment which were deposited on top of the Capilano Sediments, generally in the higher elevation areas. These wave-washed sediments are termed Salish Sediments, and are thin units capping or draped over the underlying Capilano Sediments (Armstrong and Hicock 1980). The overburden-bedrock interface in the study area is approximately 300 m below surface and so has negligible effect on the hydrogeologic properties of the surface sediment units.

Agricultural soils within the study area were mapped at a general scale when the land was still mostly undeveloped (Kelley and Spilsbury 1939). Two soil series: Alderwood Series silt loam; and Mixed Area 1 (a mixture of Whatcom silt loam and Alderwood Sandy loam parent materials) were mapped in the study area. Alderwood silt loam consists of 50 cm of silt to sand to loam with stones, over weathered boulder clay (gravelly sandy loam) and grey, unweathered, hard, cemented, impervious sandy boulder clay. The boulder clay layer was noted to be impervious to roots and water, and caused perched water table conditions. Where the boulder clay layer was thin, stratified sands and gravels were found below. The Mixed Area 1 soil series had 40 – 76 cm of sandy to clay loam over impervious Whatcom or Alderwood type soils. Whatcom soils are silt loams, found in hilly terrain with poorly drained depressions. The Whatcom soils are developed in sand, silt, clay, and grit with some stones, with possible cementing, which reduced the drainage capacity. The soils were not developed for agriculture, due to the rough topography, low plant nutrients and seasonally wet conditions. These soil types did support a second growth forest of Douglas fir, cedar, hemlock, alder, maple and birch, with scattered dogwood.

3.5.4 Hydrogeology Overview

The hydrogeology of the site area has been investigated in one general overview study, Halstead (1986), and one detailed groundwater assessment related to stream base flow, Piteau (1999).

Halstead (1986) defines various “hydrostratigraphic units”, which are major glacial and post glacial depositional units with consistent hydrogeological properties. Hydrostratigraphic Unit A is co-related with the Capilano sediments, and includes marine and glaciomarine clay, stoney clay and silty clays, with varying stone content. Hydrostratigraphic Unit A is found at or near surface over the central part of the Lower Fraser Valley and is generally less than 30 m thick. The unit may be capped by near shore Salish sediments.

Few specific groundwater studies of Hydrostratigraphic Unit A have been completed as no groundwater supply wells are developed in it, no solid waste disposal sites are located on it, and no groundwater studies related to deep building foundations have been published.

The B.C. Water Resources Atlas was queried as to the presence and nature of aquifers in the study area (Ministry of Environment 2011a). The compiled information indicates that at depth beneath the study area, there is a low demand, low vulnerability, high productivity aquifer in unconsolidated sediments. The atlas indicates there is no surface or near surface aquifer. Inspection of the few water well records in the study area indicates several widely dispersed wells which encountered 20 to 30 m of dense gravelly silts, overlying a deep aquifer of sands and gravels. There are many more well records for the area east of the watershed, which show a combination of deep drilled wells and shallow dug wells in dense till or clay. It is inferred that in the study area, there were many shallow dug wells before the municipal water system was constructed.

Piteau Associates (1999) conducted a groundwater recharge study for stream base flow in the Bear Creek basin, with the objective of determining how summer base flow could be augmented to provide fisheries habitat. The stream flow data used in the study was based on City of Surrey stream gauge records. Their study area included the Cruikshank-Grenville watershed but also areas east and southeast of the watershed. The results are summarized as follows:

1. Approximately 80 % of annual precipitation runs off as stream flow, and there is low groundwater recharge.
2. The long-term base flow trend for Bear Creek does not appear to be declining, suggesting that land development is not significantly impacting base flow.
3. The shallow groundwater table recharges in winter from heavy precipitation.
4. Adding recharge within the creek corridor areas may assist with summer base flow as flow paths are short and summer rainfall can reach the streams via shallow groundwater flow.

Piteau Associates (1999) developed a conceptual model of groundwater flow systems in the Bear Creek basin, to identify creek base flow impacts and water quality changes. It was indicated that the weathered soil horizon was silty to sandy, with a hydraulic conductivity from 10-4 m/s to 10-6 m/s estimated from grain size. The thick glaciomarine unit of dense silty sand (in places also with clay) has a low hydraulic conductivity of 10-7 m/s to 10-10 m/s, based on grain size. Any more fractured or sandier intervals within the glaciomarine unit had better permeability.

Piteau (1999) indicated that the upland surface is mainly a recharge zone, with most occurring from October to April. Discharge areas were restricted to areas close to creeks, in the lower section of creek bank. The interpreted groundwater flow regime included:

- Infiltration during winter, causing saturation of the surface soil and higher runoff,
- In the upper soil, groundwater flow down topographic gradient until discharge at a ditch or creek,
- Some vertical groundwater flow into the underlying unweathered glaciomarine unit,
- Some of the vertical flow will encounter fine fractures or sandy zones and be conducted laterally to creek banks,
- Deep regional groundwater flow occurs in the aquifer under the glaciomarine deposits, and likely toward the Serpentine River valley. Discharge for the deep regional flow will be outside the study area.

Piteau (1999) concluded that seasonal shallow groundwater flow predominates in the upper soil horizon, depending on local soil conditions. Drainage courses nearby may receive groundwater discharge during and immediately after the periods with high precipitation. Base flow from groundwater discharge declines soon after winter and may be very low over summer when the near surface soil is dry. Slow groundwater flow between approximately 2 m and 20 m depth will occur year round and may contribute to stream base flow. The overall base flow component of stream flow is very low, suggesting low groundwater contribution to stream flow year round.

3.5.5 Field Hydrogeology Observations

The hydrogeologic conditions encountered reflect the climate, the surficial sediment composition, the layering and superposition, the post glacial weathering, and the low gradient surface and therefore hydraulic potential gradients. Most of the local groundwater cycle occurs in the top 3 m to 5 m of surficial sediment. This interpretation is in agreement with earlier hydrogeological studies (Halstead (1986), Piteau (1999), and Ministry of Environment (2011b)).

We noted slow, horizontal seepage of groundwater out of the glaciomarine stony silts and clays at a number of natural, vertical sediment exposures, where seepage began at a horizon approximately 3 m to 5 m below ground surface (Photo 3-1 and Photo 3-2, Appendix C). We infer that this perched water table relates to a change from weathered, fractured sediment with low permeability, to a less-weathered sediment with very low permeability.

Minor groundwater seepage into stream ravines was also noted where modern alluvial sands and gravels overlay dense silty fine sand of glaciomarine origin (Photo 3-3 in Appendix C). We infer that soil water movement to the stream may occur quite quickly in the deeper stream ravines where colluvial deposits. These deposits originated from weathered and sloughed sediments located on steep slopes, and this disaggregated material has larger pore spaces that facilitate more rapid groundwater movement. However, these colluvial deposits are found over such a restricted area, and on such steep slopes, that they do not provide an opportunity for stormwater infiltration.

We identified perched water tables just below the surface at many locations overlying the low permeability glaciomarine unit. The occurrence of these perched water tables was likely due to heavy rains in an overall abnormally wet season preceding the field assessment,. Some natural forested areas had fine, degraded humic material at surface, along with water ponding marks, suggesting surface inundation by standing water for at some time over the course of the year. In many locations, iron and manganese was deposited in natural fractures of the soil parent material, indicating gleyed soil conditions from seasonal saturation and varying conditions of oxidation and reduction.

We interpret that there is a high amount of surface runoff, and only a small proportion of near surface groundwater infiltrates into the surficial deposits below approximately 1 m or 2 m. Groundwater infiltration is likely on the order of 1 mm/h or less through the thick (3 m – 30 m) layer of glaciomarine deposits to the deep aquifer in the underlying sands and gravels. Most groundwater remains near surface and travels laterally as “interflow” to discharge points in ditches or streams, or is intercepted by utility trenches in developed areas.

The areas of inferred groundwater discharge are indicated on Map 3-10. We determined these locations through site observations, interpretation of topography, and presence of indicator vegetation. We infer that a large ravine area with deciduous vegetation along Bear Creek east of 132 Street receives groundwater discharge. Some areas in Bear Creek Park, and along some hydro line rights-of-way, also exhibit wet surface soils and vegetation suggesting groundwater discharge. The distribution of groundwater discharge areas suggests there are many small discharge areas, most of which drain through surface ditches and into the stormwater system.

Our literature review did not identify specific infiltration rates or hydraulic conductivity values for the study area, although other nearby studies in areas with similar surface sediments suggested possible values for these parameters. Refer to Table 3-14 for a summary of representative soil infiltration rates in the vicinity of the study area. Based on these published values, we estimate that the maximum infiltration rate of soils in the study area likely ranges from approximately 0.20 mm/hr to 6.00 mm/hour.

Areas with a high seasonal water table are present throughout the study area, such as topographic depressions, along active or former hydro-line right-of-ways, and where extensive sloped areas lead downslope to flatter areas. In aerial photographs, areas with deciduous forest (big leaf maple, vine maple, black cottonwood) and dense deciduous brush and plants (salmonberry, willow, skunk cabbage) are indicative of high seasonal water tables, and indicate areas of groundwater discharge. Areas with dense, second growth cedar trees also indicate high seasonal water tables.

3.5.6 Stream Morphology

We expect that both historic logging and urban development has altered stream hydrology and therefore channel morphology. During logging approximately 90 - 120 years ago, mature large conifers were harvested and removed by temporary railways or oxen (Brown 2011). This included the conifers in and near the watercourses. After logging, rainfall interception, evaporation and evapotranspiration were reduced, resulting in an increase in total runoff.

Table 3-14
Summary of Local Soil Infiltration Rates

Location	Soil Type	Initial Infiltration Rate	Final Infiltration Rate
Kerr Wood Leidel (2006)			
East Clayton, east central Surrey	Till, Observed Values	0.90 mm/hr with interflow 1.60 mm/hr without interflow	-
	Clay, Observed Values	0.70 mm/hr	-
Literature Values Cited	Till	0.50 – 2.50 mm/hr	-
	Clay	0.20 – 2.50 mm/hr	-

A second disturbance to the existing stream morphology likely occurred as a result of urban development activities, contributing additional storm runoff from impervious surfaces. At that time, the stream channels likely experienced a further phase of lateral and vertical erosion. Finer sediment was likely mobilized and flushed from the creek channels, along with a reduction of in channel large woody debris (LWD), constriction of flow above culverted road crossings, and scouring of plunge pools below.

On three power line rights-of-way that we observed, it appeared that topsoil was scraped off and existing stream courses were deepened and widened to accommodate higher surface flows and ensure no diversion of stream flow occurred near this infrastructure. During residential development, some topsoil would have been redistributed or removed from the surface, resulting in a lower capacity for surface retention of precipitation. Fill has been added to the top edges of stream ravines near 84 Avenue, 88 Avenue, and in Bear Creek Park.

Near most road crossings, and in Bear Creek Park, boulders were added to the stream banks and bed to limit erosion. However, in places the boulders have been displaced and moved downstream. Some early bank stabilization measures using metal stakes and geotextile have become ineffective after degradation of the geotextile and loss of the retained soil. Some riparian areas were rehabilitated with on-contour logs and fibre-mat meant to retain soil, but where no new vegetation cover was established, these have also begun to erode after the logs and mat rotted.

Along most watercourses, small plastic and concrete pipes drain directly to the watercourse or at top of bank, with no riprap or splash guards. Some of these pipes appear to be part of the municipal stormwater infrastructure, such as in parks, and some appear to have been installed informally during land development.

Current-day channels appear freshly eroded, with bare, unvegetated banks and beds in many locations. The vegetation beside streams appears to be pioneer deciduous brush and small trees, with only a few second growth conifers. Many stream reaches have little or no sub-aqueous or sub-aerial moss growing on the stream cobbles and boulders, suggesting frequent flood flows with sediment transport and shifting and abrasion of the larger cobbles and boulders, which disturbs the moss.

In the smaller tributaries, some sand and gravel lateral bars are present. In the main stems of Bear Creek, Quibble Creek, Cruikshank Creek and Grenville Creek, there are generally lateral bars of imbricated cobbles, some large berms of gravel from floods, and large sediment wedges of sand and finer gravel where woody debris forms blockages (Photo 3-5, Photo 3-6 and Photo 3-7 in Appendix C). Sand and finer gravel is not retained in the larger channels, due to mobilization from larger winter flows. Occasional sand and gravel “bars” are deposited in the lee of large permanent boulders.

The original dendritic pattern of the stream network has been significantly modified by urban development, channelization and underground routing of stream flow through the piped stormwater system. Cruikshank Creek and Bear Creek have channelized upper reaches where they pass through industrial park developments.

The stream ravines range from just large enough to contain the stream, to several tens of metres wide and up to 10 m deep, depending on the erosional history. Stream incision to create the ravines occurred over various phases, leaving some low terraces. Stream incision and lateral erosion has left cobbles and boulders as lag.

The stream morphologic forms include riffle – pool and cascade – pool. The stream gradients range from approximately 1 % to 10 %, reflecting the low land gradient, and the lack of bedrock control. The main stream beds consist of imbricated cobble lateral bars and pools carved in dense cobbly silty sand sediment. There is a moderate amount of LWD from deciduous tree sources, in and over the channels from windfall and tree rot (Photo 3-5 and Photo 3-7 in Appendix C). Some new tree fall from the ravine sides into the channels has occurred. Where woody debris blocks the channels, large sediment wedges of gravel, sand and silt have accumulated, indicating a large amount of sediment transport in the streams (Photo 3-5 in Appendix C).

Channel erosion representing both natural processes and stormwater-influenced processes were noted at several locations. Eroded banks up to 5 m to 8 m high, at near vertical slope angles, have formed where the stream current naturally impinged on already steep banks (Photo 3-1 and Photo 3-2 in Appendix C). At these locations, recent evidence of soil falls into the watercourses were noted. Most naturally eroded banks range between approximately 1 m – 2 m high. There are sites where old cut stump evidence suggests the channel has eroded laterally up to 5 m in the last 90 to 120 years. Since the drainage infrastructure was installed, or creek reaches channelized, some banks have eroded 1 to 2 m laterally (Photo 3-8 in Appendix C). Where King Creek passes out of Bear Creek Park and passes through the power line right of way, there has likely been significant channel re-routing due to the presence of the decommissioned landfill in this area.

We also observed other anthropogenic related changes to channels and riparian areas. Near most road crossings, and particularly in the industrial park areas, domestic garbage has been deposited in or near watercourses, including: plastic chairs and boxes, plastic tarps and bags, cut lumber, skids, metal barrels, food containers, grocery carts, and other items. This deflects or slows some stream flow. Many riparian areas have invasive domestic plants (ivy, holly, poppies and other species) which are replacing natural riparian plants.

3.5.7 Hydrogeology Summary

The watershed is underlain by a dense, silty sand glaciomarine deposit, with some thin surficial deposits of littoral sand and gravel. While the thin sand and gravel layers are permeable, the underlying glaciomarine silty sands are not naturally well drained and show evidence of seasonal saturation and perched water tables.

Over the watershed, there is restricted natural infiltration below the immediate surficial layers of weathered soils and organic deposits. The surficial unit is thick (3 m – 30 m) and has a low infiltration rate. Natural “windows” into underlying surficial geological units with better infiltration were not found within the study area.

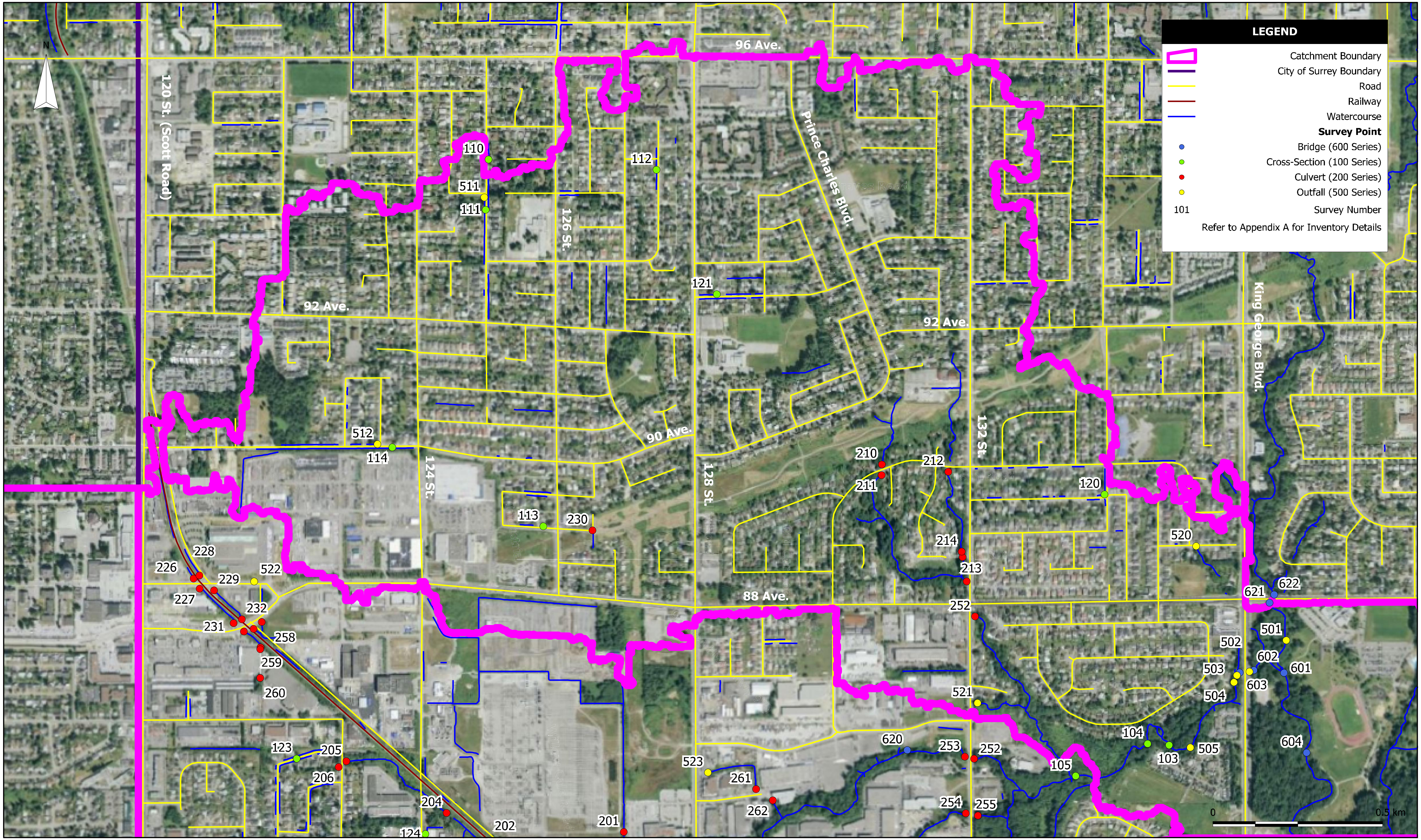
A dendritic pattern stream system developed post glacially, draining generally east and southeast. The watercourses are now entrenched, having been through phases of increased runoff after logging and urban development. The urban road system has been built over top of the stream system and residential, commercial and industrial development has encroached to the edge of the stream ravines in most locations. The extensive impervious coverage of these developments provides little opportunity for local infiltration into subsurface soils.

The top 1 m to 4 m of the glaciomarine deposit is weathered, has somewhat higher permeability than below, and has naturally slow lateral and vertical drainage.

Based on our site investigations of the surficial deposits and the infiltration capacities, and interpretations of groundwater table elevations and discharge areas, we present the following two suggested investigative actions:

1. In order to confirm soil characteristics and infiltration capacity in key areas, a program of soil evaluation by test pitting should be undertaken in areas considered for infiltration facilities, such as hydro rights-of-way, parks or large development properties. The rights-of-way and park areas may provide opportunities for development of centralized infiltration facilities. Test pits would also serve to assess infiltration adjacent to local streets where installation of infiltration swales or rain gardens may be considered. As per the recommendation in the Piteau (1999) report, these test pits can be located within approximately 300 m of watercourses, so that soil testing would concentrate on areas which contribute to streams, and especially stream base flow in summer. Testing sites should be located in proximity to likely redevelopment activity.

2. In areas closest to existing streams, roadside infiltration swales or rain gardens may be installed as experimental sites, and extra topsoil and vegetation added to the surface. These pilot facilities would assess local soil capacity for infiltration, and determine if these are viable approaches. Operation of these infiltration swales or rain gardens may increase local surface water tables but discharge to streams would be attenuated and a benefit provided in buffering of stream baseflows.



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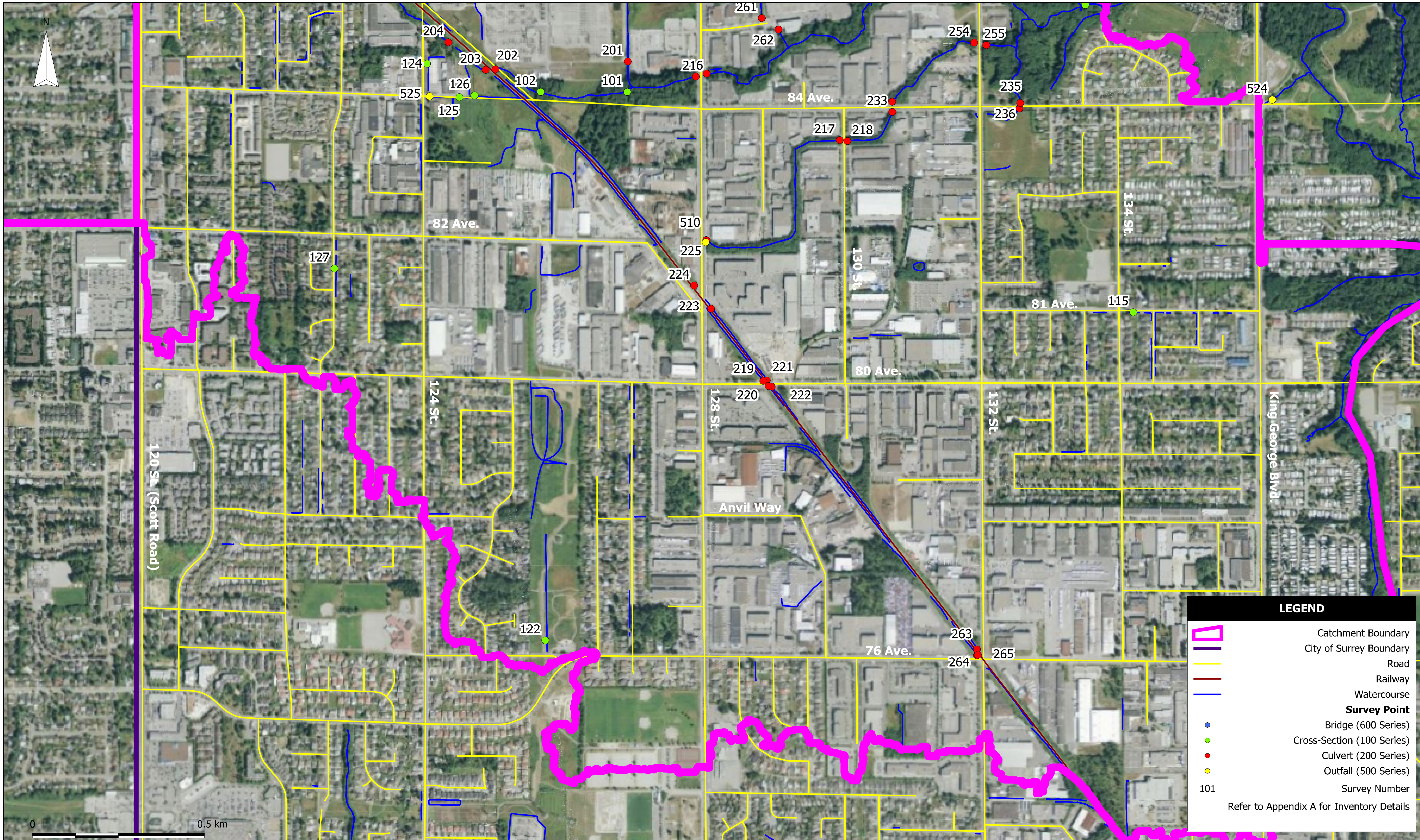
Cruikshank and Grenville ISMP

Map 3-1A: Inventoried Infrastructure



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Map 3-1B: Inventoried Infrastructure

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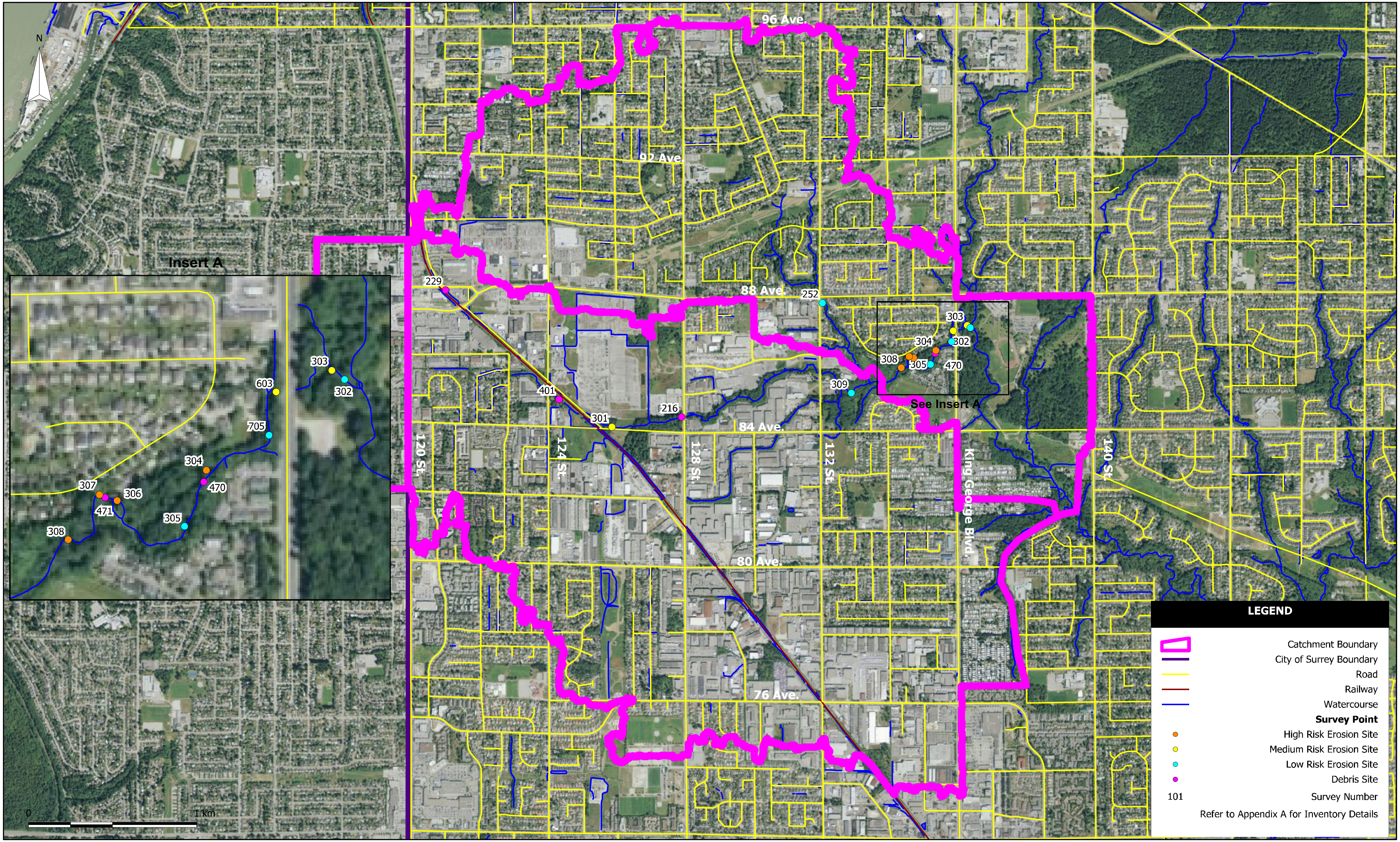

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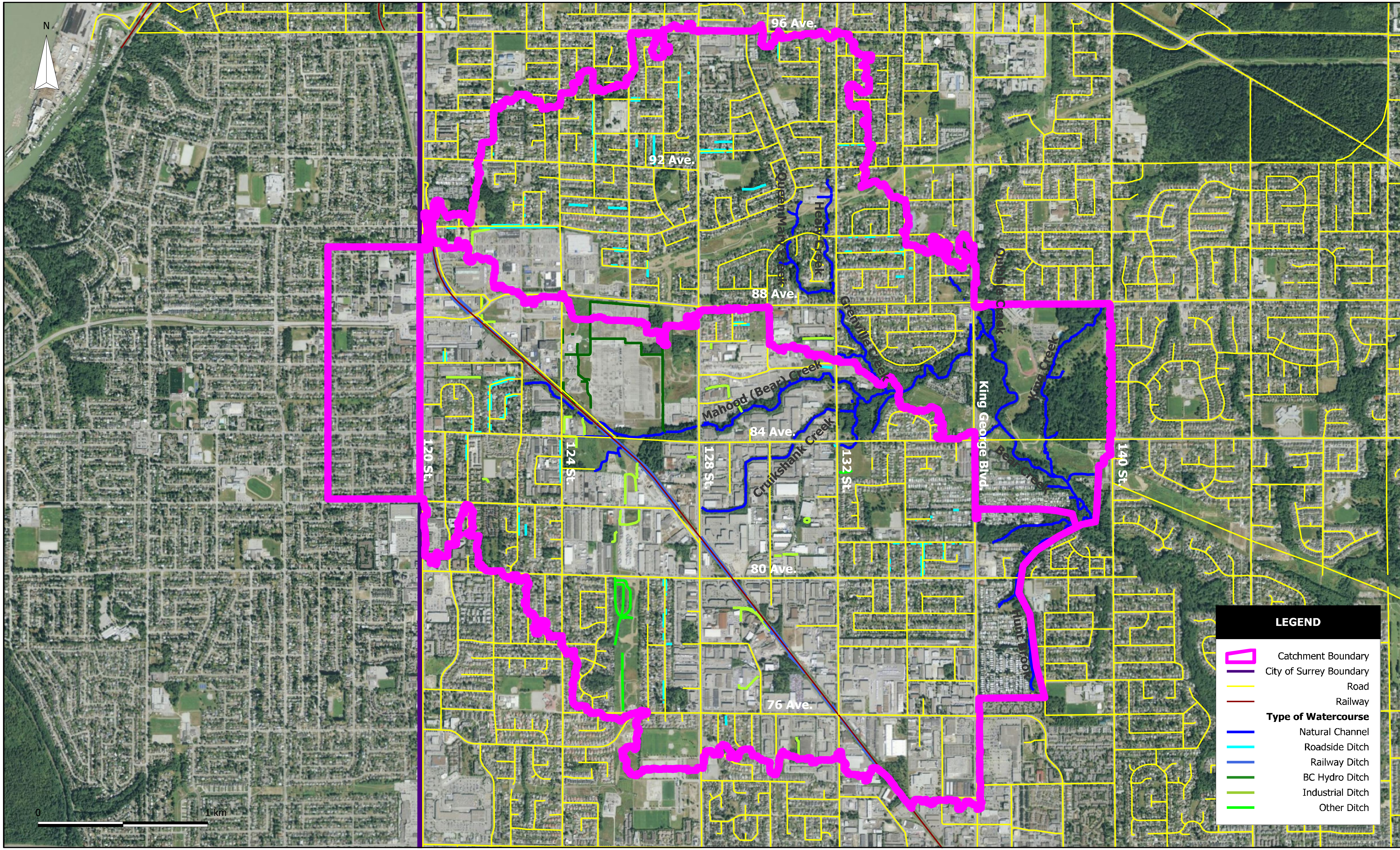
Map 3-2: Erosion and Debris Sites



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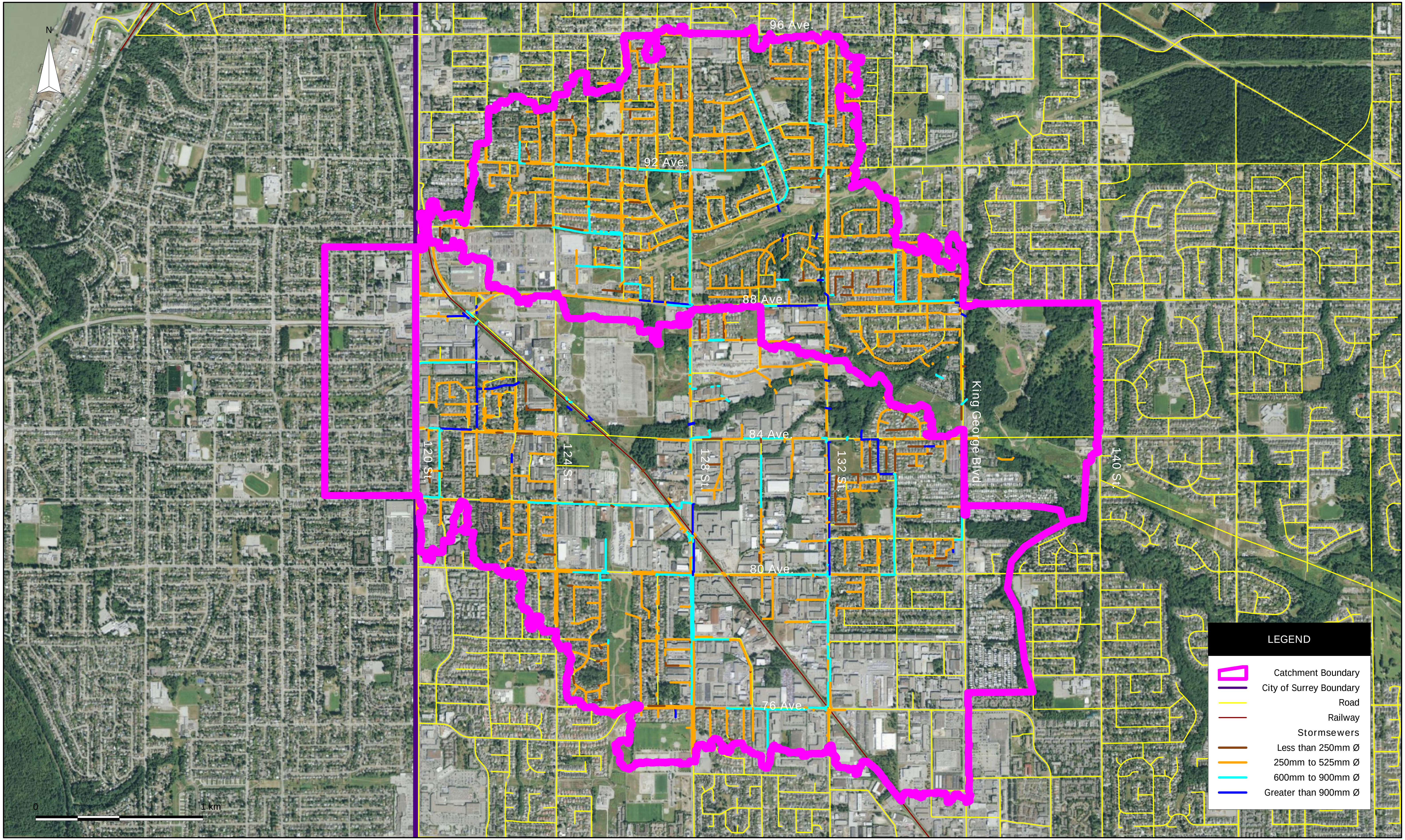
Map 3-3: Identified / Known Open Channels



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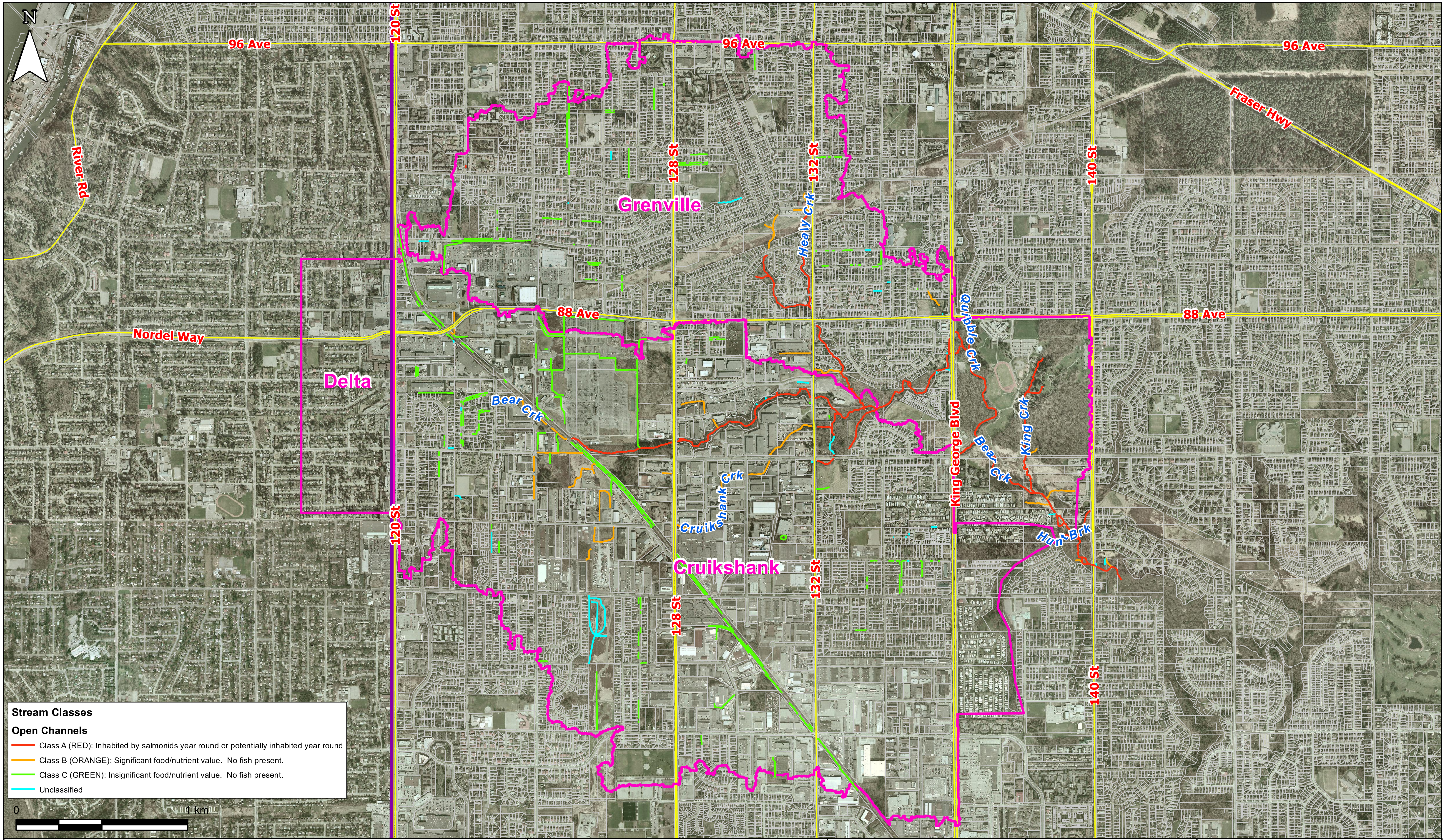
Map 3-4: Piped Drainage System



Major Roads | Catchment Boundary
City of Surrey Boundary | Cadastral Lines

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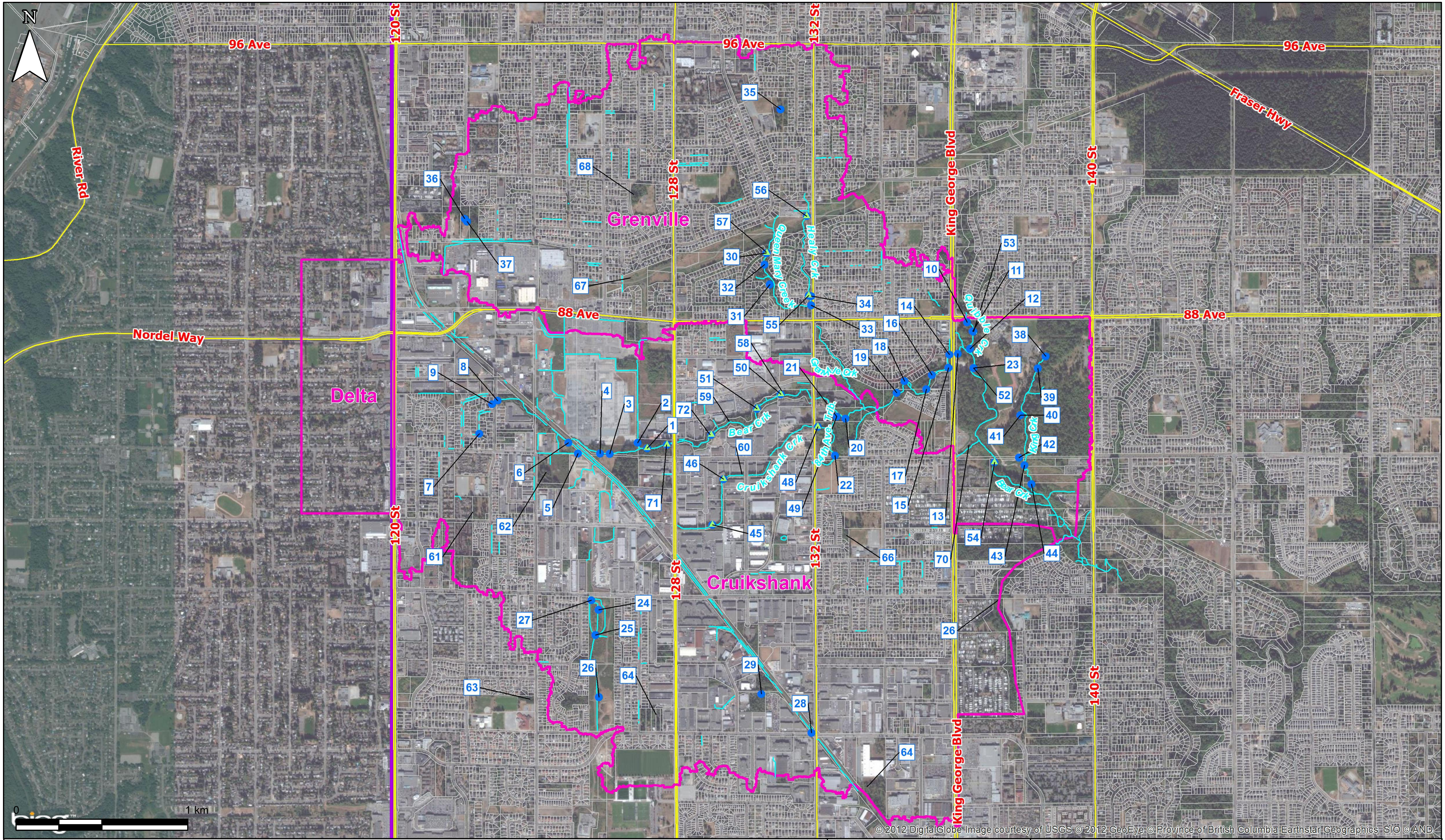
Map 3-5: Stream Classifications



Environmental Sites (APPENDIX B)
Groundwater Sites (APPENDIX C)
Stream
City of Surrey Boundary
Catchment Boundary
Cadastral Lines

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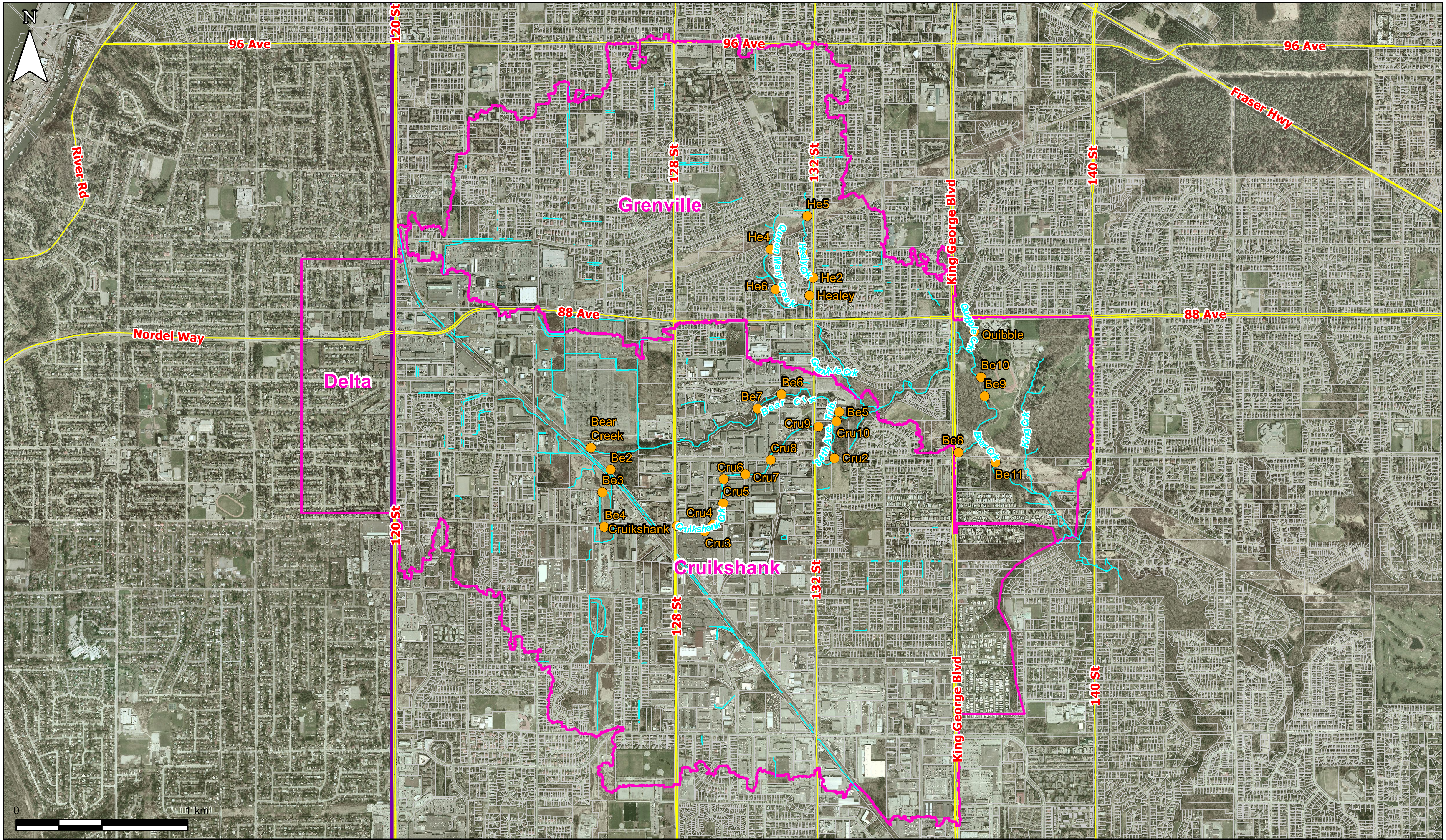
Map 3-6: Aquatic and Surficial Geological Observations Sites



Terrestrial Assessment Site	Major Roads
Stream	Catchment Boundary
City of Surrey Boundary	Cadastral Lines

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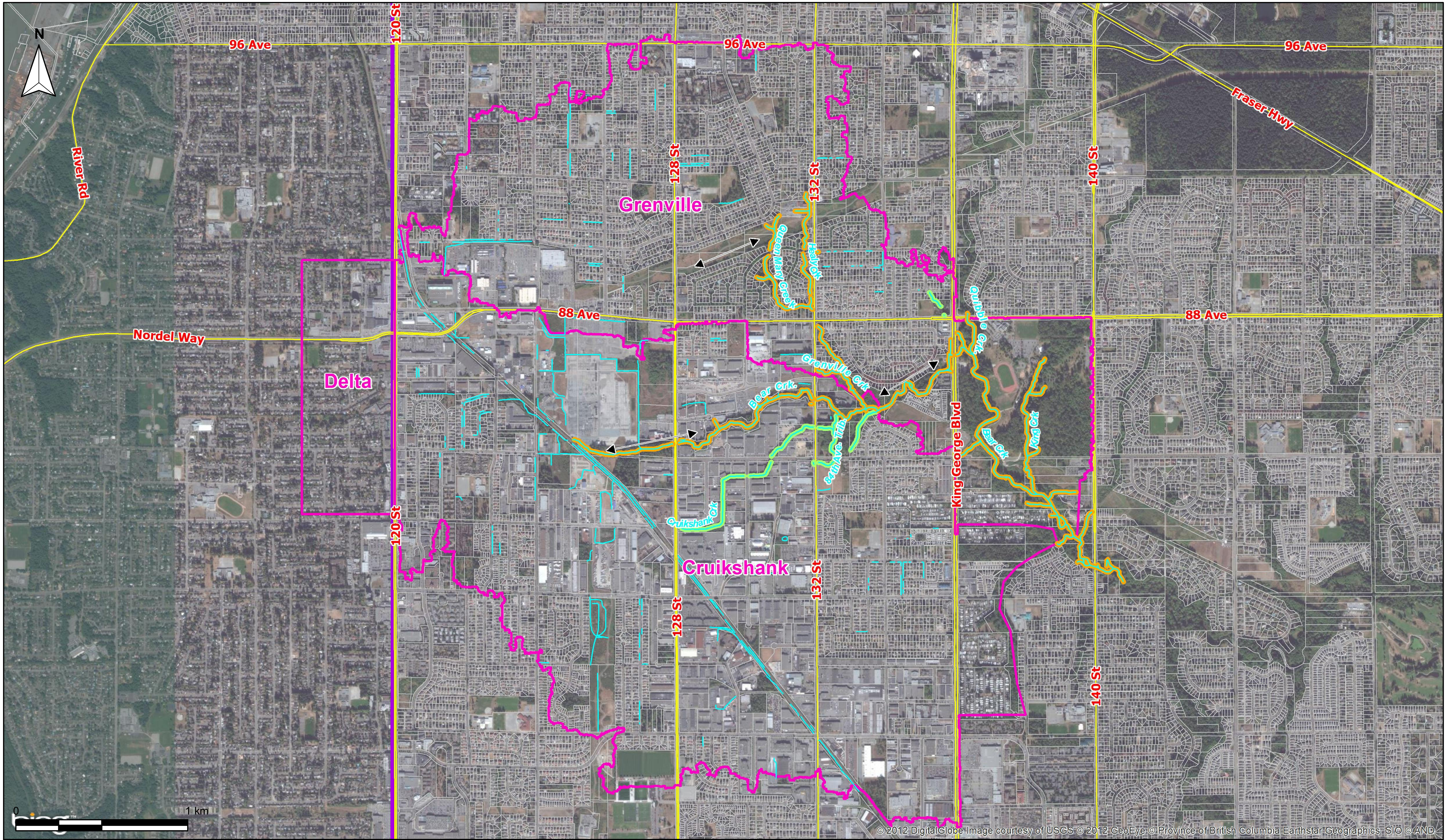
Map 3-7: Terrestrial Assessment Sites



ESA Class
- ESA 1
- ESA 2
- ESA 3

- Stream
- Wildlife Corridor
- Major Roads
- City of Surrey Boundary
- Cadastral Lines
- Catchment Boundary

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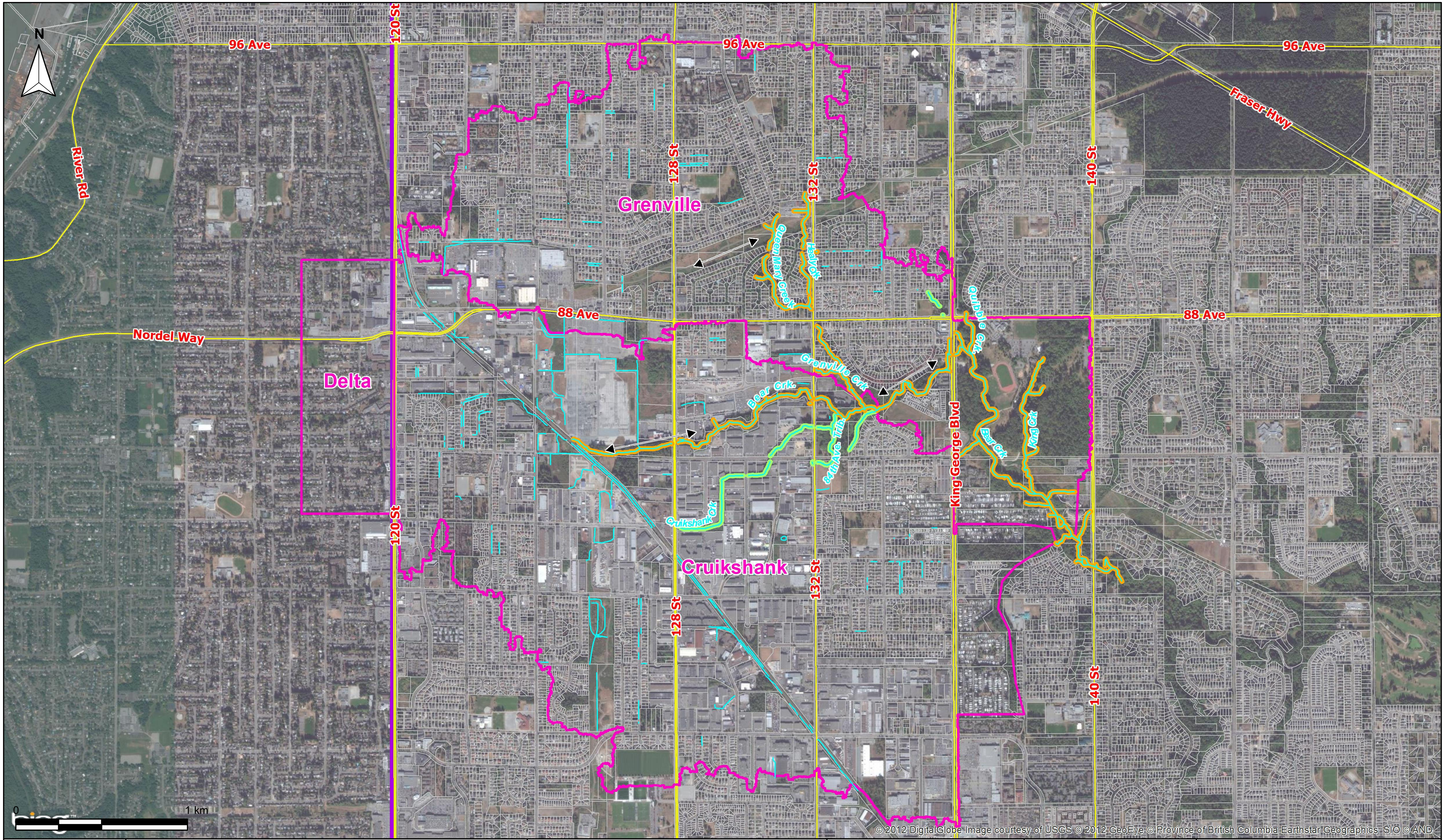
Map 3-8: Environmentally Sensitive Areas



ESA Class
ESA 1
ESA 2
ESA 3

Stream
Wildlife Corridor
Major Roads
City of Surrey Boundary
Cadastral Lines
Catchment Boundary

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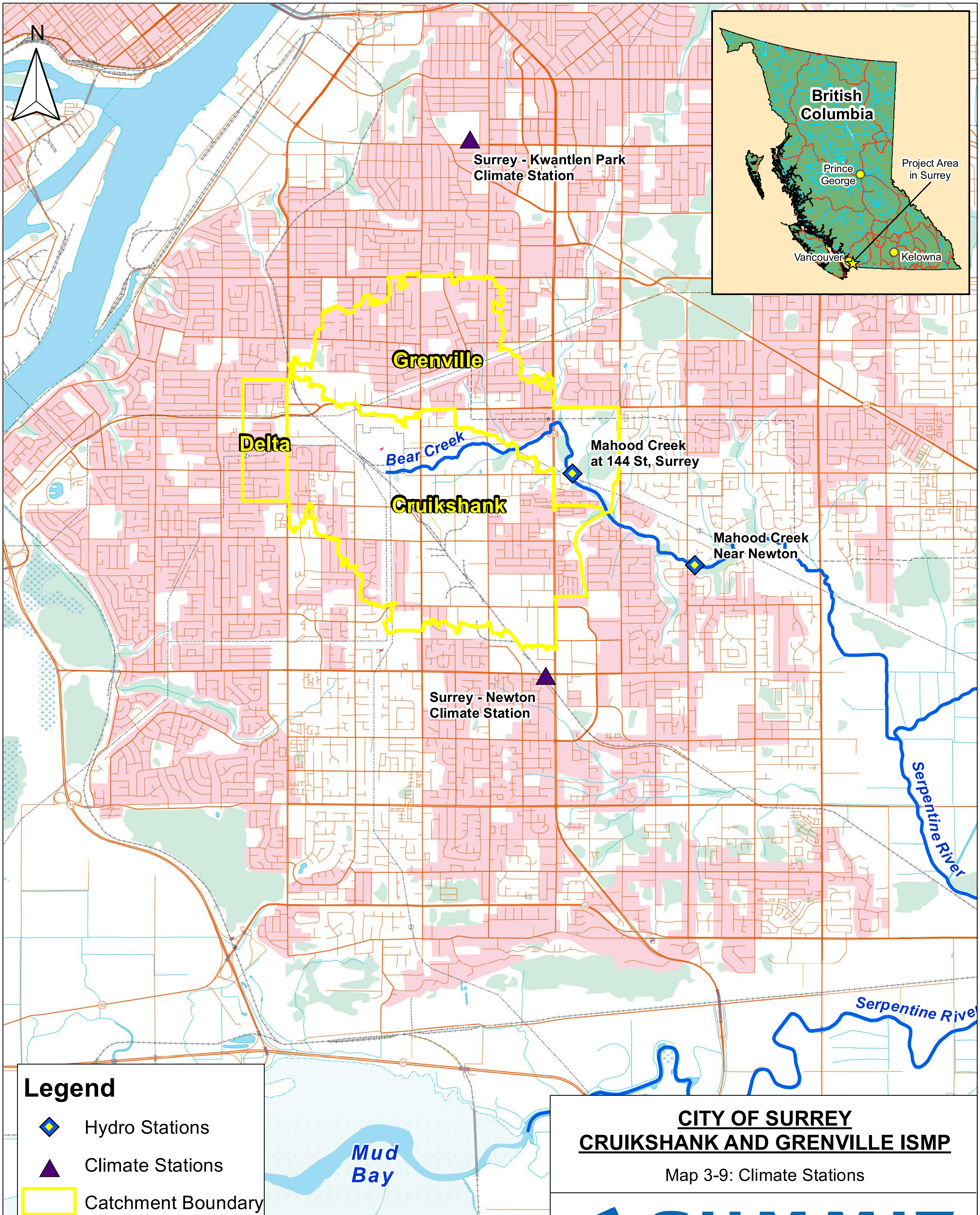
Map 3-8: Environmentally Sensitive Areas



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Map 3-9: Climate Stations

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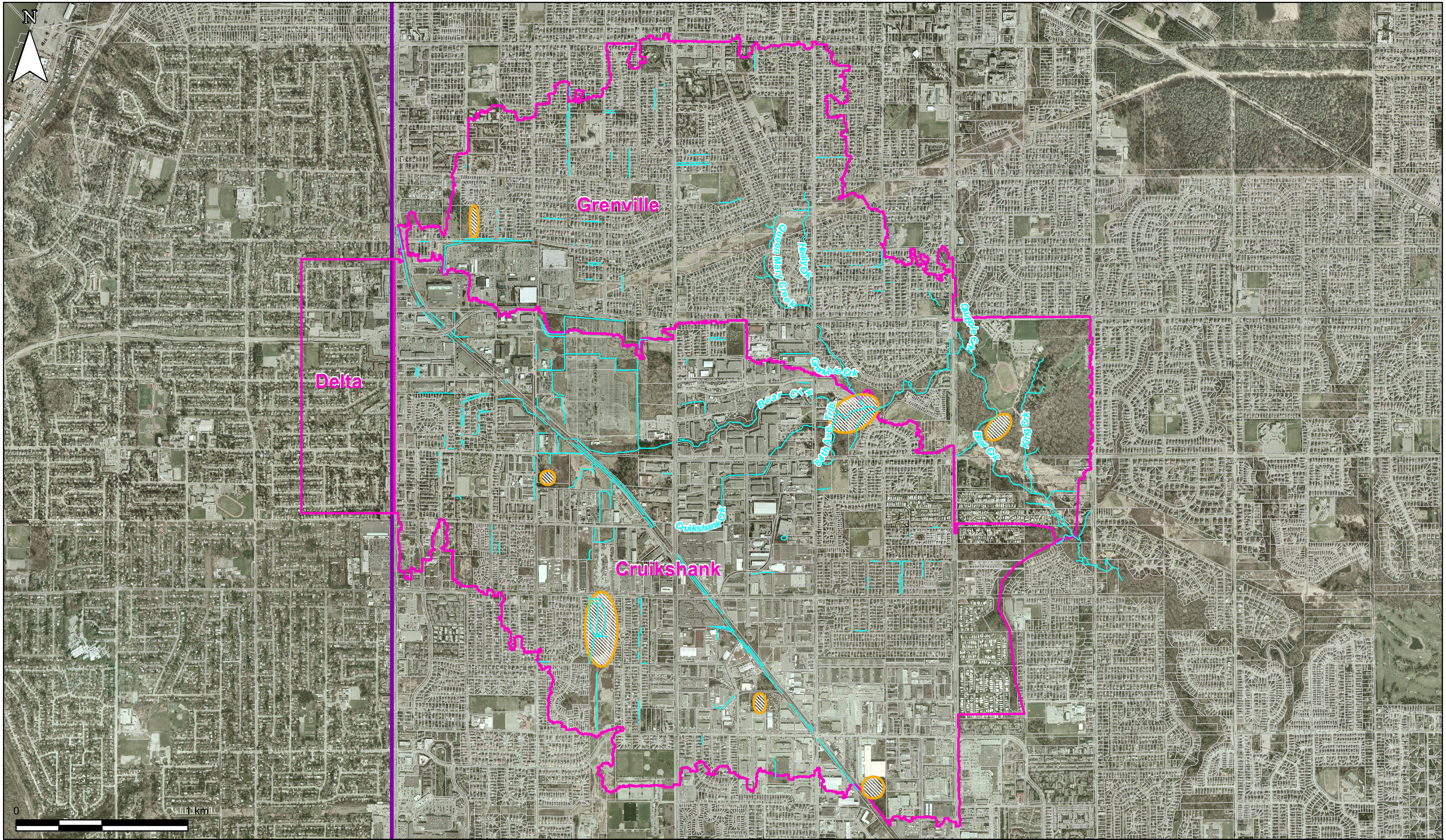

Major Roads	Catchment Boundary
Stream	Cadastral Lines
City of Surrey Boundary	Groundwater Discharge Area

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Map 3-10: Areas of Observed or Inferred Groundwater Discharge

4 Watershed Health Assessment

The Metro Vancouver template for Integrated Stormwater Management Planning provides guidance on preparing watershed health assessments using two physical characteristics: total impervious area and percent riparian integrity. Watershed health ratings are then calculated and compared to biological assessments obtained from measurements of benthic invertebrate communities. Existing watershed health was evaluated based on 2010 values.

The riparian integrity assessment estimates the proportion of riparian corridor (habitat within 30 m of top of bank to each side of a water course, a nominal minimum of 60 m) that retains natural forest habitat. Natural forest vegetation within this corridor provides many ecological benefits to stream and watershed health, including shade, nutrients, bank stability, stable soils that promote infiltration and purification of water, and habitat for many species of birds, fish, and wildlife. Restrictions on developing property within this riparian corridor are regulated through the provincial Fish Protection Act (Riparian Area Regulations) and/or municipal bylaws and best management practices.

Total impervious area (TIA) provides an estimate of the paved and hard surface areas in the watersheds. Impervious areas such as roads, buildings, and paved surfaces restrict the amount of land available for natural infiltration of precipitation. Increased impervious area results in changes to stream hydrology including higher peak flows and lower base flows which have been correlated to a reduction in the ability of streams to support salmonids and other species. The TIA calculation is based on the assumption that paved and hard surface areas do not provide any infiltration. Effective impervious area (EIA) is a more representative metric, as this represents the area that produces surface runoff conveyed directly to a watercourse or storm drain, and is also a measure of the benefit provided by the application of best management practices to reduce the volume of stormwater runoff. Under existing (2010) conditions the TIA and EIA values within the study area are 65.0 % and 57.0 %, respectfully. The intent of many of the stormwater best management practices developed as part of the ISMP will be to reduce the EIA of individual lots and the watershed as a whole.

4.1 RIPARIAN CORRIDOR ASSESSMENT

We delineated the existing riparian forests along the major watercourses and tributaries within the Cruikshank and Grenville watersheds in GIS, based on available TRIM data and orthophotos taken in 2010. The desired riparian assessment corridor is based on a theoretical 30 m buffer on either side of the watercourse with a total width of 60 m. As top of bank data was not available, riparian corridor width was measured from stream centrelines. In creeks where top-of-bank data is available, the riparian corridor width would be 60 m plus the bankful width. In the majority of the study area, existing riparian corridors have less than the desired 30 m setback. Refer to Map 4-1 for a comparison of the extent of the existing riparian forest to the 60 m wide reference riparian corridor.

The watershed contains a mix of primarily industrial and residential land uses, with areas of intact riparian vegetation generally located along the lower reaches of the creek system. The headwater areas of both watersheds are largely developed with channelized or piped drainage system eliminating significant lengths of natural creek channel and associated riparian corridor.

Riparian forest integrity (RFI) is one of two key factors the Metro Vancouver ISMP template uses to characterize watershed health. RFI is calculated as the proportion of intact forest cover within the entire riparian corridor and includes culverted and other developed areas (assessed as 0 % forest cover), and drainage ditches in agricultural areas (Metro Vancouver, 2005).

A desktop assessment of RFI was performed using GIS, available orthophotos and mapping to evaluate current watershed conditions. RFI was calculated for each watershed as a whole. The total theoretical riparian area based on 30 m setbacks is approximately 170 hectares. The total intact riparian area is approximately 53 hectares. This results in an overall RFI of 34.9 %. The RFI and TIA assessments are listed separately for the Cruikshank and Grenville watersheds in Table 4-1.

Table 4-1
Riparian Forest Integrity and Total Impervious Area Calculations for Cruikshank/ Grenville Creek and their Tributaries

Sub-Watershed	% RFI	Estimated % TIA
Cruikshank	27 %	74 %
Grenville	47 %	51 %
Combined	**35 %**	**65 %**

4.2 TOTAL IMPERVIOUS AREA ASSESSMENT

Total impervious area (TIA) is the second of two key watershed health indicators identified by the ISMP template (Metro Vancouver 2002, 2005), and provides an estimate of the proportion of hard surfaced area producing runoff in the two watersheds. With mitigation measures in place or planned, it is more appropriate to assess EIA, the impervious area directly connected to a storm drain. However, EIA is not directly measurable using mapping and aerial photographs.

The estimate of TIA for the two watersheds together is approximately 65 %, based on typical impervious cover associated with road rights-of-way and land development (Table 4-1). Although TIA values were not calculated separately for the headwater and lower reaches of the watersheds, the lower reaches of each watershed appear to have lower TIAs, in part due to the higher proportion of surviving riparian corridor and remnant green spaces.

The preliminary estimate of EIA for the study area is approximately 57 %, based on an interpretation of the total impervious area, existing zoning information, aerial photography, and field observations. Determining the exact effective impervious area requires detailed evaluation on a lot by lot basis and was not included in the scope of this ISMP.

Future development conditions are expected to have greater total impervious coverage than existing development conditions for the same land use. Also, future zoning changes as outlined in the City of Surrey OCP indicate that some existing low density and medium density residential developments will be replaced with more land intensive industrial, commercial, and multiple residential developments. We estimate the future impact of these changes will be an increase to the overall imperviousness of the watersheds by approximately 9%. Refer to Table 4-2 for a summary of the change in impervious coverage expected in each watershed.

Table 4-2
Changes to Percent Impervious Values

Land Use	Existing Average Percent Impervious	Future Average Percent Impervious	Increase in Average Percent Impervious
Cruikshank	74 %	80 %	6 %
Grenville	51 %	65 %	14 %
Combined	**65 %**	**74 %**	**9 %**

4.3 BENTHIC INVERTEBRATE COMMUNITIES

Results of benthic invertebrate community monitoring are used to augment preliminary watershed health assessments, as recommended by the ISMP template (Metro Vancouver, 2005) and Metro Vancouver Benthic Invertebrate Index of Biotic Integrity (B-IBI) guide (EVS 2003). Benthic surveys provide a biologically based performance measure of the effectiveness of watershed planning and implementation processes because these organisms, which inhabit the cobble and gravel substrates of the stream, experience the ambient conditions and stressors of the watershed such as changes in flow regime and in-stream habitat and the presence of sediment and toxic substances that enter through storm drains and other runoff.

In principle, a B-IBI assessment incorporates environmental and community characteristics such as taxon richness and composition, pollution tolerance versus sensitivity, feeding ecology, and population structure. Index scores have been shown to correlate with TIA and RFI (Metro Vancouver 2005). Values range from 10 (very poor) to 50 (excellent), although a maximum of 40 has been observed for pristine mountainous streams within Metro Vancouver (Metro Vancouver 2005). The stream condition rating system used in Metro Vancouver is described in Table 4-3.

Table 4-3
Stream Condition Ratings Based on B-IBI Scores (EVS 2003)

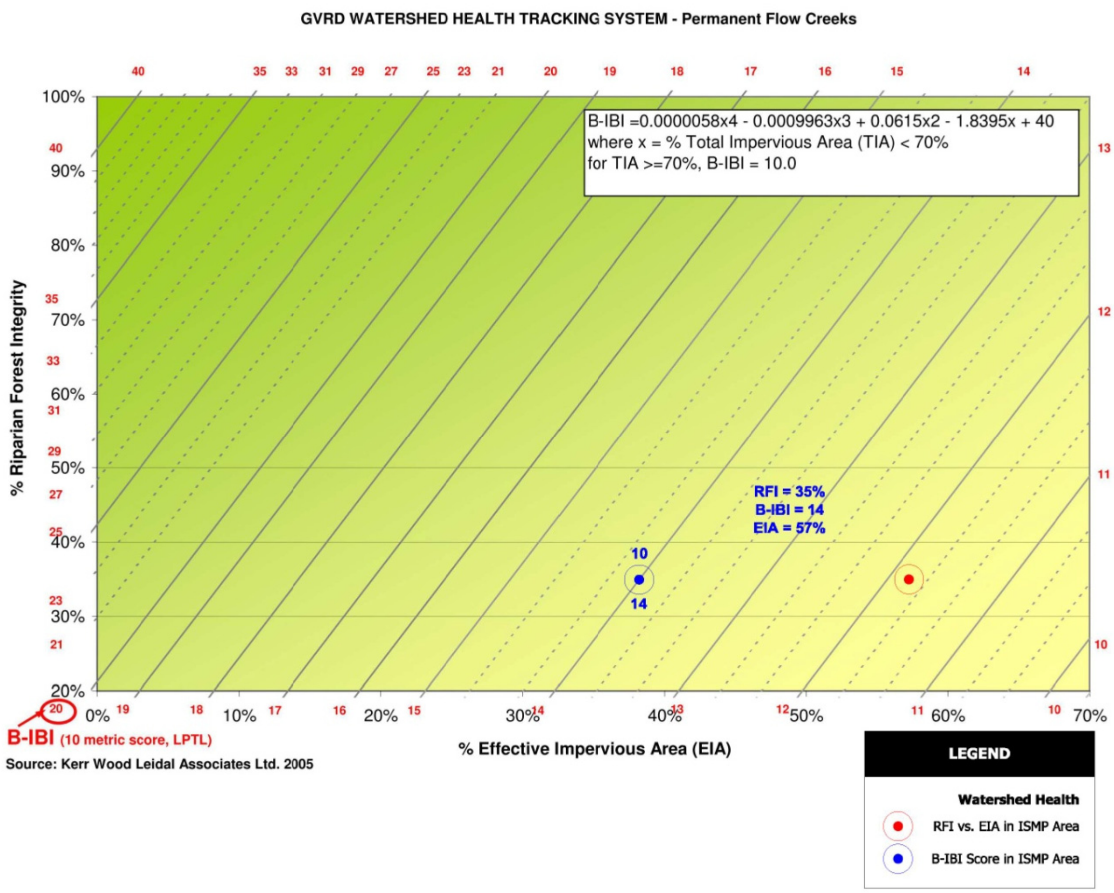
10 Metric B-IBI Score	Stream Condition Rating
46 to 50	Excellent
38 to 44	Good
28 to 36	Fair
18 to 26	Poor
10 to 16	Very Poor

The City of Surrey has monitored benthic invertebrates at 29 stations within 19 streams and rivers since 1999. Benthic invertebrate sampling was not undertaken as part of the ISMP. Instead, existing data for biological integrity (B-IBI) for the study area was reviewed. Within the study area, benthic invertebrate sampling has taken place at two locations on Bear Creek (BEAR1-2 and BEAR1-3). The mean B-IBI values recorded in the spring and fall of 2009 was 14 for both sites. No other existing B-IBI data was identified for the study area.

4.4 WATERSHED HEALTH OVERVIEW

The preliminary watershed health assessment was prepared using TIA and RFI, and following the Watershed Health Tracking System described in the revised ISMP template (Metro Vancouver, 2005). TIA and RFI are considered key physical performance measures that correlate strongly with watershed health. Values shown in Table 4-1 for existing conditions were overlain on the template chart (Figure 4-1). For watershed health tracking purposes the estimated EIA of 57 %, was used.

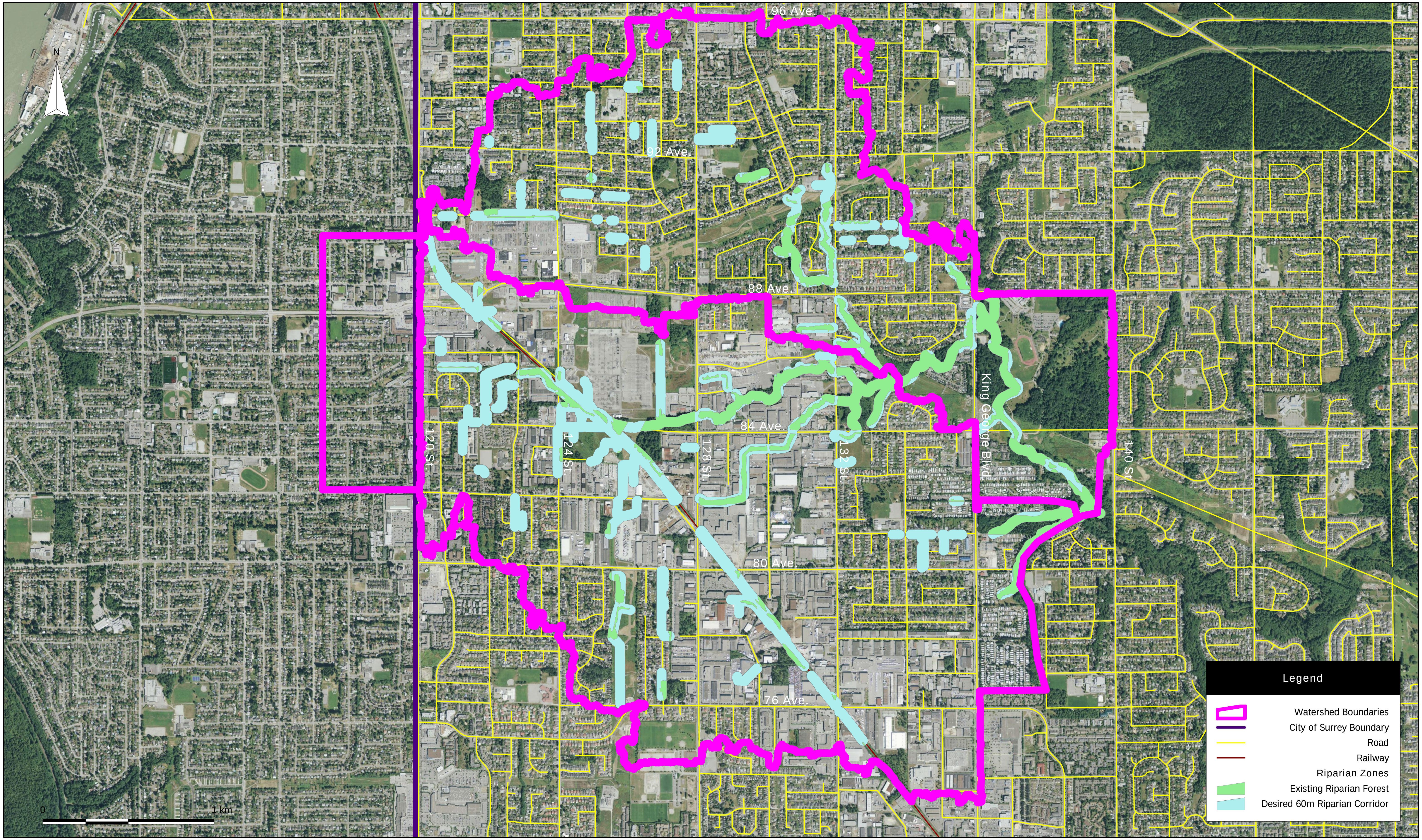
Figure 4-1
Metro Vancouver Watershed Health Tracking System



The measured and calculated values for B-IBI are plotted against % RFI in the Watershed Health Tracking chart (Figure 4-1). The calculated B-IBI value of 10 is somewhat lower than the measured B-IBI of 14, which may indicate that watershed health is functionally better than indicated by the plotting position of RFI against TIA on the Watershed Health Tracking chart.

However, despite the low watershed health ranking supposedly indicated by the methodology discussed above and presented in Figure 4-1, it is noteworthy that the Cruikshank and Grenville watersheds retain significant functionality as fish habitat (Refer to Section 3.3). A majority of the surviving watercourses have documented fish presence or have a supporting role in providing food and nutrients (Refer to Map 3-5). Preservation of the remaining habitat value is important and suitable measures are required to prevent further degradation and to provide opportunities for improvement.

Accordingly, implicitly “writing off” the remaining fish population and habitat through a lack of sufficient actions is not an acceptable strategy for this ISMP. Measures that will protect and enhance the ecology of the watersheds are developed and advanced in the following sections.



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Map 4-1: Riparian Forest Integrity

5 Hydrologic and Hydraulic Model Development

We developed a hydrologic and hydraulic model of the Cruikshank and Grenville watersheds using PC SWMM software, a derivative of the United States Environmental Protection Agency's (USEPA) Storm Water Management Model version 5.0 (SWMM 5.0). It is a dynamic rainfall-runoff simulation model with the ability to model runoff hydrology and hydraulic routing within a watershed.

5.1 BASE HYDROLOGIC MODEL

We developed the base hydrologic model of the Cruikshank and Grenville watersheds to examine the study area under existing development conditions. The base hydrologic model utilized information obtained during the reconnaissance phase of the ISMP, as well as GIS data provided by the City. Our model includes that portion of the Cruikshank catchment that is located within the Corporation of Delta.

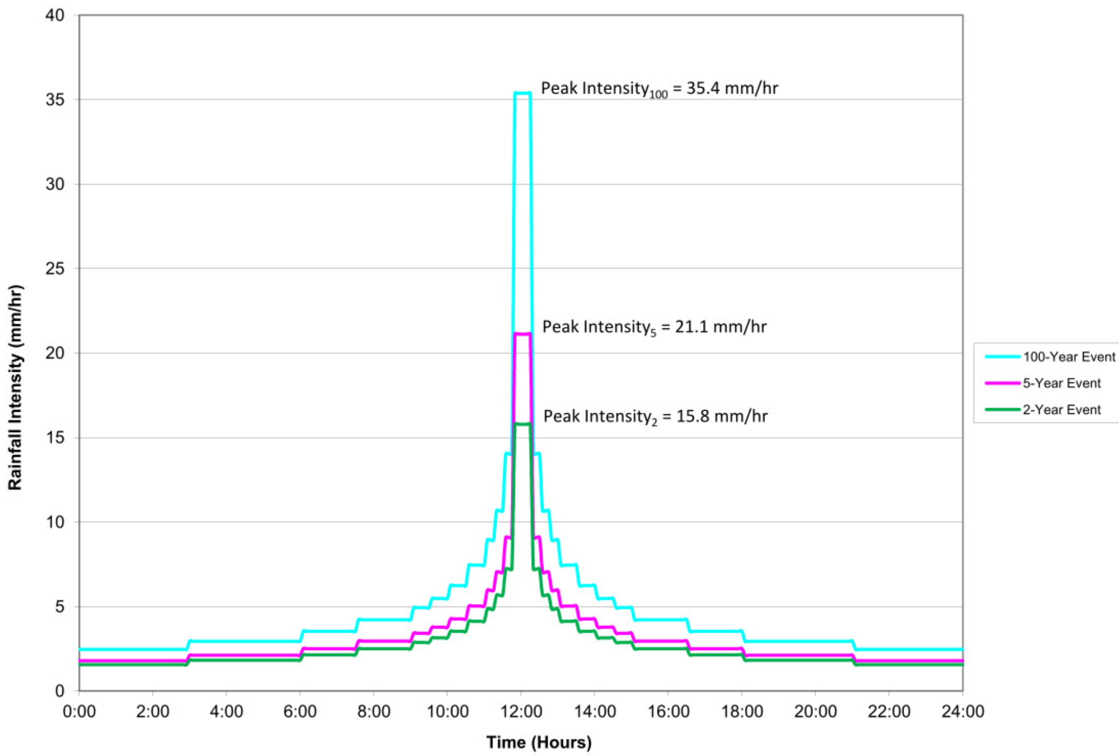
5.1.1 Design Storm Events

To evaluate the drainage characteristics of the Cruikshank and Grenville watersheds we developed 2-year, 5-year and 100-year return period storm events. Minor system infrastructure including storm sewers, ditches, driveway and ditch culverts, and low flow channels should have the capacity to convey flows from storm events up to and including the 5-year return period. Major system infrastructure including surface flow paths, major culverts, bridges, and major watercourses should be able to convey flows from storm events up to and including the 100-year return period.

Precipitation data was developed from the data recorded at the Surrey Kwantlen Park station, approximately 1.60 km north of the study area. This rain gauge was selected because of its close proximity to the study area and its extensive period of data collection. From the data, we created 24-hour all-duration storm events for the 2-year, 5-year, and 100-year return period storm events based on a non-skewed Chicago distribution. All-duration-storms are applicable for planning purposes as they provide a conservative estimation of rainfall input. Our design storms for this assignment utilize ten minute time step intervals, and have a 30 minute duration peak rainfall. At each time increment in the storm distribution the IDF rainfall volume and intensity is replicated. Refer to Figure 5-1 for graphical representations of the storm events.

The detailed design of stormwater management facilities and infrastructure should continue to be based on the City's specified design storms at critical storm durations.

Figure 5-1
24-Hour All-Duration Storm Events



5.1.2 Watershed Delineation

The objective of watershed delineation is to confirm, or redefine as necessary, the boundaries of the Cruikshank and Grenville catchments and to further divide the catchments into sub-catchments to create detailed mapping of flow paths and drainage areas for the entire study area. Our delineation is based on information gathered during field reconnaissance, GIS data of stormwater infrastructure provided by the City of Surrey, air photographs, and digital Terrain Resource Inventory Mapping (TRIM) data. The process was completed using sophisticated GIS algorithms that interpret topography and flow lines consistent with identified drainage features, such as culverts, ditches, natural channels, storm sewers, inlets, outfalls, and overland flow routes to establish the boundaries for each sub-catchment.

The three (3) drainage catchments Cruikshank, Delta, and Grenville, were further subdivided into 146 sub-catchments. An additional lumped subcatchment was used to represent the Quibble Creek watershed upstream of the confluence with this ISMP's creek system. Refer to Map 5-1, and Table 5-1, for an overview of the sub-catchment delineation and details respectively. Detailed subcatchment delineation is provided as Map E-1 in Appendix E.

Table 5-1
Sub-Catchment Delineation

Catchment	Total Drainage Area	Number of Delineated Sub-Catchments
Delta	80 ha	2
Cruikshank	779 ha	89
Grenville	521 ha	55

Note: Detailed Subcatchment Delineation is provided on Map E-1 in Appendix E.

5.1.3 Sub-Catchment Parameters

The Cruikshank and Grenville watersheds have a combined area of approximately 1,380 hectares. Approximately 1,300 hectares are located within the City of Surrey. The remaining 80 hectares are located within the Corporation of Delta.

We estimated hydrologic parameters specific to the topology and topography of each sub-catchment such as flow widths and slopes using GIS digital elevation mapping and interpretation of aerial photography. We assumed typical manning's roughness values associated with surface type and typical depression storage values corresponding to land use type. Depression storage values of each sub-catchment were weighted based on land use. Existing condition subcatchment parameters are provided in Table E-1 in Appendix E.

The existing zoning plan was obtained from the City of Surrey and was verified with field visits and satellite imagery. Future condition land use mapping was obtained from the City of Surrey Official Community Plan (OCP) (November 2010). For the purpose of this study, we assumed that the portion of the Cruikshank catchment located within the Corporation of Delta will not experience land use changes. A comparison of existing zoning land use types and land use types from the City of Surrey OCP is located in Table 5-2. Refer to Map 5-2 and Map 5-3 for maps of existing zoning and projected OCP future land use designations, respectively.

Table 5-2
Existing Zoning and OCP Designation Land Use Comparison

Land Use Type	Existing Zoning Land Use Plan (ha)	OCP Future Land Use Designation (ha)	City of Surrey Design Criteria Manual (May 2004) TIA (%)
Commercial	15	38	90
Industrial	383	477	90
Institutional	39	39	80
Multiple Residential	2	47	80
Park	142	97	20
Riparian Zones	40	40	20
Large Lot Residential	7	0	50
Undeveloped Lots	52	0	20
Urban Residential	700	642	65
Total Area	1,380	1,380	-

The most significant land use changes between existing and long range scenarios is the addition of approximately 117 ha of industrial and commercial land and the loss of approximately 52 ha of undeveloped lots. The majority of the lots that will likely undergo land use changes are located within or in close proximity to creek corridors, and in some cases are the only significant undeveloped areas remaining in the headwaters of their respective creek branches. They currently function hydrologically as pervious vegetated land that, if taken away, will further impact the health of downstream watercourses. Refer to Map 5-4 for the areas at the most risk of impact due to development activity.

Soil types within the watershed were defined by Summit and were discussed in detail in Section 3. Glaciomarine stony silty sand is the prominent soil type in the study area. For input into the hydrologic model, we assumed Horton infiltration parameters for this soil type as shown in Table 5-3, based on the hydrogeology assessment discussed in Section 3.5.

Table 5-3
Horton Infiltration Values

Soil Type	Maximum Infiltration Rate	Minimum Infiltration Rate
Glaciomarine Silty Sand	1.60 mm/hr	0.90 mm/hr

5.2 BASE HYDRAULIC MODEL

We developed a hydraulic model of the Cruikshank and Grenville watersheds to evaluate the capacity of the storm drainage system and to evaluate alternatives to improve their performance. The model contains all components of the drainage system with service areas greater than 20 ha. The model is fully dynamic and can simulate backwater effects.

During the reconnaissance phase of the ISMP we collected background information and completed a hydraulic inventory to determine general drainage patterns and identify existing drainage features such as culverts, storm drainage outfalls, ditches, and natural watercourses. We used this information to develop a macro-scale hydraulic computer model of the existing drainage network. We assume that stormwater infrastructure located outside of the Cruikshank and Grenville ISMP study area (i.e. downstream or in Delta) is adequately sized to convey runoff from the minor storm event.

The minor system consists primarily of storm drainage pipes. The performance of the modeled portion of minor system was evaluated for the 5-year return period storm event. The minor system is present in the model when modeling the impact of 100-year return period events on the major system, but under those scenarios the results from the minor system are not evaluated.

Flow paths and linkages were generated by processing LIDAR based digital elevation mapping with GIS software during delineation of the sub-catchments. A total of approximately 163 open channel segments (ditches and natural watercourses) and 373 closed conduit segments (pipes and culverts) were created and included in the model. Generated flow paths were verified with aerial photography and field reconnaissance data. We estimated average channel cross-sections and Manning's roughness coefficients of open channels from observations made during field investigations. We estimated physical channel characteristics such as lengths and slopes using digital elevation mapping and GIS data.

Culvert lengths, slopes, and invert elevations were estimated by analyzing digital elevation mapping using GIS software. We assumed typical manning's roughness values of 0.022 for corrugated steel, 0.013 for concrete, and 0.013 for polyvinyl chloride pipes. We assumed typical entry loss coefficients of 0.90 for projecting culverts, 0.70 for culverts mitered to conform to the fill slope, and 0.50 for culverts with headwalls. The shape, material type, and dimensions of each culvert were based on field measurements. Within the model, each culvert was connected upstream and downstream to an open channel segment.

The City of Surrey's GIS mapping provided the locations of the piped storm drainage system within the study area. The majority of the materials, dimensions, and inverts were also provided in the City's GIS database. Pipes with missing materials and dimensions were assumed to be equal to those of upstream pipes. Missing inverts were calculated from the nearest upstream or downstream pipe of known invert.

Model conduit data for the existing system is provided in Table E-3 in Appendix E, and model junction/node data is provided in Table E-4 in Appendix E.

5.3 MODEL CALIBRATION

We calibrated the base model to ensure that it reflects current hydrologic conditions in the study area. There is an existing City of Surrey stream flow gauge station located within the Grenville watershed on Bear Creek at King George Boulevard, approximately 215 m south of 88 Avenue. It receives flow from approximately 1,245 hectares or 90 % of the Cruikshank and Grenville study area. We calibrated the existing conditions model to the hourly continuous stream flow data at this gauge station.

We compared the hourly rainfall data from the gauges at Surrey Kwantlen Park and Surrey Municipal Hall to the Bear Creek stream flow gauge to determine the most appropriate data for the study area. Peak rainfall intensities at the Surrey Kwantlen Park gauge occurred at relatively the same time as peak flow rates at the Bear Creek gauge, therefore, the Kwantlen Park gauge was selected to calibrate the model.

We calibrated the model with continuous simulation modelling with summer rainfall between June 1, 2008 and June 16, 2008 and winter rainfall between November 1, 2008 and November 16, 2008. To calibrate the model, we focussed on matching the timing and rate of peak flow and replicating the volume experienced during the summer and winter periods within acceptable tolerance.

Results of the calibration indicate that the model reproduces the measured flow rates reasonably well while remaining slightly conservative. Refer to Figure 5-1 and Figure 5-2 for the rainfall hyetographs and flow gauge and model output hydrographs at Bear Creek and King George Boulevard for the summer and winter periods, respectfully. The calibration results are also summarized in Table 5-4.

Figure 5-1
Summer Calibration Results

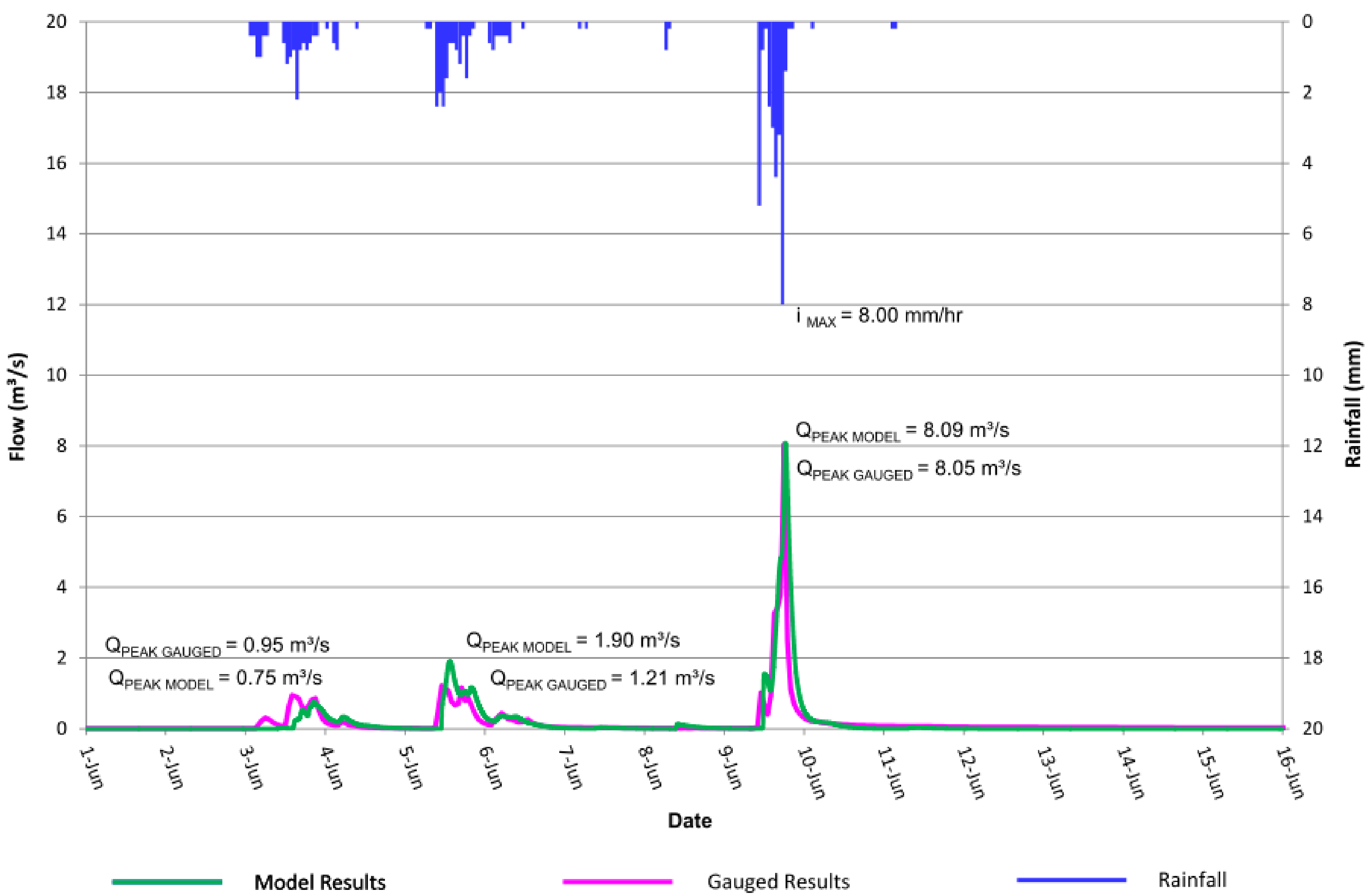


Figure 5-1
Summer Calibration Results

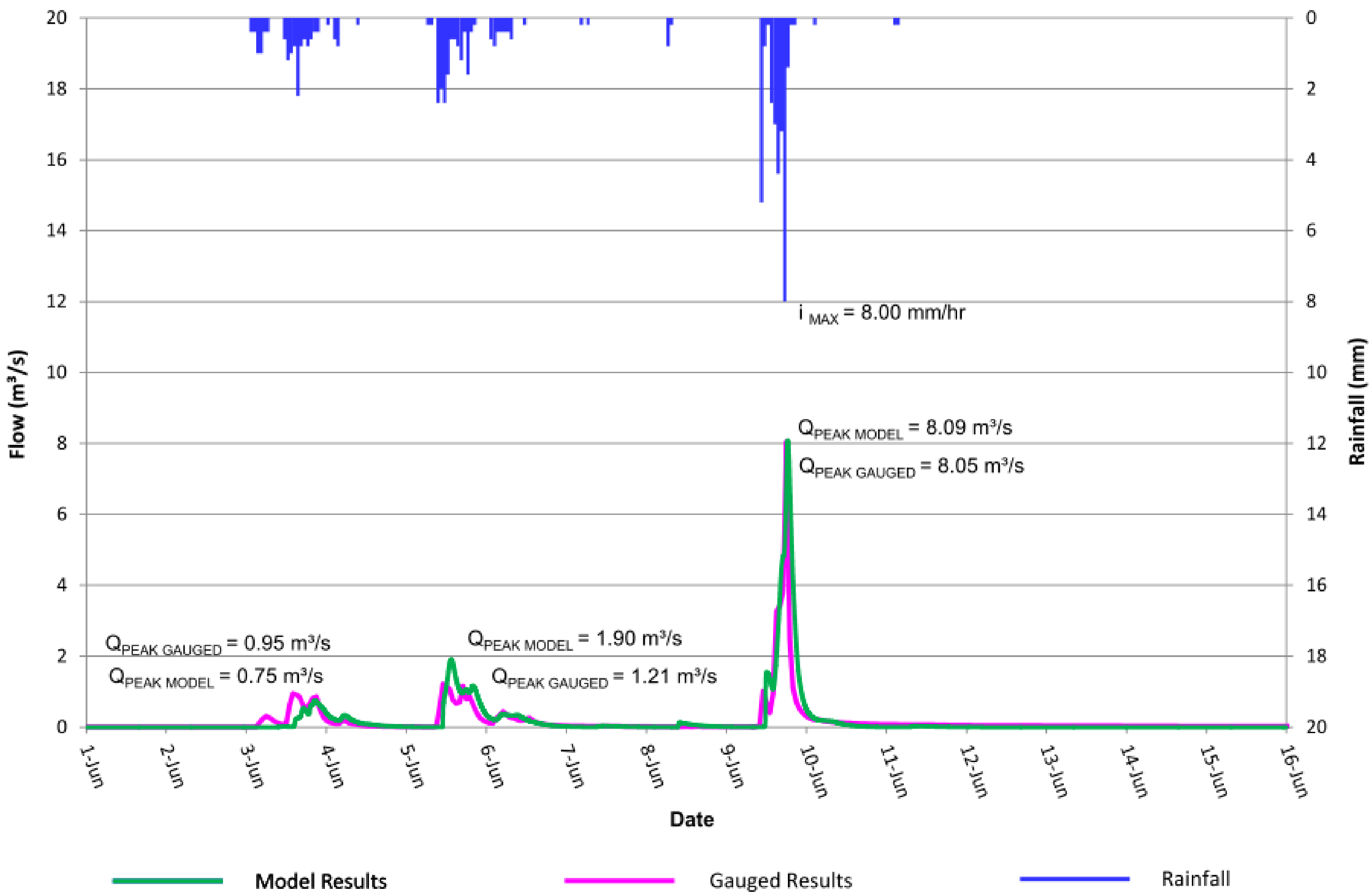


Figure 5-2
Winter Calibration Results

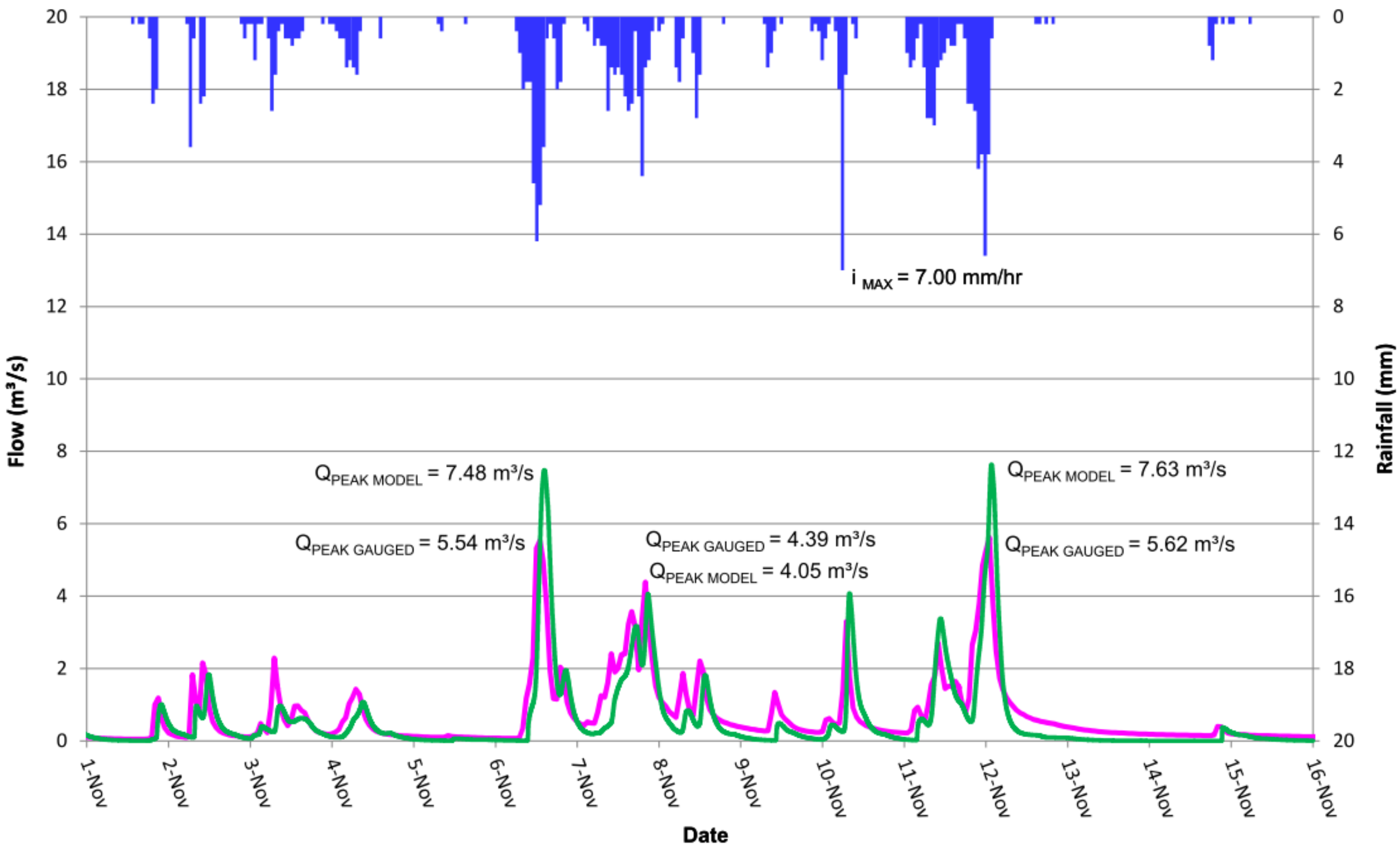


Figure 5-3
2003 to 2008 Continuous Simulation Rainfall Data

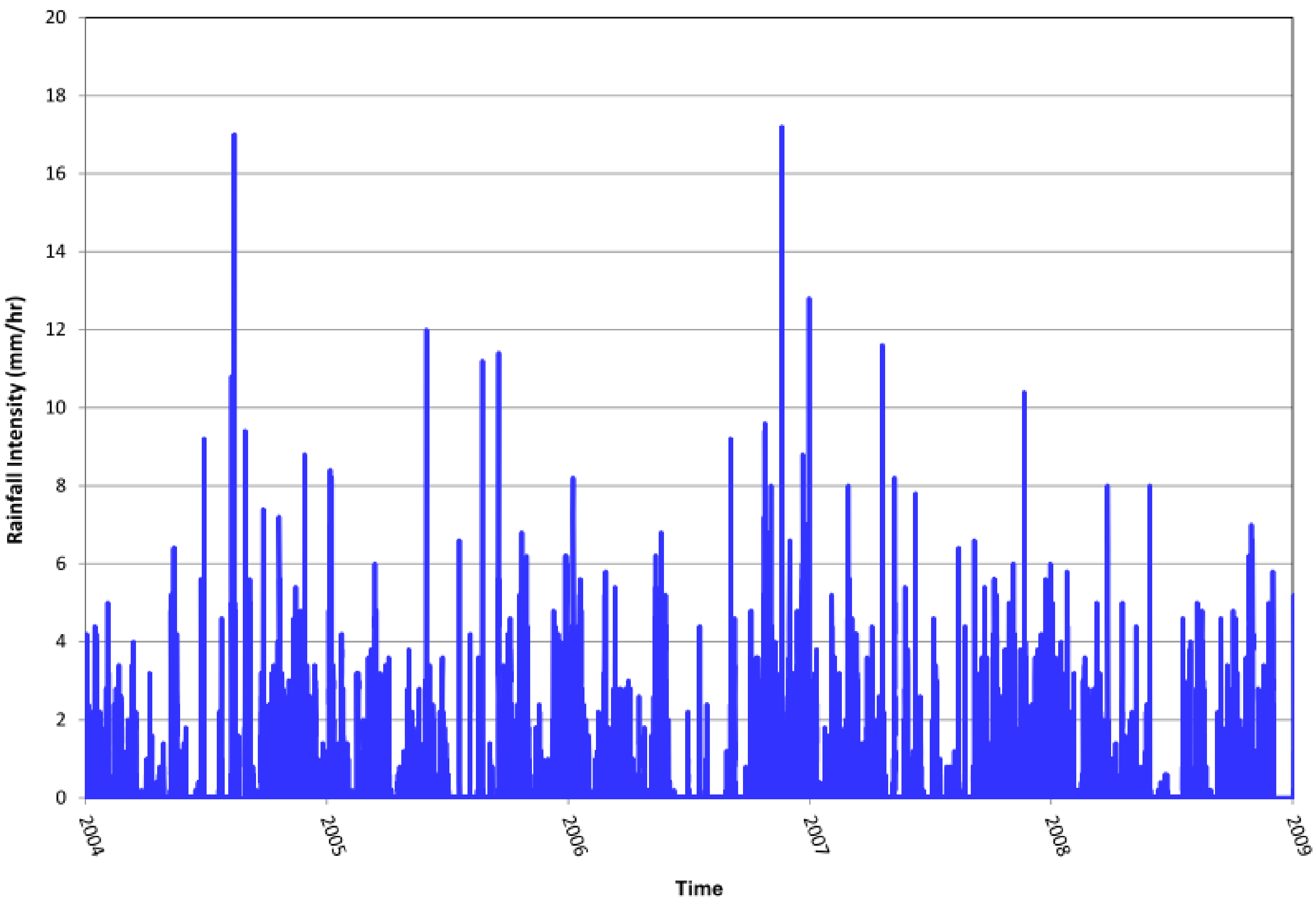


Table 5-4
Calibration Results

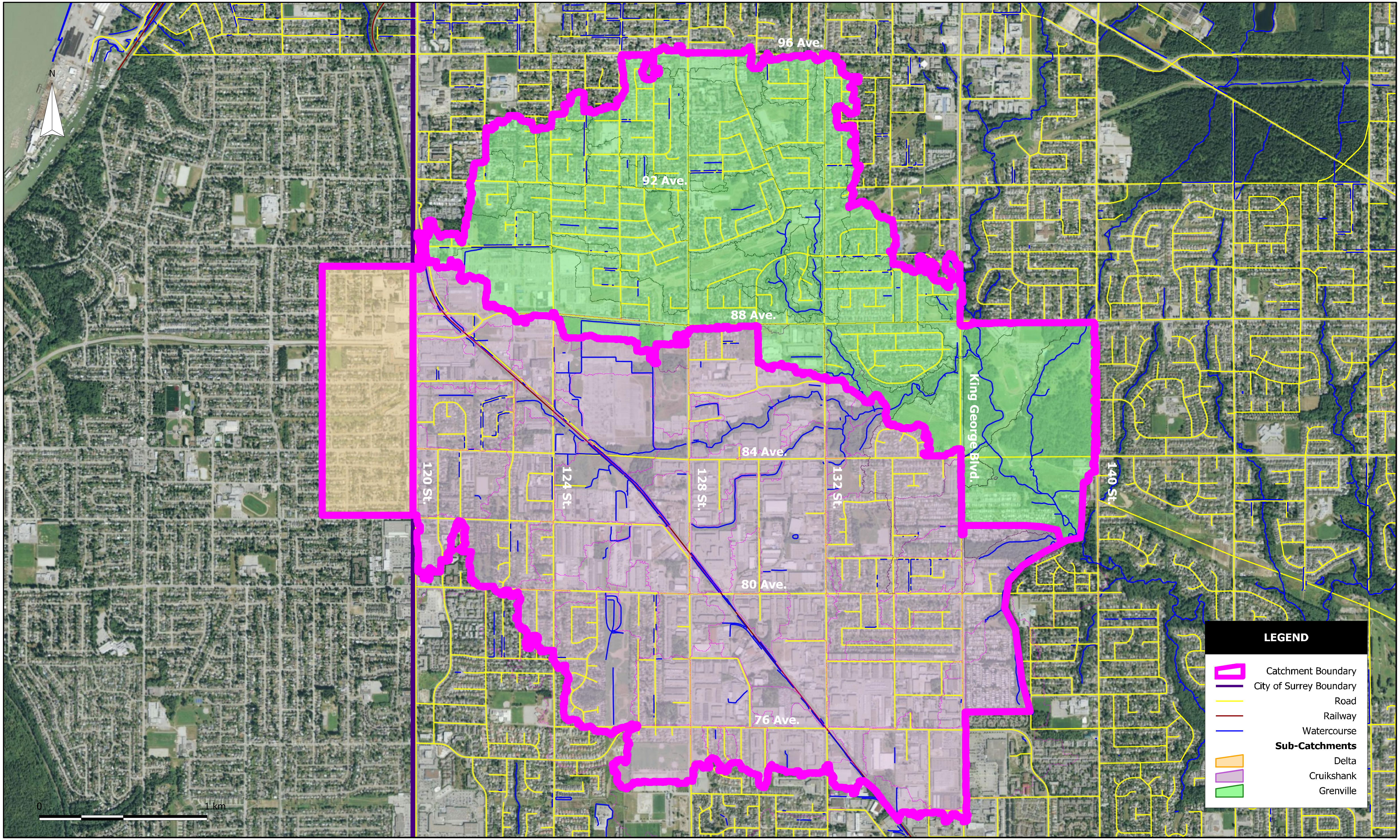
Bear Creek at King George Boulevard	Peak Flow Rate	Timing of Peak Flow	Total Volume During Simulation
Summer Period (June 1, 2008 to June 16, 2008)			
Gauged Flow	8.05 m^3/s	June 9, 2008 at 6:00pm	81,989,800 m^3
Modelled Flow	8.09 m^3/s	June 9, 2008 at 6:27pm	87,713,800 m^3
Winter Period (November 1, 2008 to November 16, 2008)			
Gauged Flow	5.6 m^3/s	November 12 at 1:00am	335,196,100 m^3
Modelled Flow	7.6 m^3/s	November 12 at 1:37am	268,402,700 m^3

During the summer calibration event, the peak flow rate in Bear Creek during the June 9th and 10th rainfall event is within 1 % of the peak flow rate observed at the gauging station. The model lags slightly behind observed flow rates, by approximately 27 minutes. The total volume generated by the model is within 7% of the gauged volume. The model provides a slightly conservative estimate of peak flow rates and volume.

For the winter calibration event, the modelled peak flow rate in Bear Creek during the November 11th and 12th rainfall event is within 36% of the peak flow rate and within 3% of the total volume observed at the gauging station and the mode is within 3% of the overall volume recorded for the period. The model lags slightly behind observed flow rates, by approximately thirty-seven minutes. The total volume generated by the model is within 20% of the gauged volume. We expect that this volume deficiency is the result of insufficient groundwater discharge in the model which, unfortunately, we were unable to replicate in the model.

5.4 CONTINUOUS SIMULATION OF EXISTING DEVELOPMENT CONDITION

We completed continuous simulation modelling of the watershed to determine how the watersheds respond to small frequently occurring rainfall events. The base hydrologic and hydraulic models were maintained in the continuous simulation model. Precipitation data for analysis of the continuous simulation modelling scenario was derived from hourly rainfall data collected at the Surrey Kwantlen Park rain gauge from January 1st 2004 to December 31st 2008. Refer to Figure 5-3 for a graphical representation of the continuous simulation rainfall data.



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Map 5-1: Sub-Catchment Delineation

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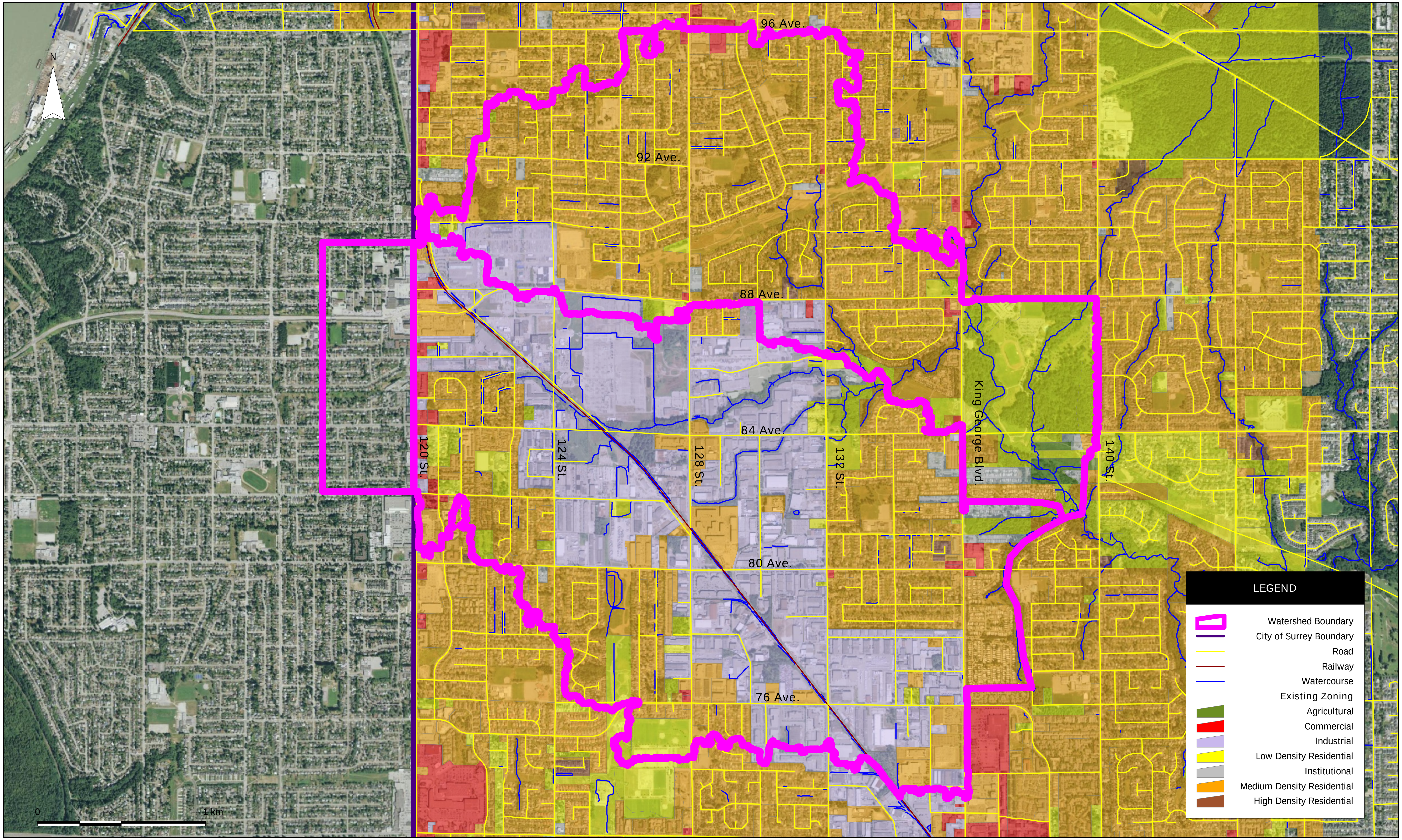

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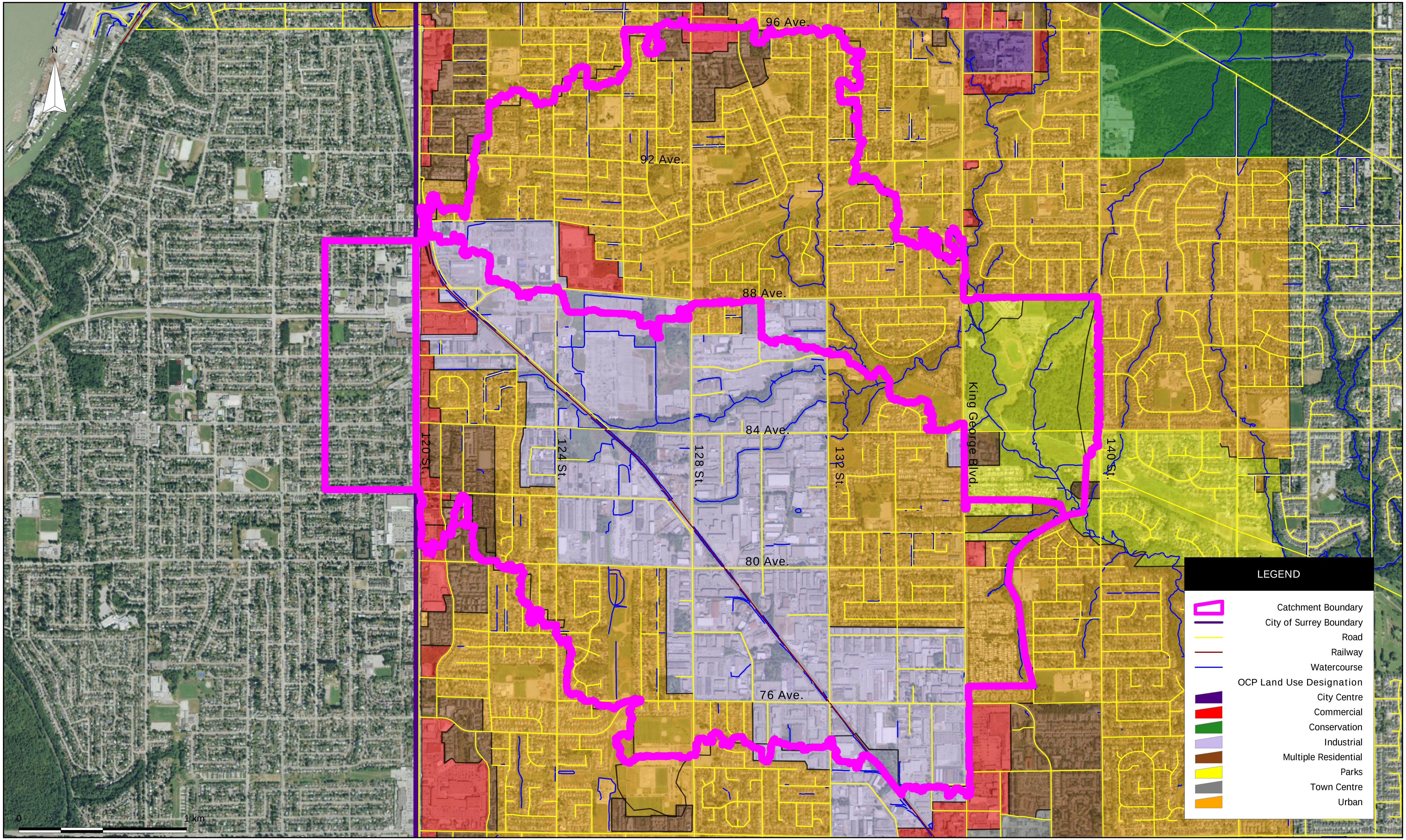
Map 5-2: Existing Zoning Land Use Designation



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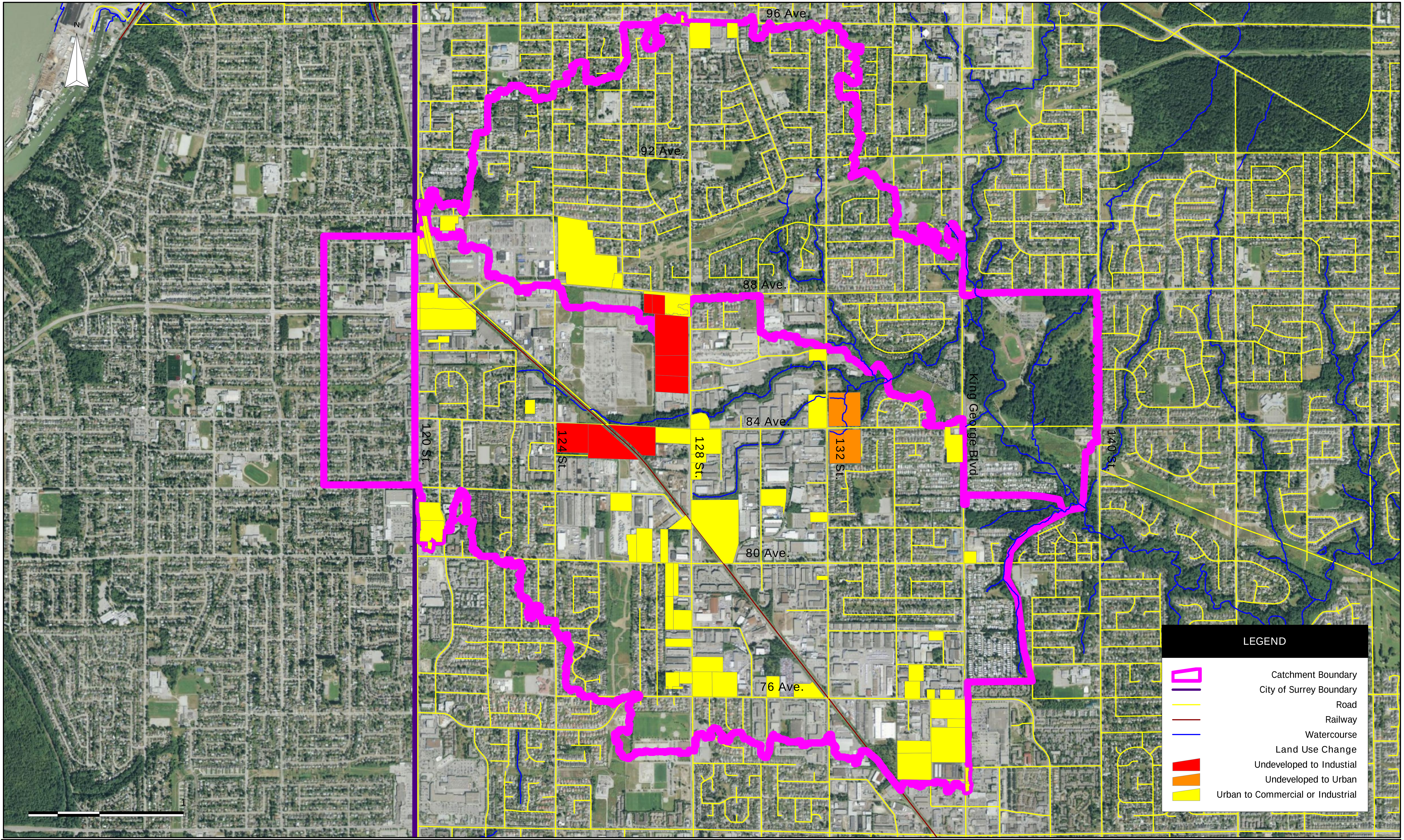
Map 5-3: Official Community Plan Land Use Designation



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Map 5-4: Areas Subject to Land Use Changes

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6 Drainage System Evaluation

We evaluated the base hydrologic and hydraulic model developed in Section 5 to identify deficiencies within the existing Cruikshank and Grenville drainage network under existing zoning conditions and projected future development conditions as outlined in the OCP. Existing development conditions model results are summarized to show the general trends and major problem areas within the watersheds. Future development condition model results have been summarized to highlight the effects of unmitigated future development.

6.1 EXISTING CONDITIONS MODEL EVALUATION

We evaluated the existing development condition to identify hydraulic deficiencies within the drainage network under existing zoning conditions. We identified approximately 12,274 m of pipe that experiences surcharging along at least a portion of its length during the minor 5-year return period event. As components of the major system, culvert surcharging is identified as a potential issue when the inlet water depth is above the crown of the culvert during a 100-year return period event. The significance of culvert surcharging varies depending upon the consequences at a particular location, such as upstream flooding due to backwater conditions, road overtopping or potential instability of the road embankment. These specific conditions were not assessed for surcharged culverts and they are identified as potentially requiring replacement subject to further assessment.

Refer to Table 6-1 for a summary of the surcharged pipes and Map 6-1 for their locations. Recommended upgrades to eliminate surcharging are discussed in Section 6.3.

Table 6-1
Summary of Existing Surcharged Stormwater Pipes

Size	Length of Surcharged Pipe (m)	Proportion of Conduit Length in Study Area(%)
< 600 mm Ø	535	1.5%
600mm Ø to 750mm Ø	6,900	20.0%
825mm Ø to 1050mm Ø	2,930	8.5%
> 1200mm Ø	725	2.1%
Total	**11,090**	**32.1%**

Surface flooding as a result of the 5-year return period storm event is indicated for one location within the study area, involving an existing 900 mm diameter storm sewer north of 80th Avenue that runs parallel to Serpentine Greenway. Based on our model results, the pipe is expected to flood at its downstream end to approximately 0.20 m above the surface elevation. This pipe also causes surcharging of approximately 270 m of upstream storm sewer. We recommend further investigation for this location.

We note that the identification of conduits with insufficient capacity is based on a high level watershed model. Prior to implementing projects to upgrade the identified conduits, the need for the upgrade should be confirmed by more detailed hydraulic analysis.

6.2 FUTURE CONDITIONS MODEL EVALUATION

The objective of the future conditions model is to identify deficiencies within the existing drainage network under future development conditions and to identify potentially unmitigated development impacts. The existing development conditions model developed and calibrated in Section 5 of the ISMP formed the basis of the future development conditions model. The drainage networks were modelled in their current configuration. The percent imperviousness and depression storage values of each sub-catchment were altered to reflect the future land use areas outlined in the City of Surrey Official Community Plan (Map 5-3), without benefit of source controls or other BMPs.

6.2.1 Hydrologic Conditions

Future development and re-development activities will reduce losses from infiltration and evapotranspiration and decrease on-site depression storage. Total infiltration loss is a function of soil infiltration rates, antecedent moisture conditions, and the ratio of pervious to impervious surfaces. The unmitigated total percent impervious (TIA) value for the study area is expected to increase by approximately 9 % with future development activity and total runoff is expected to increase accordingly. The majority of remaining rainfall from a storm event becomes surface runoff. Future condition hydrologic parameters for the model subcatchments are provided as Table E-2, in Appendix E.

Infiltration losses and runoff volumes generated by each sub-catchment were calculated in the hydrologic model. We compared the results of the existing conditions model and the future conditions model to determine hydrologic impact of unmitigated future development activity within the Cruikshank and Grenville watersheds. Refer to Table 6-2 for a comparison of the results.

Table 6-2
Hydrologic Changes

Storm Event	Percent Decrease in Infiltration Losses	Percent Increase in Runoff Volume
100-Year Design Storm Event	36.0 %	3.0 %
5-Year Design Storm Event	35.9 %	4.5 %
2-Year Design Storm Event	35.8 %	5.6 %
5-Year Continuous Simulation Period	30.3 %	7.9 %

Future development and re-development activities will decrease infiltration losses and increase total runoff volumes. Larger percent increases in runoff volumes will be experienced during small frequent storm events. If individual sites are not modified to detain additional runoff, increased volumes will flow to receiving watercourses and downstream stormwater infrastructure. Increased runoff volumes in combination with increased peak flow rates have the effect of increasing erosion potential and pollutant mobility.

6.2.2 Peak Flow Rates

We examined the model output hydrographs in Bear Creek at King George Boulevard to compare the peak flow rates and total runoff volumes generated in the existing conditions model and the future development conditions model. This location was selected because the existing development conditions model was calibrated to the City of Surrey flow monitoring gauge in Bear Creek at King George Boulevard and the majority, 93.5 %, of runoff from the study area contributes to flow at this location. Refer to Table 6-3 for a summary of the peak flow rates and Figure 6-1, Figure 6-2, and Figure 6 3 for hydrographs of the 100-year, 5-year, and 2-Year return period design storm events in Bear Creek at King George Boulevard.

Table 6-3
Peak Flow Rates and Total Runoff Volumes in Bear Creek at King George Boulevard

Design Storm Event	Peak Rainfall Intensity (mm/hr)	Peak Flow Rate			Total Runoff Volume		
		Existing Conditions (m^3/s)	Future Conditions (m^3/s)	Percent Increase (%)	Existing Conditions (m^3)	Future Conditions (m^3)	Percent Increase (%)
100-Year	35.4	42.4	43.3	2.1	50,645,600	52,259,400	3.2
5-Year	21.1	30.3	31.3	3.3	34,936,100	36,681,600	5.0
2-Year	15.8	24.6	25.6	4.1	28,745,800	30,580,700	6.4

Figure 6-1
100-Year Hydrograph Comparisons

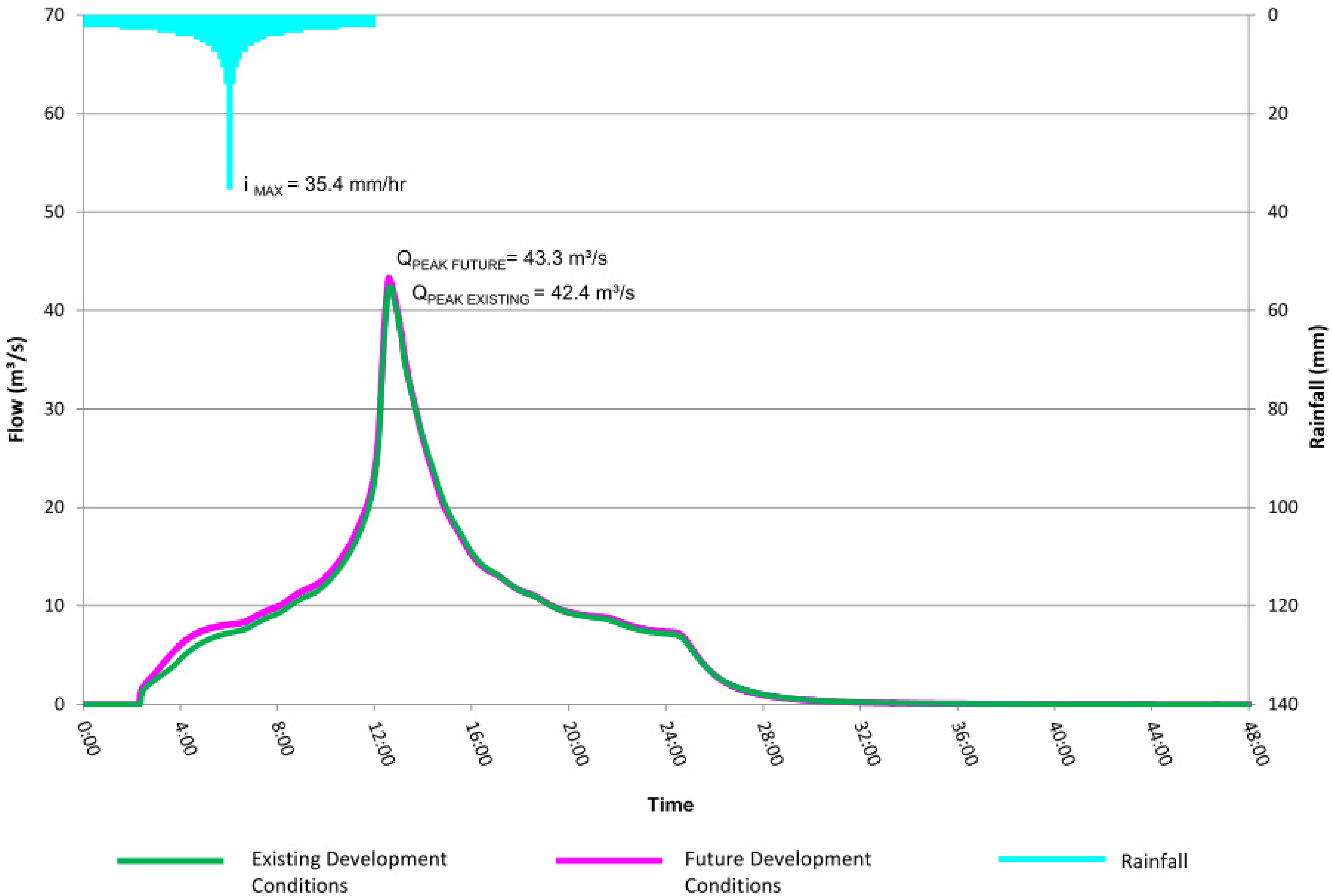


Figure 6-2
5-Year Hydrograph Comparisons

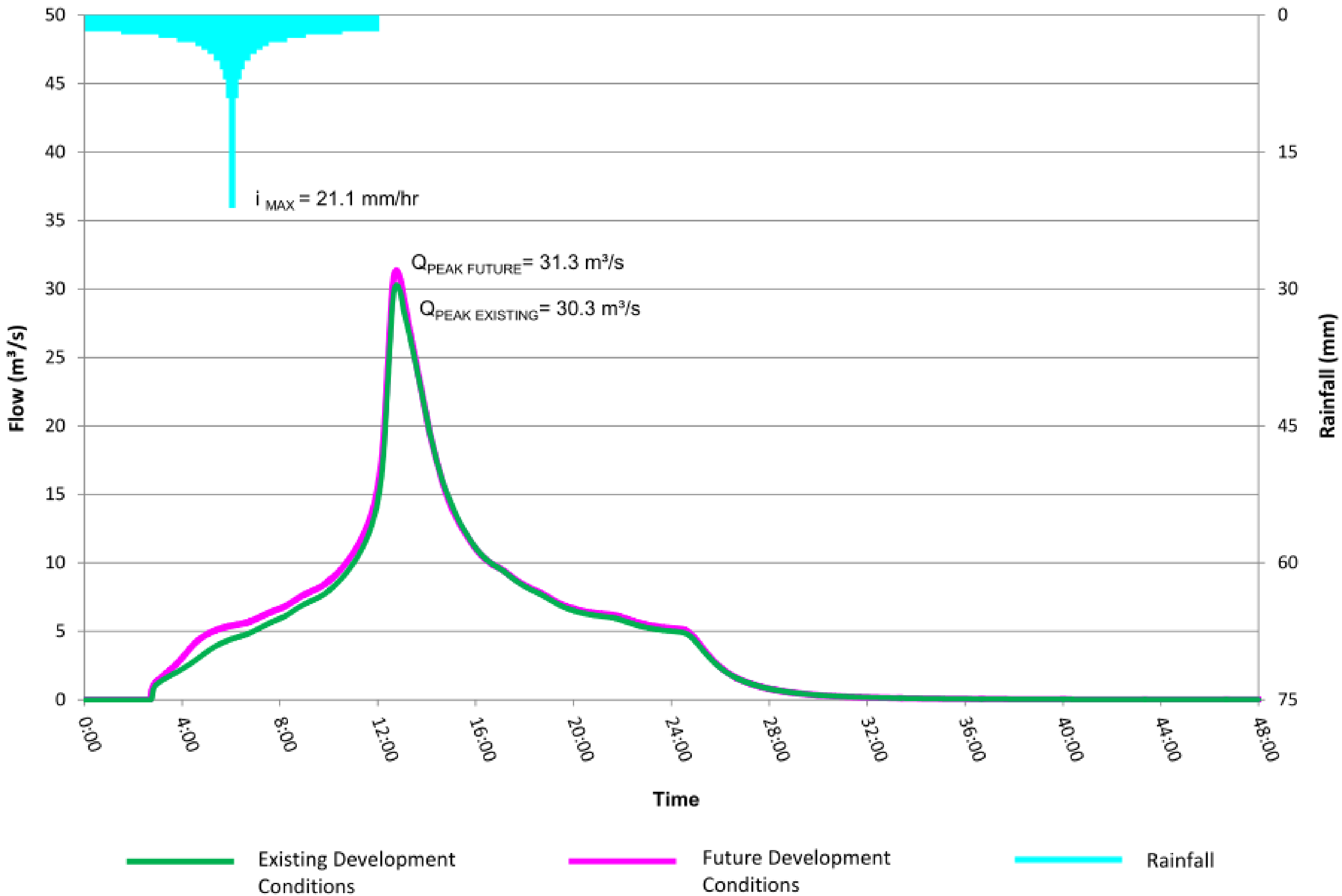
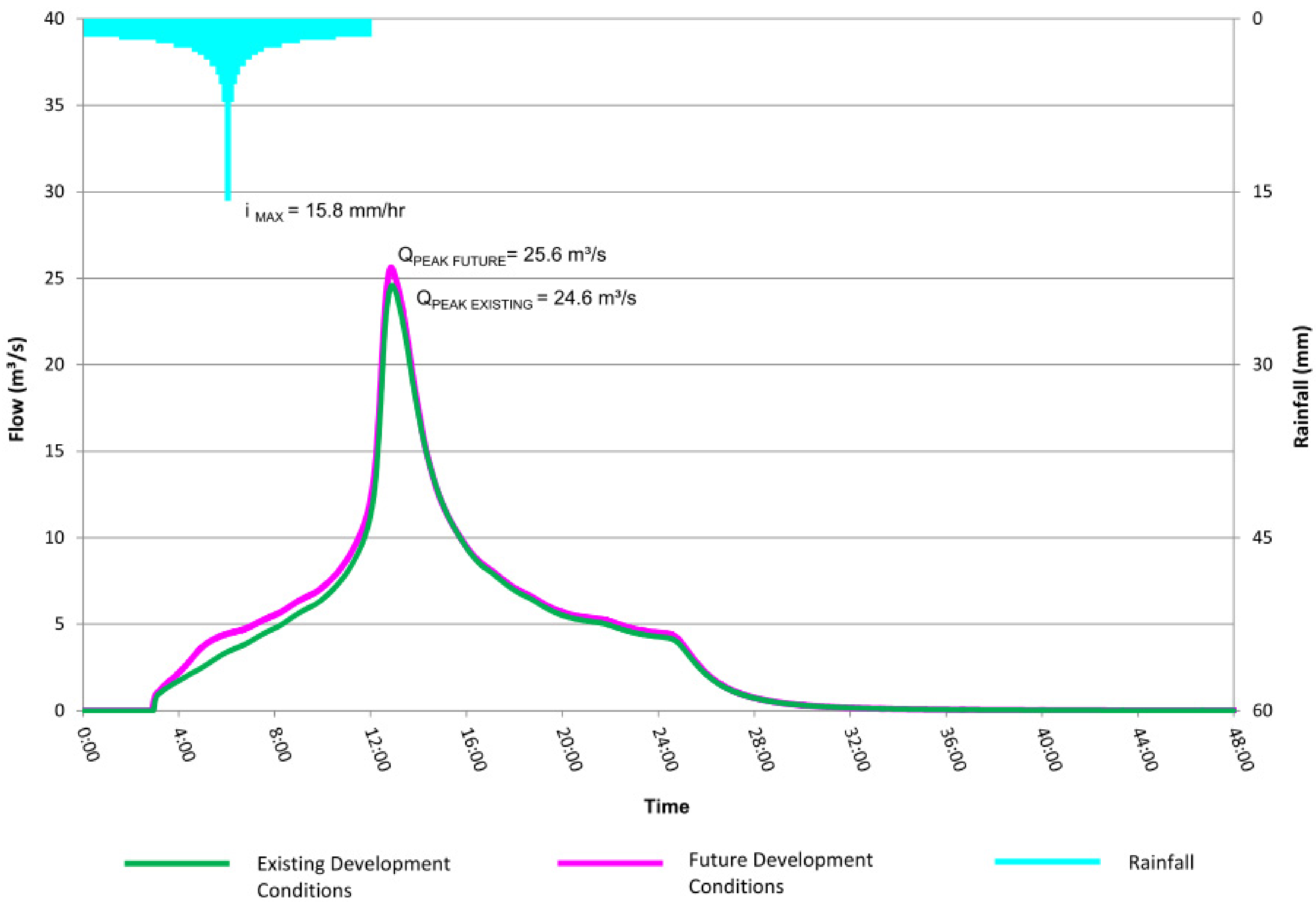


Figure 6-3
2-Year Hydrograph Comparisons



The hydrographs from the existing and future development conditions generally peak within five minutes of each other and have very similar shapes in their rising limbs and recession limbs. Future condition hydrographs indicate greater peak flow rates and larger total runoff volumes.

6.2.3 Hydraulic Deficiencies

The hydraulic deficiencies encountered under existing development conditions will remain or become worse under future development conditions. Surcharging that occurs in storm sewers under existing development conditions is expected to increase by an average of approximately 0.05 m under future development conditions. Refer to Table 6-4 for a summary.

Table 6-4
Changes to Surcharged Storm Sewers under Future Development Conditions

Size	Average Increase in Surcharging (m)
< 600 mm Ø	0.000
600 mm Ø to 750 mm Ø	0.035
825 mm Ø to 1050 mm Ø	0.082
> 1200 mm Ø	0.079
Total	0.048

An additional seven storm sewers in three locations within the study area are expected to surcharge under future development conditions. Two locations are within systems that were already surcharged under existing development conditions. The other is a newly affected area. Refer to Map 6-2 for their locations.

6.3 IDENTIFIED PIPE UPGRADES

If the City of Surrey wishes to eliminate surcharging storm sewers within the Cruikshank and Grenville watersheds, approximately 10,115 m of storm sewers will need to be upgraded to service existing land use conditions and an additional 1,410 m of storm sewer will need to be upgraded to service future projected land use. Refer to Maps 6-3A to 6-3F for the locations and Table 6-5 for a summary of the upgrade sizes and associated costs. Note that inverts and slopes were assumed to be maintained, new storm sewers were assumed to be concrete pipe, and culverts were assumed to be concrete box structures. Detailed pipe segment information is included in Appendix D.

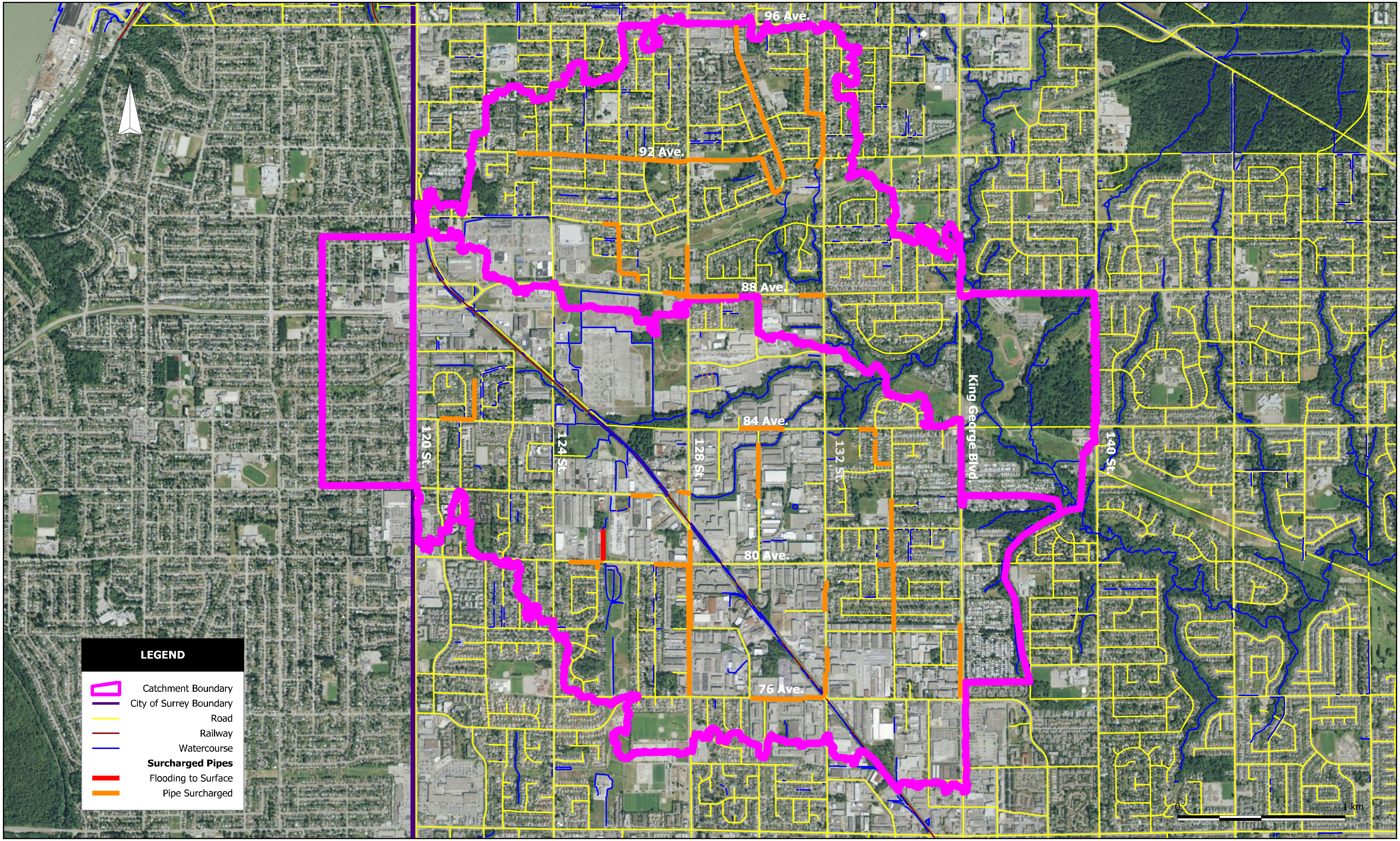
Table 6-5
Summary of Identified Pipe Upgrades

Size	Length (m)		Unit Cost ($/m)	Total Estimated Cost ($) (Rounded to Nearest Ten Thousand)	
	Existing	Future		Existing	Future
Storm Drainage Pipes (Minor System)					
675 mm Ø	1,228	1,826	$900	$1,110,000	$1,650,000
750 mm Ø	107	195	$950	$110,000	$190,000
825 mm Ø	475	596	$1,000	$480,000	$600,000
900 mm Ø	2,282	2,056	$1,040	$2,380,000	$2,140,000
1,050 mm Ø	2,088	1,934	$1,130	$2,360,000	$2,190,000
1,200 mm Ø	2,457	3,361	$1,200	$2,950,000	$4,040,000
1,350 mm Ø	968	947	$1,280	$1,240,000	$1,220,000
1,500 mm Ø	402	203	$1,350	$550,000	$280,000
1,800 mm Ø		243	$1,470		$360,000
Culverts (Major System)					
600 mm Ø	10	10	$8,500	$90,000	$90,000
750 mm Ø	15	15	$9,500	$150,000	$150,000
1.20 m x 1.35 m box	21	21	$18,000	$380,000	$380,000
1.20 m x 1.50 m box	27	27	$20,000	$540,000	$540,000
1.20 m x 1.50 m box	33	33	$25,000	$830,000	$830,000
Total	**10,113**	**11,467**		**$13,170,000**	**$14,660,000**

We note that the identified pipe system upgrades are based on a watershed scale model analysis. As such, all identified drainage system upgrades, should be confirmed by detailed analysis prior to entering the design and implementation process.

Similarly, the necessity of identified culvert upgrades should be confirmed by assessing the following:

- depth of surcharge relative to road crest spill elevations,
- the impacts to upstream properties and infrastructure due to backwater conditions,
- and the potential for high seepage pressures to destabilize road fills.



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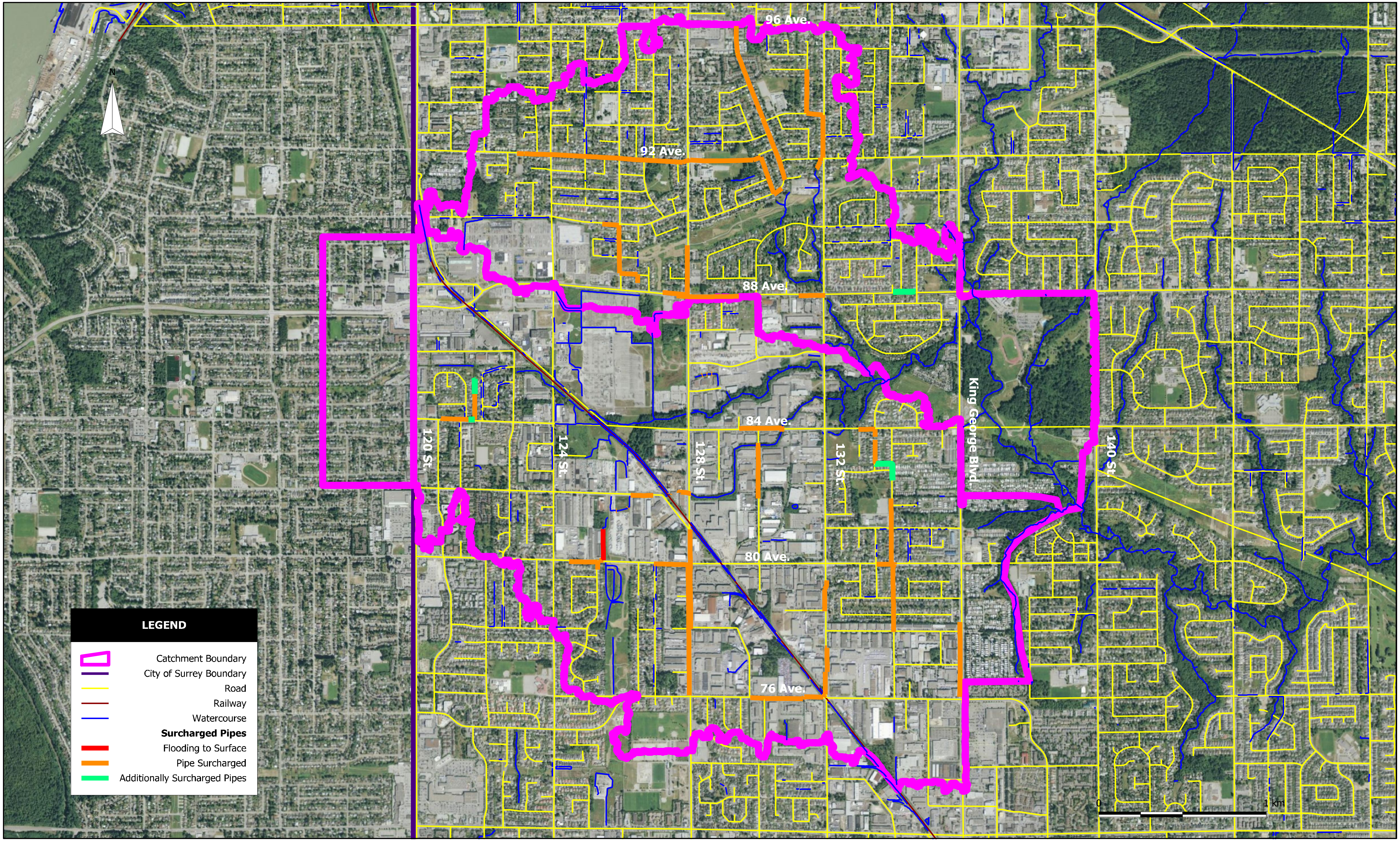
Map 6-1: Minor System Deficiencies - Existing Development Conditions



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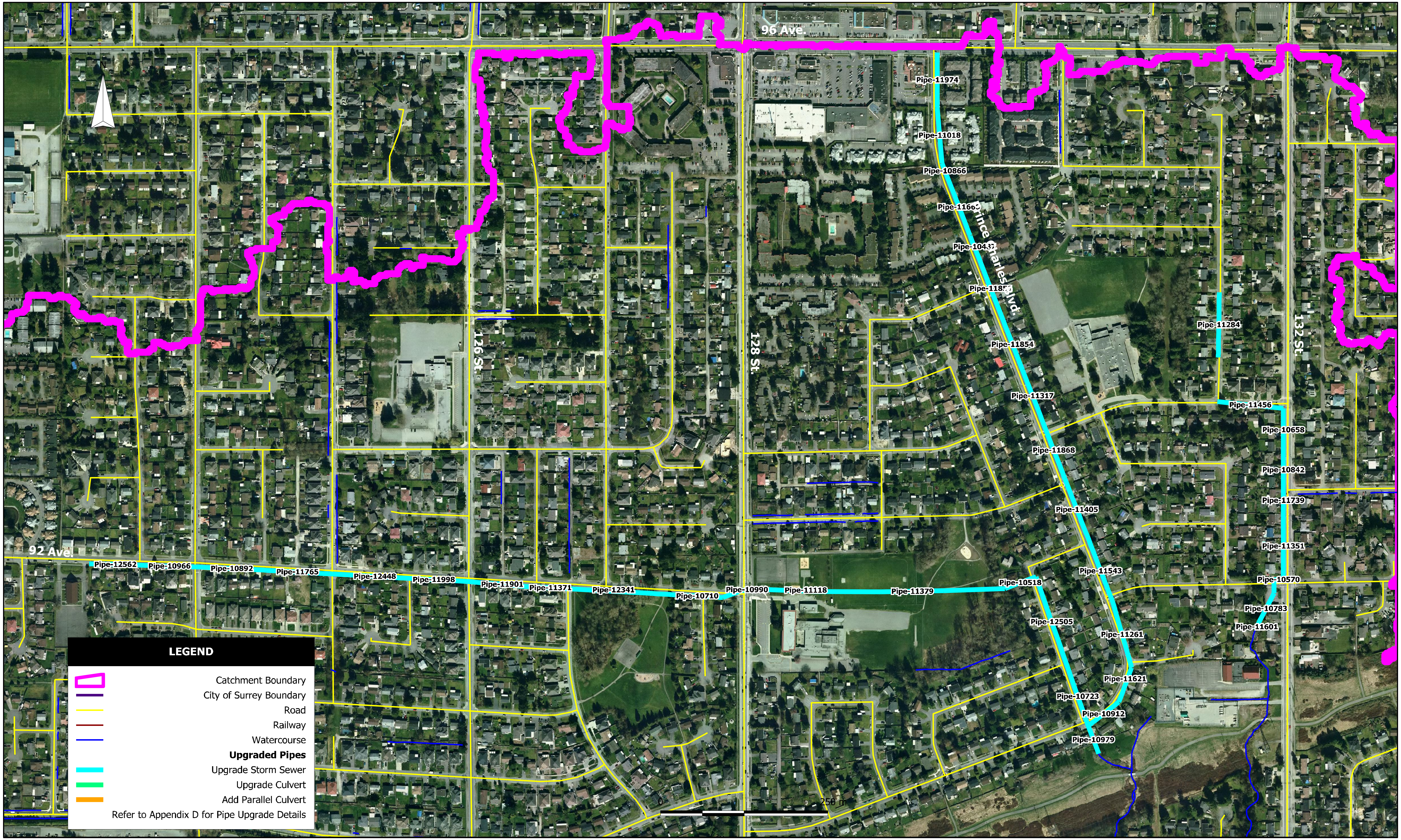
Map 6-2: Minor System Deficiencies - Future Development Conditions



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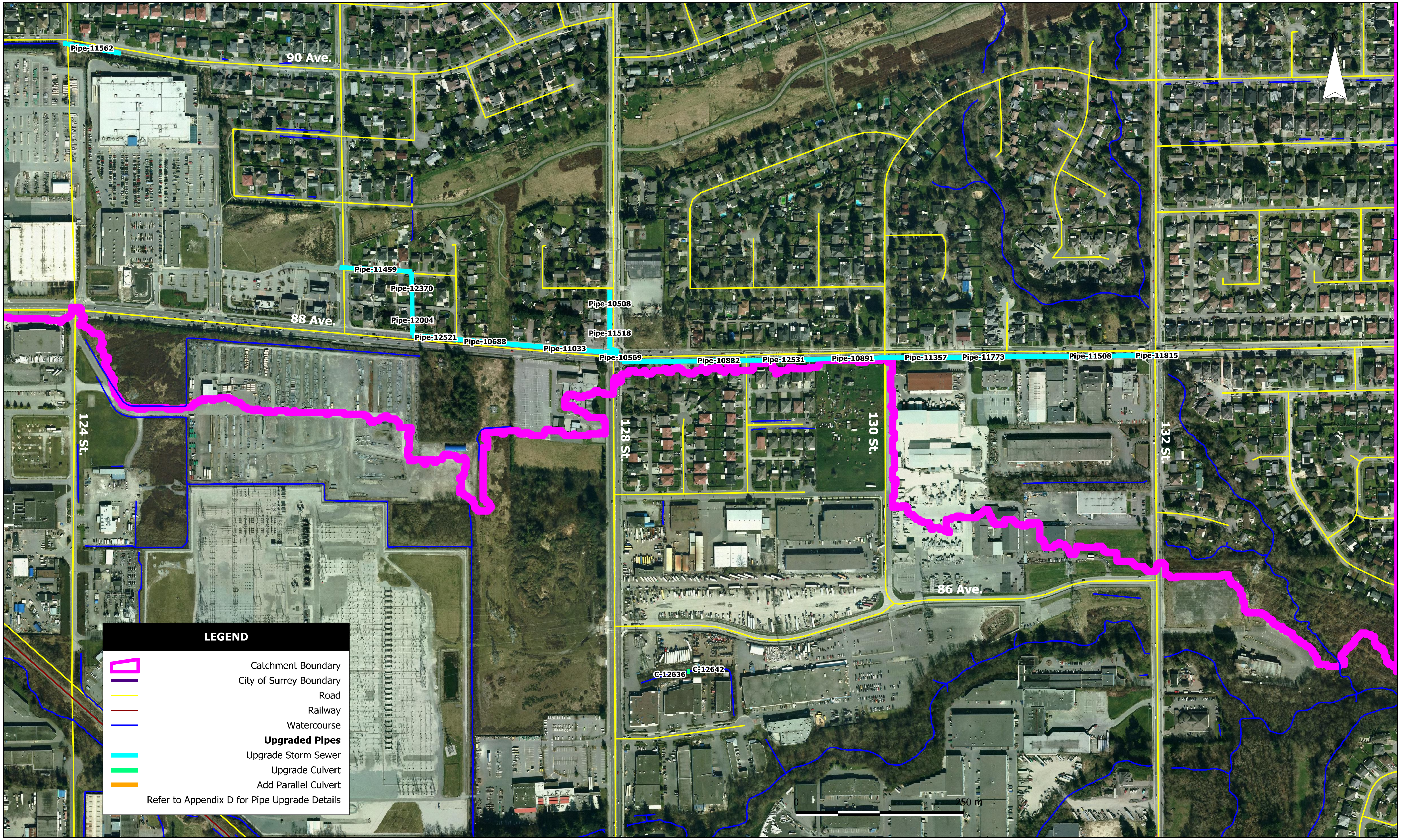
Map 6-3A: Minor System Upgrades



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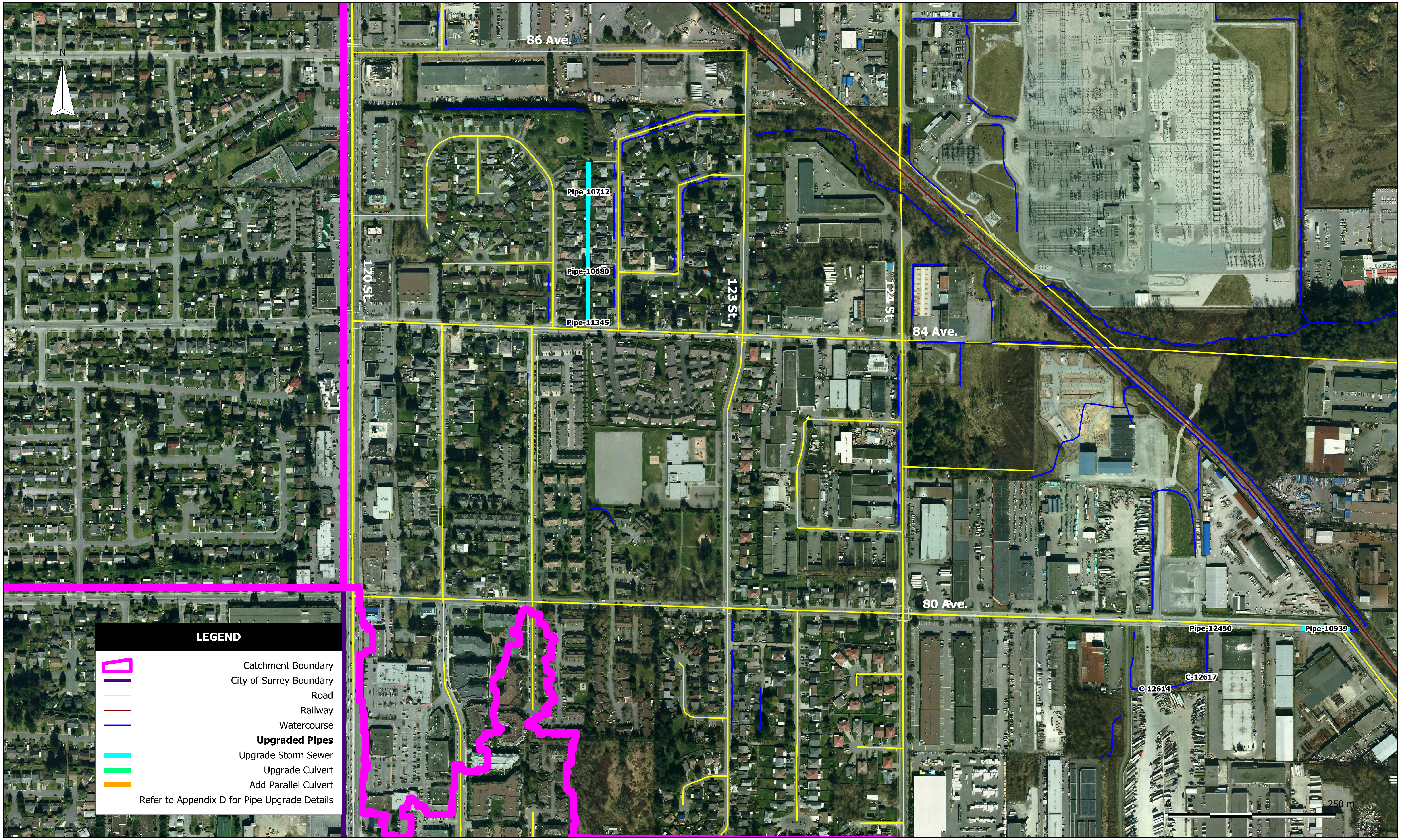
Map 6-3B: Minor System Upgrades



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Map 6-3C: Minor System Upgrades

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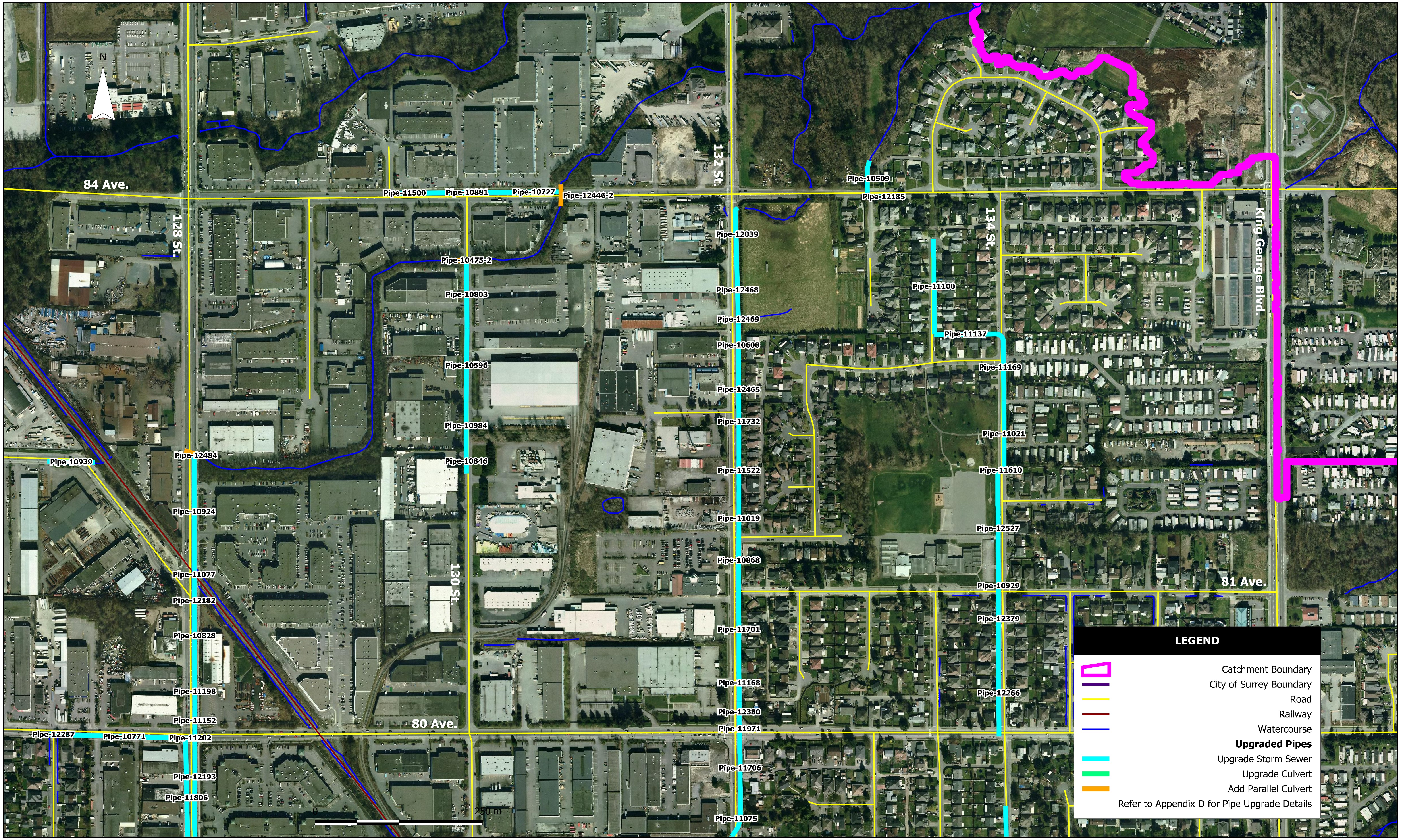

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Map 6-3D: Minor System Upgrades

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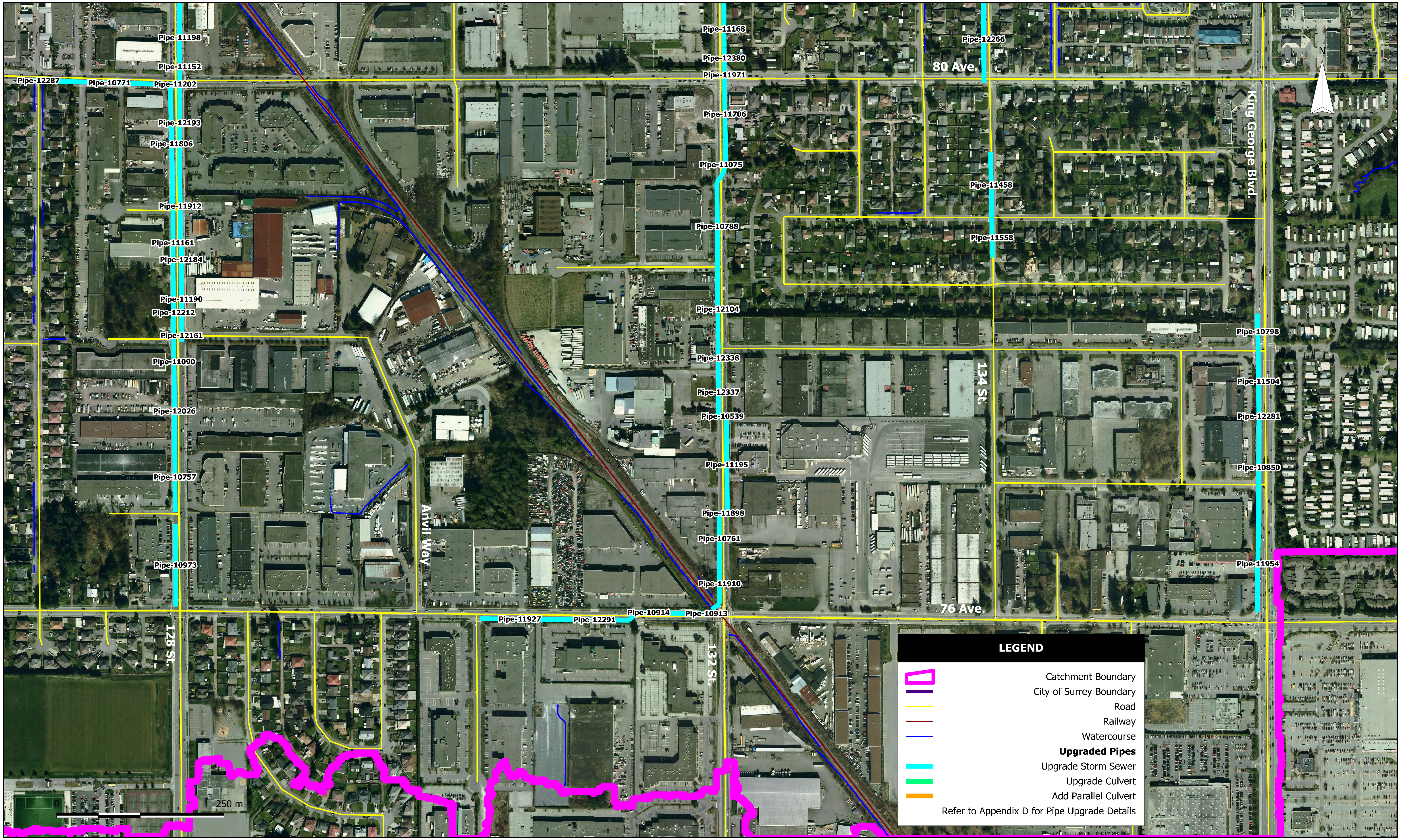

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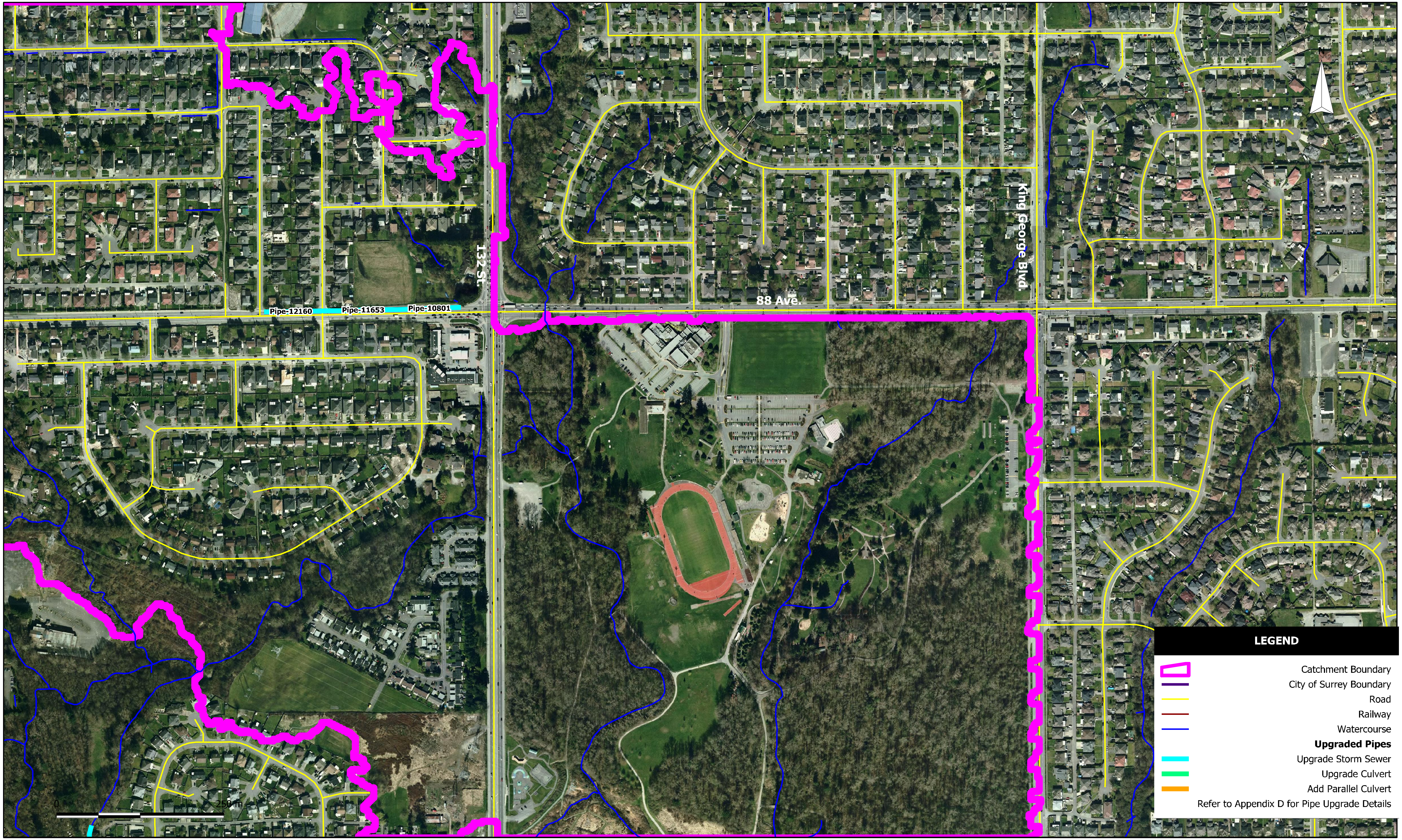
Map 6-3E: Minor System Upgrades



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Map 6-3F: Minor System Upgrades

7 Goals and Objectives

In a broad context, the objective of this ISMP is to create a document that defines the direction of change for the Grenville and Cruikshank watersheds that meets the short term and long term development objectives of the City of Surrey while meeting the specific needs of the watersheds and preventing environmental degradation. A primary objective of most ISMPs is to balance flood protection with sustainable community planning. Environmentally, the bare minimum standard is to maintain existing watershed health and functionality, combined with no-net loss of aquatic habitat, though this is increasingly seen as insufficient for watersheds that are already significantly impacted.

As indicated in Section 3, the Cruikshank and Grenville watersheds retain significant functionality as fish habitat. A majority of the surviving watercourses have documented fish presence or have a supporting role in providing food and nutrients (Refer to Map 3-5). Preservation of the remaining habitat value is important and suitable measures are required to prevent further degradation and to provide opportunities for improvement.

Accordingly, the following are the specific objectives of the Cruikshank and Grenville ISMP:

- Prevent flooding and promote health and safety within the watersheds.
- Direct long-term re-development and economic activity to more sustainable practices, including the widespread application of feasible green infrastructure, and stewardship principles.
- Provide a healthier and more appealing watershed for the people who live and work in it, by improving amenities such as green space, passive recreational and park areas.
- Protect and enhance aquatic and terrestrial habitat.
- Improve overall watershed health.

These objectives are translatable into specific goals and measures, including:

- Preserve existing green space and undeveloped lands.
- Restore riparian corridors in association with re-development opportunities.
- Reduce overall watershed effective impervious area in association with re-development opportunities and infrastructure renewal.
- Enhance fisheries habitat.
- Maintain and improve terrestrial habitat connectivity.
- Define and enforce water quality management objectives.
- Manage rainfall on site to improve the hydrological characteristics of the watershed, and better replicate natural conditions.

However, even the goals stated above are not defined in terms of the desired level of effort and outcomes. If improvement in watershed health and community sustainability is desired, then how far should we go? This question remained as a key point of discussion as this ISMP was developed.

We revisited and refined the list of goals and objectives throughout the development of the Cruikshank and Grenville Integrated Stormwater Management Plan to ensure practical and enforceable stormwater management strategies.

In consideration of the goals and objectives presented above, we propose the following vision statement for the Cruikshank and Grenville ISMP:

"The vision for the Cruikshank and Grenville ISMP is to achieve a significant improvement in watershed health and the aesthetic and community values in the watershed. This ISMP will present a strategy for the successful implementation of stormwater best management practices that balance economic activities in the watershed with preserving and enhancing natural features, environmental health and engaging the public."

The City of Surrey has several policy and land use planning tools in place to facilitate controlled development. We have highlighted components of each tool that can be applied within the Cruikshank and Grenville watersheds to help to meet the goals and objectives of the ISMP. In Section 8 of the ISMP we will expand upon the concepts behind these tools to develop stormwater management solutions for the Cruikshank and Grenville watersheds.

7.1 POLICY TOOLS

A number of Surrey's policy documents establish the context for stormwater management and environmental protection and enhancement. These are discussed below.

7.1.1 Sustainability Charter

The City's Sustainability Charter sets high level and specific goals, as well as actions based on social, economic and environmental pillars of sustainability; the City's three spheres of influence are short, medium and long time frames. Supporting the implementation of the Sustainability Charter, the City generated 87 indicators and targets. The following are two specific targets relevant to this ISMP:

- 40% minimum tree canopy cover by 2058 to achieve a healthy urban forest, excluding ALR lands.
- 50% of total urban area with vegetative coverage by 2058 excluding the ALR.

7.1.2 Official Community Plan

The City of Surrey's Official Community Plan (OCP) is currently in the process of being updated with some key components being managing growth for compact communities and protecting natural areas. There are policies related to retaining significant trees, replacing trees based on the Tree Protection Bylaw, managing the quality and quantity of stormwater to help protect and enhance aquatic habitats, and protecting the quality and integrity of ecosystems.

The OCP does not include specific policies related to rainwater management or low impact development. Recommendations of this nature have been developed as part of this ISMP.

Neighbourhood Concept Plans (NCPs) provide more detail on future land use, and these have been prepared for 17 neighbourhoods in the City, with more under way. Currently there are no NCPs completed or underway for the Cruikshank and Grenville watersheds.

7.1.3 Tree Canopy Cover Analysis

The study, Balancing Growth of Today with Trees for Tomorrow: City of Surrey Tree Canopy Cover Analysis has not been adopted by Council; however, it is providing City staff with background information that is enabling them to better manage the City's tree canopy. Using the data and methods from that study, the Cruikshank and Grenville ISMP study area has an overall tree canopy cover of 14.5%. Calculating the two watersheds individually, the tree canopy in the Grenville watershed is 21% of the total land area (largely due to Bear Creek Park), and the tree canopy in the Cruikshank watershed is 10% of the total land area.

7.2 LAND USE PLANNING TOOLS

The Cruikshank and Grenville watersheds are almost completely developed with the primary land uses being industrial and urban residential. Most of the urban residential areas, which are designated as "urban" OCP, are currently single family housing. There are two commercial areas (see Map 7-1) and several higher density residential developments.

Bear Creek Park is the largest green space in the study area. In addition, there are some creek corridors, smaller parks and greenways (mostly along power lines), most of which are relatively narrow ribbons of green winding through the watershed.

Anticipated changes in land use include:

- Potential development of approximately five to ten privately owned properties that are currently vacant or lightly developed.
- Re-development of the Scott Road corridor south of Nordel Way to more commercial or mixed use and less industrial development.
- Re-development of the 128 Street corridor between 80 Avenue and 84 Avenue to more commercial or mixed use (CD zone) and less industrial development.
- Additional industrial development on the BC Hydro property.
- Additional commercial development on the Smart Centres property.
- Re-development of the Cedar Hill Shopping Centre, likely to mixed use.

7.3 SURREY'S ECOSYSTEM MANAGEMENT STUDY

Surrey's Ecosystem Management Study (EMS) (HB Lanarc, 2011) provides an update to and an enrichment of the City's environmental areas mapping as currently identified in the Official Community Plan.

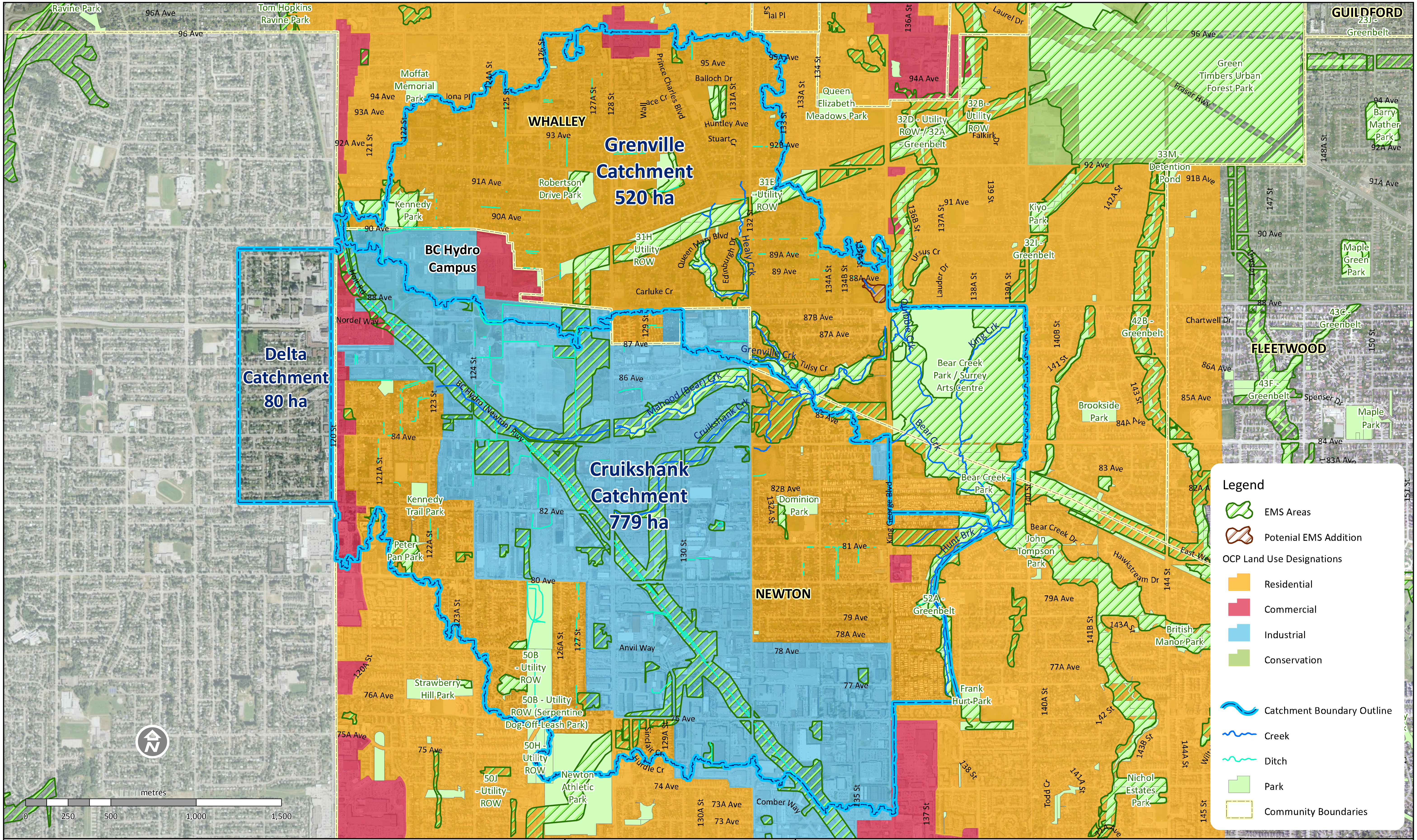
The EMS is based on a City-wide Green Infrastructure Network (GIN) where all parts of the City have a role to play in the creation and enhancement of ecological processes. Phase 1 of the EMS includes the mapping, proposed ecosystem management strategies, and topics for policies and guidelines. Phase 2 of this project will identify the management strategies in more detail.

The EMS mapping and related policy directions will replace the existing environmental ESA mapping and development permit area guidelines in an updated OCP. The EMS identifies a City-wide network of "hubs", "sites" and "corridors" that support the quality of communities and sustain ecological processes and their functions (see Map 7-2). Hubs and sites were identified based on their relative size and the degree of "naturalness" of the vegetation they contained.

The EMS Phase 1 report identifies nine proposed ecosystem management strategies, of which the following are most relevant to the Cruikshank and Grenville ISMP:

1. Continue to develop programs and information to raise public and development community awareness and understanding of ecosystem planning and management.
2. When considering Neighbourhood Concept Plans and development applications, work to ensure that the core areas of key remaining large natural areas (hubs) are protected in sufficient scale to be refuges of biodiversity, while having regard to economic and social priorities.
3. Give priority to the protection and/or restoration of effective aquatic and/or wildlife corridors that link hubs and sites together, so that plant and animal species are able to disperse and intermix for genetic diversity and population security.
4. Where possible, integrate smaller natural sites and neighbourhood tree canopy and 'naturescape' practices into the general urban matrix.
5. Continue with City strategies that effectively manage stormwater, control sediment and erosion, promote tree cover and minimize harmful emissions recognizing that clean water and natural stream flow regimes, clean air, and mitigation of climate change are key ingredients to support a Green Infrastructure Network.
6. Incorporate protection and restoration of ecosystems and biodiversity into the planning and development processes of the City. Neighbourhood scale planning in particular should incorporate green infrastructure features as a part of any development planning or development application process.

Given the importance of the EMS, we recommend that properties within or bordering EMS areas implement additional best management strategies.



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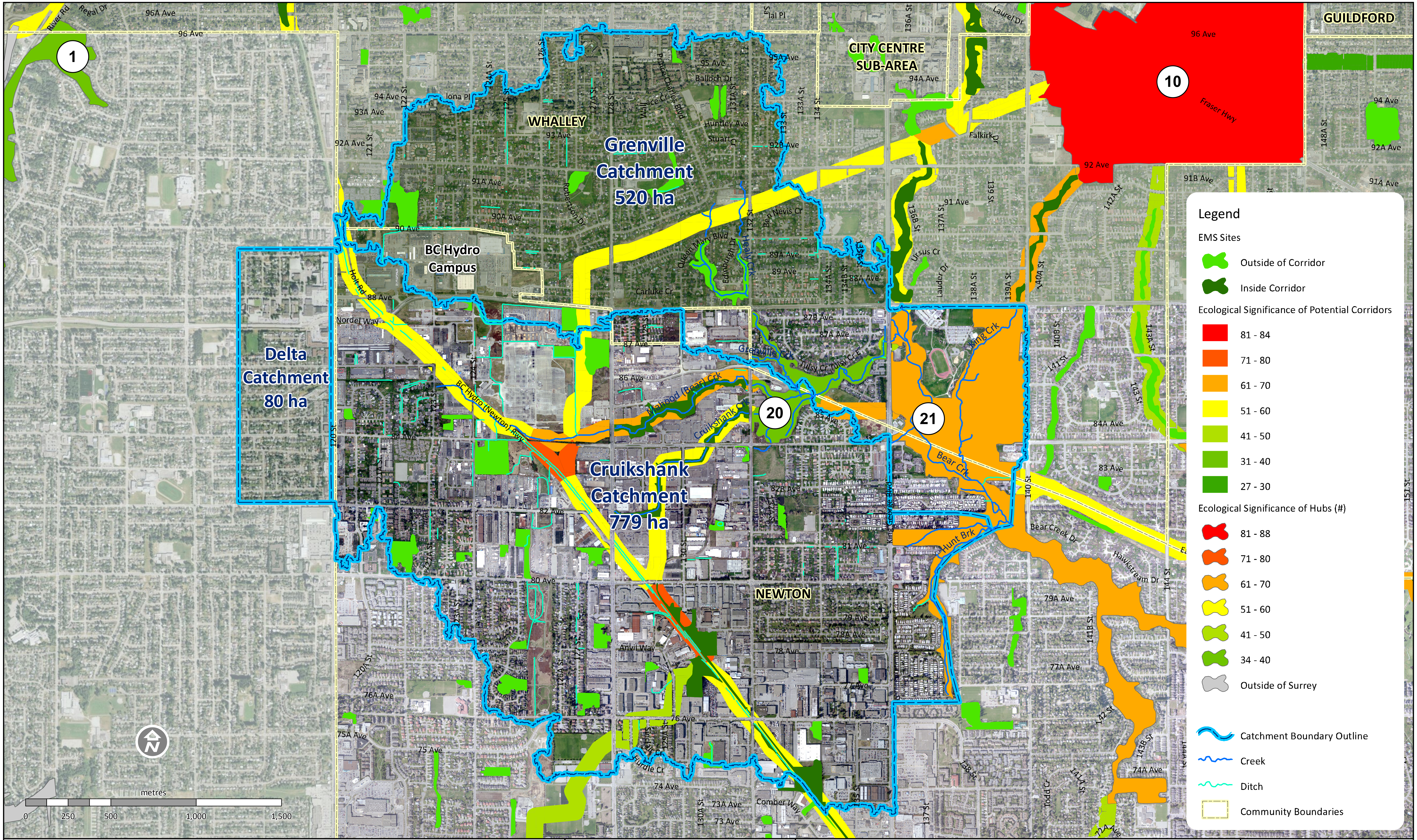
Map 7-1: EMS Areas and Generalized Land Use

Date: August 2012



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Map 7-2: EMS - Ecological Significance

Date: August 2012

8 Application and Evaluation of Best Management Strategies

In this section of the ISMP we discuss and outline stormwater management strategies that can be applied within the Cruikshank and Grenville watersheds. A combination of strategies will be needed to effectively manage stormwater at the site, sub-watershed, and watershed levels. Stormwater best management strategies include source controls, which are defined as approaches to land development or re-development that work to manage stormwater close to its source.

We note the results of our extended period simulation, which indicate an increase in total runoff volumes of 8% over the course of five (5) years of rainfall (Section 6.2, Table 6-2) as an impact of future development conditions. While increases in peak flow rates may be addressed by detention storage, mitigating increases in total runoff volume requires source controls to counteract increases in total impervious cover. If not mitigated, increased runoff volumes represent a direct increase in the erosive power of watercourses with degraded fish habitat and increased stream instabilities as a consequence.

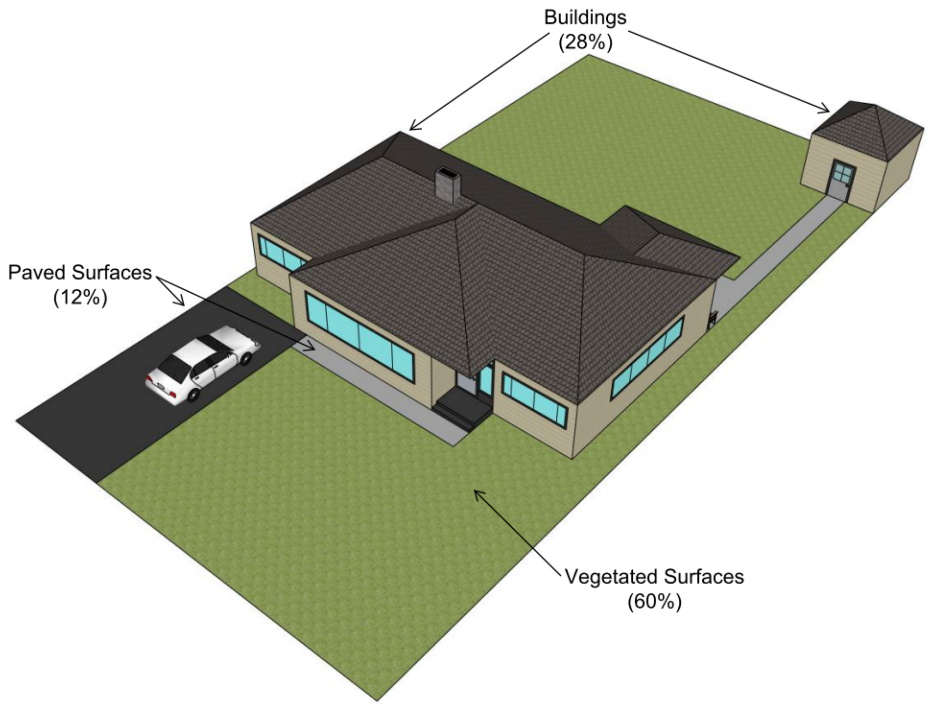
Excluding watercourse setbacks, the majority of the available land base in both the Cruikshank and Grenville watersheds is currently developed. Accordingly, the majority of future development activity within these watersheds will consist of re-development and densification of already altered lands. The strategies described in this section of the report can be applied to both new development and re-development projects. The identified best management strategies are presented in this section based on the land use to which they will be applied. We present recommendations for privately owned urban residential lots, commercial, industrial, and multiple residential lots, publicly owned road rights-of-way, and other City owned property.

8.1 URBAN RESIDENTIAL LOTS

Urban residential development within the Cruikshank and Grenville watersheds consists primarily of single family residential dwellings. According to existing zoning mapping, urban residential development currently represents approximately 51% of the study area. According to the City of Surrey Official Community Plan, urban residential development will comprise approximately 49% of the study area in the future. The majority of urban residential development will consist of re-development of existing urban lots.

We examined building footprint information provided by the City of Surrey and satellite imagery of the study area to determine the composition of older existing urban residential lots. We determined that older lots typically have percent total impervious areas of 40 % and are generally comprised of a single house, backyard shed, paved driveway, paved walkways, paved backyard patio, and vegetated front, side and rear yards. Buildings typically comprise 28%, paved surfaces cover 12%, and vegetated surfaces make up 60% of older existing lot areas (Figure 8-1).

Figure 8-1
Older Urban Residential Lots

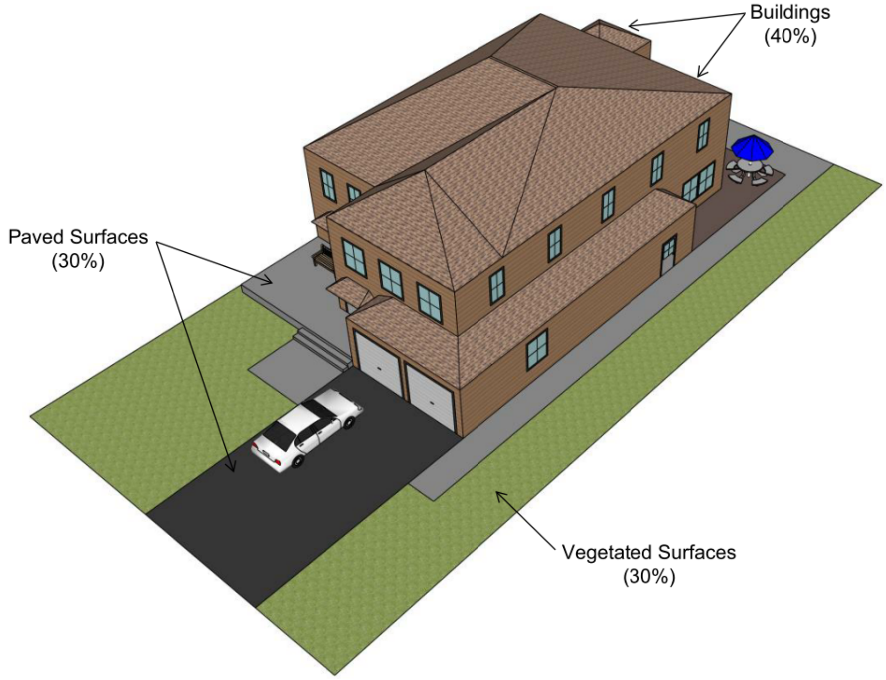


For comparison, we used building footprint information provided by the City of Surrey and satellite imagery of the study area to identify the composition of recently developed and redeveloped urban residential lots, which we assume to be representative of current and future urban residential development forms. We also consulted the City of Surrey Zoning Bylaw 12000 that specifies maximum lot coverage of 40%. We determined that recently developed lots typically have total impervious coverage of 70 % and are generally comprised of:

- a single house,
- backyard shed,
- paved driveway and walkway,
- impervious porch,
- paved backyard patio,
- paved service area,
- and vegetated front, side and rear yards.

Recently constructed buildings typically have larger footprints than older buildings, comprising approximately 40% of future lots. Paved surfaces on recently developed lots generally occupy an additional 30% of the lot area leaving the remaining 30 % as vegetated surfaces (Figure 8-2).

Figure 8-2
More Recently Developed or Re-Developed Urban Residential Lots



Recently developed and re-developed urban residential lots have total impervious coverages that are approximately 30 % higher than older urban residential lots. Without applying appropriate best management practices, future urban residential development will significantly increase the effective impervious area within the Cruikshank and Grenville watersheds. In order to partially mitigate the impacts of coverage changes on future urban residential lots, measures to reduce total runoff volumes and slow the movement of water from lots are required.

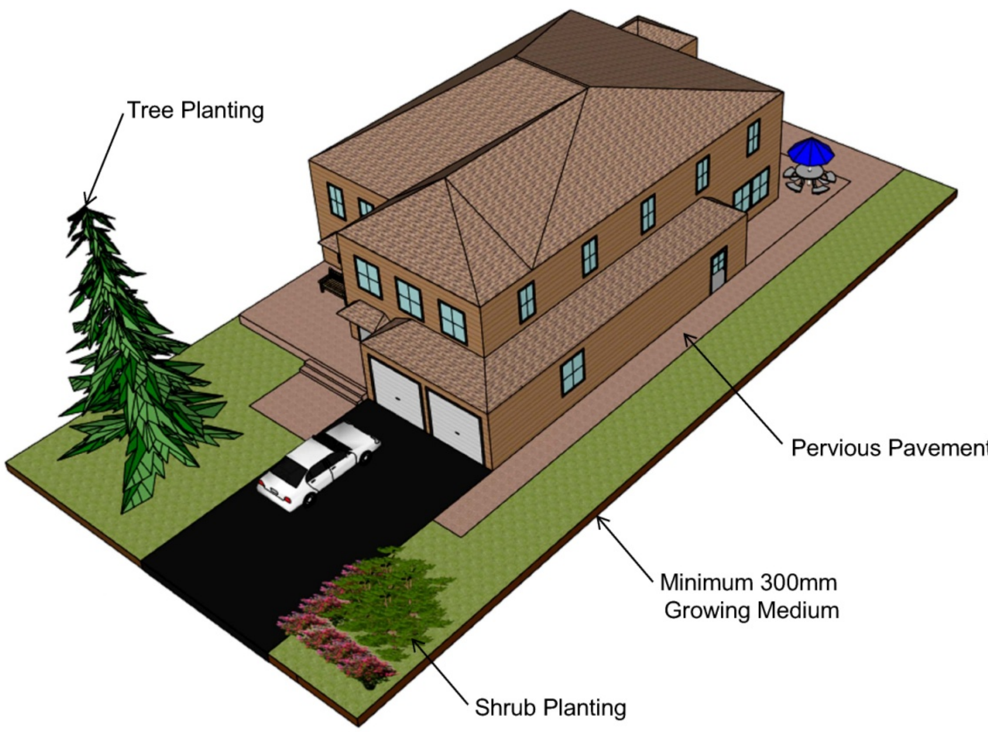
8.1.1 Recommended Source Controls

Source control stormwater best management strategies mitigate the negative hydrologic effects of development. Source controls focus on preserving existing natural areas or creating landscape features through progressive planning and construction initiatives to promote managing runoff at its source. Source controls decrease runoff volumes and peak runoff rates reducing the load placed on receiving watercourses and improving overall watershed health. We recommend that the following source control measures be applied to urban residential lots in both ISMP watersheds:

- Shrub Planting,
- Tree Planting,
- Growing Medium Depth, and
- Pervious Pavement.

The City indicated that it has a greater ability to monitor and control what property owners construct or place in their front yards than in their back yards. For that reason, front yard source controls are more viable and will be the focus of source control approaches for single family urban residential lots. The application of each source control to future urban residential lots are described in detail below and shown in Figure 8-3.

Figure 8-3
Typical Future Urban Residential Lot with Source Controls



Shrub Planting

Shrub planting consists of a variety of native herbaceous vegetation with a thickly matted rooting zone. Shrub planting should be underlain with a minimum 450 mm growing medium to promote plant growth and provide important hydrologic functions such as water-holding capacity and pollutant and sediment absorption. We recommend that shrubs be concentrated at the downstream section of urban residential lots, where possible, to allow runoff to drain to the plantings. If present, suitable existing shrubs should be preserved and protected from disturbance during construction.

Tree Planting

Tree planting consists of native deciduous and coniferous trees with high leaf density. Tree planting should be underlain with a minimum 600 mm growing medium to promote plant growth and provide important hydrologic functions. We recommend that tree plantings be located in depressions to ensure that runoff flows in their direction. Large established trees will provide more significant hydrologic functions than smaller newly planted trees. If suitable trees are not present within the existing lot, we recommend that trees be planted as soon as possible, be adequately maintained with ties and stakes, and be protected from disturbance. During the construction process trees and their growing medium should be protected from compaction, erosion, and deposition of materials.

Enhanced Growing Medium Depth

A minimum 300 mm growing medium for landscaped areas not containing shrubs or trees, such as lawns, will provide important hydrologic functions such as water-holding capacity, pollutant and sediment absorption, and promotion of grass growth. Ideally, all pervious surfaces that do not contain shrub or tree plantings should consist of a grassed lawn underlain by a minimum 300 mm growing medium. All pervious surfaces should be protected from compaction, sediment, and erosion during construction so that its hydrological properties are maintained.

Areas with shrubs or trees should be provided with a greater depth of growing medium, 450 mm and 600 mm, respectively.

Pervious Pavement

Pervious pavement provides for movement of water through surfaces that would conventionally be paved, which reduces runoff volumes and flow rates, and improves water quality. On urban residential lots, pervious pavement can replace paved driveways, walkways, porches, patios, and service areas. According to the Metro Vancouver Stormwater Source Control Guidelines, pervious pavement is most suitable for low traffic areas.

8.1.2 Source Control Performance Targets

We developed performance targets for urban residential lots. A combination of the above source control measures should be combined to achieve the target peak flow rates and runoff volumes. We used the Water Balance Model (WBM) to evaluate the effectiveness of source control measures applied to urban residential lots. The WBM is a web-based tool that enables the user to determine the hydrologic benefits of applied source controls. Hydrologic information including areas occupied by rooftops, impervious pavement, and pervious cover and the presence of source controls such as shrub plantings, tree plantings, growing medium, pervious pavement, green / detention roofs, bioswales / infiltration trenches, and rain gardens were entered into the WBM. Rainfall data was based on records from the Surrey Kwantlen Park station from 1965 to 1990. The WBM then generated an approximate 25-year runoff volume per area of development which we related to a corresponding effective impervious ratio. Volume and flow rate targets per hectare of urban residential development are listed in Table 8-1.

Table 8-1
Source Control Performance Targets for Urban Residential Lots

Event	Total Rainfall Depth	Target Peak Flow Rate	Total Rainfall Volume (m^3 / hectare)	Target Runoff Volume (m^3 / hectare)
24 hour 2-Year Return Period Event	64.8 mm	3 L/s / hectare	648	535
Mean Annual Total Rainfall	1650 mm	N/A	16,500	9,700

The hydrological benefits and improvements to watercourse health achieved through source control measures are discussed in Section 8.8. The results presented above indicate that 17% of the 24 hour, 2-year return period rainfall volume is dissipated and does not become direct runoff, while 42% of the mean annual rainfall volumes is similarly dissipated.

Applied source control measures will be selected by property owners or developers. Any combination of the above listed source controls can be used to achieve the 2-year return period event and mean annual total rainfall target peak flow rates and runoff volumes. For reference, we included typical unit prices of each source control. Detailed cost estimates can be found in Appendix D and are summarized in Table 8-2.

Table 8-2
Urban Residential Source Control Unit Prices

Source Control	Unit Price ($/$m^2$)
Shrub Planting	$30
Tree Planting	$30
Enhanced Growing Medium	$15
Pervious Pavement	$115

8.1.3 Urban Residential Development within EMS Zones

Since urban residential lots within the study area do not individually represent a large area, imposing significant setback requirements when bordering on EMS zones may be onerous or make lot development unfeasible. To maintain the ability to develop urban residential lots bordering or extending within EMS zones and provide enhanced ecological and hydrologic function, we recommend that the side yard or rear yard adjacent to or within the EMS be planted with native vegetation to a minimum width of 3.6 m. (3.6 m represents the minimum setback from a side yard flanking a roadway as listed in the City of Surrey Zoning Bylaw 12000). (See Figure 8-4).

Figure 8-4
Urban Residential Lots Bordering or Extending within EMS Zones

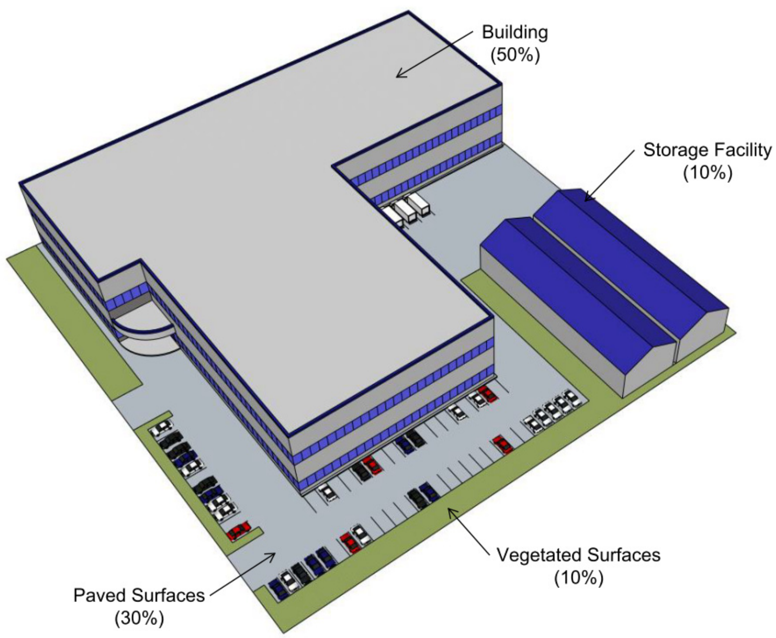
Ideally, minimum setbacks of 15 m of native vegetation will be provided when bordering EMS zones. However, a planted area 15 m wide cannot be accommodated on an individual urban residential lot but likely can be accommodated on a larger multiple residential lots through appropriate placement of structures and facilities. Where the opportunity exists, we recommend that urban residential lots bordering or extending within the EMS be consolidated and rezoned to multiple residential to allow for a greater depth of buffer.

8.2 INDUSTRIAL, COMMERCIAL AND MULTI-FAMILY RESIDENTIAL

Existing industrial development within the study area is located primarily within the Cruikshank watershed on either side of the SRBC railway line that traverses the Cruikshank catchment from northwest to southeast. According to existing zoning mapping, industrial development currently represents approximately 33% of the overall study area. Per the current City of Surrey Official Community Plan, industrial development will comprise approximately 38% of the overall study area in the future. The majority of future industrial development will be re-development of existing industrial properties or conversion of urban residential land use to industrial. Commercial and multiple residential land uses are expected to represent only approximately 3 % and 4 %, respectively, of future development within the study area. We developed identical recommendations for commercial, industrial, and multiple residential developments since these types of developments typically have similar impervious footprints and land utilization characteristics.

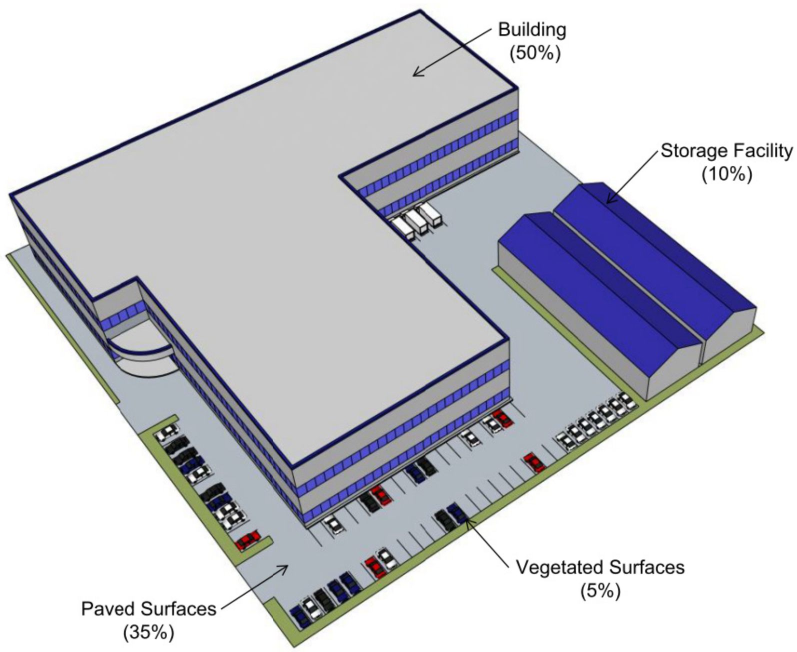
We examined building footprint information provided by the City of Surrey and satellite imagery of the study area to determine the composition of typical older commercial, industrial, and multiple residential lots. We determined that older commercial/industrial lots are generally comprised of a main building, storage facility, paved parking lot and driveways, and open green space. Main buildings typically occupy 50%, storage facilities comprise 10%, paved surfaces cover 30%, and vegetated surfaces make up the remaining 10% of the existing lot area of older industrial developments (see Figure 8-5). Total impervious coverage on existing lots approaches 90%.

Figure 8-5
Older Commercial, Industrial, and Multiple Residential Lots



We examined building footprint information provided by the City of Surry and satellite imagery of the study area and determined that the majority of recently developed or re-developed commercial, industrial, and multiple residential lots have total impervious area ratios of approximately 95%. According to the City of Surrey Engineering Design Criteria Manual (2004), future commercial and industrial developments should have maximum impervious ratios of 90% and future multiple residential developments should have maximum impervious ratios of 80 %. However, recently developed or re-developed industrial and commercial lots tend to have higher proportions of impervious cover when compared to older industrial sites in the area and the City of Surrey design standard (see Figure 8-6).

Figure 8-6
Typical Impervious Coverage on Recent Commercial and Industrial Lots



Older and recently developed or re-developed commercial, industrial, and multiple residential lots within the Cruikshank and Grenville watersheds tend to have very high impervious coverage. Without implementing appropriate best management strategies, future industrial development will continue to negatively impact the hydrologic response of the watershed, resulting in deterioration of stream corridors, stressed infrastructure, and increased flood risk. In order to mitigate the impacts of industrial development, measures to reduce total runoff volumes and slow the movement of water from lots must be implemented.

8.2.1 Recommended Source Controls

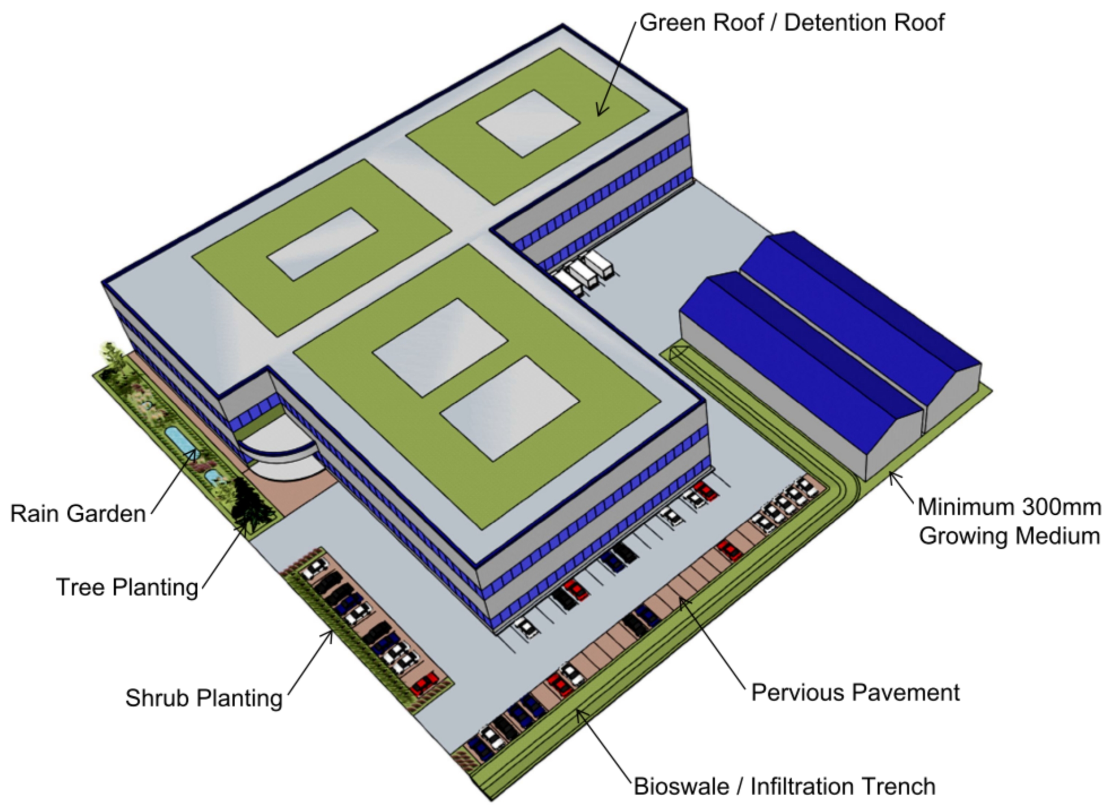
We recommend that the following source control measures be applied to commercial, industrial, and multiple residential lots:

- Shrub planting,
- Tree planting,
- Pervious pavement,
- Green roof / detention Roof or other detention/retention systems,
- Enhanced growing medium depth,

- Bioswale / infiltration trench, and
- Rain garden.

The application of each source control on industrial lots are described in detail below and shown in Figure 8-7.

Figure 8-7
Typical Future Industrial or Commercial Lot with Source Controls



Shrub Planting

Absorbent landscaping such as shrub plantings capture rainfall, reduce runoff volumes and flow rates, and improve water quality by promoting rainfall interception, throughfall and stemflow, evapotranspiration, soil water storage, soil infiltration, interflow and groundwater recharge. Shrub planting should be underlain with a minimum 450 mm growing medium. We recommend that shrubs be concentrated at the downstream section of industrial lots, where possible, to allow runoff to drain to the plantings. If present, suitable existing shrubs should be preserved and protected from disturbance during construction.

Tree Planting

Tree planting acts much like shrub planting to capture rainfall, reduce runoff volumes and flow rates, and improve water quality. Tree planting should be underlain with minimum 600 mm growing medium to promote plant growth and provide important hydrologic functions. We recommend that tree plantings be located in depressions to ensure that runoff flows in their direction. Large established trees will provide more significant hydrologic functions than smaller newly planted trees. If suitable trees are not present within the existing lot, we recommend that trees be planted as soon as possible, be adequately maintained with ties and stakes, and be protected from disturbance. During the construction process trees and their growing medium should be protected from compaction, erosion, and deposition of materials.

Pervious Pavement

Pervious pavement increases the permeability of surfaces that would conventionally be paved, which reduces runoff volumes and flow rates, and improves water quality. On lots, pervious pavement will be most easily applied to walkways and parking spaces. Other paved areas such as driveways and service areas are candidates for pervious pavement but will require structural reinforcement to service heavy surface loads. In soils with partial or low infiltration capabilities, like those in the study area, pervious pavement can be supplemented with an under drain and connected to the storm sewer system or downstream stormwater management facility to prevent excess surface ponding.

Green Roof / Detention Roof or other Surface Detention Systems

Green roofs are tops of buildings that are either fully or partially covered with vegetation. Green roofs intercept and store rainfall that falls directly on the roof promoting evapotranspiration and pollutant removal by vegetation and slowing the movement of water from the runoff. Green roofs can also be designed with shallow storage systems to provide detention storage.

The roof areas of main industrial buildings often occupy approximately 50 % of an industrial lot. Large portions of industrial building roofs are generally occupied by HVAC equipment meaning that not all roof space will be available for use as a green roof. When unusable area is factored out, approximately 50 % of the roof top area, or 25 % of the lot area, is still available for use as a green roof or detention roof. This large area provides an attractive opportunity for stormwater management. If roof space is not available, detention storage can also be provided under parking lots, infiltration holding areas, surface ponds, or through other methods.

Enhanced Growing Medium Depth

On industrial sites, pervious surfaces that do not contain other best management features should at a minimum be grassed surfaces underlain by a minimum 300 mm growing medium. All pervious surfaces should be protected from compaction, erosion, and sediment during construction and under the site's normal operations so that hydrologic properties of the growing medium are maintained.

Landscaped areas with shrubs or trees should be provided with a greater depth of growing medium, 450 mm and 600 mm, respectively.

Bioswale / Infiltration Trench

Bioswales or infiltration trenches are shallow grassed or vegetated channels that capture, detain, treat, and convey stormwater runoff. On industrial sites, bioswales can be constructed adjacent to driveways and roads or located within or around parking lots. Bioswales can also be applied where they receive runoff from conventional drainage installations, such as curb and gutter with catch basins, and provide attenuation and water quality improvement prior to discharging into conventional infrastructure. These applications are loosely termed gray-green-gray systems. We recommend that industrial sites be graded to allow runoff from parking lots, roofs, and other impervious surfaces to be directed to bioswales / infiltration trenches.

Rain Garden

Rain gardens are landscaped features that capture, detain, treat, and infiltrate stormwater runoff. Rain gardens should be designed to receive runoff from parking lots, roofs, and other impervious surfaces. Ideally, rain gardens service drainage areas equal to or less than approximately 5 hectares. Rain gardens are best suited to areas with relatively shallow slopes, which encompass most of the study areas. They should be configured with a minimum of 0.50 m of soil media, and be planted with carefully selected deep rooted, native, water resistant vegetation with strong pollutant removal capabilities. We recommend that runoff with high pollutant levels be treated for quality before entering rain gardens.

8.2.2 Source Control Performance Targets

We developed performance targets that should be applied to commercial, industrial, and multiple residential lots. As with urban residential lots, we used the Water Balance Model (WBM) to evaluate the effectiveness of source control measures. Volume and flow rate targets per hectare of urban residential development are listed in Table 8-3.

Table 8-3
Performance Targets for Commercial, Industrial, and Multi-Family Residential

Event	Total Rainfall Depth	Target Peak Flow Rate	Total Rainfall Volume (m^3 / hectare)	Target Runoff Volume (m^3 / hectare)
24 hour 2-Year Return Period Event	64.8 mm	4 L/s / hectare	648	580
Mean Annual Total Rainfall	1650 mm	N/A	16,500	13,500

The hydrological benefits and improvements to watercourse health achieved through source control measures are discussed in Section 8.8. The rainfall volume dissipation is 10% for the 24 hour, 2-year return event and 18% for the mean annual rainfall volume for the WBM estimates presented in Table 8-3.

Applied source control measures will be selected by property owners or developers. Any combination of the above listed source controls can be used to achieve the 2-year return period event and mean annual total rainfall target peak flow rates and runoff volumes. For reference, we included typical unit prices of each source control. Detailed cost estimates can be found in Appendix D and are summarized in Table 8-4.

Table 8-4
Commercial, Industrial, and Multi-Family Residential Source Control Unit Prices

Source Control	Unit Price ($/m²)
Shrub Planting	$30
Tree Planting	$30
Pervious Pavement	$160
Green Roof / Detention Roof	$75 / $110
Enhanced Growing Medium	$15
Bioswale / Infiltration Trench	$60
Rain Garden	$50

8.2.3 Sub-Surface Detention and Retention Storage

We recommend that future commercial, industrial, and multiple residential developments provide detention and retention storage. The available open space within typical lots of these land use types is limited. Surface stormwater detention facilities typically occupy a large portion of developable land negatively impacting the functionality of lots. Instead, we recommend that on-site stormwater storage facilities be used to provide stormwater retention and detention.

We recommend that commercial, industrial, and multiple residential developments control peak flow rates in accordance to the following condition:

Limit peak flows released from the site for a 5-year return period – 24 hour storm event under post (re)development conditions to 50% of the peak flow rate generated by the site for a 2-year return period- 24 hour storm event under baseline (current) development conditions.

This criteria provides for improved stormwater management even if the site's impervious coverage is not changed significantly by redevelopment.

From the above criteria, we developed generalized, and more easily applied, performance requirements for detention/retention of stormwater runoff from site. Refer to Table 8-5 for the required storage volumes and recommended release rates per hectare of industrial, commercial, or multi-family development.

Table 8-5
Commercial, Industrial and Multi-Family Residential Detention Facility Performance Criteria

Peak Flow Control Criteria	Minimum Required Storage Volume	Maximum Allowable Release Rate	Volume Release Pattern
50% of the 24 hour-2-Year Baseline Event	350 m^3 / hectare	9.0 L/s / hectare	50% in first 24 h 50% in next 48 h

Note: Criteria estimated assuming 90% post development impervious coverage, 24-hour Surrey Design Storms.

Runoff can enter storage facilities directly through catch basins and piped systems or after passing through surface source controls such as pervious pavement, green roofs, bioswales, or rain gardens. We recommend that catch basins, sediment traps, and oil and grit separators be included in the design to prevent debris, sediment, and oil from entering storage facilities. These provisions will improve water quality, prevent clogging of the inlet and outlet structures, and reduce maintenance requirements.

When used, we recommend that sub-surface storage facilities be placed under parking surfaces or service areas. Sub-surface storage tanks must be fitted with outlet structures designed to satisfy flow control objectives. An emergency outlet or bypass structure must also be provided to allow outflow should the primary outlet structure become blocked or flows exceed the design event. The location and detailed design of storage facility outlet structures should consider accessibility for maintenance and operation and potential consequences to downstream habitat and infrastructure.

8.2.4 Water Quality Devices

We recommend that future commercial, industrial, and multiple residential sites install water quality devices to treat runoff prior to its release to downstream storm water infrastructure. Water quality devices improve the quality of stormwater runoff by removing sediment and oils. Devices of proprietary design are available from numerous vendors. The most common devices separate sediment and oils by settling or floatation and segregation from the water stream. Newer designs incorporate absorbent materials or controlled release dosing with chemical agents that promote coagulation and settling of fine particles. In general these devices are most effective when applied to areas that are concentrated pollution sources, such as parking lots, soil or sediment stockpiles, vehicle maintenance and some manufacturing activities.

These devices are useful in protecting stormwater source control measures, such as infiltration systems and vegetated features, from excessive loadings that could degrade their performance. These devices can also function as traps in the event of spills or other accidental releases and facilitate emergency cleanup and response.

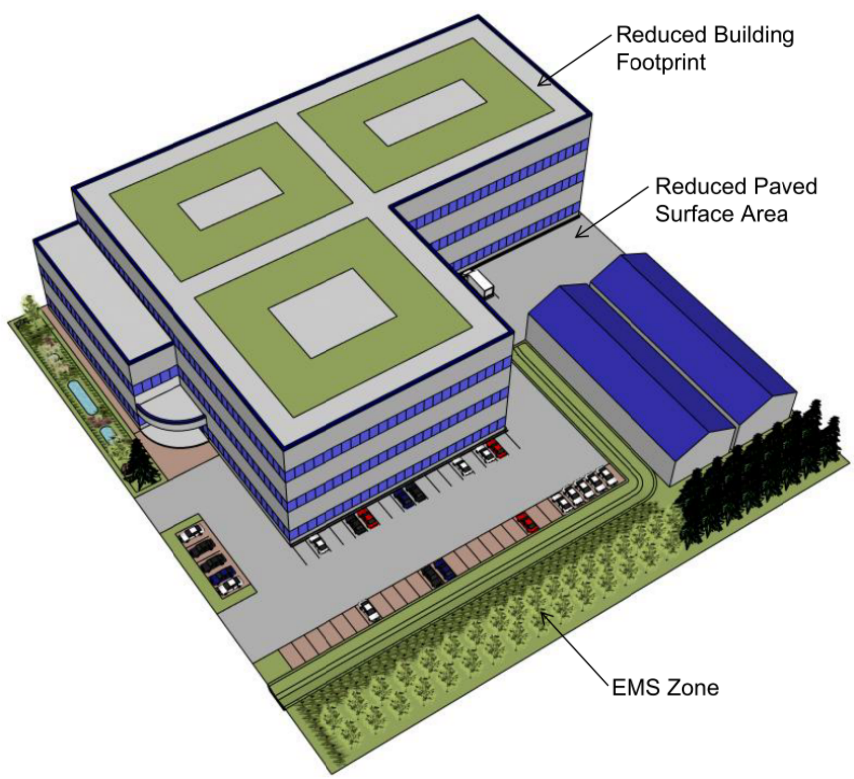
Some industrial activities will require more intense management to prevent the excursion of pollutants from their respective sites. These activities may require specific engineered solutions and management or operational practices, and should be identified, with the responsibility to address them resting with the property owner. The City should maintain an oversight, monitoring and enforcement capacity for such circumstances.

8.2.5 Industrial, Commercial and Multiple Residential Development within EMS Zones

According to the City of Surrey Zoning Bylaw No. 12000, lots must provide minimum setbacks of 7.5 m from lot lines abutting land that is not zoned as commercial or industrial. We recommend that industrial lots bordering or extending within the EMS provide a minimum setback of 15 m planted with native vegetation. This setback can also be applied to commercial and multiple residential developments.

To offset the reduction in the available building footprint and to ensure that these lots still present attractive development opportunities, we recommend that the City allow buildings on these lots to be built higher than the maximum height of 18 m for principle buildings and/or 6 m for accessory buildings as stated in the City of Surrey Zoning Bylaw No. 12000. (See Figure 8-8).

Figure 8-8
Typical Industrial, Commercial, and Multiple Residential Lots Bordering or Extending within EMS Zones



8.3 LOCAL AND COLLECTOR ROAD RIGHTS-OF-WAY

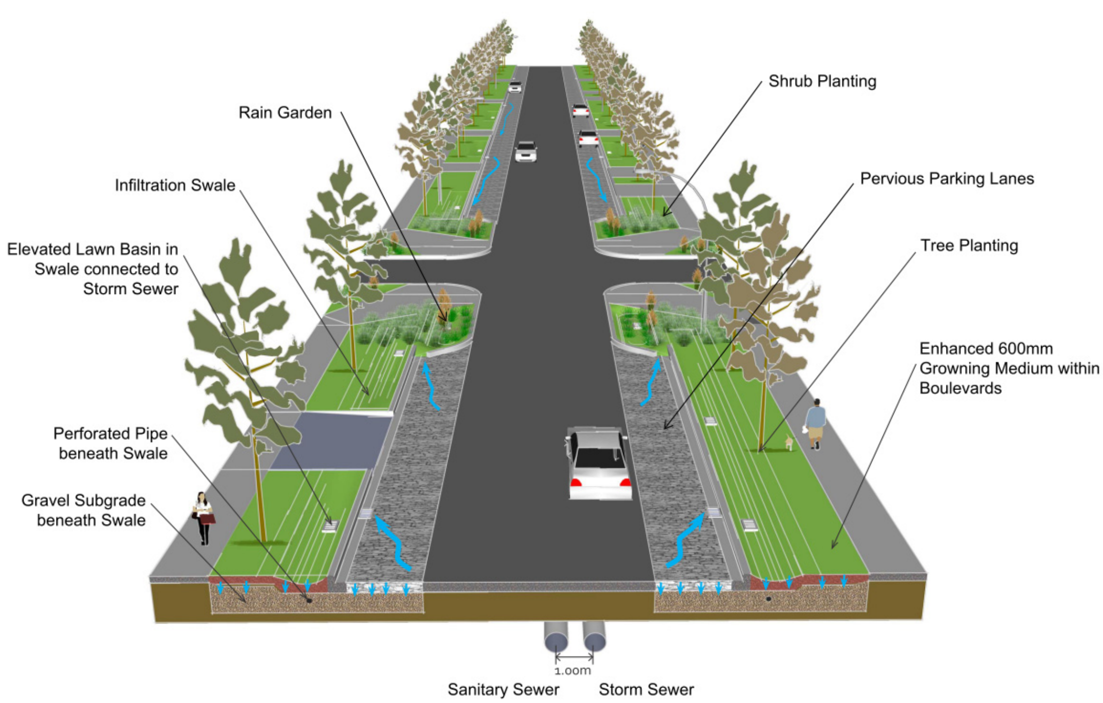
Local and collector road rights-of-way account for approximately 62.5% and 10.7%, respectively, of the total road length within the study area. We examined cadastral road data provided by the City of Surrey, satellite imagery of the study area, and City of Surrey Supplementary Standard Drawings to determine the representative local and collector right-of-way configuration. Local and collector road rights-of-way within the Cruikshank and Grenville watersheds typically consist of 20 m total right-of-way widths comprised of two 3.0 m wide travelled lanes, two 2.25 m wide on-street parking spaces, two 3.25 m wide grassed boulevards, and two 1.5 m wide sidewalks.

Since the study area is primarily developed, the majority of road works will be road improvement projects. Road rights-of-way widths and composition are unlikely the change significantly because of land constraints from adjacent private properties and traffic considerations. We recommend that, where feasible the following source control measures be applied to future local and collector road rights-of-way:

- Enhanced Growing Medium,
- Tree Planting,
- Shrub Planting,
- Pervious Parking Lanes, and
- Infiltration / Retention Systems.

Representative applications of source controls on local and collector road rights-of-way are described in detail below and shown in Figure 8-9.

Figure 8-9
Typical Local and Collector Right-of-Way Source Controls



Enhanced Growing Medium

The City of Surrey standard minimum depth of growing medium within boulevards is 600 mm. A 600 mm growing medium will occupy all boulevard green space, approximately 32.5% of future local and collector road rights-of-way. Trees and shrubs located in boulevards will also be planted with a minimum 600 mm growing medium. All pervious surfaces should be protected from compaction, erosion, and sediment during construction and throughout the life cycle of the road so that hydrologic properties of the growing medium are maintained.

Tree Planting

Large trees can be planted within the pervious portion of road rights-of-way. Large trees effectively reduce peak flow rates, reduce total volumes, and enhance water quality during rainfall events by intercepting and storing rainfall, reducing soil moisture through transpiration, and improving the holding capacity of soil with their root systems. Tree canopies also reduce soil erosion by limiting the impact of rainfall on bare soil. Additional benefits of street trees include energy saving through shading and wind speed reduction, carbon dioxide reduction through cellular respiration, improved air quality through absorption, and improved community aesthetics.

We recommend that street trees be placed within the vegetated boulevards of local and collector road rights-of-way and with minimum 600 mm growing medium. Tree spacing will be dependent on the presence of shrub plantings, existing utilities, walking paths, and required site lines. Runoff from sidewalks and other paved surfaces in the boulevard should be directed to trees.

Shrub Planting

Shrubs can be planted within the pervious portion of road rights-of-way. Shrub planting consists of a variety of native herbaceous vegetation with a thickly matted rooting zone. Like tree planting, absorbant landscaping such as shrub plantings capture rainfall, reduce runoff volumes and flow rates, reduce soil erosion by limiting the impact of rainfall on bare soil, and improve water quality by promoting rainfall interception, throughfall and stemflow, evapotranspiration, soil water storage, soil infiltration, interflow and groundwater recharge.

We recommend that shrubs be placed within the vegetated boulevards of local and collector road rights-of-way and with minimum 600 mm growing medium. Placement of shrubs will be dependent on the presence of trees, existing utilities, walking paths, and required site lines. Runoff from sidewalks and other paved surfaces in the boulevard should be directed to shrubs.

Pervious Parking Lanes

On local and collector roads, pervious pavement can be applied to parking lanes. We recommend that under drains be placed within the bottom layer of the pervious pavement structure to capture and convey runoff to the storm sewer system or downstream stormwater management facility to prevent excess ponding on the road surface. We also recommend that catch basins be placed at the downstream end of road sections to capture runoff from large infrequent storm events.

Infiltration / Retention Systems

Infiltration systems can consist of rain gardens, soakaway pits, infiltration trenches, or other measures. Each is designed to capture, detain, treat, and dispose of runoff from impervious surfaces by promoting infiltration of runoff into adjacent soil.

On local and collector roads, infiltration / retention systems can be located near intersections to form the boundary between parking lanes and intersecting roads. This will allow runoff from paved road surfaces and sidewalks to be directed to the infiltration / retention systems. We recommend that under drains be placed beneath infiltration systems and overflow devices be incorporated into their design to convey excess runoff and prevent localized flooding.

Source control measures applied to future local and collector road rights-of-way will be selected by the City of Surrey. Any combination of the above listed source controls can be used. We did not specify target peak flow rates or target runoff volumes for right-of-way improvements. These targets should be determined by the City of Surrey on a case-by-case basis. For reference, we included typical unit prices of each source control. Detailed cost estimates can be found in Appendix D and are summarized in Table 8-6.

Table 8-6
Local and Collector Right-of-Way Source Control Unit Prices

Source Control	Unit Price ($/m²)
Enhanced Growing Medium	$30
Tree Planting	$40
Shrub Planting	$40
Pervious Parking Lanes	$160
Infiltration / Retention Systems	$60

8.4 ARTERIAL ROAD RIGHTS-OF-WAY

Arterial road rights-of-way account for approximately 26.8% of the total road length within the study area and include King George Boulevard, 132nd Street, 128th Street, 120th Street, 88th Avenue, 84th Avenue, 80th Avenue, and 76th Avenue. We examined cadastral road data provided by the City of Surrey, satellite imagery of the study area, and City of Surrey Supplementary Standard Drawings to determine a representative arterial right-of-way configuration. Arterial road rights-of-way within the Cruikshank and Grenville watersheds generally consist of 27 m total right-of-way widths comprised of four 3.65 m wide travelled lanes, one 4.4 m wide centre median, two 2.5 m wide grassed boulevards, and two 1.5 m wide sidewalks.

As with local and collector roads, arterial road rights-of-way widths and composition are unlikely to change significantly in the future. The arterial roads within the study area are already well defined within the transportation network. We recommend that during future road improvement projects, source controls and sub-grade storage be incorporated into arterial road rights-of-way.

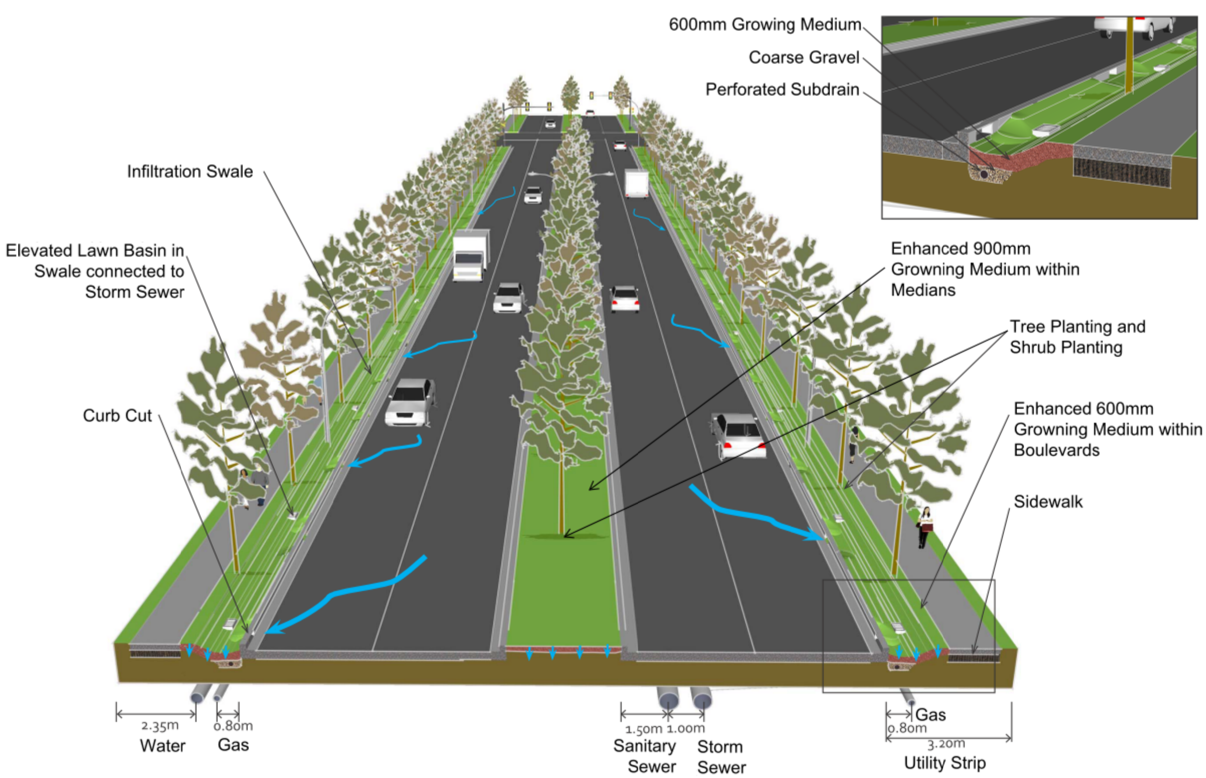
8.4.1 Recommended Source Controls

We recommend that the following source control measures be applied to future arterial road rights-of-way:

- Enhanced Growing Medium in Medians,
- Tree Planting in Medians and Boulevards,
- Enhanced Growing Medium in Boulevards,
- Shrub Planting in Medians and Boulevards, and
- Infiltration / Retention in Boulevards.

Representative applications of source controls on arterial road rights-of-way are described in detail below and shown in Figure 8-10.

Figure 8-10
Typical Arterial Right-of-Way Source Controls



Enhanced Growing Medium in Medians

The City of Surrey standard minimum depth for growing medium in medians is 900 mm. A 900 mm growing medium will occupy all median green space, approximately 15% of future arterial road rights-of-way. Trees and shrubs in medians will also be planted with a minimum 900 mm growing medium. All pervious surfaces should be protected from compaction, erosion, and sediment during construction and throughout the life cycle of the road so that hydrologic properties of the growing medium are maintained.

Tree Planting in Medians and Boulevards

We recommend that street trees be placed within the vegetated medians and boulevards of arterial road rights-of-way. Tree spacing will be dependent on the presence shrub plantings, existing utilities, walking paths, and required site lines. If possible, a portion of the runoff from the paved road surface should be directed to trees in medians.

Enhanced Growing Medium in Boulevards

The City of Surrey standard minimum depth for growing medium in boulevards is 600 mm. A 600 mm growing medium will occupy all boulevard green space, approximately 15% of future arterial road rights-of-way. Trees and shrubs in boulevards will also be planted with a minimum 600 mm growing medium. All pervious surfaces should be protected from compaction, erosion, and sediment during construction and throughout the life cycle of the road so that hydrologic properties of the growing medium are maintained.

Shrub Planting in Medians and Boulevards

We recommend that shrubs be placed within the vegetated medians and boulevards of arterial road rights-of-way. Placement of shrubs will be dependent on the presence of tree plantings, existing utilities, walking paths, and required site lines. If possible, a portion of the runoff from the paved road surface should be directed to shrubs in medians and runoff from sidewalks and other paved surfaces should be directed to shrubs in the boulevard.

Infiltration / Retention in Boulevards

Within arterial rights-of-way, infiltration trenches can be located within grassed boulevards between sidewalks and travelled lanes and can be planted with shrubs, if desired. Curb cuts will have to be introduced to allow runoff to drain from the road surface into infiltration / retention measures. We recommend that elevated lawn basins be placed on the surface of infiltration trenches and connected to the storm sewer to capture runoff from large infrequent storm events and prevent excess ponding on the road surface.

Source control measures applied to arterial road rights-of-way will be selected by the City of Surrey. Any combination of the above listed source controls can be used. We did not specify target peak flow rates or target runoff volumes for right-of-way improvements. These targets should be determined by the City of Surrey on a case-by-case basis. For reference, we included typical unit prices of each source control. Detailed cost estimates can be found in Appendix D and are summarized in Table 8-7.

Table 8-7
Arterial Right-of-Way Source Control Unit Prices

Source Control	Unit Price ($/m²)
Enhanced Growing Medium in Medians	$45
Tree Planting	$40
Enhanced Growing Medium in Boulevards	$30
Shrub Planting	$40
Infiltration / Retention Systems	$60

8.5 STORMWATER MANAGEMENT PONDS

When properly designed and managed, ponds are attractive community amenities that provide recreational benefits and habitat for wildlife. Given the land constraints and the high runoff volumes from develop in the study area, we recommend that the primary objectives of stormwater management ponds be to control peak flows and provide extended detention to runoff from small frequently occurring rainfall events to provide relief to downstream stormwater infrastructure and watercourses.

We identified five parcels of land that are suitable locations for siting future stormwater management ponds. The City would have to secure them through purchase when the opportunity arises. Refer to Map 8-1 for the pond locations, Table 8-10 for a summary of the design information, and Appendix D for detailed cost estimates.

We note that these stormwater detention pond locations and sizes are generally consistent with those identified in the previous Bear Creek Master Drainage Plan (Bear Creek Master Drainage Plan – Summary Report on Stormwater Management and Master Plan for Drainage System Upgrading, KWL-CH2M, 1998)

Table 8-10
Stormwater Management Ponds

Pond No.	Pond Footprint	Land Owner	Approximate Location	Approximate Upstream Drainage Area	Available Storage Volume (m^3)	Cost Estimate
1	1.53 ha	BC Hydro	West of 128 St., south of 88 Ave.	65 ha	16,475	$7,107,500
2	1.10 ha	BC Hydro	East of 124 St., south of 84 Ave.	206 ha	10,355	$4,866,800
3	0.98 ha	Private	84 Ave. east of 132 St.	315 ha	9,400	$4,382,100
4	1.23 ha	City of Surrey	Greenway south of Prince Charles Blvd., between 128 St. and 132 St.	135 ha	7,150	$4,541,600
5	0.64 ha	City of Surrey	Greenway east of 126 St. at 89 Ave.	30 ha	4,505	$2,651,900

Pond 1, Pond 2, and Pond 3 are located within the Cruikshank watershed. Pond 4 and Pond 5 are located within the Grenville watershed. The drainage areas upstream of each location are fairly significant. Since maximum storage volumes are fixed based on individual site constraints, stormwater management ponds should be designed to augment peak flow control and provide water quality enhancement of small frequently occurring rainfall events.

Pond layout and configuration was based on the following design criteria from the City of Surrey's Engineering Design Criteria Manual (2004):

- Minimum 1.50 m depth from normal water level to pond bottom,
- Maximum 7:1 side slopes from top of pond to pond bottom,
- Minimum 0.60 m freeboard from the 100-year water surface elevation to the top of the pond, and
- Minimum 3.00 m wide access road for all-weather maintenance vehicles accessible from a public road right-of-way.

The following layout and configuration constraints were also considered:

- Minimum 30 m riparian setbacks from the top of bank of natural watercourses,
- Avoid conflict with existing hydro poles,
- Pond invert elevations based on existing elevations of surrounding areas,
- Minimum 7.50 m setbacks from adjacent roads and properties,
- Maximum 4:1 side slopes to tie into existing elevations, and
- Minimum 1.50 m active storage depth.

Stormwater management ponds will provide relief to downstream watercourses and infrastructure in the form of decreased peak flow rates and reduced erosion potential. We investigated the flow and erosion characteristics of watercourses or infrastructure downstream of each recommended pond site to evaluate its effectiveness. Refer to Table 8-11 for the results.

Table 8-11
Hydraulic Benefits of Stormwater Management Ponds

Pond No.	Downstream Watercourse or Infrastructure	Percent Decrease in Erosion Potential (2003 – 2008 Continuous Simulation)		Percent Decrease in Peak Flow Rate	
		Maximum Tractive Force	Impulse	2-Year Event	5-Year Event
1	Bear (Bear) Creek at 128 St.	40 %	28 %	18 %	18 %
2	Bear (Bear) Creek at railway	25 %	24 %	7 %	5 %
3	Cruikshank Creek east of 132 St.	8 %	6 %	64 %	57 %
4	Queen Mary Creek at Queen Mary Blvd.	5 %	2 %	11 %	8 %
5	1050mm Ø STM at 88 Ave. & 128 St.	-	-	24 %	10 %

Stormwater management ponds significantly decrease peak flow rates in downstream watercourses. The larger ponds, Pond No. 1 and Pond No. 2, have the most benefit in reducing peak flows and erosion potential. Improvements in erosion potential was not evaluated downstream of Pond No. 5 since it is not immediately connected to a natural watercourse.

We note that the stormwater management ponds identified above are generally consistent with those identified in the previous Bear Creek Master Drainage Plan (Bear Creek Master Drainage Plan – Summary Report on Stormwater Management and Master Plan for Drainage System Upgrading, KWL-CH2M, 1998)

8.6 RIPARIAN AREAS

Riparian areas include the natural vegetation along watercourse corridors. Development adjacent to the remaining watercourses in the Cruikshank and Grenville watersheds has reduced the riparian forest cover, as represented by the overall study area RFI score of 34.9 %. Intact riparian corridors reduce erosion potential, filter sediment and pollutants from runoff, reduce peak flow rates and total volume of runoff, and act as a natural buffer between watercourses and development, provided stormwater discharges are not introduced directly into the stream. In addition, riparian corridors provide fish and wildlife habitat.

We recommend restoring riparian areas in the Cruikshank and Grenville watershed along the remaining natural or quasi-natural watercourses. This will explicitly require that properties adjacent to watercourses surrender the required land to form the riparian corridor, with re-vegetation and restoration effort to re-establish appropriate conditions. The proportional hydrologic benefits of riparian zones are greatest in areas with high existing percent impervious values since, in the absence of vegetation, they exhibit a greater increase in total runoff than areas with lower percent impervious values. Consequently, we recommend focussing riparian zones protection efforts on commercial, industrial, and multiple residential developments as this will have the greatest impact on the overall health of the watersheds. This will be an opportunity driven process, linked to re-development proposals. Restoration will likely be possible when significant reconfiguration of an industrial property or a change in its specific use occurs.

Riparian corridor restoration will be less viable with one major component of the drainage system - that being the drainage ditches on either side of the Southern Railway of BC (SRY) corridor. Due to safety concerns with sight lines in proximity to railway lines, as well as maintenance requirements for the railway roadbed, we anticipate that significant re-vegetation will not be acceptable in this corridor on the railway side of the ditches. Some vegetation does exist outside of ditches, close to property lines, and could potentially be enhanced in specific locales, but is again subject to safety regulations for visibility, as well as being intersected by numerous railway spurs that cross out of the main right-of-way. As this railway line provides both local service to industries within the study area, as well as regional service to Surrey, the Langleys, Abbotsford and Chilliwack, there is currently no expectation that railway operations will be discontinued.

Riparian areas can be associated with community amenity features, such as greenways, and, though DFO usually prefers that access to the creek itself be minimized to perpendicular crossing sites, multi-use paths and pedestrian bridges placed outside the setback limits will encourage the public to use riparian zones as passive recreational areas. Educational signage can inform users of the sensitive ecosystems within riparian zones and foster a sense of environmental stewardship.

8.7 OPERATION AND MAINTENANCE

Operation and maintenance considerations were factored into the evaluation process used to select the most appropriate best management strategies for the ISMP. Specifically, best management strategies with significant maintenance requirements were not recommended for privately owned lots but were included for road rights-of-way that will be operated and maintained by the City.

Best management strategies for private property include practices that, after installation, will effectively reduce runoff volumes and slow the movement of water with little required maintenance. Operation and maintenance procedures will be the responsibility of individual land owners. The City of Surrey will be responsible for operation and maintenance of best management strategies located within City of Surrey owned road rights-of-way and green space. Table 8-12 describes the required operation and maintenance associated with each identified private property stormwater best management strategy.

Table 8-12
Operation and Maintenance Procedures for Best Management Strategies

Strategy	Required Operation and Maintenance Procedures
Shrub Planting	• Irrigate during dry periods. • Prevent compaction or disturbance of growing medium. • Trim shrubs, as necessary.
Tree Planting	• Irrigate during dry periods. • Prevent compaction or disturbance of growing medium. • Check stakes and ties and repair, if necessary. • Remove stakes after one (1) year.
Enhanced Growing Medium	• Irrigate during dry periods. • Prevent compaction. • Remove accumulated sediment and debris. • Aerate annually.
Pervious Pavement	• Prevent compaction and clogging. • Remove accumulated sediment and debris. • Replace pavement layers, if necessary.
Green Roof / Detention Roof	• Prevent compaction or disturbance of growing medium. • Remove weeds. • Prevent clogging of overflow pipe and/or under drain.
Bioswale / Infiltration Trench	• Remove accumulated sediment and debris. • Prevent clogging of overflow pipe and/or under drain.
Rain Garden	• Remove accumulated sediment and debris. • Prevent clogging of overflow pipe and/or under drain. • Prevent compaction and clogging on the surface.
Sub-Surface Detention and Retention Storage	• Remove accumulated sediment and debris from upstream treatment system and underground storage facility, as necessary. • Ensure that inlet, outlet, and overflow are not blocked.

Strategy	Required Operation and Maintenance Procedures
Water Quality Devices	• Inspect post-construction prior to being put into service. • Inspect every six months for the first year of service to verify ability to treat projected pollutant loads. • Inspect and clean annually, after the first year. • Remove oil and sediment and dispose of properly.
Stormwater Management Pond	• Remove submerged accumulated sediment and debris from pond bottom. • Remove floatables from pond surface. • Ensure that inlet, outlet, and overflow are not blocked. • Maintain vegetation.

Proper operation and maintenance is integral to the long-term effectiveness of the recommended best management strategies and the health of the Cruikshank and Grenville watersheds. Detention and retention facilities such as sub-surface detention and retention storage, right-of-way sub-grade storage, and stormwater management ponds will require regular operation and maintenance to ensure optimum performance. Water quality devices will also require regular maintenance. Management of facilities on private property will be the responsibility of individual land owners but should be enforced and monitored by the City. Maintenance should be completed annually, at a minimum, during dry weather when flow will not disrupt maintenance operations. The sediment load captured by these facilities should be recorded so that operation and maintenance schedules can be developed for each individual site. Management of new City of Surrey facilities will presumably be incorporated with the operation and maintenance programs for existing City owned stormwater management facilities.

8.8 EVALUATION OF COMBINED STORMWATER BEST MANAGEMENT STRATEGIES

To complete the evaluation of the proposed improvements, we created two (2) PC SWMM models that incorporate the identified stormwater best management strategies. The first, future conditions with source controls model, represents future conditions in the study area with fully implemented source control measures on urban residential properties (Section 8.1.1), commercial, industrial, and multiple residential properties (Section 8.2.1) as well as on City of Surrey owned local and collector road rights-of-way (Section 8.3), arterial road rights-of-way (Section 8.4.1), and enhancement of riparian areas (Section 8.6). The second, future conditions with all BMPs model, represents future conditions in the study area with fully implemented source control measures, sub-surface detention and retention storage facilities (Section 8.2.3), and stormwater management ponds (Section 8.5).

8.8.1 Hydrologic Conditions

Recommended source control measures will increase the infiltration losses and decrease total runoff volumes generated by the lots and rights-of-way to which they are applied. Infiltration losses and runoff volumes generated by each sub-catchment were calculated in the hydrologic model. We compared the results of the future conditions model and the future conditions with source control measures model to determine the positive hydrologic impact of applied source controls within the Cruikshank and Grenville watersheds. Please refer to Table 8-13 for a comparison of the results.

Table 8-13
Hydrologic Benefits of Applied Source Control Measures

Storm Event	Increase in Infiltration Losses[1]	Percent Decrease in Runoff Volume[1]
100-Year Design Storm Event	45.8 %	0.7 %
5-Year Design Storm Event	47.8 %	0.8 %
2-Year Design Storm Event	47.9 %	1.8 %
5-Year Continuous Simulation Period	39.7 %	4.1 %

Note 1: Relative to existing conditions in the study area.

Applied source controls measures are expected to increase infiltration losses and decrease total runoff volumes. Larger percent increases in runoff volumes will be experienced during small frequent storm events. Decreased runoff volumes will result in decreased peak flow rates, lower erosion potential, and decreased pollutant mobility.

8.8.2 Peak Flow Rates

We examined the model output hydrographs in Bear Creek at King George Boulevard to evaluate the effectiveness of the recommended management strategies in reducing flow rates in Bear Creek during the 2-year, 5-year, and 100-year return period events. Each rainfall event was modelled using PC SWMM using the existing conditions model, the future conditions model, the future conditions with source control measures model, and the future conditions with all BMPs model.

Refer to Table 8-14 for a summary of the peak flow rates, Table 8-15 for a summary of the total runoff volumes, and Figure 8-11, Figure 8-12 and Figure 8-13 for hydrographs of the 100-year, 5-year, and 2-Year return period design storm events in Bear Creek at King George Boulevard.

Figure 8-11
100-Year Hydrograph Comparisons

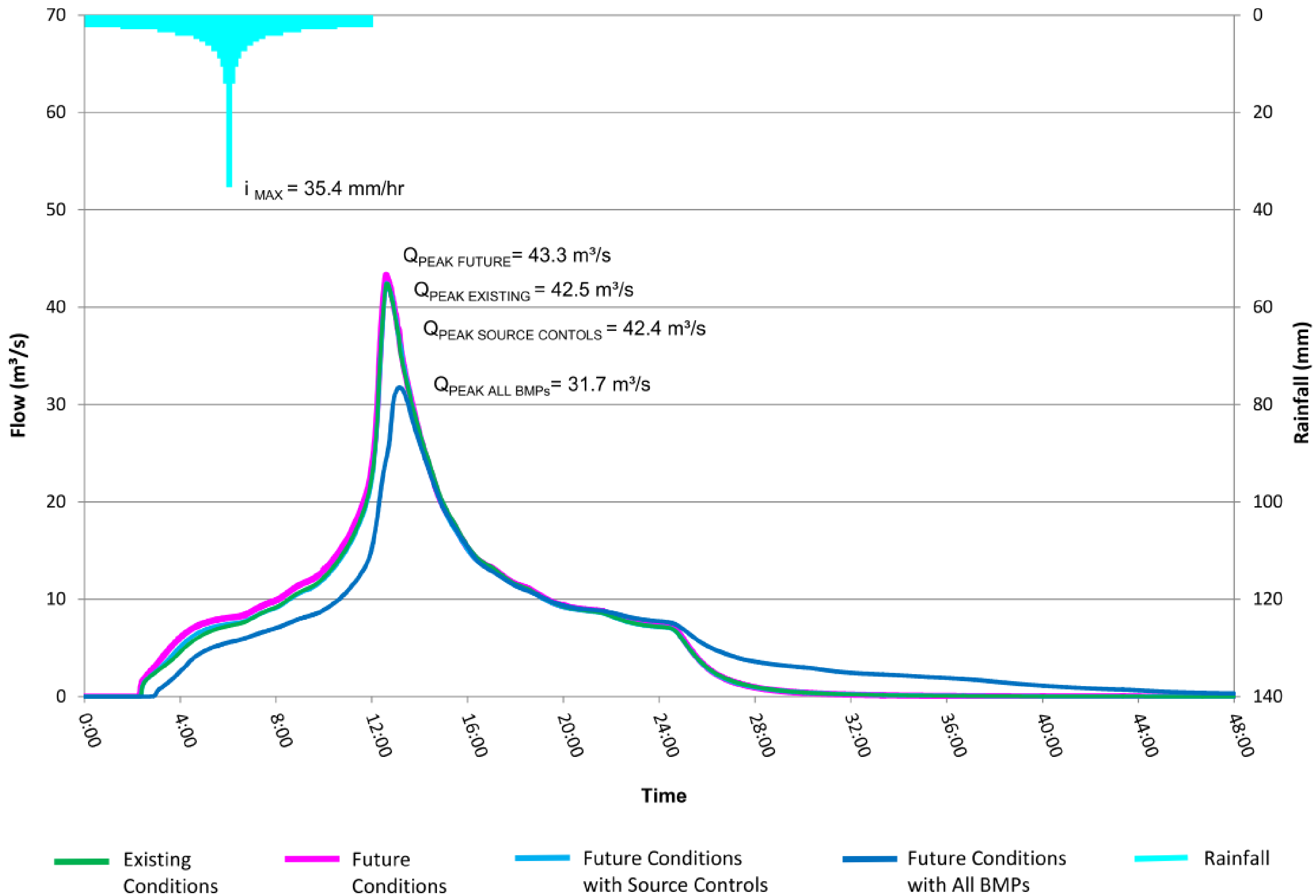


Figure 8-12
5-Year Hydrograph Comparisons

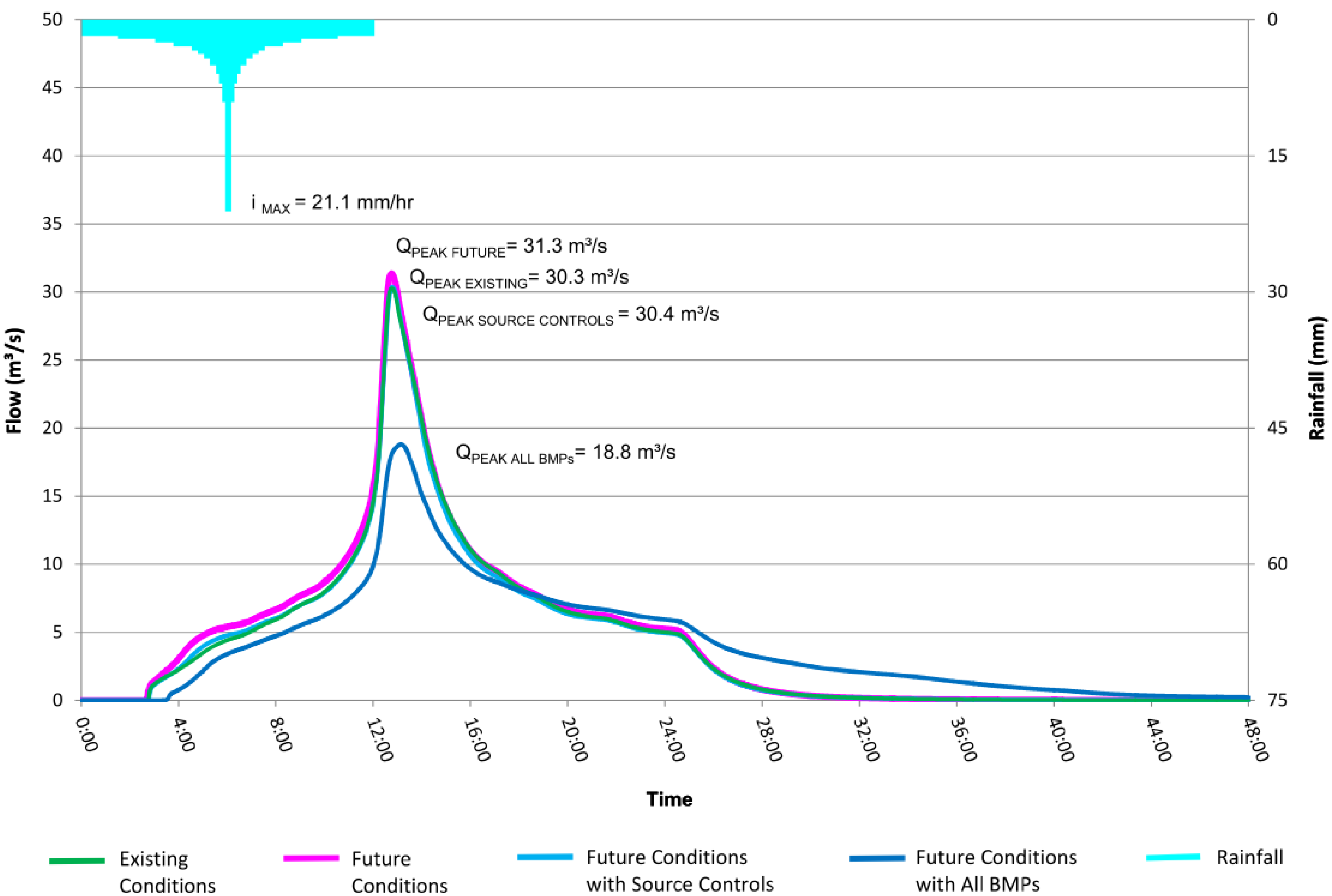


Figure 8-13
2-Year Hydrograph Comparisons

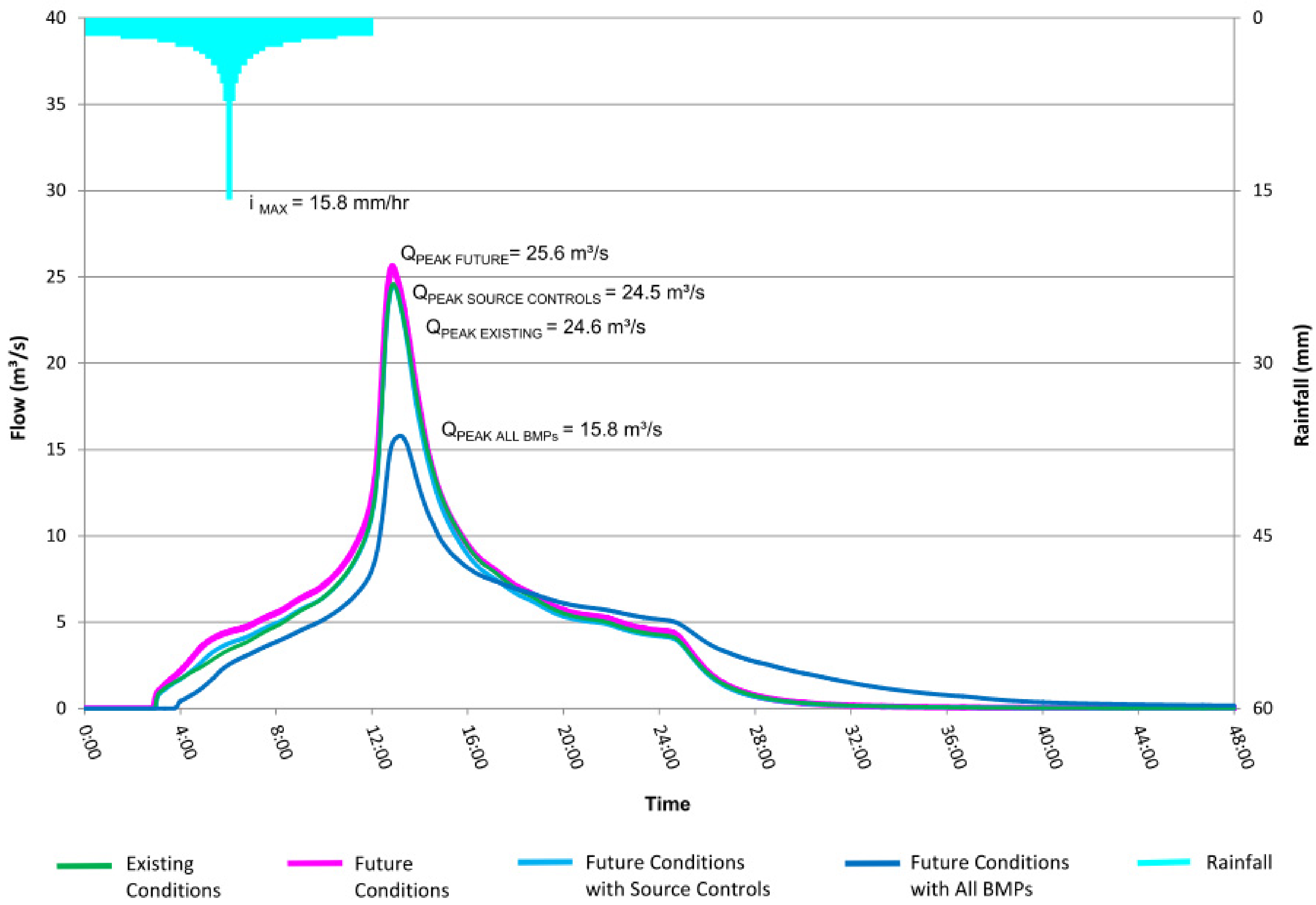


Table 8-14
Peak Flow Rates in Bear Creek at King George Highway

Storm Event	Existing Development Conditions (m^3/s)	Future Development Conditions (m^3/s)	Future Conditions with Source Controls (m^3/s)	Future Conditions with all BMPs (m^3/s)
100-Year	42.4	43.3	42.5	31.7
5-Year	30.3	31.3	30.3	18.8
2-Year	24.6	25.6	24.5	15.8

Maximum flow rates in Bear Creek at the City of Surrey flow station are not noticeably influenced by source control measures. However, flow rates are significantly reduced during each event when stormwater management ponds and sub-surface detention and retention storage facilities are included in the model. The peak flow rate in Bear Creek is expected to decrease by approximately 36%, 38%, and 25% during the 2-year, 5-year, and 100-year return period events, respectfully, when the recommended best management practices are fully incorporated within the watershed.

Table 8-15
Total Storm Runoff Volumes in Bear Creek at King George Highway

Storm Event	Existing Development Conditions (m^3)	Future Development Conditions (m^3)	Future Conditions with Source Controls (m^3)	Future Conditions with all BMPs (m^3)
100-Year	50,650,000	52,260,000	50,420,000	49,830,000
5-Year	34,940,000	36,680,000	34,520,000	33,820,000
2-Year	28,750,000	30,580,000	28,290,000	27,620,000

Maximum runoff volumes observed in Bear Creek at the City of Surrey flow station are influenced by both source control measures and storage facilities. With the application of source control measures, runoff volumes in Bear Creek are expected to decrease by approximately 2 %, 1 %, and 0 % compared to existing conditions during the 2-year, 5-year, and 100-year return period events, respectively. With the combined effects of source controls, stormwater management ponds, and sub-grade storage facilities, runoff volumes in Bear Creek are expected to decrease by approximately 4 %, 3 %, and 2 % compared to existing conditions during the 2-year, 5-year, and 100-year return period events, respectively.

The combined effort of the applied stormwater best management measures and facilities will provide relief to downstream watercourses and infrastructure. Some of the pipe upgrades identified in Section 6.3 of the ISMP can be eliminated or reduced with the incorporation of stormwater best management practices. Refer to Map 8-2 and Table 8-16 for a summary of the results. Detailed pipe segment information is included in Appendix D.

Table 8-16
Estimated Reduction in Recommended Pipe Upgrade Costs due to Management Strategy

Size	Length (m)		Unit Cost ($/m)	Estimated Cost (Rounded to nearest ten thousand)	
	Future	With All BMPs	Future	Future	With All BMPs
Storm Drainage Pipes (Minor System)					
675 mm Ø	1,826	1,555	$900	$1,650,000	$1,400,000
750 mm Ø	195	88	$950	$190,000	$90,000
825 mm Ø	596	1,341	$1,000	$600,000	$1,350,000
900 mm Ø	2,056	1,484	$1,040	$2,140,000	$1,550,000
1,050 mm Ø	1,934	595	$1,130	$2,190,000	$680,000
1,200 mm Ø	3,361	1,930	$1,200	$4,040,000	$2,320,000
1,350 mm Ø	947	1,150	$1,280	$1,220,000	$1,480,000
1,500 mm Ø	203		$1,350	$280,000	
1,800 mm Ø	243	243	$1,470	$360,000	$360,000
Culverts					
600 mm Ø	10	10	$8,500	$90,000	$90,000
750 mm Ø	15	15	$9,500	$150,000	$150,000
1.20 m x 1.35 m box	21	21	$18,000	$380,000	$380,000
1.20 m x 1.50 m box	27		$20,000	$540,000	
1.20 m x 1.50 m box	33	33	$25,000	$830,000	$830,000
Total	**11,467**	**8,465**		**$14,660,000**	**$10,680,000**

8.8.3 Erosion Potential

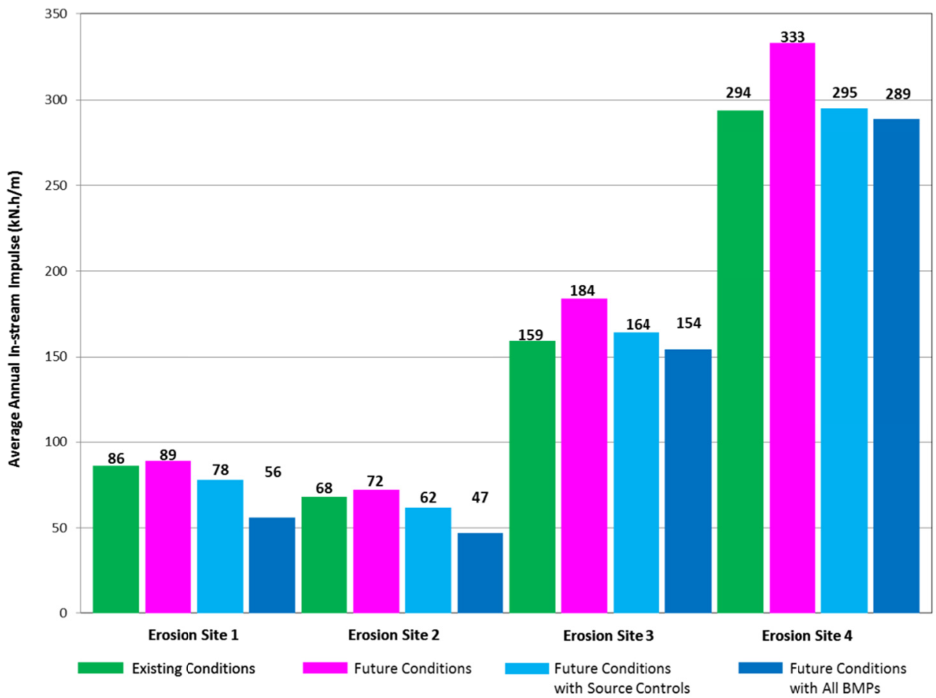
To estimate erosion potential in watercourses, we investigated the tractive forces applied to the stream bed at each site and the resulting total impulse for the January 1st, 2004 to December 31st, 2008 continuous simulation period. The four locations were analyzed with the existing development conditions model, the future development conditions model, the future development conditions with source controls measures model, and the future development conditions with all BMPs model. Refer to Map 8-3 for the locations.

Tractive force is a measure of the energy available to cause stream erosion. It is the product of the unit weight of water, hydraulic radius of flow, and slope of the channel at the cross section of interest. Impulse is a measure of the force applied to a stream cross section in the form of friction. From each tractive force an impulse can be determined from the product of the impulse, wetted perimeter, and time step. The total impulse is the sum of the impulses that are greater than or equal to the critical tractive force. The critical tractive force is the allowable tractive force below which erosion will not occur, is a function of the bed material, and has been calculated to be 12 N/m^2 for the watercourses in the study area. Refer to Table 8-17 for a summary of the changes in average annual erosive impulse and Figure 8-14 for a graphical representation of the resulting average annual erosive impulse, for the four development scenarios. The City of Surrey can expect to see decreased erosion and improved watershed health when the recommended source controls measures are implemented within the Cruikshank and Grenville watersheds. Conversely, without source control measures, increased erosion and degraded watershed health is probable under future development conditions.

Table 8-17
Average Annual Erosive Impulse

Erosion Site	Watershed	Existing Conditions (kN.hour/m)	Future Conditions (kN.hour/m)	Future Conditions with Source Controls (kN.hour/m)	Future Conditions with All BMPs (kN.hour/m)
1	Cruikshank	86	89	78	56
2	Cruikshank	68	72	62	47
3	Grenville	159	184	164	154
4	Grenville	294	333	295	289

Figure 8-14
Average Annual Erosive Impulses

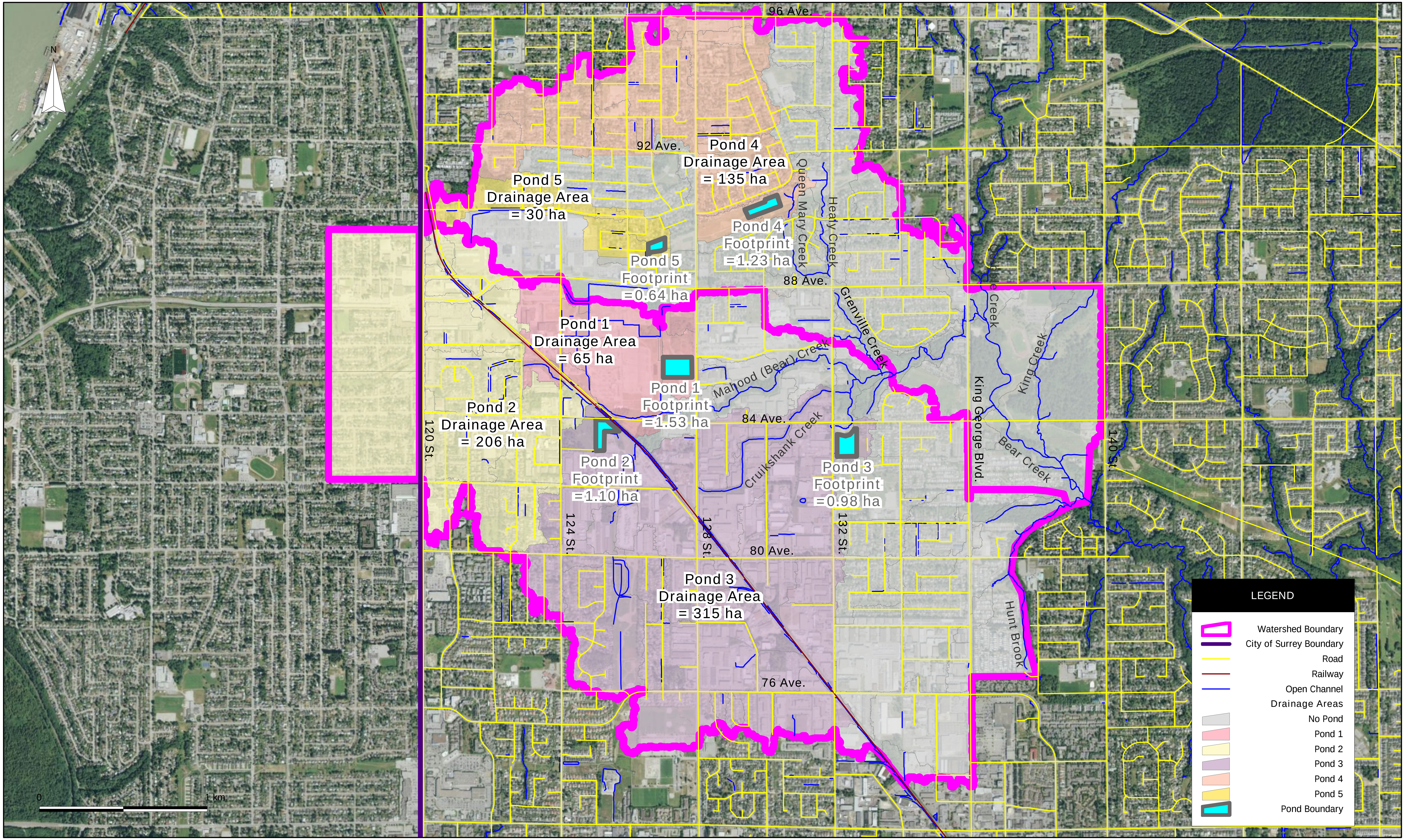


8.9 BEST MANAGEMENT STRATEGIES SUMMARY

In combination, the source controls and stormwater management ponds identified in this section as required measures serve to control or reduce the erosion potential experienced by the creek system. An additional benefit is that the number of surcharged pipes that may require replacement in the future is reduced, with an estimated cost savings of approximately $4.0 million, if a full program to replace all surcharged pipes were pursued.

However, the main impetus for implementing the identified stormwater management strategy is to mitigate the potential impact of future re-development on the creek system in the study area. Without these efforts, creek erosion processes and damage to riparian and aquatic habitat will increase, which is not consistent with the City's Sustainability Charter or OCP, as well as conflicting with the desires of the regulatory agencies. Overall, a modest improvement is watershed health should be achieved.

The various proposed measures that address terrestrial habitat, riparian habitat and landscaping features on both municipal rights-of-way and larger private properties (industrial, commercial and multi-family) will contribute to a more attractive and liveable community.



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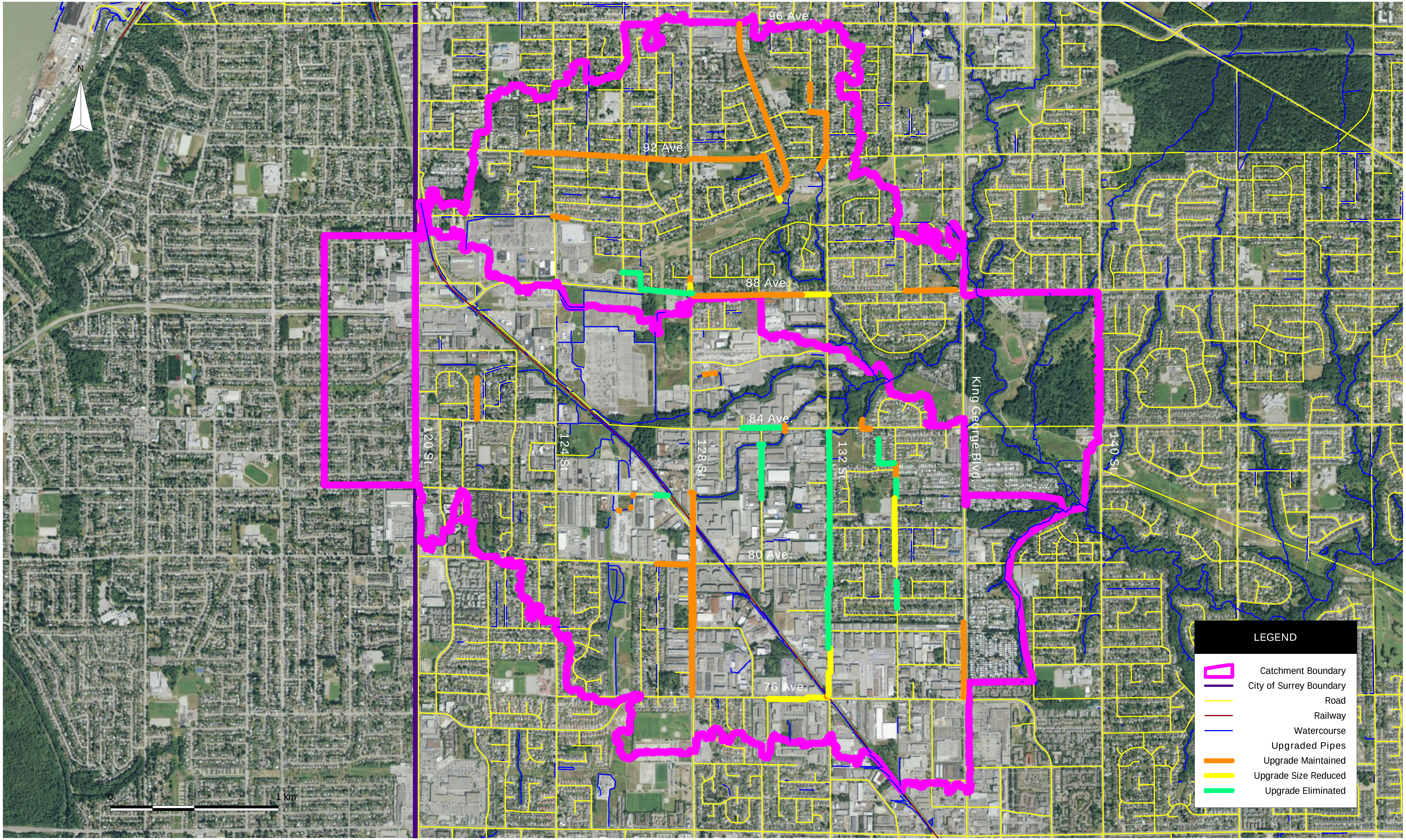
City of Surrey
Cruikshank and Grenville ISMP

Map 8-1 Stormwater Detention Pond Locations and Service Areas



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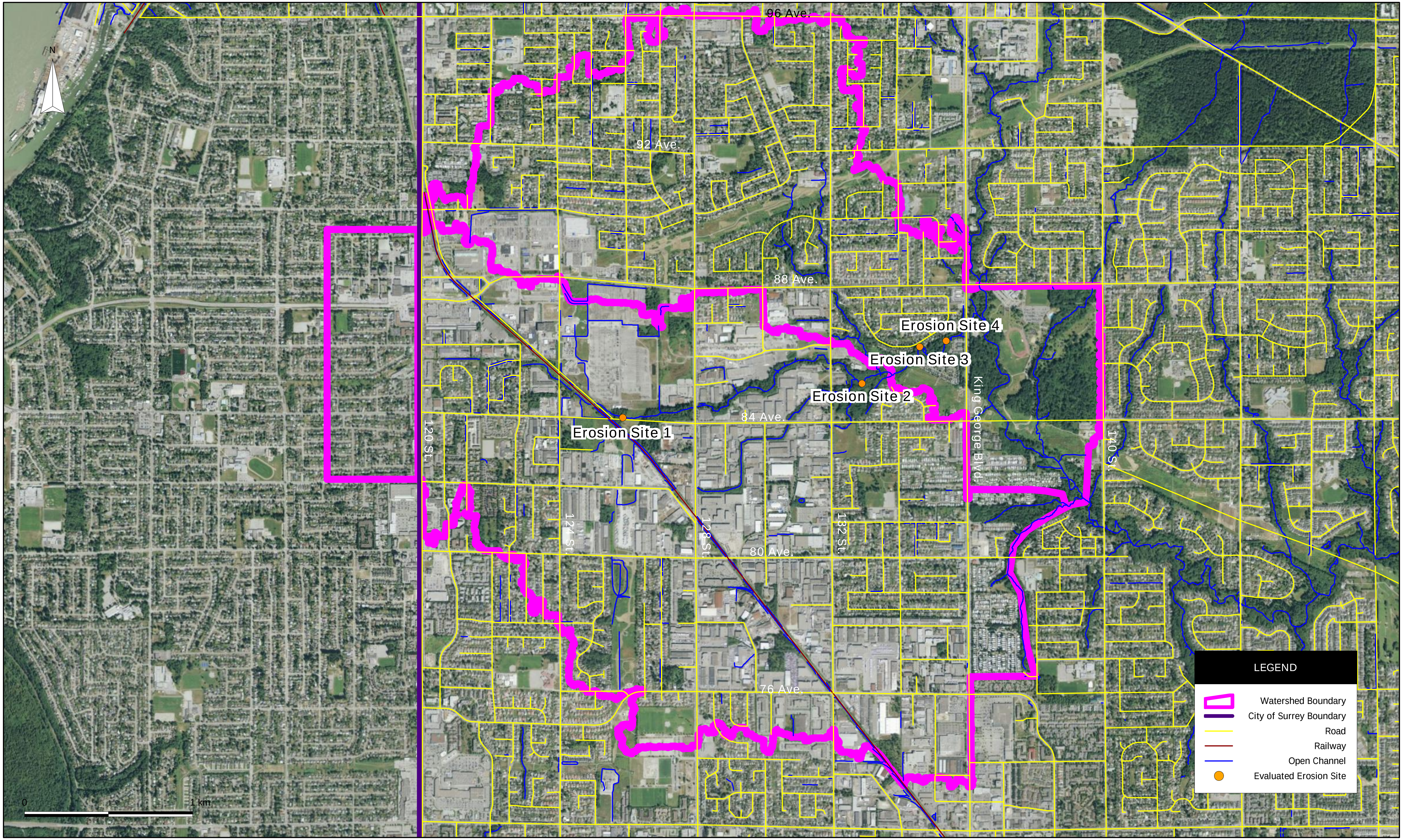
City of Surrey
Cruikshank and Grenville ISMP
Map 8-2 Minor System Upgrades with All BMPs



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City of Surrey
Cruikshank and Grenville ISMP
Map 8-3 Erosion Sites Evaluated for Stream Power

9 Implementation Strategy

To effectively support the Cruikshank and Grenville ISMP, the City of Surrey must implement and enforce this ISMP's recommendations. In this section of the report we discuss funding requirements and options for the design and construction of the stormwater best management practices previously discussed. We also introduce an enforcement strategy in which we provide suggestions that can be applied to checklists for development and re-development applications, develop incentive approaches to create mechanisms to support compliance with the recommendations of the ISMP, and identify changes to City of Surrey By-Laws and documents that are impacted by the recommendations of the ISMP.

9.1 FUNDING SOURCES

Funding to implement, operate, and maintain the stormwater best management practices developed in the Cruikshank and Grenville ISMP will come from a variety of sources. Individual land owners are directly responsible for funding and implementation of required stormwater management source controls and BMPs specific to their own properties. In addition, offsite upgrades to City controlled infrastructure specifically related to their development activities (i.e. not eligible for funding through DCC mechanisms) will also be chargeable to the subject property owner. The City will be responsible for City owned property and infrastructure upgrades that are either eligible for DCC funding or are not otherwise related to development activities. We discuss several funding options below.

9.1.1 City of Surrey Capital Construction Program

The City of Surrey's Capital Construction Program typically funds a variety of roads, drainage, sewer, and water projects. The objective of the program is to improve and advance the City's infrastructure and provide basic necessities of urban living while helping to fulfill the long-term strategic goals of the City. Based on the 2011 Capital Construction Projects Report produced by the City's Engineering Department, approximately $8.9 million of the $88.7 million 2011 project budget was allocated to drainage improvements.

We encourage the City of Surrey to consider including the following projects in future Capital Construction Programs:

- Local and collector road rights-of-way source control measures,
- Arterial road rights-of-way source control measures, and
- Stormwater management ponds.

We note that development driven upgrades servicing catchments greater than 20 hectares are eligible to be funded from DCCs. Development driven upgrades for service areas smaller than 20 hectares must be directly funded by development proponents.

9.1.2 Stormwater Utility Fee

The City currently collects a stormwater utility fee from every parcel of land in the City. At this time it is structured as a flat fee ($166/parcel) and does not reflect the magnitude of discharge to the drainage system. These funds are specifically allocated to drainage system expenditures.

9.1.3 Land Owners and Developers

Land owners and developers do not receive City controlled funding for stormwater best management practices located on private property or these development driven upgrades applied to City systems with service areas less than 20 hectares. The cost of constructing, operating, and maintaining source controls, EMS zone buffers, stormwater detention and retention facilities, and system upgrades that fall into the description above is the responsibility of land owners and developers.

9.1.4 Federal Funding

The federal government provides funding for infrastructure and environmental projects primarily through Infrastructure Canada and Environment Canada. The federal funding programs below are the most applicable to future City of Surrey ISMP related projects. While these sources are not widely utilized for storm drainage related projects, on rare occasions they may provide useful funds for specific projects and should be considered when advancing projects.

Canada Building Fund

The Canada Building Fund was established by Infrastructure Canada in 2007 under the 2007 Building Canada Plan to fund infrastructure and community projects from 2007 to 2014. In early 2014 the Government of Canada renewed the Building Canada Plan with $1.1 Billion allocated to British Columbia. Applications for project funding are currently being accepted. We encourage the City of Surrey to pursue funding opportunities to support implementation of community projects that may develop from the recommendations of the Cruikshank and Grenville ISMP, such as stormwater management ponds.

EcoAction Community Funding Program

Environment Canada supports community projects through the EcoAction Community Funding Program. The program was established in 1995 and has provided financial support for community-based projects that have measurable, positive impacts on the environment. The most recent funding accepted applications through to November 1st 2013. If renewed in the future, this program could support watershed initiatives in Surrey.

In the past the program has encouraged action focussed projects that protect, rehabilitate, or enhance the natural environment, and build the capacity of communities to sustain these activities into the future and supports projects that address the themes of clean air, clean water, climate change, and nature (Environment Canada). Grants were only available to non-profit environmental groups, community groups, youth and senior groups, community-based associations, service clubs, and aboriginal organizations; however, municipalities may seek these funds through non-profit organizations. If the program is continued, we encourage the City of Surrey to partner with a non-profit organization based in the study area such as the Sikh Academy or the Surrey Environmental Partners to apply for funding for applicable source control measures, stormwater management facilities, or environmental enhancements.

Green Municipal Fund

Environment Canada funds and supports the Green Municipal Fund. Funding is granted through the Federation of Canadian Municipalities (FCM) via project application from a member municipality. The Green Municipal Fund finances and provides knowledge to municipal governments and their partners across Canada to provide support for municipal environmental projects that improve water and soil quality, reach higher standards of air quality, and promote climate protection. Initiatives must result in significant environmental benefits and have the potential to be replicated in other communities (Federation of Canadian Municipalities).

Through the Green Municipal Fund, FCM funds three types of initiatives including grants to develop plans, grants to conduct feasibility studies or field tests, and below-market loans, usually in combination with grants, to implement capital projects. We believe that the City of Surrey could utilize the Green Municipal Fund to construct a pilot project to evaluate the long term and short term performance of source controls and/or right-of-way subgrade storage facilities.

9.1.5 Provincial Funding

The British Columbia provincial government provides funding for community and stormwater management projects through the Ministry of Community, Sport, and Cultural Development. Currently, the only applicable funding source is the Infrastructure Planning Grant Program described below.

Infrastructure Planning Grant Program

The Ministry of Community, Sport, and Cultural Development supports the Infrastructure Planning Grant Program which offers grants to support local governments in projects related to the development of sustainable community infrastructure. Studies that evaluate new practices such as source control measures are eligible for grants up to $10,000. A grant of this nature could be used to evaluate the performance of source control measures implemented as part of the recommendations of the ISMP.

9.2 CHECKLISTS FOR DEVELOPMENT AND RE-DEVELOPMENT PROJECTS

We recommend that the City of Surrey develop a set of checklists to ensure that the recommended best management strategies developed in the ISMP are properly accounted for at every stage of the development process from planning, design, and permitting, to construction inspection and long term operation and maintenance. Checklists can be incorporated into existing processes and will encourage proper implementation of the stormwater management recommendations promoting improved long term health of the watersheds.

9.2.1 Application for Development

Individuals wanting to develop or change the use of land in the City of Surrey must obtain proper approval from the City. As stated on the City's website, land development applications must meet the requirements set out in the Official Community Plan, Zoning By-Law, and other public documents. Individuals wanting to re-develop an existing property within the same land use type must obtain proper approval from the City of Surrey with a building permit. Building permits within the City of Surrey are divided into two categories, Residential Section and Commercial Section. The Residential Section applies only to single family residential buildings. The Commercial Section applies to all commercial, industrial, institutional, and multi-family buildings.

We recommend that the stormwater best management strategies developed in the ISMP be reflected in the appropriate land development and building permit application forms and checklists to ensure that they are successfully implemented into the planning and permitting phases of development.

Single Family Residential Criteria

The following should be incorporated into development and building permit applications for residential land development projects and new single family dwellings:

- Landscaping plans showing tree and/or shrub plantings and enhanced growing medium,
- Site plans showing the locations and extents of pervious pavement, and
- Summary of hydrologic calculations used to determine that selected source control measures meet the performance targets in Table 9-1 below.

Table 9-1
Source Control Performance Targets for Urban Residential Lots

Event	Total Rainfall Depth	Target Peak Flow Rate	Total Rainfall Volume (m^3 / hectare)	Target Runoff Volume (m^3 / hectare)
24 hour 2-Year Return Period Event	64.8 mm	3 L/s / hectare	648	535
Mean Annual Total Rainfall	1650 mm	N/A	16,500	9,700

Commercial, Industrial and Multi-Family Residential Criteria

The following should be incorporated into development and building permit applications for commercial, industrial, or multiple family residential land development projects or building re-construction:

- Landscaping plans showing tree and/or shrub plantings, enhanced growing medium, green roof vegetation, bioswales, and rain gardens,
- Site plans showing the locations and extents of pervious pavement, green roofs / detention roofs, bioswales / infiltration trenches, and rain gardens,
- Summary of hydrologic calculations used to determine that selected source control measures meet the performance targets in Table 9-2 below.

Table 9-2
Source Control Performance Targets for Commercial, Industrial, and Multi-Family Lots

Event	Total Rainfall Depth	Target Peak Flow Rate	Total Rainfall Volume (m^3 / hectare)	Target Runoff Volume (m^3 / hectare)
24 hour 2-Year Return Period Event	64.8 mm	4 L/s / hectare	648	580
Mean Annual Total Rainfall	1650 mm	4 L/s / hectare	16,500	13,500

- Summary of the calculations and methodology used to design and locate the sub-surface detention and retention storage facility, which may consist of calculations and specifications from suppliers in the case of proprietary design products. On-site detention storage should meet the performance criteria in Table 9-3 below.

Table 9-3
Commercial, Industrial and Multi-Family Residential Detention Storage Performance Criteria

Peak Flow Control Criteria	Minimum Required Storage Volume	Maximum Allowable Release Rate	Volume Release Pattern
50% of the 24 hour-2-Year Baseline Event	350 m^3 / hectare	9.0 L/s / hectare	50% in first 24 h 50% in next 48 h

Note: Criteria estimated assuming 90% post development impervious coverage, 24 hour Surrey Design Storms.

Small lot land developers or property owners may not have qualified individuals capable of evaluating the performance of the stormwater best management strategies to provide the required calculations. If this is the case, we recommend that the City of Surrey charge a fee to complete the analysis on behalf of the developer or property owner.

9.2.2 Inspection

Engineering inspectors are responsible for inspecting City of Surrey construction works. Building inspectors are responsible for inspecting construction works on private lots. We recommend that City of Surrey engineering and building inspectors conduct daily or weekly inspections, as appropriate, during the construction of the stormwater best management strategies recommended in Section 8 including on lot source controls measures, sub-surface detention and retention facilities, water quality devices, and stormwater management ponds. This will likely require broadening the responsibilities of inspectors to include landscaped areas. Inspectors should have access to checklists detailing construction requirements for source controls and other stormwater management features and be properly educated regarding acceptable and improper construction practices. This will promote the proper installation and placement of source controls and stormwater management facilities.

Once constructed and active, stormwater best management strategies must be properly maintained. We recommend that, at a minimum, stormwater management facilities be inspected annually. Operation and maintenance of source controls and stormwater management ponds on City owned road rights-of-way and other public property will be the direct responsibility of the City of Surrey. Management of new City of Surrey facilities can be incorporated in the operation and maintenance programs for existing City owned stormwater management infrastructure. City of Surrey inspectors should have access to checklists detailing operation and maintenance procedures and be properly educated and trained so that they understand the intended function of each facility. This will allow them to better evaluate the state of each facility, complete the required maintenance, and flag any observed problems.

Operation and maintenance of stormwater management source controls and large scale stormwater detention and retention facilities located on private property will be the responsibility of individual land owners. We recommend that, prior to final construction inspection approval, individual land owners submit an operation and maintenance plan to the City. At a minimum, the plan should include the operation and maintenance considerations described in Section 8.7. Submission of this plan will better enable the City of hold land owners accountable for proper operation and maintenance of constructed source controls and sub-surface detention and retention facilities.

9.3 INCENTIVES

Compliance with the recommendations of the Cruikshank and Grenville ISMP may be facilitated if land owners and developers are offered incentives for implementing, operating, and monitoring stormwater best management strategies. In this section we discuss several incentives that could be employed to increase compliance.

9.3.1 One Time Rebates

The City of Surrey currently has two programs in place that offer residents and business owners financial incentives for participating in voluntary programs. The first is the Tree Voucher Program which enables participants to purchase a tree voucher for $25 and receive a tree worth $75. Tree vouchers are purchased at the Building Counter at City Hall and are redeemed at a participating nursery. This program encourages residents to plant trees on their property effectively increasing the tree canopy. The second program is the Surrey Water Meter Program which allows participants to pay for their water use according to how much water they use instead of being charged a flat rate. The program encourages water conservation through reduced costs to participants.

Similar to these two existing programs, we recommend that the City create a Stormwater Management Rebate Program to encourage land owners and developers to construct stormwater source control measures and detention and retention systems on their properties. The program could be administered through the City of Surrey Planning and Development Department.

We recommend that in the initial stages of the project that the approval process for rebates be relatively easy to meet and administer. For example, a fixed rebate of a monetary value set by the City of Surrey can be offered to participating land owners who show proof of on-site stormwater management control measures. Proof can take the form of a photo or receipt for construction works.

Once the program is well established, we recommend that the approval process for rebates be more thorough to ensure proper design and installation of works. The procedure will require more effort from both the City and the participant. Rebates should no longer be fixed but based on compliance with the approval process and projected reduction in total annual runoff volume. For example, participants could have to satisfy a sequence of steps as follows:

1. Submit to the City the conceptual design including design drawings, engineering calculations and/or computer modelling of the proposed works.
2. Submit to the City detailed design drawings of the proposed works.
3. Submit to the City operation and maintenance plans of the proposed works.
4. Provide the City with a construction plan and schedule.
5. Facilitate inspection and monitoring by City of Surrey inspectors.

Administering a Stormwater Management Rebate Program for works completed on private property will prove to be more challenging than tree planting or water metering programs. Successful completion of the program will require proper introduction to developers and a thorough understanding of the approval process by those City of Surrey staff administering or involved in the program.

9.3.2 Stormwater Utility Fees

Stormwater utility fees are charged to property owners to offset the cost of stormwater management infrastructure. The advantages of stormwater utility fees include equity of payment for services, a predictable and reliable source of revenue, the ability to develop long term stormwater management programs, and the ability to encourage responsible land use and development. Stormwater utility fees are a viable alternative to fund stormwater management projects, provide funding for ongoing operation and maintenance costs, and provide a stable source of income to assist with planning and implementing long term stormwater management objectives.

The City of Surrey currently has a stormwater utility fee. According to the City of Surrey Utility Rate webpage, the 2012 drainage parcel tax has a flat rate of $166 annually for all serviced properties, regardless of zoning or the effective impervious area of the property. We recommend that the drainage utility rates within the Cruikshank and Grenville watersheds be restructured to reflect the effective impervious area of each property and/or total serviced lot size. This will ensure that properties producing the most runoff pay the highest fees thus more greatly benefiting compliant property owners and promoting a reduction of impervious surfaces on private properties. Linking the stormwater utility fee to effective impervious area will require periodic assessment by City of Surrey staff but will encourage the implementation and maintenance of recommended stormwater best management practices.

Initially, a property's rates could be determined on the basis of the total impervious coverage (TIA), combined with lot area, which is more easily determined from aerial photography and zoning than is EIA. For a property owner to be granted a lower rate to reflect a difference between TIA and EIA, they could submit a request for re-evaluation of their rates with supporting evidence such as photographs, contractor's invoices, etc.

We recommend that future development and re-development projects be charged a stormwater utility fee based on the land owner's commitment to implement and maintain source control best management strategies on their property. This will help to ensure that source controls function as intended during and after construction. The fee structure should be prorated based on lot size and effective impervious area and remain revenue neutral so that the City of Surrey does not decrease its revenue source. The proposed utility rate structure will require relatively accurate measurement of the effective impervious ratios of each lot which may prove to be difficult. We recommend that the City of Surrey determine the proposed fee structure so that they can develop a system tailored to their needs and abilities.

9.3.3 Publicity Achievement Recognition Program for Compliant Businesses

A large portion of the existing study area is comprised of industrial and commercial developments. Future industrial and commercial development and re-development projects are expected to represent a large portion of future development activity within the study area. We recommend that businesses that implement recommendations of the Cruikshank and Grenville ISMP be able to advertise their compliance. The advertisement could consist of a sign or plaque, recognizing their status as “good citizens” or “watershed stewards” or similar terminology, to be placed at an appropriate location on their property. The ability to place a status symbol on their property will encourage participation among business owners especially those striving to improve their image within the community.

9.4 RECOMMENDED CHANGES TO CITY OF SURREY BY-LAWS AND DOCUMENTS

The City of Surrey has By-Laws in place to regulate and enforce practices within the City. We identified five (5) By-Laws that will be impacted by the best management strategies recommended in the ISMP. We recommend that each by-law be amended accordingly to promote the implementation of best management strategies. The recommended changes to each By-Law are described below.

City of Surrey Zoning By-Law, 1993, No. 12000

The Zoning By-Law is in place to divide the City of Surrey into zones and regulate the location, use, and height of buildings, size of yards and other open spaces, and the use of land. We used existing zoning mapping provided by the City of Surrey to determine the specific zoning types within the Cruikshank and Grenville watersheds. There are currently twenty-five different zoning types in the study area. To ensure that the recommendations of the ISMP are properly implemented within development of each zoning type, we recommend that Surrey Zoning By-Law No. 12000 be amended to include the recommended best management strategies associated with each for each zoning type in the study area.

The affected sections relating to urban residential development are as follows:

- Part 16 – RF, Single Family Residential Zone,
- Part 16A – RF-SS, Single Family Residential Secondary Suite Zone,
- Part 17 – RF-G, Single Family Residential Gross Density Zone,
- Part 17A – RF-12, Single Family Residential (12) Zone, and
- Part 17C – RF-9, Single Family Residential (9) Zone.

Sub-section I sets out landscaping requirements for individual residential lots. Sub-section I.1 of each part reads, “All developed portions of the lot not covered by buildings, structures or paved areas shall be landscaped including the retention of mature trees. This landscaping shall be maintained.” We recommend that this sub-section be reworded to include the required performance targets for control of runoff, with suggested (but not mandatory) means to achieve these targets.

The above amendment can also be applied to the affected sections relating to industrial developments:

- Part 18 – RM-D, Duplex Residential Zone,
- Part 19 – RM-M, Manufactured Home Residential Zone,
- Part 21 – RM-15, Multiple Residential 15 Zone,
- Part 22 – RM-30, Multiple Residential 30 Zone,
- Part 23 – RM 45, Multiple Residential 45 Zone,
- Part 31 – PA-1, Assembly Hall 1 Zone,
- Part 32 – PA-2, Assembly Hall 2 Zone,
- Part 34 – C-4, Local Commercial Zone,
- Part 36 – C-8, Community Commercial Zone,
- Part 39 – CHI, Highway Commercial Industrial Zone,
- Part 40 – CG-1, Self-Service Gasoline Station Zone,
- Part 41 – CG-2, Combined Service Gasoline Station Zone,
- Part 42 – CTA, Tourist Accommodation Zone,
- Part 43 – CCR, Child Care Zone,
- Part 44 – CPR, Commercial Recreation Zone, and
- Part 47 – IB, Business Park Zone,
- Part 48 – IL, Light Impact Industrial Zone,
- Part 49 – IH, High Impact Industrial Zone, and
- Part 52 – CD, Comprehensive Development Zone.

We recommend that sub-section I.1 of each part be reworded to include the required performance targets for control of runoff, with suggested/acceptable source control measures for commercial, industrial, and multiple residential developments.

City of Surrey Drainage Parcel Tax By-Law, 2001, No. 14593

The Drainage Parcel Tax By-Law is in place to allow the City to construct and operate storm drainage systems for the convenience and safety of the residents and businesses within the City of Surrey. The by-law describes the imposition of flat rate parcel tax on all properties within the City that is used to fund the construction and operation of drainage and stormwater management services. Prorating stormwater utility fees based on lot area and effective impervious ratios as described in Section 9.3.2 of the ISMP will affect the Drainage Parcel Tax By-Law. We recommend that the by-law be amended to reflect the changes, when implemented.

City of Surrey Stormwater Drainage Regulation and Charges By-Law, 2008, No. 16610

The Stormwater Drainage Regulation and Charges By-Law is in place to allow the City to operate and maintain a stormwater drainage system as a municipal service for the benefits of residents and property owners in the City of Surrey. The by-law states that the cost of servicing a property within the City with drainage works should be paid for in whole or in part by the owners of the property requiring connection to the stormwater drainage system.

Part 5 of the by-law pertains to on-site stormwater management requirements. Reference is given to compliance with ISMPs, specifically that "Newly created parcels shall be constructed with on-site stormwater management facilities when these are prescribed through Council approved neighbourhood plans, master drainage plans, integrated stormwater management plans or as required in a Servicing Agreement or specific service connection." The by-law also lists a number of pollutants that no person shall discharge or allow or cause to be discharged into the stormwater drainage system, ditches, watercourses, or other water bodies including, but not limited to, prohibited or hazardous wastes, sediment laden water, industrial cooling water, and untreated wash water. We recommend that specific consequences for non-compliance be developed and enacted.

City of Surrey Erosion and Sediment Control By-Law, 2006, No. 16138

The Erosion and Sediment Control By-Law is in place to allow the City to protect the best interests and environmental well-being of the streams, creeks, waterways, watercourses, ditches, storm sewers, and drains that make up community drainage systems. This includes protection from pollution, obstructions, sediment, and sediment laden water during construction activity. The by-law consists of several sections including Prohibition of Discharge, Erosion and Sediment Control (ESC) Permit, ESC Plan, Monitoring and Reporting, and Offences and Enforcement.

Erosion and sediment control best management practices are defined in Schedule "B". We recommend that special provisions for construction of source control stormwater best management facilities be added to Schedule "B". Requirements regarding the following practices should be added:

- Stock piling and placement of growing medium, and
- Protection of trees, shrubs, and their planting locations.

City of Surrey Supplementary Master Municipal Construction Documents, 2004

We recommend that the City of Surrey develop specifications and standard drawings for several of the recommended source control best management strategies. The standards can be integrated into the City's Supplementary Master Municipal Construction Documents and detail the design, construction, and operation and maintenance procedures for pervious pavement, green roofs / detention roofs, bioswales / infiltration trenches, and rain gardens. Formal specifications and standards will encourage their use, promote effective design, construction, and implementation, and support proper operation and maintenance.

10 Recommendations

The context for the following recommendations is provided by the assessment of the watersheds and general goals and objective discussed in earlier sections.

As discussed in Section 3, the Cruikshank and Grenville watersheds retain significant and important functionality as fish habitat. A majority of the surviving watercourses have documented fish presence or have a supporting role in providing food and nutrients (Refer to Map 3-5). Preservation of the remaining habitat value is important and suitable measures are required to prevent further degradation and to provide opportunities for improvement. This provides a primary motivation for ensuring that sufficient measures are implemented to prevent further degradation of the watersheds, and preferably, provides for an improvement in watershed health.

Modelling of development impacts (refer to Section 6) indicated that there was an 8% increase in mean annual runoff volumes if no measures were implemented to address the changes in watershed hydrology. This increase implies a further degradation of the watercourses in the study area due to increased erosion and disruption of fish habitat. Mitigation of runoff volumes is primarily accomplished by the application of source controls, which form an important part of the recommendations of this ISMP.

The following vision statement guides the recommendations of this Cruikshank and Grenville ISMP:

"The vision for the Cruikshank and Grenville ISMP is to achieve a significant improvement in watershed health and the aesthetic and community values in the watershed. This ISMP will present a strategy for the successful implementation of stormwater best management practices that balance economic activities in the watershed with preserving and enhancing natural features, environmental health and engaging the public."

In the remainder of this section we finalize the recommendations made throughout the Cruikshank and Grenville ISMP including environmental enhancements, stormwater management measures, and implementation and enforcement strategies. Each recommendation is classified as either short term (10-year horizon or less) or long term (10 to 20 year horizon). Short term recommendations should be included in the City of Surrey's 10-year Servicing Plan. Long term recommendations should be implemented when either an opportunity arises, or during the 10 to 20 year horizon. If necessary, some programs initiated under the immediate 10-year plan can be extended through to the later period to control expenditures, and address opportunities as they arise.

10.1 SHORT TERM (10-YEAR PLAN) RECOMMENDATIONS

All short term recommendations are listed in Table 10-1 and described below.

Table 10-1
10-Year Plan Actions

No.	Recommendations	Location	Unit Cost	Qty.	Sub-Total Cost
Environmental Enhancements/Actions – Locations of Site Specific Actions are Indicated on Figure 10-1					
E.1	Remove Log Jams and Debris within Watercourses, place LWD along banks	Bear, Cruikshank, and King Creek	$30,000/ea	5	$150,000
E.2	Remediate High Risk Erosion Sites	Bear Creek	$100,000/ea	4	$400,000
E.3	Improve In-Stream Habitat and Channel Complexity	Healy Creek	$100,000		$100,000
E.4	Improve Fish Passage at Vertical Drop Structures	Cruikshank Creek	$100,000		$100,000
E.5	Re-Vegetate Bare Earth and Exposed Soils	Riparian Corridors	$500,000		$500,000
E.6	Enhancement of Flooded Field Adjacent to Bear Creek to a more Permanent “Wetland” Feature	Adjacent to Bear Creek, east of railway	$1,900,000		$1,900,000
E.7	Place Interpretive Signage along Trail Systems	Bear, Quibble, Healy, & Queen Mary Creek	$20,000		$20,000
E.8	Soil Evaluation Test Pitting Program	Vacant land	$50,000		$50,000
E.9	Infiltration Testing Pilot Program	Lots adjacent to watercourses	$50,000		$50,000
E.10	Restrictive Covenant Fencing for Future Development	Riparian Corridors	varies		varies
E.11	Remove Invasive and Nuisance Weed Species and Re-Vegetate Weed Control Areas	Adjacent to Cruikshank, Quibble, Bear, Healy, & Queen Mary Creek	$100,000		$100,000
E.12	Native Vegetation Planted Adjacent to EMS Zones	Development Adjacent to EMS	varies		varies

No.	Recommendations	Location	Unit Cost	Qty.	Sub-Total Cost
		Zones			
Stormwater Management Infrastructure					
S.1	Construct Stormwater Management Ponds • assumes half of capital work undertaken in short term, half in long-term	Shown on Map 10-2	$11,775,000		$11,775,000
S.2	Implement Pipe System Upgrades • assumes half of upgrades undertaken in short term, half in long-term • cost assumes source controls and BMPs fully implemented	Throughout Study Area – Refer to Maps 6-3A to 6-3F, and Table D-1, Appendix D, for details	$5,340,000		$5,340,000
S.3	Future Urban Residential Source Controls	Future Development	varies		varies
S.4	Future Commercial, Industrial, and Multiple Residential Source Controls	Future Development	varies		varies
S.5	Sub-Surface Detention and Retention Storage	Future Development	varies		varies
S.6	Future Right-of-Way Source Controls	Road Improvements	varies		
Implementation and Enforcement Strategies					
I.1	Update Land Development and Building Permit Application Forms and Checklists	N/A	$25,000		$25,000
I.2	Stormwater Management Rebate Program	N/A	$200,000		$200,000
I.3	Revise the Drainage Utility Rate Structure	N/A	$50,000		$50,000
I.4	Update City of Surrey By-Laws	N/A	$50,000		$50,000

ENVIRONMENTAL ENHANCEMENTS

An environmental overview of the study area, environmental constraints and opportunities, and a hydrogeological assessment were discussed in Section 3. The recommendations listed below were derived from the work completed in these sections. Locations of site specific environmental enhancements are indicated on Map 10-1.

E.1: Remove Log Jams and Debris within Watercourses

Objective: To promote seasonal fish movement and replace with appropriate large-woody debris to create appropriate fish habitat. 5 sites, nominal cost allowance as no engineering design undertaken.

Location: Bear, Cruikshank, and King Creek

Cost: $150,000

E:2: Remediate Erosion Sites

Objective: To monitor and remediate erosion sites within Bear Creek that have resulted in bank instability which may contribute to downstream sedimentation and decrease available habitat for juvenile salmonids and benthic invertebrates. 4 sites, nominal cost allowance as no engineering design undertaken.

Location: Bear Creek

Cost: $400,000

E.3: Improve In-Stream Habitat and Channel Complexity

Objective: To Improve in-stream habitat and channel complexity as well as riparian vegetation within Healy Creek and the unnamed tributary to Healy Creek upstream of 88 Avenue. The lack of in-stream habitat is limiting the capacity to support juvenile fish and poor in-stream complexity reduces the amount of available aquatic habitat for rearing or migration of salmonids. Nominal cost allowance as no engineering design undertaken.

Location: Healy Creek

Cost: $100,000

E.4: Improve Fish Passage at Vertical Drop Structures

Objective: Vertical drop structures within Cruickshank Creek are currently barriers to fish migration and should be made passable by creation of fish ladders or weir structures or removal or reducing the height of the centre portion of the vertical drop structure, as well as enhancing in-stream fish habitat (such as creation of deep pools, installation of coarse woody debris, etc.) aquatic habitat for rearing or migration of salmonids. Nominal cost allowance as no engineering design undertaken.

Location: Cruikshank Creek

Cost: $100,000

E.5: Re-Vegetate Bare Earth and Exposed Soils

Objective: To reduce the potential for future weed invasions by establishing native vegetation. Nominal cost allowance as no engineering design undertaken.

Location: Numerous sites along existing riparian corridors

Cost: $500,000

E.6: Enhancement of Flooded Field Adjacent to Bear Creek to a more Permanent "Wetland" Feature

Objective: To promote further use by native amphibians of the currently flooded land adjacent to Bear Creek, east of the railway. Secondary benefits of water quality improvements, some flow attenuation function.

Location: Adjacent to Bear Creek, east of railway.

Cost: $1,900,000

E.7: Place Interpretive Signage along Trail Systems

Objective: To highlight the uniqueness and values of the riparian ecosystems; in addition to the restoration and management activities in progress or completed in the areas. Collaboration with local businesses, school and community groups will not only decrease the cost to the City but also increase pride and accountability of environmental stewardship in the community.

Location: Bear Creek, Quibble Creek, Healy Creek, Queen Mary Creek

Cost: $20,000

E.8: Soil Evaluation Test Pitting Program

Objective: To confirm soil characteristics and infiltration capacity in key areas near watercourses. These test pits would also serve to indicate infiltration capacity for soil beside local streets where installation of infiltration swales or rain gardens may be considered.

Location: Hydro line right-of way or park area. As per the recommendation in the Piteau (1999) report, these test pits can be located within approximately 300 m of watercourses, so that soil testing would concentrate on areas which contribute to streams, and especially stream base flow in summer.

Cost: $50,000

E.9: Infiltration Pilot Program

Objective: To determine the effectiveness of infiltration based stormwater management strategies.

Location: Undeveloped areas adjacent to or within close proximity of watercourses.

Cost: $50,000

E.10: Restrictive Covenant Fencing for Future Development

Objective: To hinder human and pet access, but not limit wildlife access to the riparian and aquatic habitats. Existing chain link fencing prevents wildlife access, forcing animals onto busy roads and parking lots. Natural materials will also increase the aesthetics of these areas, encouraging protection by trail users and business owners, and minimizing further degradation of the vegetation.

Location: Riparian corridors

Cost: varies

E.11: Remove Invasive and Nuisance Weed Species and Re-Vegetate Weed Control Areas

Objective: To allow native vegetation to return to disturbed areas remove English ivy, Scotch broom, false lamium, morning glory and horticultural and cultivated grasses. To prevent weed species from reintroducing into these areas and increase nesting habitat for forest passerines, plant with native species such as red alder, willow, red-osier dogwood, thimbleberry, trailing blackberry, and salmonberry, and with native shrubs such as red alder and black cottonwood trees, willows, more baldhip rose, salmonberry bushes and native grasses.

Location: Cruikshank Creek and Quibble Creek and beneath power lines adjacent to Bear Creek, Healy Creek, and Queen Mary Creek

Cost: $100,000

E12: Native Vegetation Planted Adjacent to EMS Zones

Objective: To maintain the ability to develop urban residential lots bordering or extending within EMS zones and provide enhanced ecological and hydrologic function of EMS zones. Setbacks should be a minimum of 3.6 m for urban residential developments and a minimum of 15 m for industrial, commercial, and multiple residential developments.

Location: Development bordering or extending within EMS zones.

Cost: Varies. Incurred by developer and/or land owner.

STORMWATER MANAGEMENT MEASURES

The state of the existing drainage system and improvements required to address future development impacts were discussed in Section 6. Stormwater best management strategies and related performance targets were discussed in Section 8. The recommendations listed below were derived from the work completed in these sections.

S.1: Stormwater Management Ponds

Objective: To provide relief to downstream watercourses and infrastructure in the form of decreased peak flow rates and reduced erosion potential. Also to act as attractive community amenities that provide recreational benefits and habitat for wildlife.

Stormwater management ponds are discussed in detail in Section 8.5. Their locations are shown on Map 10-2. The City of Surrey should evaluate the cost and benefits of placing ponds at each location to determine their desired order of preference. Based on the land acquisition and construction costs and hydraulic benefits of each pond, we believe that ponds should be constructed in the following order: Pond 2, Pond 3, Pond 1, Pond 4, and Pond 5.

Location: Locations as shown on Map 10-2.

Cost: $11,775,000

S.2: Drainage System Upgrades

Objective: To undertake upgrades to the piped drainage system to address existing and future capacity deficiencies.

Required pipe system upgrades for existing and future conditions were identified in Section 6 and re-evaluated under the assumption that all BMP's are implemented in Section 8. Approximately half of the upgrades are related to existing deficiencies, and the remainder to future development impacts.

The recommended pipe system upgrades are based on a watershed scale model analysis. As such, all identified drainage system upgrades, should be confirmed by detailed analysis prior to entering the design and implementation process.

Culvert upgrades should be confirmed by assessing the depth of surcharge relative to road crest spill elevations, the impacts of backwater conditions on upstream properties, and the potential for high seepage pressures to destabilize road fills.

Location: Throughout study area, as indicated on Maps 6-3A to 6-3F (adjusted on Map 8-2), with an overview provided on Map 10-2. Details of pipe upgrades are provided in Table D-1 in Appendix D.

Cost: $5,340,000

S.3: Future Urban Residential Source Controls

Objective: To restrict peak flow rates and total runoff volumes generated by future urban residential developments to the values listed in Table 10-2.

Table 10-2
Performance Targets for Urban Residential Lots

Event	Total Rainfall Depth	Target Peak Flow Rate	Target Runoff Volume
2-Year Return Period Event	64.8 mm	3 L/s / hectare	535 m^3 / hectare
Mean Annual Total Rainfall	1650 mm	3 L/s / hectare	9,700 m^3 / hectare

Target peak flow rates and runoff volumes should be achieved using a combination of source control measures including shrub planting, tree planting, enhanced growing medium, and pervious pavement.

Location: At locations of future urban residential development.

Cost: Varies. Incurred by developer and/or land owner.

S.4: Future Commercial, Industrial, and Multiple Residential Source Controls

Objective: To restrict peak flow rates and total runoff volumes generated by future commercial, industrial, and multiple residential developments to the values listed in Table 10-3.

Table 10-3
Performance Targets for Commercial, Industrial, and Multiple Residential Lots

Event	Total Rainfall Depth	Target Peak Flow Rate	Target Runoff Volume
2-Year Return Period Event	64.8 mm	4 L/s / hectare	580 m^3 / hectare
Mean Annual Total Rainfall	1650 mm	4 L/s / hectare	13,500 m^3 / hectare

Target peak flow rates and runoff volumes should be achieved using a combination of source control measures including shrub planting, tree planting, enhanced growing medium, pervious pavement, green roofs / detention roofs, bioswales / infiltration trenches, and rain gardens.

Location: At locations of future commercial, industrial, and multiple residential developments.

Cost: Varies. Incurred by developer and/or land owner.

S.5: Sub-Surface Detention and Retention Storage

Objective: To control peak flow rates and total runoff volumes from future commercial, industrial, and multi-family residential developments. On-site sub-surface stormwater retention and detention facilities will provide relief to downstream stormwater infrastructure and natural watercourses. Storage volumes and allowable post development release rates during the 5-year return period storm event are indicated in Table 10-4 below.

Table 10-4
Commercial/Industrial/Multi-Family Detention Facility Performance Criteria

Peak Flow Control Criteria	Minimum Required Storage Volume	Maximum Allowable Release Rate	Volume Release Pattern
5-year post dev. storm ≤ 50% of the 24 hour-2-Year Baseline Event	350 m^3 / hectare	9.0 L/s / hectare	50% in first 24 h 50% in next 48 h

Note: Criteria estimated assuming 90% post development impervious coverage, 24 hour Surrey Design Storms.

Water quality devices should also be installed to treat runoff prior to its release to downstream stormwater infrastructure or natural watercourses.

Location: At locations of future commercial, industrial, and multiple residential developments.

Cost: Varies. Incurred by developer and/or land owner.

S.6: Future Road Right-of-Way Source Controls

Objective: To provide control of stormwater runoff from frequently occurring rainfall events in City of Surrey rights-of-way. Source controls will also act as community amenities and may encourage individual land owners to implement source controls on their properties.

Local and collector road rights-of-way should use a combination of enhanced growing medium, tree planting, shrub planting, pervious parking lanes, and infiltration / retention systems.

Arterial road rights-of-way should employ a combination of enhanced growing medium in medians, tree planting, shrub planting, enhanced growing medium in boulevards, and infiltration / retention systems.

Location: Within future road improvement projects.

Cost: Varies and depends on type and footprint of selected source controls.

IMPLEMENTATION AND ENFORCEMENT STRATEGIES

I.1: Update Land Development and Building Permit Application Forms and Checklists

Objective: To ensure that the source controls measures, sub-surface detention and retention facilities, EMS setbacks, and water quality devices are properly incorporated within future developments. Both categories, the Residential Section and the Commercial Section, of building permits should be revised.

Location: N/A

Cost: $25,000

I.2: Stormwater Management Rebate Program

Objective: To encourage land owners and developers to construct stormwater source control measures and detention and retention systems on their properties. The program should be similar to the existing Tree Voucher Program and the Surrey Water Meter Program and can be administered through the City of Surrey Planning and Development Department.

Location: N/A

Cost: $200,000, Costs reflect anticipated administrative effort for City staff over 10-year horizon. Program should be configured to be revenue neutral.

I.3: Revise the Drainage Utility Rate Structure

Objective: To encourage land owners to implement and maintain source control measures by restructuring the drainage utility rate to be based on either the effective impervious area of each property and/or total serviced lot size. This will ensure that properties producing the most runoff pay the highest fees thus more greatly benefiting compliant property owners and promoting a reduction of impervious surfaces on private properties.

Location: N/A

Cost: $50,000

I.4: Update City of Surrey By-Laws

Objective: To give the City of Surrey tools to enforce the recommendations of the ISMP and to ensure compliance from developers and land owners. The following By-Laws should be revised:

- City of Surrey Zoning By-Law, 1993, No. 12000,
- City of Surrey Drainage Parcel Tax By-Law, 2001, No. 14593,
- City of Surrey Stormwater Drainage Regulation and Charges By-Law, 2008, No. 16610,
- City of Surrey Erosion and Sediment Control By-Law, 2006, No. 16138, and
- City of Surrey Supplementary Master Municipal Construction Documents, 2004.

Location: N/A

Cost: $50,000

Overall, the short term (10-Year Plan) recommended actions have an estimated cost of approximately $18,910,000 over the 10-year span, or approximately $1,890,000 per year.

10.2 LONG TERM (10-20-YEAR PLAN) RECOMMENDATIONS

All long term or on-going recommendations are listed in Table 10-5 and described below.

Table 10-5
Long Term (On-Going) Recommendations

No.	Recommendations	Location	Cost
Stormwater Management Measures			
S.1	Construct Stormwater Management Ponds assumes half of capital work undertaken in short term, half in long-term	Shown on Map 10-2	$11,775,000
S.2	Implement Pipe System Upgrades • assumes half of upgrades undertaken in short term, half in long-term • cost assumes source controls and BMPs fully implemented	Throughout Study Area – Refer to Maps 6-3A to 6-3F, and Table D-1, Appendix D, for details.	$5,340,000

STORMWATER MANAGEMENT MEASURES
S.1: Stormwater Management Ponds

Objective: To provide relief to downstream watercourses and infrastructure in the form of decreased peak flow rates and reduced erosion potential. Also to act as attractive community amenities that provide recreational benefits and habitat for wildlife.

Stormwater management ponds are discussed in detail in Section 8.5. Their locations are shown on Map 10-2. The City of Surrey should evaluate the costs and benefits of placing ponds at each location to determine their desired order of preference. Based on the land acquisition and construction costs and hydraulic benefits of each pond, we believe that ponds should be constructed in the following order: Pond 2, Pond 3, Pond 1, Pond 4, and Pond 5.

Location: Locations as shown on Map 10-2.

Cost: $11,775,000

S.2: Drainage System Upgrades

Objective: To undertake upgrades to the piped drainage system to address existing and future capacity deficiencies.

Required pipe system upgrades for existing and future conditions were identified in Section 6 and adjusted to reflect the implementation of BPM's and source controls. Approximately half of the upgrades are related to existing deficiencies, and the remainder to future development impacts. (Refer to Map 8-2)

Location: Throughout study area, as indicated on Maps 6-3A to 6-3F, with an overview provided on Map 10-2. Details of pipe upgrades are provided in Table D-1 in Appendix D.

Cost: $5,340,000

The long term (10 to 20 Year Plan) recommended actions have an estimated capital cost of approximately $17,120,000 over the 10-year period, or approximately $1,710,000 per year.

10.3 ONGOING MANAGEMENT EFFORTS

Ongoing management efforts related to this ISMP, including operations and maintenance related to specific ISMP recommendations are listed in Table 10-5 and described below.

Table 10-6
Ongoing Management Efforts

No.	Recommendations	Location	Cost
Operations and Maintenance (Annual)			
O.1	Regular Maintenance of Culverts and Removal of Debris	Bear, Cruikshank, and King Creek	$10,000
O.2	Annual Maintenance and Upkeep of Setback Fencing within Bear Creek Park	Bear Creek Park	$5,000
O.3	Remove Garbage	Riparian Corridors	$10,000
O.4	Annual Pruning and Maintenance of Himalayan Blackberry	Riparian Corridors	$25,000
O.5	Undertake a bird and bat-box program	Riparian Corridors	$5,000

No.	Recommendations	Location	Cost
Management Activities (Annual)			
M.1	Enforcement Monitoring of Implemented Urban Residential Source Controls	Future Development	$25,000
M.2	Enforcement Monitoring of Future Commercial, Industrial, and Multiple Residential Source Controls	Future Development	$25,000
Implementation and Enforcement Strategies (Annual)			
I.5	Inspection Services	Future Development	varies
I.6	Publicity Achievement Recognition Program for Compliant Businesses	Future Development	$10,000

ENVIRONMENTAL ENHANCEMENTS

O.1: Regular Maintenance of Culverts and Removal of Debris

Objective: To promote fish passage and improve culvert integrity and safety.

Location: Bear Creek (upstream of 128 Street), Cruikshank Creek (downstream of 132 Street) and King Creek.

Cost: $10,000 annually

O.2: Annual Maintenance and Upkeep of Setback Fencing with Bear Creek Park

Objective: To maintain fish habitat within Bear Creek Park and promote existing restoration and enhancement projects including in-stream installation of root wads and large-woody debris with adequate setback fencing and signage to deter pedestrian traffic within the riparian corridors.

Location: Within Bear Creek Park watercourses.

Cost: $5,000 annually

O.3: Remove Garbage

Objective: To promote long-term maintenance of healthy ecosystems.

Location: Riparian corridors

Cost: $10,000 annually

O.4: Annual Pruning and Maintenance of Himalayan Blackberry

Objective: To discourage further expansion of these patches and promote growth of native shrubs, while maintaining the valuable nesting habitat that this blackberry species provides.

Location: Riparian corridors

Cost: $25,000 annually

O.5: Undertake a bird and bat-box program

Objective: To highlight the value of these species in insect control and general ecosystem health. Program should include installation of nest boxes within the riparian areas and collaborate with schools and community groups for long-term monitoring and maintenance. Bird nest boxes should range from housing songbirds as small as chickadees to larger birds such as woodpeckers and owls. Bat boxes are a standard size, sufficient to house a small colony of bats. Monitoring should occur a minimum of three visits during the active wildlife season (March to October) to observe nesting, breeding and fledging of the box inhabitants.

Location: Riparian corridors

Cost: $5,000 annually

MANAGEMENT ACTIVITIES

M.1: Enforcement Monitoring Future Urban Residential Source Controls

Objective: To undertake general monitoring of activities in the watershed to ensure that source controls on urban residential lots are properly maintained and are not being compromised.

Location: At locations of future urban residential development.

Cost: $25,000 annually

M.2: Enforcement Monitoring of Future Commercial, Industrial, and Multiple Residential Source Controls

Objective: To undertake general monitoring of activities in the watershed to ensure that source controls on industrial/commercial and multi-family lots are properly maintained and are not being compromised.

Location: At locations of re-developed industrial, commercial, multifamily, land-uses.

Cost: $25,000 annually

IMPLEMENTATION AND ENFORCEMENT STRATEGIES

I.5: Inspection Services

Objective: To ensure that on lot source controls measures, sub-surface detention and retention facilities, water quality devices, and stormwater management ponds are properly constructed. City of Surrey engineering inspectors and building inspectors should conduct daily or weekly inspection of construction works, as appropriate.

Location: At locations of future development on public and private properties
Cost: Varies

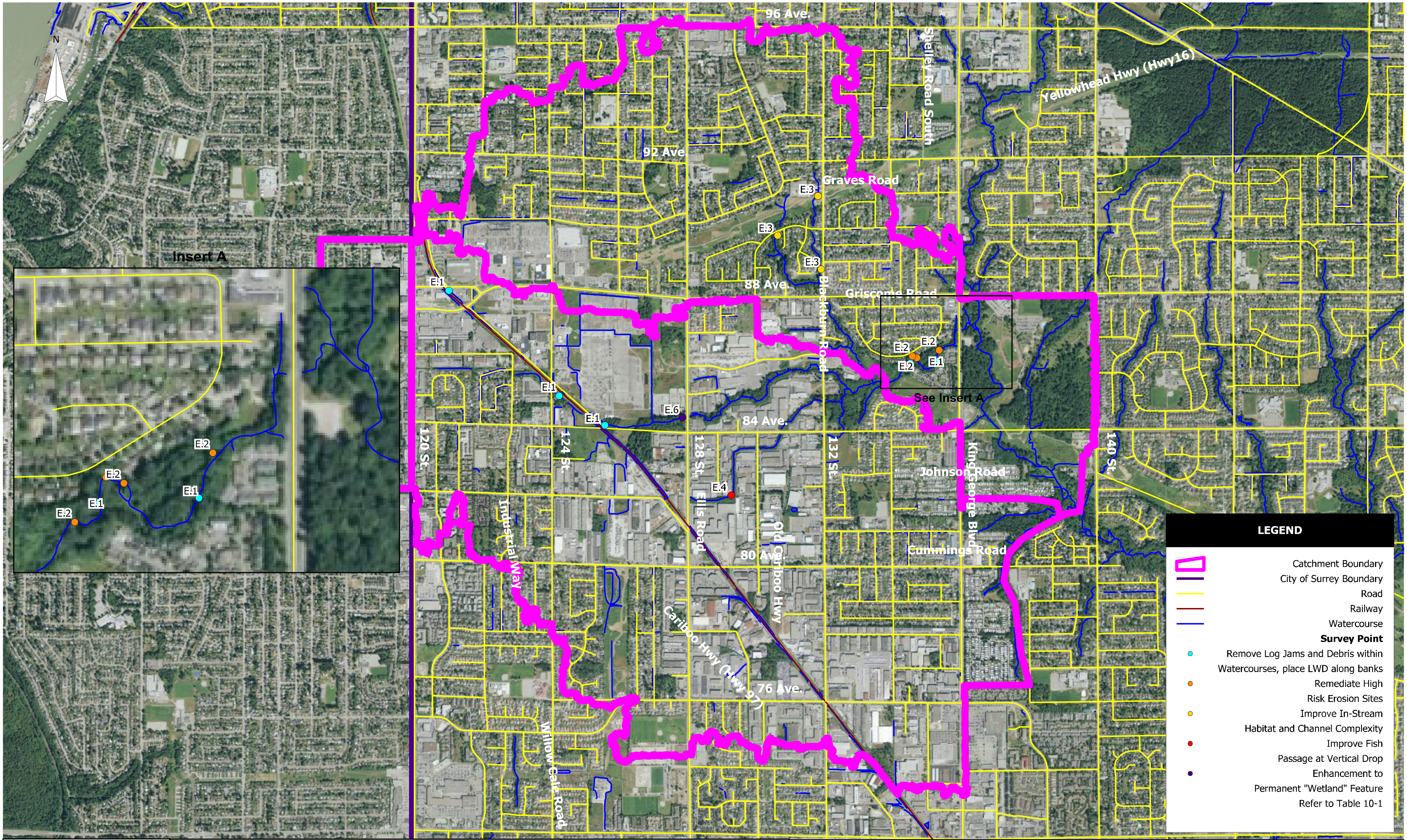
I.6: Publicity Achievement Recognition Program for Compliant Businesses

Objective: To encourage developers and land owners to implement and maintain on lot source controls measures, sub-surface detention and retention facilities, EMS zone setbacks, and water quality devices. The advertisement could consist of a sign or plaque, recognizing their status as “good citizens” or “watershed stewards” or similar terminology, to be placed at an appropriate location on their property.

Location: On lots of developers or land owners who comply with the environmental and engineering recommendations of the Cruikshank and Grenville ISMP.

Cost: $10,000

If all required monitoring and maintenance activities are implemented they represent a budget requirement of approximately $115,000 per annum. This amount does not include the monitoring of performance indicators discussed in the following section.



No.	REVISION	DATE

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY — the future lives here.

Project No.: 20112781	
Date: March 2014	
Scale: 1:20,000	

City of Surrey
Cruikshank and Grenville ISMP
Map 10-1: Recommended Environmental Enhancements

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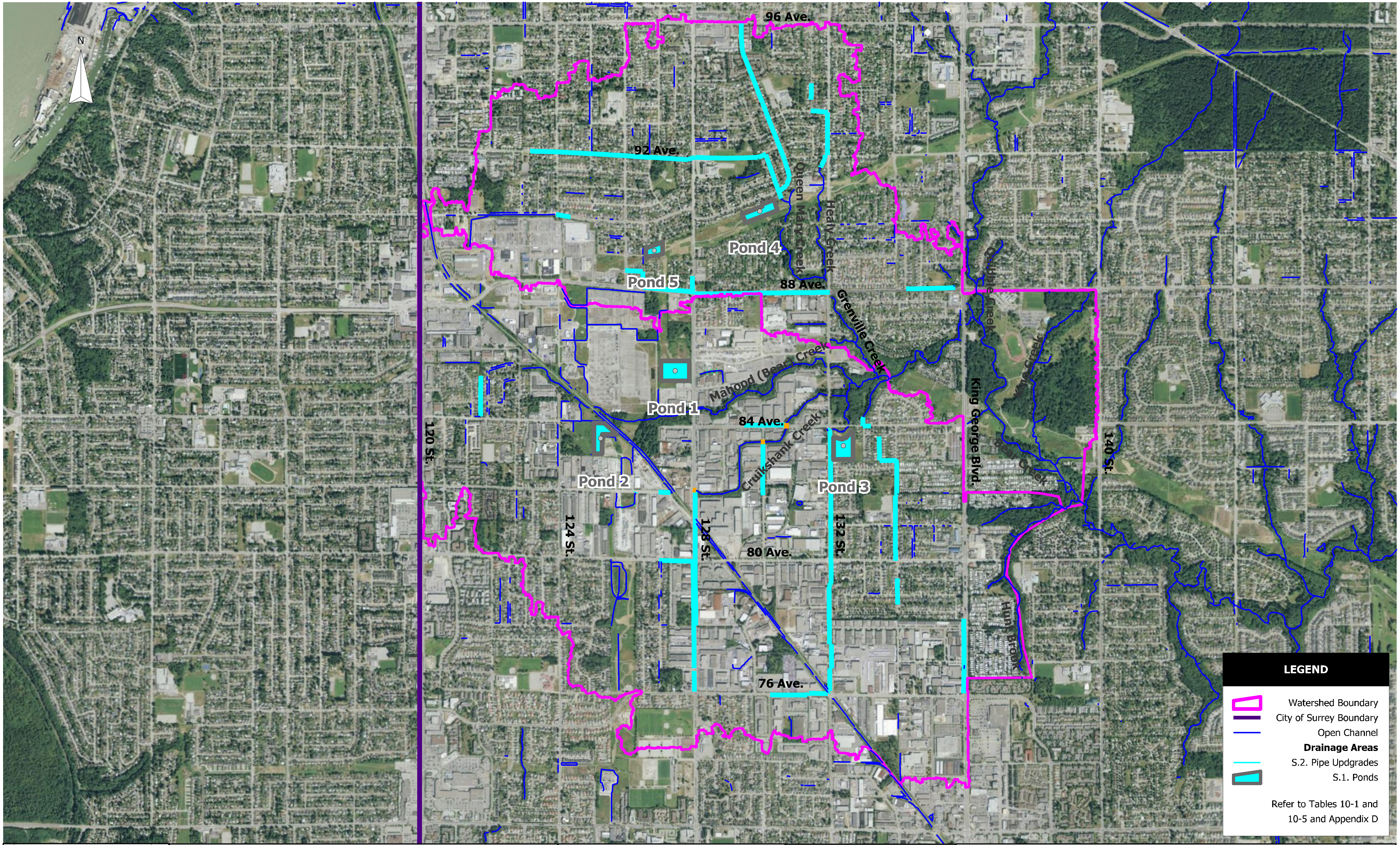

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No.	REVISION	DATE

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Project No.: 20112781
Date: March 2014
Scale: 1:20,000

City of Surrey
Cruikshank and Grenville ISMP

Map 10-2: Recommended Stormwater Infrastructure Upgrades

11 Key Performance Indicators

The long term success of the Cruikshank and Grenville ISMP in meeting the objectives of improving watershed health while supporting the City's land use objectives requires a process to monitor the performance of the watersheds, to identify issues and opportunities, and to modify or adapt the ISMP to address these issues as implementation progresses. The first requirement is an ongoing program that monitors key metrics that are most indicative of the state of the watersheds and how they are changing over time. Next is a process to assess challenges as they arise, and identify the required actions to ensure that the ISMP's objectives will still be met. Finally, implementation of those actions is required.

This section identifies key performance indicators to assess the effectiveness of the ISMP recommendations and provide triggers for adaptive management. In Metro Vancouver's template for Integrated Stormwater Management Planning, 2005, the collection and reporting of a minimum of 18 monitoring parameters was originally recommended. However, the scope and cost of a monitoring effort based on the template is now recognized as a significant challenge for the member municipalities, particularly when multiple ISMP study areas are considered.

Subsequently, to address the required level of effort, Metro Vancouver has developed a draft Monitoring and Adaptive Management Framework (October, 2013), which provides guidance on the minimum monitoring activities and response mechanisms for ensuring that ISMPs stay "on track" in meeting their objectives. This framework does not preclude the possibility of additional monitoring effort if the particulars of a watershed make it advisable.

The Cruikshank and Grenville watersheds are hybrid systems, with extensive piped urban areas, and significant open channel reaches supporting fisheries resources. Under the draft framework, these watersheds generally qualify for monitoring of water quality, hydrometric response (flow regime metrics) and benthic invertebrate (B-IBI). Notably, the City already undertakes all three of these monitoring actions in the watersheds on a regular basis.

We also recommend that the following monitoring parameters identified in Metro Vancouver's Template for Integrated Stormwater Management Planning (2005), be added to the framework parameters to provide an appropriate monitoring program:

- % Tree (Forest) Cover,
- % TIA,
- % EIA,
- % RFI,
- Fisheries Habitat Assessment,
- Ravine Stability Assessment.

Other parameters suggested in the ISMP template that could be monitored include:

- Watershed Area
- % Large Lot Residential Development
- Road Density
- Population Density
- Density of Storm Sewers

However, the linkages between these parameters to watershed health and the effectiveness of the ISMP are not directly demonstrable. For example, an increase in population density would not necessarily be linked to impairment of watershed health if the additional population is accommodated without increasing the development footprint, and/or appropriate low impact development approaches are included. Similarly, an increase in road density may not have a direct effect on watershed health. Therefore, we do believe that they are beneficial components of a monitoring effort related to the Cruikshank and Grenville ISMP.

11.1 RECOMMENDED KEY PERFORMANCE INDICATORS

Based on the unique characteristics and concerns within the Cruikshank and Grenville watersheds, we developed a suite of performance metrics that we believe will enable the City of Surrey to effectively monitor the short term and long term health of the watersheds. These parameters can be categorized as a land use, flow regime, or environmental metric. Some of the performance indicators combine two or more of the above parameters. Refer to Table 11-1 for a list of the recommended key performance indicators.

Each key performance indicator is described in detail below with monitoring methods, measurement requirements, frequency and triggers for evaluation, and approximate costs.

11.2 LAND USE METRICS

Metric 1 - Percent Tree Cover

The majority of the Cruikshank and Grenville watersheds are currently developed. As a result, we recommend that percent tree cover be monitored instead of percent forest cover, as recommended in the Metro Vancouver template for Integrated Stormwater Management Planning, 2005. We determined the percent tree cover in the study area by analysing aerial photographs to determine the locations and surface occupied by the canopies of stands of multiple trees. The analysis did not account for single stand-alone trees, but future efforts should consider single trees if their size exceeds a minimum threshold (to be determined by the City) that can be readily identified in aerial photography. Based on our analysis, approximately 137 hectares or 14.5 % of the study area is occupied by trees. The majority of this area is located within Bear Creek Park or within watercourse riparian zones.

Tree cover will provide a measure of the health of the watershed. An increase in the percent tree cover will likely indicate that riparian zones and green areas are being maintained or expanded. A decrease in the percent tree cover will likely indicate that riparian zones and green space are being lost to development

Table 11-1
Key Performance Indicators

No.	Key Performance Indicator	Monitoring Strategy	Base (2010) Values	Improvement Target	Maximum Frequency of Monitoring	Unit Cost
Land Use Metrics						
1	% Forest (Tree) Cover	GIS analysis of aerial photographs. Should include landscaping trees.	14.5 %	Increase	4 years	$1,000
2	% TIA	GIS analysis of aerial photographs and existing zoning.	65.0 %	None, basis for comparison with EIA	4 years	$2,000
3	% EIA	Site investigations and GIS analysis of aerial photographs and existing zoning. Qualitative interpretation of extent and effectiveness of source controls necessary, can also be interpreted from rainfall and flow data.	52.7 %	Stable or Decrease	4 years	$15,000
4	% RFI	GIS analysis of aerial photographs.	34.9 %	Stable or Increase	4 years	$4,000
Flow Regime Metrics						
5	Number of Erosion Sites	Ravine Stability Assessment	72 Sites	Stable or reduction in numbers and/or severity	2 years	$40,000
6	Average, Peak Flow Rates	Analysis of flow rates at flow monitoring station on Bear Creek.	Qavg. = 0.24m³/s Qpeak = 8.58m³/s	Reduction	Annually	$1,500
7	Base Flow	Analysis of summer and winter base flow rates at flow monitoring station on Bear Creek.	Summer = 10L/s Winter = 83L/s	Increase in Summer	Bi-annually	$2,000
Water Quality Metrics						
8	Benthic Invertebrates (B-IBI)	Sampling and B-IBI scores.	Mean = 14	Increased numbers and diversity	Bi-annually	$2,500
9	Fisheries Habitat Assessment	Fish Species Assessment	see Table 21-11	Stable or Increasing	4 years	$10,000
10	Continuous Water Quality	Water quality monitoring over extended period.	unknown	Reduction in contaminant loadings	4 years	$15,000 setup & $5,000 annually
11	Periodic Water Quality	Annual water quality monitoring program. Grab samples at established site(s).	unknown	Reduction in contaminant loading	Annually	$7,500

activity. Tree cover can be improved through progressive planning initiatives such as planting street trees and greening riparian zones.

Measurement: Percentage of tree cover to total watershed area.

Timing / Triggers: Development of future ISMPs, passing of 12 years, or if development and/or re-development within the watersheds equal or exceed 5% of the total study area.

Cost: Built in to the cost of an ISMP. $1,000 per assessment when completed separately.

Metric 2 - Percent Total Impervious Area

Percent total impervious area (TIA) is a measure of the proportion of the total area covered by impervious surfaces, and is a reasonable indicator of the intensity of development and whether zoning requirements are being complied with. In theory more land intensive developments of commercial, industrial, and multiple residential land uses will create large total impervious areas upwards of 90%. Urban residential and institutional developments are expected to have total impervious ratios generally between 40% and 70%, based on zoning requirements. In practice, many urban residential lots are modified over time to have higher TIAs, sometimes exceeding 90%. Using GIS methods, TIA coverage can be subdivided into zoning or land-use types, and used to assess recently re-developed lots for excessively high TIA.

To determine the total impervious area for the watersheds, we analysed existing building, pavement, and lot information provided by the City of Surrey and information obtained from satellite imagery. Buildings and pavement were assumed to be impervious and open space was assumed to be pervious. In 2010, the percent total impervious value for the study area was approximately 65.0 %. Refer to Table 11-2 for a summary of the analysis.

Table 11-2
Base (2010) Total Impervious Area

Surface Type	Area	Proportion of Study Area	Impervious Value of Surface Type	Weighted Percent Impervious
Building	248 ha	18.0 %	100%	18.0 %
Pavement	648 ha	47.0 %	100%	47.0 %
Open Space	484 ha	35.0 %	0%	0.0 %
Total	**1,380 ha**	**100 %**	**N/A**	**65.0 %**

The percent TIA within the Cruikshank and Grenville watersheds is expected to increase in both the short term and long term. Based on comparisons of existing zoning mapping and the City of Surrey OCP, highly land intensive industrial, commercial, and residential developments are expected to replace moderately land intensive urban residential and low density residential developments. In addition, urban residential developments are becoming more land intensive with home owners occupying more of their lot space with houses, garages, patios, driveways and other typically impervious surfaces. Estimation of TIA is necessary as a basis for estimating EIA, and for placing changes in EIA into context.

Measurement: Percentage of total impervious area to total watershed area.

Timing / Triggers: Once every four (4) years or if development and/or re-development within the watersheds equal or exceed 5% of the total study area.

Cost: $2,000 per investigation.

Metric 3 - Percent Effective Impervious Area

In principle, percent effective impervious area (EIA) provides a more precise measure of runoff generation does percent total impervious area. Effective impervious area accounts for nominally pervious open space that hydrologically functions like impervious surfaces and for nominally impervious surfaces that hydrologically function like pervious surfaces. It also accounts for the difference in runoff generated by directly connected and disconnected impervious surfaces.

An objective determination of effective impervious area requires a detailed evaluation of the watershed, to almost a lot by lot scale. A detailed evaluation of this nature was not included in the scope of this ISMP and would be challenging for the City to undertake even once. Instead, we estimated the effective impervious area subjectively based on an interpretation of the total impervious area, existing zoning information, aerial photography, field observations and an expectation that source controls are not widely applied in the study area. We estimate that the percent effective impervious value for the study area in 2010 was approximately 57.0 %. Refer to Table 11-3 for a summary of the analysis.

Table 11-3
Base (2010) Effective Impervious Area

Land Use	Area	Proportion of Study Area	Estimated Effective Impervious Ratio	Weighted Effective Impervious Area
Commercial	15 ha	1.1 %	90 %	1.0 %
Industrial	383 ha	27.8 %	90 %	25.0 %
Institutional	39 ha	2.8 %	65 %	1.8 %
Multiple	2 ha	0.1 %	90 %	0.1 %

Land Use	Area	Proportion of Study Area	Estimated Effective Impervious Ratio	Weighted Effective Impervious Area
Residential				
Park Space	142 ha	10.3 %	20 %	2.1 %
Riparian Zone	40 ha	2.9 %	20 %	0.6 %
Large Lot Residential	7 ha	0.5 %	35 %	0.2 %
Undeveloped Lots	52 ha	3.8 %	20 %	0.8 %
Urban Residential	700 ha	50.7 %	50 %	25.4 %
Total	**1,380 ha**	**100 %**	**N/A**	**57.0 %**

Any estimate of EIA can be partially verified by comparing the runoff volumes from a reasonable size of storm to the total rainfall of that storm. This will provide an indication of the overall EIA of the study area, but will not provide a detailed breakdown according to land-use or neighbourhood.

While the total impervious area of the watershed may increase in the future, many of the source control best management strategies developed in the ISMP aim to decrease or maintain the effective impervious ratio of the site(s) to which it is applied. By estimating effective impervious areas, the City of Surrey can track the extent to which source controls are providing a benefit to the watershed.

Measurement: Percentage of effective impervious area to total watershed area.
Timing / Triggers: Once every four (4) years or if development and/or re-development within the watersheds equal or exceed 5% of the total study area.

Cost: $15,000 per investigation.

Metric 4 - Riparian Forest Integrity

Riparian forest integrity is a key factor used to characterize watershed health. It is calculated as the proportion of intact forest cover within the desired riparian corridor. The desired riparian corridor within the Cruikshank and Grenville watersheds is based on a theoretical 30 m buffer on either side of the stream for a total width of 60 m.

There are seven watercourses located within the study area including Healy Creek, Queen Mary Creek, Grenville Creek, Hunt Brook, Bear (Upper Bear) Creek, Cruikshank Creek, and Bear Creek, Quibble Creek, and King Creek. There are also several ditches and unnamed watercourses. In 2010, riparian forest integrity for the study area was approximately 34.9 %. Refer to Table 11-4 for a summary of the analysis. Ditches and other open channels are classified as other open channels. Unnamed tributaries are included within their respective watercourses.

Table 11-4
Base (2010) Riparian Forest Integrity

Watercourse	Desired Riparian Area	Actual Riparian Area	% RFI
Healy Creek	5.0 ha	0.9 ha	18.7 %
Queen Mary Creek	5.5 ha	2.7 ha	48.7 %
Grenville Creek	4.7 ha	2.6 ha	55.0 %
Hunt Brook	9.4 ha	7.3 ha	78.0 %
Upper Bear Creek	46.6 ha	16.0 ha	34.3 %
Cruikshank Creek	10.7 ha	5.7 ha	53.3 %
Bear Creek (Main)	13.1 ha	11.7 ha	90.1 %
Quibble Creek	1.0 ha	0.9 ha	90.0 %
King Creek	8.3 ha	7.6 ha	91.6 %
Other Open Channel	74.4 ha	6.9 ha	9.3 %
Total	**178.7 ha**	**62.3 ha**	**34.9 %**

At 34.9%, the existing riparian forest integrity is slightly less than one third of the theoretical maximum. Some of the recommendations of the ISMP aim to increase the setbacks required by development and re-development of properties within or bordering riparian and EMS zones. By monitoring the riparian forest integrity, the City of Surrey will be able to determine if setbacks are being properly implemented.

Measurement: Percentage of actual riparian forest cover to the desired riparian corridor based on the ideal 60 m width.

Timing / Triggers: Once every four (4) years or if development and/or re-development within the watersheds equal or exceed 5% of the total study area.

Cost: $4,000 per investigation.

11.3 FLOW REGIME METRICS

Metric 5 – Number of Erosion Sites

In the City of Surrey Ravine Stability Assessment (2009) completed by Web Engineering Ltd., approximately 72 erosion sites were identified within the Cruikshank and Grenville watersheds. The erosion sites identified during field reconnaissance of the ISMP are included in Web 2009 sites. Six of the seven watercourses within the study area have documented erosion sites. There are three on Healy Creek, ten on Grenville Creek, thirteen on Hunt Brook, thirty Bear Creek, and sixteen on Cruikshank Creek. It will be important to monitor all erosion sites and identify the formation of new erosion sites to evaluate the health of the watercourses within the study area.

Measurement: Locations and level of severity of erosion sites. Other information to be collected includes the following:

- Date of and conditions during survey,
- Photographs,
- Bank location,
- Channel dimensions,
- Risk probability and consequence,
- Description of stability issue(s),
- Approximate dimensions, and
- Cost to mitigate.

Timing / Triggers: Once every two (2) years.

Cost: $40,000 per investigation.

Metric 6 - Average and Annual Peak Flow Rates in Bear Creek

The City of Surrey implemented a flow monitoring program in 1996 to collect stormwater flow measurements, rainfall data, and limited water quality information at several sites throughout the City. Data is collected and stored in FlowWorks, a web-based data server that analyzes and summarizes collected data from the monitoring program annually and provides collection, reporting, and flow analysis tools. There is a FlowWorks station located within the study area on Bear Creek at King George Boulevard, approximately 215 m south of 88th Avenue. We recommend that this station be used to monitor the average annual and peak annual flow rates in this section of Bear Creek.

To determine the baseline flow values, we analyzed the 2008 FlowWorks data. The annual average flow rate, 0.24 m^3/s, was taken as the average of recorded flows over the period of record. Recording intervals with missing flow rate data were removed from the analysis. The mean annual peak flow rate, 8.58 m^3/s, was taken as the average of the maximum flow rate observed at the monitoring station.

Annual average flow rates will provide an estimate of the amount of development and re-development within the watersheds and the effectiveness of source control best management practices. A decrease in average flow rates over an extended period will indicate that source controls are being properly constructed and implemented. An increase will indicate that the required source controls are either not being implemented or are being improperly constructed and/or maintained. Peak annual flow rates will provide an estimate of the level of development within the watersheds and the effectiveness of large scale best management practices.

Measurement: Annual average park flow rate (m^3/s) and mean annual peak flow rate (m^3/s).

Timing / Triggers: Annually.

Cost: $1,500 annually, based on analysis of average and peak flows.

Metric 6 Base Flow in Bear Creek

Base flow data is also collected by the City of Surrey monitoring station in Bear Creek at King George Boulevard. Based on the results of our hydrologic and hydraulic model, runoff will leave the conveyance system within the watershed approximately 24 hours after the end of a rainstorm event. The remaining flow rate at the monitoring station will represent the base flow in Bear Creek when runoff from storm events is not significantly impacting stream flows. The study area is characterized as having relatively dry summers and wet winters with different base flow regimes in each season. For that reason, the average annual summer and winter base flows should be calculated separately. The average annual summer base flow in Bear Creek is 10 L/s. The average annual winter base flow in Bear Creek is 83 L/s.

Average annual summer and winter base flows in Bear Creek will provide an estimate of the health of the watershed indicating if important hydrological processes such as infiltration, percolation, and interflow are taking place. A decrease in base flow will likely indicate that source control measures are not being successfully implemented and more rainfall is leaving the system as surface runoff. An increase in base flow will likely indicate that the source control measures are being effectively implemented and maintained to promote infiltration of rainfall. We note that water extractions and climate change may also impact base flows in Bear Creek.

Measurement: Minimum monthly summer base flow (L/s) and minimum monthly winter base flow (L/s).

Timing / Triggers: Bi-annually.

Cost: $2,000 annually, based on analysis of summer and winter base flows.

11.4 ENVIRONMENTAL METRICS

Metric 7 - Benthic Invertebrates (B-IBI)

Measuring the presence of benthic invertebrates, or streambed insects, provides an estimate of the population and species present within the sediments of watercourses. Monitoring benthic invertebrates provides a biologically based performance measure of the effectiveness of watershed planning and implementation of best management strategies since benthic invertebrates are susceptible to and experience changes in the watershed. Changes include alterations in the flow regime, in-stream habitat, and the presence of sediment and toxic substances.

The City of Surrey completed benthic invertebrate sampling at two locations within the study area (Bear 1-2 and Bear 1-3) in the spring and fall of 2009. The mean B-IBI scores at both sampling locations in the spring and fall were 14. Based on the stream conditions rating system used by Metro Vancouver, a B-IBI value of 14 relates to a stream condition rating of “very poor.

We recommend that the City of Surrey continue benthic invertebrate sampling at the two identified locations within the study area. By monitoring B-IBI values, the City of Surrey will be able to determine if implemented recommendations are having a positive impact on the health of the watershed.

Measurement: Mean B-IBI score.

Timing / Triggers: Bi-annually if development and re-development within the watershed equals or exceed 5% of the total study area. A reduced frequency to a maximum of every six (6) years can be employed if no development or re-development activity occurs within the study area.

Cost: $2,500 per investigation, based on collection of two samples.

Metric 8 - Fisheries Habitat Assessment

The British Columbia Ministry of Environment created and regularly updates Habitat Wizard which provides information on fish observations, fish ranges, and fish stocking records among other data. Fish species listed in Habitat Wizard for the study area are presented in Table 11-11.

Table 11-11
Fish Presence from BC Ministry of Environment

Watercourse	Fish Species Present
Bear (Bear) Creek	Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), cutthroat trout (*O. clarkii*), rainbow trout (*O. mykiss*), peamouth chub (*Mylcheilus caurinus*), prickly sculpin (*Cottus* sp.), redside shiner (*Richardsonius balteatus*), threespine stickleback (*Gasterosteus aculeatus*), western brook lamprey (*Lampetra planeri*), dolly varden (*Salvelinus malma malma*), catfish.
Cruikshank Creek	Coho salmon
Healy Creek	Coho salmon, cutthroat trout, rainbow trout, steelhead (*O. mykiss*), sculpin, threespine stickleback
Bear Creek	Chinook salmon, coho salmon, chum salmon, pink salmon, sockeye salmon, cutthroat trout, rainbow trout, Dolly varden, kokanee, steelhead.

The City of Surrey Watercourse Classification Map classifies streams based on fish presence and duration and source of water and surrounding vegetation potential. It is updated on a regular basis to include new information when it becomes available. In order to achieve a no net loss to fisheries habitat, we recommend conducting a habitat assessment of the watershed to review conditions. Surveys of stream reaches should be conducted in accordance with the Resource Inventory Standards Committee in the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures (April 2001).

Stream reaches should be assessed on foot by a Qualified Environmental Professional (QEF) to collect information including:

- Channel morphology,
- Wetted width and depth,
- Bank full width and depth,
- Substrate composition,
- Habitat values,
- Fish presence,
- Barriers to fish passage, and
- Riparian characteristics.

Habitat characteristics should be evaluated and the habitat should be classified and compared to baseline conditions. Where there is degradation of habitat occurring, restoration projects should be suggested to resolve degradation.

Measurement: Evaluation of fisheries habitat assessment.
Timing / Triggers: Once every four (4) years or after development or if development and/or re-development within the watersheds equal or exceed 5% of the total study area.

Cost: $10,000 per investigation

Metric 9 - Continuous Water Quality Monitoring

Continuous water quality monitoring will provide insight into the overall health of the watershed. We recommend continuous monitoring of water temperature (°C) and conductivity (µS/cm). Monitoring should take place at the most downstream location in the watershed in Bear Creek approximately 15 m downstream of the confluence with Hunt Brook. The site is located within a riparian zone approximately 100 m west of 8212 – 140th Street, the closest civic address.

Several water temperature and conductivity metrics can be calculated including maximum daily and weekly averages, maximum daily and weekly maxima, minimum daily and weekly minima, and mean annual. These metrics can be used to determine whether water temperatures are harmful to fish or occur outside the optimal temperature for rearing or spawning.

Measurement: Continuous temperature and conductivity measurements within Bear Creek at downstream reach of study area.

Timing / Triggers: Continuous monitoring with annual data collection.
Cost: $15,000 for equipment, installation, and calibration. $5,000 annually for downloading of information.

Metric 10 - Periodic Water Quality Monitoring Program

We recommend that selected water quality indicators be sampled annually at two locations within the study area. The first should be located downstream of industrial development. We recommend that periodic sampling be performed in Bear Creek just downstream of its confluence with Cruikshank Creek. This site is located within a riparian zone approximately 140 m east of 8515 – 132nd Street, the closest civic address. The second should be located at the most downstream reach of the study area, which is approximately 15 m downstream of the confluence of Bear Creek and Hunt Brook. The site is located within a riparian zone approximately 100 m west of 8212 – 140th Street, the closest civic address. We recommend sampling the following water quality parameters:

- Temperature (°C),
- Conductivity (µS/cm)
- pH,
- Dissolved oxygen (mg/L),
- Total dissolved solids (ppm),
- Salinity (ppm),
- Biological and chemical oxygen demand (mg/L),

- Fecal coliform bacteria (MPN/100mL),
- Total coliform bacteria (MPN/100mL),
- Metals: copper, zinc, aluminium, iron, and lead (ppm), and
- Ammonia nitrogen (mg/L).

Sampling should follow the BC Field Sampling Manual for Continuous Monitoring and the Collection of Air / Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples prepared by the Water, Air, and Climate Change branch of the Ministry of Water, Land and Air Protection, 2003 Edition, as well as the Freshwater Biological Sampling Manual prepared by the Resources Information Standards Committee, 1998 Edition.

Measurement: Water quality samples collected in Bear Creek at two locations, one downstream of a large area of industrial development and the other at the most downstream location in the study area.

Timing / Triggers: Metro Vancouver's Integrated Stormwater Management Planning, 2005, recommends that sample water quality monitoring be completed bi-annually to collect dry-weather and wet-weather samples if there are significant changes and development occurring in the upstream drainage area. Reduced frequency of sampling should apply only when there is no activity in the watershed to a maximum frequency of six (6) years.

Cost: $7,500 annually.

Metric 11 - Reported Spills

A spill reporting procedure should be in place to protect the Cruikshank and Grenville watersheds from the release of contaminants. The program will help to prevent, prepare for, mitigate, and respond to spills that affect the health of the watersheds. The program will rely on reporting by residents and business owners in the area. There are a number of ways for individuals to report spills including:

- City of Surrey Engineering Department – 604.590.7226 (regular business hours)
- City of Surrey Engineering Department – 604.591.4431 (after regular business hours)
- Provincial Emergency Program, Emergency Management BC – 1.800.663.3456
- Environment Canada, Environmental Emergencies – 604.666.6100
- Department of Fisheries and Oceans, 24-hr Hotline – 604.666.3500

We recommend that the City of Surrey develop a program to track the reported spills within the study area. The program will be most useful if a database is created in GIS and updated regularly. Below is a list of items that spill reports should include based on the Emergency Management BC Spill Reporting Regulation:

- Reporting person's name and telephone number,
- Name and telephone number of the person who caused the spill (if available),
- Location and time of the spill,

- Type and quantity of substance spilled,
- Cause and effect of the spill,
- Details of actions taken or proposed to stop, contain and minimize the effects of the spill,
- A description of the spill location and of the area surrounding the spill,
- Details of further action contemplated or required,
- Names of agencies on the scene, and
- Names of other persons or agencies advised concerning the spill.

Measurement: Number and details of reported spills.

Timing / Triggers: When a spill has been reported.

Cost: $500 per incident.

Certification Page

In the process of developing this ISMP a review of available data and a field inventory were undertaken, providing the basis for assessing existing conditions and future impacts to the watershed. The field inventory data is provided in Appendix A for the hydraulic system, and Appendices B and C for the environmental and hydrogeology aspects, respectively.

Collected data was processed using GIS methods to produce a watershed scale hydrologic and hydraulic model in PCSWMM, which was used to estimate the potential impacts, and required upgrades to the drainage system to address existing and future deficiencies. Model data is provided in Appendix E, while identified deficiencies are detailed, with cost estimates for upgrades, are provided in Appendix D.

The management strategies developed and recommended in this Cruikshank and Grenville ISMP, once implemented, will provide an incremental improvement in watershed health while accommodating the expected increase in the intensity of development in the watershed. Both the Cruikshank and Grenville watersheds retain a significant, functioning aquatic and terrestrial ecosystem, so while impacted by development, these actions are required to ensure these ecological values are retained and enhanced in the future.

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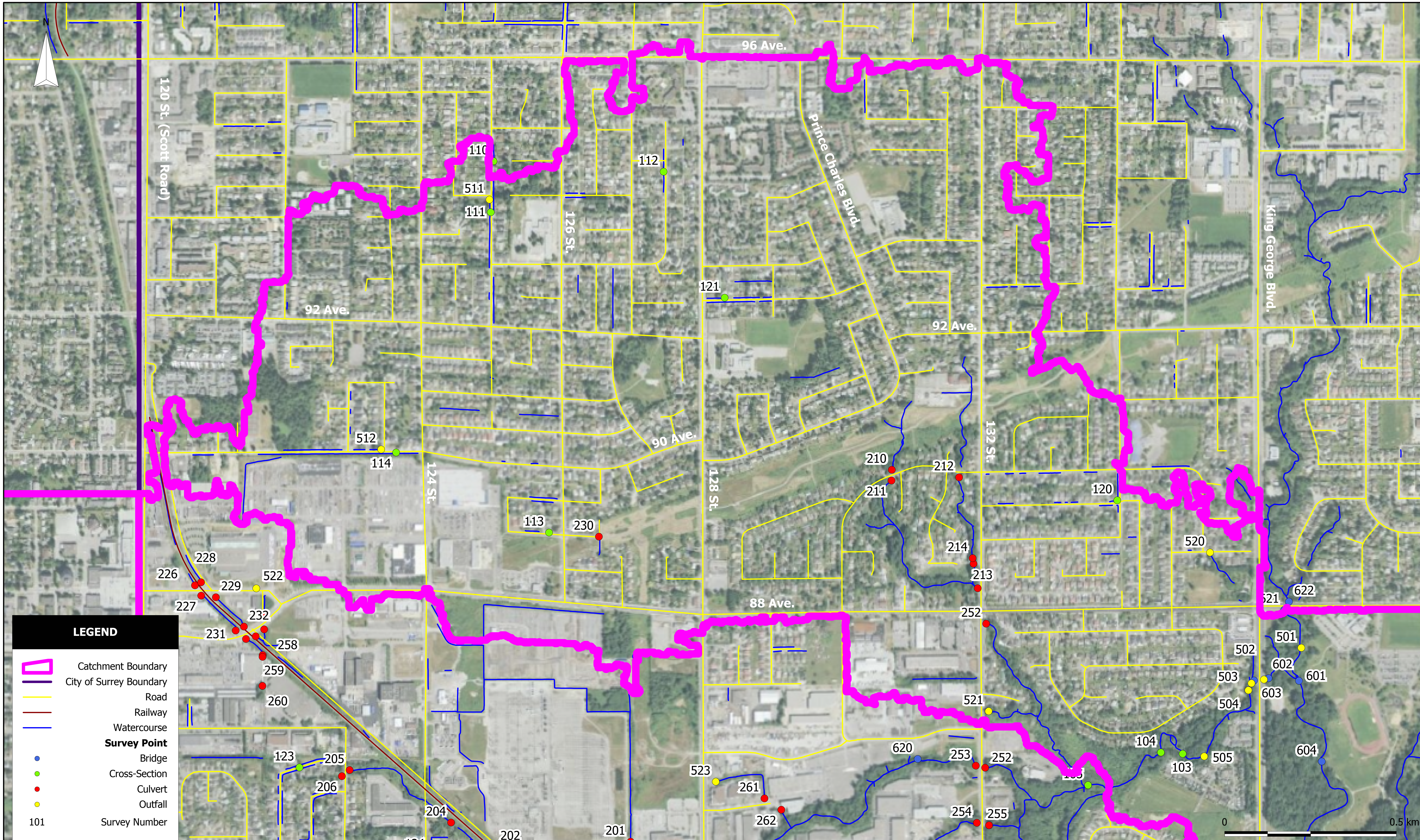
Appendix A - Hydraulic Inventory

Hydraulic Inventory Report

City of Surrey

Cruikshank and Grenville Integrated Stormwater Management Plan

December 2012



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No.	REVISION	DATE

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CITY OF SURREY
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DATE: July 2011
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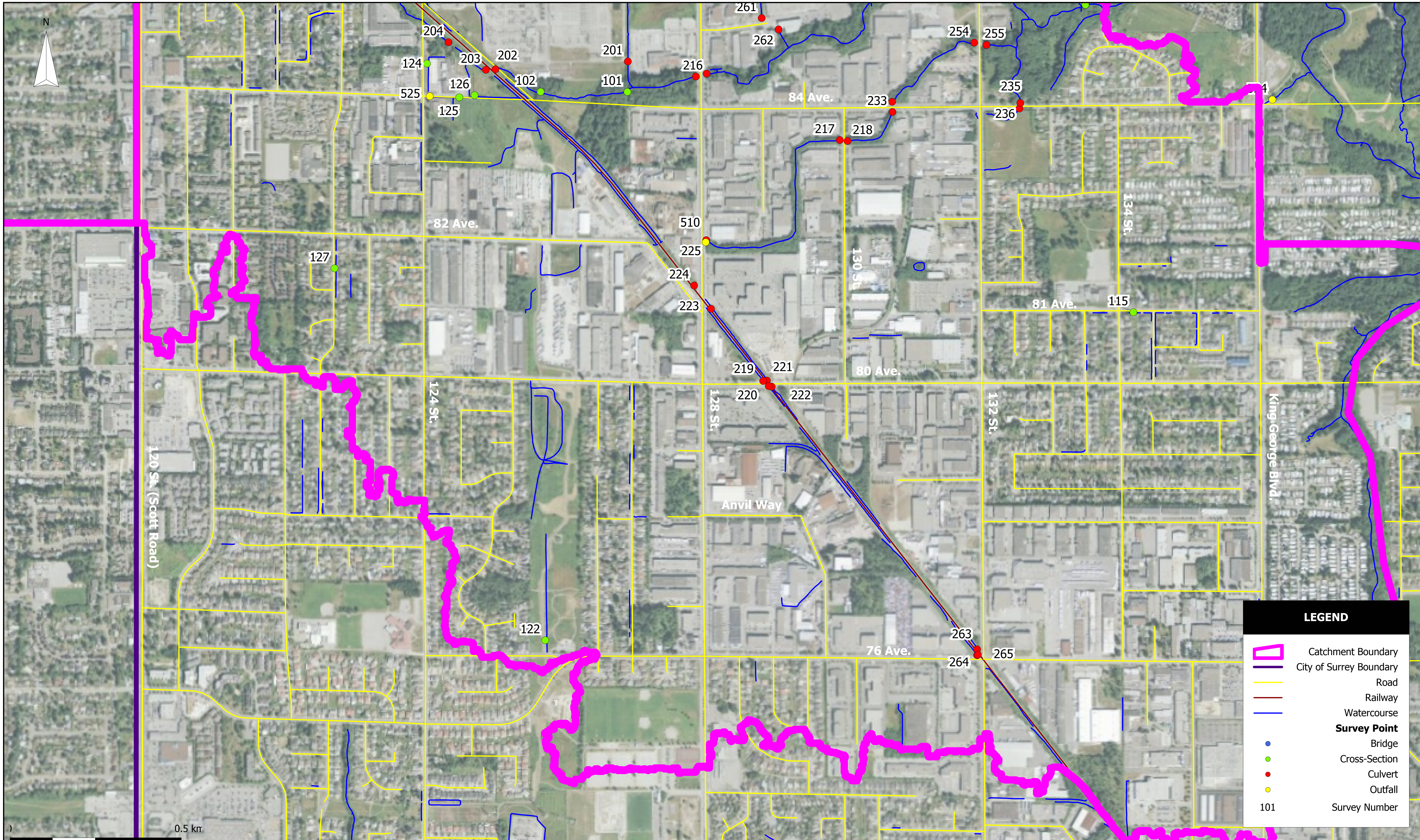
CITY OF SURREY
CRUIKSHANK AND GRENVILLE ISMP

Figure 3-3A: Surveyed Infrastructure



No.	REVISION	DATE

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CITY OF SURREY
CRUIKSHANK AND GRENVILLE ISMP

Figure 3-3B: Surveyed Infrastructure

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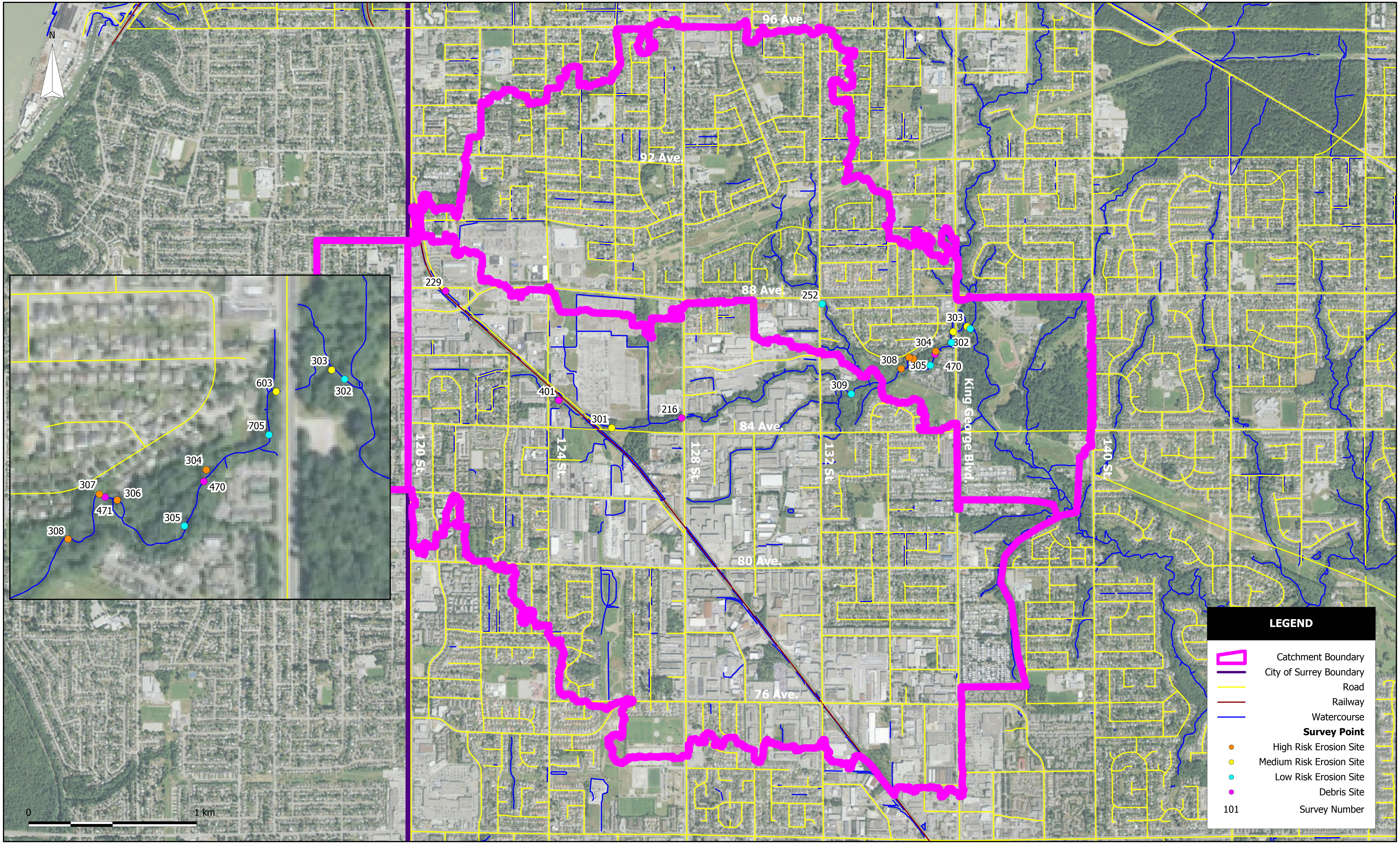

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No.	REVISION	DATE

Associated Engineering
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PROJECT No.: 20112781
DATE: July 2011
SCALE: 1:20,000

CITY OF SURREY
CRUIKSHANK AND GRENVILLE ISMP

Figure 3-4: Observed Deficiencies

Cruikshank and Grenville Watersheds Hydraulic Inventory Report

Cross Sections

Survey Number: 101

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope (%):	0.33	Right Bank Slope:	0.15
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	4.50	Channel Roughness:	0.045
Low Channel Depth (m):	0.70		

Comment:

Easting: 509409.674

Northing: 5444785.332

Survey Number: 102

Left Bank Height (m):	4.00	Right Bank Height (m):	4.00
Left Bank Slope (%):	0.70	Right Bank Slope:	0.10
Left Bank Roughness:	0.100	Right Bank Roughness:	0.150
Low Channel Width (m):	2.00	Channel Roughness:	0.040
Low Channel Depth (m):	0.10		

Comment:

Easting: 509157.275

Northing: 5444785.579

Survey Number: 103

Left Bank Height (m):	1.00	Right Bank Height (m):	1.50
Left Bank Slope (%):	1.00	Right Bank Slope:	1.00
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	5.00	Channel Roughness:	0.050
Low Channel Depth (m):	0.50		

Comment:

Easting: 511019.011 Northing: 5445130.008

Survey Number: 104

Left Bank Height (m):	0.75	Right Bank Height (m):	0.75
Left Bank Slope (%):	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	6.00	Channel Roughness:	0.050
Low Channel Depth (m):	0.50		

Comment:

Easting: 510955.640   Northing: 5445133.840

Survey Number: 105

Left Bank Height (m):	0.75	Right Bank Height (m):	0.75
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	5.00	Channel Roughness:	0.050
Low Channel Depth (m):	0.30		

Comment: Cross section taken downstream of confluence.

Easting: 510743.637 Northing: 5445038.827

Survey Number: 110

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope (%):	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.060	Right Bank Roughness:	0.060
Low Channel Width (m):	0.30	Channel Roughness:	0.060
Low Channel Depth (m):	0.10		

Comment: Typical road ditch in area.

Easting: 509012.186 Northing: 5446856.134

Survey Number: 111

Left Bank Height (m):	0.50	Right Bank Height (m):	0.50
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.060	Right Bank Roughness:	0.060
Low Channel Width (m):	0.30	Channel Roughness:	0.040
Low Channel Depth (m):	0.10		

Comment: Ditches on both sides of road.

Easting: 509003.863

Northing: 5446707.643

Survey Number: 112

Left Bank Height (m):	0.75	Right Bank Height (m):	0.75
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.040	Right Bank Roughness:	0.040
Low Channel Width (m):	0.40	Channel Roughness:	0.035
Low Channel Depth (m):	0.20		

Comment: Typical road ditch in area.

Easting: 509507.316 Northing: 5446825.697

Survey Number: 113

Left Bank Height (m):	0.75	Right Bank Height (m):	0.75
Left Bank Slope (%):	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.045	Right Bank Roughness:	0.045
Low Channel Width (m):	0.50	Channel Roughness:	0.040
Low Channel Depth (m):	0.20		

Comment: Typical road ditch in area.

Easting: 509173.840 Northing: 5445774.585

Survey Number: 114

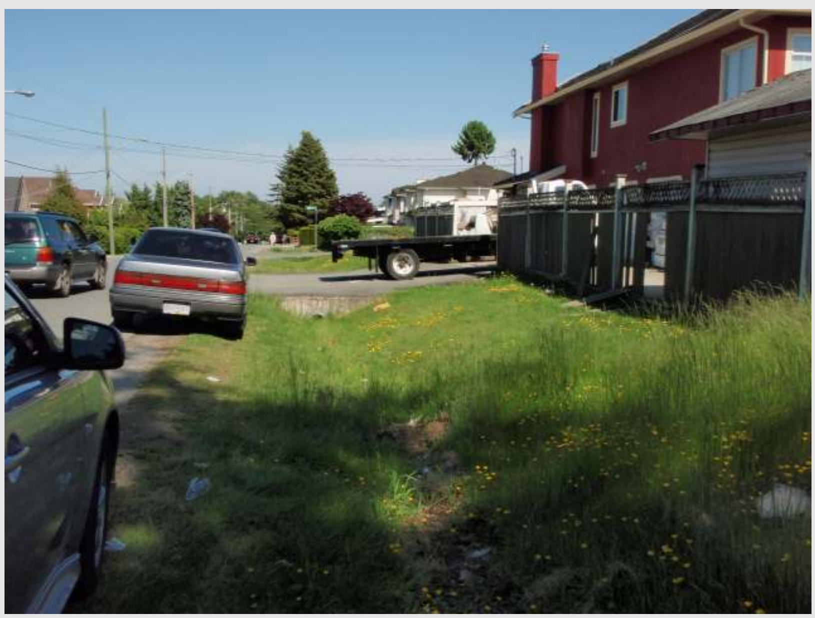
Left Bank Height (m):	1.50	Right Bank Height (m):	1.50
Left Bank Slope (%):	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	0.50	Channel Roughness:	0.045
Low Channel Depth (m):	0.20		

Comment: Typical road ditch in area.

Easting: 508728.569 Northing: 5446007.596

Survey Number: 115

Left Bank Height (m):	0.75	Right Bank Height (m):	1.00
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.045	Right Bank Roughness:	0.045
Low Channel Width (m):	0.50	Channel Roughness:	0.035
Low Channel Depth (m):	0.20		



Comment: Typical road ditch in area.

Easting: 510883.367 Northing: 5444143.733

Survey Number: 120

Left Bank Height (m):	0.75	Right Bank Height (m):	1.00
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.040	Right Bank Roughness:	0.040
Low Channel Width (m):	0.30	Channel Roughness:	0.030
Low Channel Depth (m):	0.10		

Comment: Typical road ditch in area.

Easting: 510828.675   Northing: 5445868.566

Survey Number: 121

Left Bank Height (m):	0.75	Right Bank Height (m):	1.00
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.045	Right Bank Roughness:	0.045
Low Channel Width (m):	1.00	Channel Roughness:	0.040
Low Channel Depth (m):	0.30		

Comment: Typical road ditch in area.

Easting: 509685.232

Northing: 5446458.781

Survey Number: 122

Left Bank Height (m):	1.50	Right Bank Height (m):	1.50
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.080	Right Bank Roughness:	0.080
Low Channel Width (m):	1.50	Channel Roughness:	0.050
Low Channel Depth (m):	0.30		

Comment: Ditch follows east side of pedestrian path.

Easting: 509170.821 Northing: 5443187.872

Survey Number: 123

Left Bank Height (m):	1.50	Right Bank Height (m):	1.00
Left Bank Slope (%):	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.045	Right Bank Roughness:	0.045
Low Channel Width (m):	1.00	Channel Roughness:	0.045
Low Channel Depth (m):	0.20		

Comment: Typical road ditch in area. Roads are higher than lots.

Easting: 508446.717

Northing: 5445090.345

Survey Number: 124

Left Bank Height (m):	2.00	Right Bank Height (m):	0.75
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.050	Right Bank Roughness:	0.050
Low Channel Width (m):	0.30	Channel Roughness:	0.050
Low Channel Depth (m):	0.20		

Comment: Top of right bank at west wall of building.

Easting: 508826.271 Northing: 5444867.778

Survey Number: 125

Left Bank Height (m):	0.50	Right Bank Height (m):	0.50
Left Bank Slope (%):	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.075	Right Bank Roughness:	0.075
Low Channel Width (m):	0.50	Channel Roughness:	0.050
Low Channel Depth (m):	0.20		

Comment: Ditch changes to naturalized channel at building edge.

Easting: 508920.600 Northing: 5444769.712

Survey Number: 126

Left Bank Height (m):	0.75	Right Bank Height (m):	0.75
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	0.75	Channel Roughness:	0.050
Low Channel Depth (m):	0.20		

Comment: Channel overgrown.

Easting: 508964.931 Northing: 5444775.486

Survey Number: 127

Left Bank Height (m):	1.00	Right Bank Height (m):	0.50
Left Bank Slope (%):	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.050	Right Bank Roughness:	0.050
Low Channel Width (m):	0.50	Channel Roughness:	0.045
Low Channel Depth (m):	0.30		

Comment: Typical road ditch in area.

Easting: 508556.913 Northing: 5444271.332

Survey Number 201

Risk Level: N/A

Type:	Driveway	Diameter or Width (mm):	1500
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.40
Material:	CSP	Road Crown Height (m):	1.50
Stability:	Steep channel em		

Left Bank Height (m):	2.00	Right Bank Height (m):	4.00
Left Bank Slope:	0.80	Right Bank Slope:	0.75
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	5.00	Channel Roughness	0.500
Low Channel Depth (m):	1.60		

Comment: Culvert under BC Hydro driveway.

Easting: 509411.200

Northing: 5444874.090

Cruikshank and Grenville Watersheds Hydraulic Inventory Report

Culverts

Survey Number 202

Risk Level: N/A

Type:	Railway	Diameter or Width (mm):	1500
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.40
Material:	CSP	Road Crown Height (m):	6.00
Stability:			

Left Bank Height (m):	6.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	2.00	Channel Roughness	0.035
Low Channel Depth (m):	0.50		

Comment: 0.70m of sediment depth in left culvert. All flow through right culvert.

Easting: 509025.521 Northing: 5444851.414

Survey Number 203

Risk Level: N/A

Type:	Railway	Diameter or Width (mm):	1500
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.30
Material:	CSP	Road Crown Height (m):	6.00
Stability:			

Left Bank Height (m):	5.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.75	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	1.50	Channel Roughness	0.040
Low Channel Depth (m):	0.50		

Comment: Large sediment deposit infront of left culvert.

Easting: 508997.446

Northing: 5444849.516

Survey Number 204

Risk Level: N/A

Type:	Railway	Diameter or Width (mm):	1200
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.35
Material:	CSP	Road Crown Height (m):	2.00
Stability:			

Left Bank Height (m):	2.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.00	Right Bank Slope:	0.50
Left Bank Roughness:	0.050	Right Bank Roughness:	0.150
Low Channel Width (m):	3.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment: 1500mm Ø culvert is left of 1200mm Ø culvert.

Easting: 508888.581

Northing: 5444930.048

Survey Number 205

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1500
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	CSP	Road Crown Height (m):	5.00
Stability:	Gabian baskets ha		

Left Bank Height (m):	4.00	Right Bank Height (m):	3.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	1.00	Channel Roughness	0.030
Low Channel Depth (m):	0.30		

Comment: CSP culvert is left of Steel culvert.

Easting: 508592.916

Northing: 5445082.628

Survey Number 206

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1500
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	CSP	Road Crown Height (m):	3.00
Stability:	Gabian baskets at		

Left Bank Height (m):	2.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.50	Right Bank Slope:	0.00
Left Bank Roughness:	0.250	Right Bank Roughness:	0.250
Low Channel Width (m):	1.50	Channel Roughness	0.025
Low Channel Depth (m):	0.50		

Comment:

Easting: 508570.633

Northing: 5445064.978

Survey Number 210

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1800
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.00
Stability:			

Left Bank Height (m):	5.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.20	Right Bank Slope:	0.20
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Trash rack at inlet.

Easting: 510171.904 Northing: 5445957.293

Survey Number 211

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1800
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.00
Stability:			

Left Bank Height (m):	5.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.75	Right Bank Slope:	0.20
Left Bank Roughness:	0.075	Right Bank Roughness:	0.075
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment:

Easting: 510171.186 Northing: 5445925.975

Survey Number 212

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1250
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	6.00
Stability:			

Left Bank Height (m):	4.50	Right Bank Height (m):	4.00
Left Bank Slope:	0.20	Right Bank Slope:	0.25
Left Bank Roughness:	0.050	Right Bank Roughness:	0.100
Low Channel Width (m):	1.00	Channel Roughness	0.040
Low Channel Depth (m):	0.25		

Comment: Could not access inlet. Culvert skewed 10 degrees.

Easting: 510367.910 Northing: 5445935.566

Survey Number 213

Risk Level: N/A

Type:	Path	Diameter or Width (mm):	750
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	6.00	Right Bank Height (m):	6.00
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.100	Right Bank Roughness:	0.050
Low Channel Width (m):	1.25	Channel Roughness	0.050
Low Channel Depth (m):	0.40		

Comment:

Easting: 510409.774

Northing: 5445684.106

Survey Number 214

Risk Level: N/A

Type:	Path	Diameter or Width (mm):	1500
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.10
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	6.00	Right Bank Height (m):	6.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.100	Right Bank Roughness:	0.120
Low Channel Width (m):	1.00	Channel Roughness	0.050
Low Channel Depth (m):	0.40		

Comment:

Easting: 510407.394

Northing: 5445700.204

Survey Number 216

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1200
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.10
Material:	Concrete	Road Crown Height (m):	7.00
Stability:			

Left Bank Height (m):	6.00	Right Bank Height (m):	6.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	4.00	Channel Roughness	0.040
Low Channel Depth (m):	0.75		

Comment: Twin culverts.

Easting: 509640.795

Northing: 5444838.709

Survey Number 217

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1500
Structure:	Conformed	Height (mm):	1200
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	3.00
Stability:			

Left Bank Height (m):	4.00	Right Bank Height (m):	4.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.50	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Concrete box culvert 1500mm wide by 1200mm high.

Easting: 510028.412 Northing: 5444644.981

Cruikshank and Grenville Watersheds Hydraulic Inventory Report

Culverts

Survey Number 218

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1500
Structure:	Conformed	Height (mm):	1200
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.10
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	6.00	Right Bank Height (m):	6.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Concrete box culvert 1500mm wide by 1200mm high.

Easting: 510050.779 Northing: 5444642.198

Survey Number 219

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	450
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.15
Material:	Concrete	Road Crown Height (m):	1.00
Stability:			

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.150	Right Bank Roughness:	0.080
Low Channel Width (m):	0.50	Channel Roughness	0.100
Low Channel Depth (m):	0.25		

Comment:

Easting: 509816.269

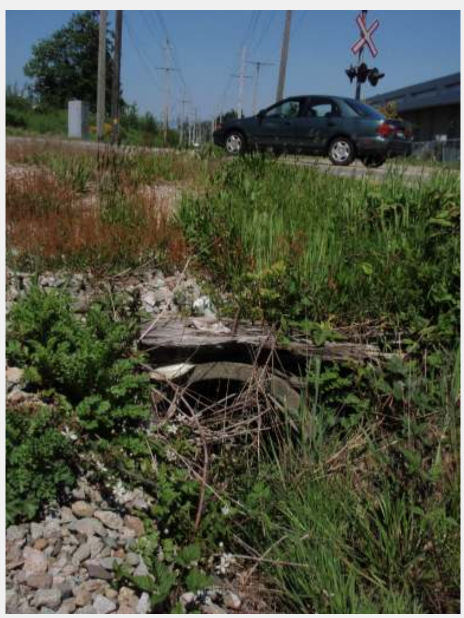
Northing: 5443944.746

Survey Number 220

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	525
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.10
Material:	Concrete	Road Crown Height (m):	1.00
Stability:			

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.060	Right Bank Roughness:	0.060
Low Channel Width (m):	0.50	Channel Roughness	0.050
Low Channel Depth (m):	0.20		



Comment:

Easting: 509830.289

Northing: 5443926.643

Survey Number 221

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	525
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.10
Material:	Concrete	Road Crown Height (m):	1.00
Stability:			

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.150	Right Bank Roughness:	0.100
Low Channel Width (m):	0.30	Channel Roughness	0.060
Low Channel Depth (m):	0.25		

Comment:

Easting: 509821.359

Northing: 5443928.484

Survey Number 222

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	525
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.10
Material:	Concrete	Road Crown Height (m):	1.00
Stability:			

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	0.30	Channel Roughness	0.060
Low Channel Depth (m):	0.25		

Comment:

Easting: 509805.383 Northing: 5443943.380

Survey Number 223

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	300
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	PVC	Road Crown Height (m):	2.00
Stability:			

Left Bank Height (m):	2.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	0.30	Channel Roughness	0.060
Low Channel Depth (m):	0.20		

Comment:

Easting: 509653.472

Northing: 5444153.659

Survey Number 224

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	300
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	PVC	Road Crown Height (m):	2.00
Stability:	Overgrown.		

Left Bank Height (m):	2.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	0.00	Channel Roughness	0.100
Low Channel Depth (m):	0.00		

Comment:

Easting: 509604.278

Northing: 5444221.350

Survey Number 225

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	2000
Structure:	Conformed	Height (mm):	1000
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	1.50
Stability:			

Left Bank Height (m):	1.25	Right Bank Height (m):	1.25
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.040
Low Channel Depth (m):	0.50		

Comment: Concrete box culvert 2000mm wide by 1000mm high.

Easting: 509639.367 Northing: 5444353.614

Cruikshank and Grenville Watersheds Hydraulic Inventory Report
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Survey Number 226

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	450
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.50
Stability:			

Left Bank Height (m):	2.50	Right Bank Height (m):	2.50
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.150
Low Channel Width (m):	0.30	Channel Roughness	0.600
Low Channel Depth (m):	0.20		

Comment:

Easting: 508142.470

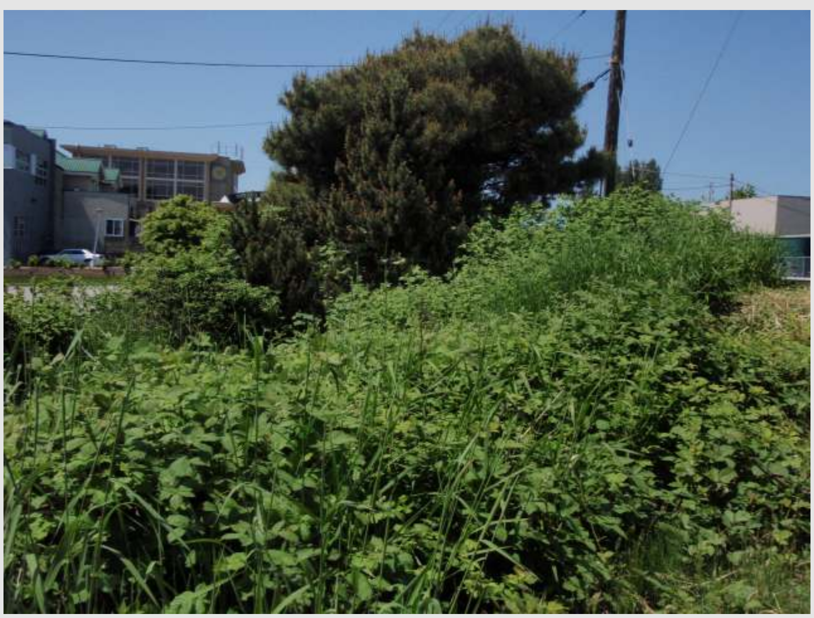
Northing: 5445621.000

Survey Number 227

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	450
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.50
Stability:			

Left Bank Height (m):	2.00	Right Bank Height (m):	0.75
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.150	Right Bank Roughness:	0.120
Low Channel Width (m):	0.30	Channel Roughness	0.600
Low Channel Depth (m):	0.20		



Comment:

Easting: 508160.630 Northing: 5445590.870

Cruikshank and Grenville Watersheds Hydraulic Inventory Report

Culverts

Survey Number 228

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	0
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Unknown	Road Crown Height (m):	4.00
Stability:			

Left Bank Height (m):	2.00	Right Bank Height (m):	4.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.150
Low Channel Width (m):	0.30	Channel Roughness	0.600
Low Channel Depth (m):	0.20		

Comment:

Easting: 508160.110 Northing: 5445629.750

Survey Number 229

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	0
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Unknown	Road Crown Height (m):	3.00
Stability:	Debris blocking o		

Left Bank Height (m):	0.75	Right Bank Height (m):	3.00
Left Bank Slope:	0.50	Right Bank Slope:	0.75
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	0.30	Channel Roughness	0.100
Low Channel Depth (m):	0.20		

Comment:

Easting: 508203.340

Northing: 5445585.960

Survey Number 230

Risk Level: N/A

Type:	Path	Diameter or Width (mm):	300
Structure:	Projecting	Height (mm):	0
Inlet or Outlet:	Inlet/Outlet	Sediment Depth (m):	0.00
Material:	CSP	Road Crown Height (m):	0.50
Stability:			

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	0.30	Channel Roughness	0.060
Low Channel Depth (m):	0.20		

Comment: Ditch crossing pedestrian path.

Easting: 509318.875

Northing: 5445762.712

Survey Number 231

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1200
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	3.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.060
Low Channel Depth (m):	0.50		

Comment:

Easting: 508291.241

Northing: 5445464.586

Survey Number 231

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1200
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	3.50	Right Bank Height (m):	5.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	1.50	Channel Roughness	0.060
Low Channel Depth (m):	0.50		

Comment:

Easting: 508260.867 Northing: 5445489.406

Survey Number 232

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	600
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	4.00
Stability:			

Left Bank Height (m):	1.50	Right Bank Height (m):	4.00
Left Bank Slope:	0.15	Right Bank Slope:	0.75
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	1.00	Channel Roughness	0.060
Low Channel Depth (m):	0.30		

Comment:

Easting: 508285.150 Northing: 5445500.786

Survey Number 232

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	600
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.20
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	5.00	Right Bank Height (m):	4.50
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.100
Low Channel Width (m):	1.00	Channel Roughness	0.060
Low Channel Depth (m):	0.30		

Comment:

Easting: 508319.661

Northing: 5445472.207

Survey Number 233

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	2000
Structure:	Conformed	Height (mm):	1000
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.50
Stability:			

Left Bank Height (m):	3.00	Right Bank Height (m):	3.00
Left Bank Slope:	0.50	Right Bank Slope:	0.25
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment: Concrete box culvert 2000mm wide by 1000mm high.

Easting: 510181.458 Northing: 5444726.946

Survey Number 234

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	2000
Structure:	Conformed	Height (mm):	1000
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.50
Stability:			

Left Bank Height (m):	2.50	Right Bank Height (m):	2.50
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment: Concrete box culvert 2000mm wide by 1000mm high.

Easting: 510180.930

Northing: 5444756.720

Survey Number 235

Risk Level: N/A

Type: Road

Diameter or Width (mm): 900

Structure: Conformed

Height (mm): 0

Inlet or Outlet: Inlet

Sediment Depth (m): 0.00

Material: Concrete

Road Crown Height (m): 4.00

Stability:

Left Bank Height (m): 4.00

Right Bank Height (m): 4.00

Left Bank Slope: 0.50

Right Bank Slope: 0.50

Left Bank Roughness: 0.120

Right Bank Roughness: 0.120

Low Channel Width (m): 4.00

Channel Roughness 0.045

Low Channel Depth (m): 0.50

Comment: Twin 900mm Ø culverts.

Easting: 510551.800

Northing: 5444736.993

Survey Number 236

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	900
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	4.00
Stability:			

Left Bank Height (m):	5.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	4.00	Channel Roughness	0.050
Low Channel Depth (m):	0.50		

Comment: Twin 900mm Ø culverts.

Easting: 510554.126

Northing: 5444752.937

Survey Number 251

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	2000
Structure:	Conformed	Height (mm):	1450
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	CSP	Road Crown Height (m):	6.00
Stability:			

Left Bank Height (m):	6.00	Right Bank Height (m):	6.00
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment: 1450mm high by 2000mm wide elliptical pipe.

Easting: 510422.226

Northing: 5445612.517

Survey Number 252

Risk Level: Low

Type:	Road	Diameter or Width (mm):	2000
Structure:	Headwall	Height (mm):	1450
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	CSP	Road Crown Height (m):	7.00
Stability:	Erosion under hea		

Left Bank Height (m):	7.00	Right Bank Height (m):	7.00
Left Bank Slope:	0.80	Right Bank Slope:	0.75
Left Bank Roughness:	0.075	Right Bank Roughness:	0.075
Low Channel Width (m):	3.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment: 1450mm high by 2000mm wide elliptical pipe.

Easting: 510446.900

Northing: 5445509.157

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Culverts

Survey Number 252

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	2500
Structure:	Conformed	Height (mm):	2100
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	0.00
Stability:			

Left Bank Height (m):	0.01	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment: Concrete box culvert 2500mm wide by 2100mm high.

Easting: 510443.867 Northing: 5445089.517

Survey Number 253

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	2500
Structure:	Conformed	Height (mm):	2100
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	7.00
Stability:			

Left Bank Height (m):	10.00	Right Bank Height (m):	7.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	3.00	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Concrete box culvert 2500mm wide by 2100mm high.

Easting: 510416.596 Northing: 5445095.685

Survey Number 254

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1800
Structure:	Headwall	Height (mm):	1200
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	5.00
Stability:			

Left Bank Height (m):	5.00	Right Bank Height (m):	5.00
Left Bank Slope:	0.30	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	0.25		

Comment: Concrete box culvert 1800mm wide by 1500mm high. Overflow 900mm Ø culert

Easting: 510419.773 Northing: 5444928.927

Survey Number 255

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1800
Structure:	Headwall	Height (mm):	1200
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	0.01
Stability:			

Left Bank Height (m):	0.01	Right Bank Height (m):	0.01
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.01	Channel Roughness	0.000
Low Channel Depth (m):	0.01		

Comment: Concrete box culvert 1800mm wide by 1200mm high.

Easting: 510455.370 Northing: 5444921.890

Survey Number 256

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1200
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.00
Stability:			

Left Bank Height (m):	2.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.30	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	4.00	Channel Roughness	0.055
Low Channel Depth (m):	0.60		

Comment: Culvert 0.60m submerged.

Easting: 508343.899 Northing: 5445492.615

Cruikshank and Grenville Watersheds Hydraulic Inventory Report

Culverts

Survey Number 257

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	1200
Structure:	Headwall	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	2.00
Stability:			

Left Bank Height (m):	2.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.30	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	3.00	Channel Roughness	0.060
Low Channel Depth (m):	0.60		

Comment: Trash rack at inlet.

Easting: 508342.997

Northing: 5445533.374

Survey Number 258

Risk Level: N/A

Type:	Other	Diameter or Width (mm):	900
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	CSP	Road Crown Height (m):	1.40
Stability:			

Left Bank Height (m):	1.50	Right Bank Height (m):	1.40
Left Bank Slope:	0.30	Right Bank Slope:	1.00
Left Bank Roughness:	0.100	Right Bank Roughness:	0.013
Low Channel Width (m):	1.50	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Could not find inlet.

Easting: 508339.963 Northing: 5445417.849

Survey Number 259

Risk Level: N/A

Type:	Driveway	Diameter or Width (mm):	1250
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	0.90
Stability:			

Left Bank Height (m):	1.50	Right Bank Height (m):	0.90
Left Bank Slope:	0.30	Right Bank Slope:	1.00
Left Bank Roughness:	0.100	Right Bank Roughness:	0.013
Low Channel Width (m):	1.50	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Trash rack.

Easting: 508339.219

Northing: 5445412.521

Survey Number 260

Risk Level: N/A

Type:	Driveway	Diameter or Width (mm):	1250
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	0.00
Stability:			

Left Bank Height (m):	0.01	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment: Fenced off.

Easting: 508339.045 Northing: 5445327.895

Survey Number 261

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	900
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	3.00
Stability:			

Left Bank Height (m):	3.00	Right Bank Height (m):	3.00
Left Bank Slope:	0.80	Right Bank Slope:	0.75
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	0.50	Channel Roughness	0.045
Low Channel Depth (m):	0.20		

Comment: Trash rack.

Easting: 509801.240 Northing: 5445000.307

Survey Number 262

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	900
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	1.10
Stability:			

Left Bank Height (m):	1.00	Right Bank Height (m):	2.50
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	1.00	Channel Roughness	0.050
Low Channel Depth (m):	0.20		

Comment: Trash rack.

Easting: 509850.289 Northing: 5444967.385

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Survey Number 263

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	10
Structure:	Unknown	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Unknown	Road Crown Height (m):	0.00
Stability:			

Left Bank Height (m):	0.01	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.150	Right Bank Roughness:	0.120
Low Channel Width (m):	0.00	Channel Roughness	0.100
Low Channel Depth (m):	0.00		

Comment: Grown over.

Easting: 510428.399 Northing: 5443161.606

Survey Number 264

Risk Level: N/A

Type:	Road	Diameter or Width (mm):	900
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Outlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	0.00
Stability:			

Left Bank Height (m):	3.00	Right Bank Height (m):	3.00
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.150	Right Bank Roughness:	0.100
Low Channel Width (m):	0.75	Channel Roughness	0.050
Low Channel Depth (m):	0.40		

Comment:

Easting: 510428.337

Northing: 5443144.415

Survey Number 265

Risk Level: N/A

Type:	Railway	Diameter or Width (mm):	825
Structure:	Conformed	Height (mm):	0
Inlet or Outlet:	Inlet	Sediment Depth (m):	0.00
Material:	Concrete	Road Crown Height (m):	0.00
Stability:			

Left Bank Height (m):	0.01	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment:

Easting: 510430.714 Northing: 5443146.033

Cruikshank and Grenville Watersheds Hydraulic Inventory Report

Erosion Sites

Survey Number: 301

Risk Level: Medium

Bank Location:

Height (m): 8.00

Length (m): 50.00

Stability: Very eroded banks.

Left Bank Height (m):	8.00	Right Bank Height (m):	8.00
Left Bank Slope:	1.00	Right Bank Slope:	1.00
Left Bank Roughness:	0.040	Right Bank Roughness:	0.040
Low Channel Width (m):	2.00	Channel Roughness	0.045
Low Channel Depth (m):	1.00		

Comment: Through powerline corridor.

Easting: 509193.676

Northing: 5444770.400

Survey Number: 302

Risk Level: Low

Bank Location: Left

Height (m): 0.00

Length (m): 0.00

Stability: Cut into bank.

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment:

Easting: 511328.670

Northing: 5445361.980

Survey Number: 303

Risk Level: Medium

Bank Location: Right

Height (m): 1.50

Length (m): 10.00

Stability: Bank erosion under tree.

Left Bank Height (m):	0.80	Right Bank Height (m):	1.50
Left Bank Slope:	1.00	Right Bank Slope:	1.00
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	15.00	Channel Roughness	0.050
Low Channel Depth (m):	0.50		

Comment: Low flow widens by a few meters at erosion site.

Easting: 511309.483

Northing: 5445375.629

Survey Number: 304

Risk Level: High

Bank Location: Left

Height (m): 4.00

Length (m): 10.00

Stability: Erosion downing trees. Debris acculumated.

Left Bank Height (m):	2.00	Right Bank Height (m):	0.50
Left Bank Slope:	1.00	Right Bank Slope:	0.20
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	3.00	Channel Roughness	0.050
Low Channel Depth (m):	0.50		

Comment: Trees extend over creek. Potential debris accumulated upstream.

Easting: 511122.794

Northing: 5445226.954

Survey Number: 305

Risk Level: Low

Bank Location: Right

Height (m): 1.00

Length (m): 8.00

Stability: Bank erosion and sediment deposit.

Left Bank Height (m):	0.50	Right Bank Height (m):	0.50
Left Bank Slope:	1.00	Right Bank Slope:	1.00
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	3.00	Channel Roughness	0.045
Low Channel Depth (m):	1.00		

Comment: Creek narrowed by sediment and flow directed to eroded bank.

Easting: 511090.491

Northing: 5445143.492

Survey Number: 306

Risk Level: High

Bank Location: Left

Height (m): 8.00

Length (m): 15.00

Stability: Erosion.

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	7.00	Channel Roughness	0.050
Low Channel Depth (m):	0.75		

Comment: Fell tree in middle of creek diverted flow to erosion site.

Easting: 510990.272

Northing: 5445181.865

Survey Number: 307

Risk Level: High

Bank Location: Left

Height (m): 15.00

Length (m): 30.00

Stability: Erosion.

Left Bank Height (m): 15.00

Right Bank Height (m): 0.50

Left Bank Slope: 1.00

Right Bank Slope: 0.75

Left Bank Roughness: 0.150

Right Bank Roughness: 0.050

Low Channel Width (m): 2.00

Channel Roughness 0.045

Low Channel Depth (m): 0.75

Comment: Hanging fencepost and tree. 90 degree bend at erosion wall.

Easting: 510963.677

Northing: 5445190.589

Survey Number: 308

Risk Level: High

Bank Location: Left

Height (m): 8.00

Length (m): 20.00

Stability: Erosion.

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	1.00	Right Bank Slope:	0.15
Left Bank Roughness:	0.750	Right Bank Roughness:	0.120
Low Channel Width (m):	3.00	Channel Roughness	0.050
Low Channel Depth (m):	0.50		

Comment: Cut underneath tree stump.

Easting: 510917.089

Northing: 5445123.755

Survey Number: 309

Risk Level: Low

Bank Location: Right

Height (m): 8.00

Length (m): 5.00

Stability: Erosion.

Left Bank Height (m):	1.50	Right Bank Height (m):	1.50
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	5.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment:

Easting: 510619.740

Northing: 5444973.350

Survey Number: 501

Risk Level: N/A

Material: PVC

Diameter (mm): 375

Left Bank Height (m):	1.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.75	Right Bank Slope:	0.80
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	10.00	Channel Roughness	0.500
Low Channel Depth (m):	0.50		

Comment: Outfall from park.

Easting: 511364.396

Northing: 5445438.953

Survey Number: 502

Risk Level: N/A

Material: PVC

Diameter (mm): 300

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment: From road drainage.

Easting: 511255.760

Northing: 5445346.440

Survey Number: 503

Risk Level: N/A

Material: PVC

Diameter (mm): 300

Left Bank Height (m): 0.00

Right Bank Height (m): 0.00

Left Bank Slope: 0.00

Right Bank Slope: 0.00

Left Bank Roughness: 0.000

Right Bank Roughness: 0.000

Low Channel Width (m): 0.00

Channel Roughness 0.000

Low Channel Depth (m): 0.00

Comment: From road drainage.

Easting: 511219.109

Northing: 5445335.487

Survey Number: 504

Risk Level: N/A

Material: PVC

Diameter (mm): 300

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment: From residential development.

Easting: 511210.270

Northing: 5445315.099

Survey Number: 505

Risk Level: N/A

Material: Concrete

Diameter (mm): 525

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment:

Easting: 511081.592

Northing: 5445122.722

Survey Number: 510

Risk Level: N/A

Material: Concrete

Diameter (mm): 1800

Left Bank Height (m):	1.25	Right Bank Height (m):	1.25
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	2.00	Channel Roughness	0.040
Low Channel Depth (m):	0.50		

Comment: 6.0m wide pool at shared outlet location.

Easting: 509638.040

Northing: 5444347.557

Survey Number: 511

Risk Level: N/A

Material: PVC

Diameter (mm): 300

Left Bank Height (m):	1.25	Right Bank Height (m):	0.75
Left Bank Slope:	0.75	Right Bank Slope:	0.50
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035
Low Channel Width (m):	0.40	Channel Roughness	0.030
Low Channel Depth (m):	0.20		

Comment: Outlet enters ditch.

Easting: 509000.014

Northing: 5446744.443

Survey Number: 512

Risk Level: N/A

Material: Concrete

Diameter (mm): 450

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.075	Right Bank Roughness:	0.075
Low Channel Width (m):	0.50	Channel Roughness	0.075
Low Channel Depth (m):	0.20		

Comment: Inlet from ditch to stormsewer with trash rack.

Easting: 508684.866

Northing: 5446016.805

Survey Number: 520

Risk Level: N/A

Material: Unknown

Diameter (mm): 0

Left Bank Height (m):	3.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.75	Right Bank Slope:	0.75
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	0.00	Channel Roughness	0.060
Low Channel Depth (m):	0.00		

Comment: Could not access.

Easting: 511098.578

Northing: 5445716.455

Survey Number: 521

Risk Level: Low

Material: Concrete

Diameter (mm): 600

Left Bank Height (m):	8.00	Right Bank Height (m):	8.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.120	Right Bank Roughness:	0.100
Low Channel Width (m):	0.50	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Headwall slightly elevated.

Easting: 510453.913

Northing: 5445254.064

Survey Number: 522

Risk Level: N/A

Material: Concrete

Diameter (mm): 0

Left Bank Height (m):	2.00	Right Bank Height (m):	2.00
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	1.50	Channel Roughness	0.050
Low Channel Depth (m):	1.00		

Comment: Found structure but could not see burried outlet.

Easting: 508321.270

Northing: 5445612.129

Survey Number: 523

Risk Level: N/A

Material: Unknown

Diameter (mm): 0

Left Bank Height (m):	1.00	Right Bank Height (m):	1.00
Left Bank Slope:	0.20	Right Bank Slope:	0.20
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	1.50	Channel Roughness	0.060
Low Channel Depth (m):	0.20		

Comment: Fenced off. Could not see outlet.

Easting: 509659.253

Northing: 5445048.954

Survey Number: 524

Risk Level: N/A

Material: Concrete

Diameter (mm): 900

Left Bank Height (m):	6.00	Right Bank Height (m):	6.00
Left Bank Slope:	0.30	Right Bank Slope:	0.20
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	1.50	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Trash rack. Headwall elevated from channel.

Easting: 511288.060

Northing: 5444762.693

Survey Number: 525

Risk Level: N/A

Material: Concrete

Diameter (mm): 600

Left Bank Height (m):	0.85	Right Bank Height (m):	0.85
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.045	Right Bank Roughness:	0.045
Low Channel Width (m):	0.40	Channel Roughness	0.040
Low Channel Depth (m):	0.20		

Comment: Outlet to manmade ditch.

Easting: 508834.112

Northing: 5444772.476

Survey Number: 601

Risk Level: N/A

Type: Path

Width (m): 20.00

Clearance (m): 5.00

Left Bank Height (m): 5.00

Right Bank Height (m): 5.00

Left Bank Slope: 0.50

Right Bank Slope: 0.50

Left Bank Roughness: 0.100

Right Bank Roughness: 0.100

Low Channel Width (m): 12.00

Channel Roughness 0.050

Low Channel Depth (m): 1.00

Comment: Bridge immediately downstream of confluence.

Easting: 511357.708

Northing: 5445342.761

Survey Number: 602

Risk Level: N/A

Type: Road

Width (m): 20.00

Clearance (m): 10.00

Left Bank Height (m):	10.00	Right Bank Height (m):	10.00
Left Bank Slope:	0.50	Right Bank Slope:	0.30
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	5.00	Channel Roughness	0.050
Low Channel Depth (m):	0.75		

Comment: Riprap trail downstream.

Easting: 511269.070

Northing: 5445350.400

Survey Number: 603

Risk Level: Medium

Type: Road

Width (m): 20.00

Clearance (m): 10.00

Left Bank Height (m):	10.00	Right Bank Height (m):	10.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	5.00	Channel Roughness	0.050
Low Channel Depth (m):	0.75		

Comment: Concrete left pier becoming undermined and concrete at right breaking.

Easting: 511226.841

Northing: 5445343.551

Survey Number: 604

Risk Level: N/A

Type: Path

Width (m): 20.00

Clearance (m): 5.00

Left Bank Height (m):	1.50	Right Bank Height (m):	1.50
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	15.00	Channel Roughness	0.050
Low Channel Depth (m):	1.00		

Comment: Single concrete pier.

Easting: 511424.142

Northing: 5445107.647

Survey Number: 620

Risk Level: N/A

Type: Path

Width (m): 30.00

Clearance (m): 10.00

Left Bank Height (m):	10.00	Right Bank Height (m):	10.00
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	3.00	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: Pedestriam bridge from parking lot to liquor store.

Easting: 510247.171

Northing: 5445115.144

Survey Number: 621

Risk Level: N/A

Type:	Road
Width (m):	15.00
Clearance (m):	2.50

Left Bank Height (m):	2.00	Right Bank Height (m):	2.50
Left Bank Slope:	0.30	Right Bank Slope:	0.30
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	8.00	Channel Roughness	0.040
Low Channel Depth (m):	0.30		

Comment:

Easting: 511315.065

Northing: 5445549.541

Survey Number: 622

Risk Level: N/A

Type:	Road
Width (m):	15.00
Clearance (m):	2.50

Left Bank Height (m):	3.00	Right Bank Height (m):	3.00
Left Bank Slope:	0.25	Right Bank Slope:	0.25
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	4.00	Channel Roughness	0.045
Low Channel Depth (m):	0.50		

Comment: Upstream banks riprapped. Small debris block 50m upstream.

Easting: 511328.412

Northing: 5445573.633

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Other Infrastructure Sites

Survey Number: 701

Risk Level: N/A

Feature Description: Pipeline.

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment:

Easting: 511336.152

Northing: 5445439.804

Survey Number: 702

Risk Level: N/A

Feature Description: Confluence.

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.000	Right Bank Roughness:	0.000
Low Channel Width (m):	0.00	Channel Roughness	0.000
Low Channel Depth (m):	0.00		

Comment:

Easting: 511355.030

Northing: 5445345.123

Survey Number: 703

Risk Level: N/A

Feature Description: Large bar of rocks.

Left Bank Height (m):	3.00	Right Bank Height (m):	3.00
Left Bank Slope:	1.00	Right Bank Slope:	0.50
Left Bank Roughness:	0.150	Right Bank Roughness:	0.150
Low Channel Width (m):	5.00	Channel Roughness	0.050
Low Channel Depth (m):	0.80		

Comment: 0.75m high river rock deposit around entire bend.

Easting: 511296.393

Northing: 5445391.257

Survey Number: 704

Risk Level: N/A

Feature Description: Lock block wall on left bank.

Left Bank Height (m):	3.00	Right Bank Height (m):	2.00
Left Bank Slope:	1.00	Right Bank Slope:	1.00
Left Bank Roughness:	0.120	Right Bank Roughness:	0.120
Low Channel Width (m):	8.00	Channel Roughness	0.050
Low Channel Depth (m):	0.00		

Comment:

Easting: 511215.592

Northing: 5445339.209

Survey Number: 705

Risk Level: N/A

Feature Description: Armouing beside highway.

Left Bank Height (m):	0.00	Right Bank Height (m):	0.00
Left Bank Slope:	0.00	Right Bank Slope:	0.00
Left Bank Roughness:	0.120	Right Bank Roughness:	0.500
Low Channel Width (m):	4.00	Channel Roughness	0.050
Low Channel Depth (m):	0.00		

Comment: Protects road embankment. Some have fallen.

Easting: 511216.227

Northing: 5445279.174

Survey Number: 706

Risk Level: N/A

Feature Description: Small tributary entering on left bank.

Left Bank Height (m):	0.25	Right Bank Height (m):	0.25
Left Bank Slope:	0.25	Right Bank Slope:	0.25
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	0.30	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment:

Easting: 511103.448

Northing: 5445182.289

Survey Number: 710

Risk Level: N/A

Feature Description: Concrete weir 3.0m wide by 1.0m high.

Left Bank Height (m):	4.00	Right Bank Height (m):	4.00
Left Bank Slope:	0.50	Right Bank Slope:	0.50
Left Bank Roughness:	0.100	Right Bank Roughness:	0.100
Low Channel Width (m):	3.00	Channel Roughness	0.045
Low Channel Depth (m):	0.30		

Comment: 1.5m high side walls at 45 degrees.

Easting: 510025.300

Northing: 5444654.796

Appendix B - Steam Habit Features

Stream Habitat Features

Bear Creek					
Station ID	**1**				
Easting	509450				
Northing	5444799				
Comments	Section of creek flows adjacent to pedestrian walking paths.				
Wetted width and depth	2.70 m, 0.15 m				
Bankful width and depth	4.60 m, 1.50 m				
% substrate type	20 boulders, 40 cobbles, 40 fines				
In-stream Cover	Undercut banks, Large woody Debris (LWD)				
Water Quality	Temp	pH	Cond	TDS	salinity
	12.50	7.99	144.70	102.00	67.90
Barriers	None				
Proposed Enhancement	Frequent pedestrian traffic into and along creeks from paths adjacent to creek; additional riparian planting and/or fencing should be installed to deter traffic. In-stream features such as LWD or deflector logs should be added to improve habitat complexity.				
Photos					

Temp = temperature in ºC; Cond = conductivity in µS/cm; TDS = total dissolved solids in ppm (parts per million); salinity in ppm.

Cruikshank Creek	
Station ID	**45**
Easting	509846
Northing	5444355
Comments	Linear channel between industrial areas; concrete Lock-Block™ weir structures every 50 m along creek. Appropriate exclusion fencing installed at TOB.
Wetted width and depth	3.00 m, 0.15 m
Bankful width and depth	3.00 m, 0.30 m
% substrate type	5 boulders, 55 cobbles, 40 fines

Cruikshank Creek					
In-stream Cover	Some LWD				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.00	8.43	237.00	174.00	110.00
Barriers	Concrete Lock-Block™ weir structures greater than 0.5 m high.				
Proposed Enhancement	None				
Photos	 				

Cruikshank Creek					
Station ID	**48**				
Easting	510459				
Northing	5444925				
Comments	None.				
Wetted width and depth	2.50 m, 0.15 m				
Bankful width and depth	5.00 m, 1.50 m				
% substrate type	40 boulders, 40 cobbles, 20 fines				
In-stream Cover	Undercut banks, large boulders, LWD and root wads				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.30	8.10	148.70	105.00	69.20

Cruikshank Creek	
Barriers	Erosion bags and garbage debris in creek east of 132 Street.
Proposed Enhancement	Removal of erosion bags and garbage debris. Installation of appropriate erosion and stability control structures.
Photos	  

Cruikshank Creek					
Station ID	**49**				
Easting	510568				
Northing	5444986				
Comments	LWD jam within creek				
Wetted width and depth	2.50 m, 0.15 m				
Bankful width and depth	5.00, 1.50				
% substrate type	40 boulders, 40 cobbles, 20 fines				
In-stream Cover	Undercut banks, large boulders, LWD and root wads				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.10	8.08	159.70	113.00	74.20
Barriers	None				
Proposed Enhancement	None				

Cruikshank Creek	
Photos	

Bear Creek					
Station ID	**50**				
Easting	510244				
Northing	5445115				
Comments	Near wooden clear span pedestrian bridge crossing				
Wetted width and depth	3.10 m, 0.08 m				
Bankful width and depth	5.50 m, 0.80 m				
% substrate type	20 boulders, 40 cobbles, 40 fines				
In-stream Cover	Undercut banks, LWD				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.30	8.25	139.80	99.20	65.80
Barriers	None; fish observed in pools.				
Proposed Enhancement	None				
Photos					

Bear Creek					
Station ID	**51**				
Easting	510104				
Northing	5445031				
Comments	None.				
Wetted width and depth	3.10, 0.08				
Bankful width and depth	5.50, 0.80				
% substrate type	20 boulders, 40 cobbles, 40 fines				
In-stream Cover	Undercut banks, LWD				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.30	8.36	139.70	98.50	65.90
Barriers	None; salmonids observed in pools.				
Proposed Enhancement	None				
Photos	 				

Bear Creek					
Station ID	**52**				
Easting	511365				
Northing	5445268				
Comments	Bridge crossing within Bear Creek Park. Root wads and LWD properly anchored within channel upstream of bridge crossing.				
Wetted width and depth	-				
Bankful width and depth	-				
% substrate type	20 boulders, 40 cobbles, 40 fines				
In-stream Cover	Undercut banks, LWD				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.80	8.32	202.00	144.00	94.80
Barriers	None.				
Proposed Enhancement	None.				
Photos	 				

Quibble Creek					
Station ID	**53**				
Easting	511364				
Northing	5445479				
Comments	Near pedestrian bridge crossing within Bear Creek Park.				
Wetted width and depth	3.80 m, 0.30 m				
Bankful width and depth	6.0 0m, 1.10 m				
% substrate type	10 boulders, 40 cobbles, 50 fines				
In-stream Cover	Undercut banks, LWD				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.60	8.20	230.00	168.00	110.00
Barriers	None.				
Proposed Enhancement	None.				
Photos					

Bear Creek					
Station ID	**54**				
Easting	511487				
Northing	5444718				
Comments	None.				
Wetted width and depth	6.50 m, 0.30 m				
Bankful width and depth	8.00 m, 2.00 m				
% substrate type	10 boulders, 40 cobbles, 50 fines				
In-stream Cover	Undercut banks, LWD				
Water Quality	Temp	pH	Cond	TDS	salinity

Bear Creek					
	14.00	8.20	201.00	143.00	94.30
Barriers	None.				
Proposed Enhancement	Deep undercut bank on left bank requires reinforcement.				
Photos	 				

Healy Creek					
Station ID	**55**				
Easting	510405				
Northing	5445689				
Comments	Linear channel with riprap lined banks with concrete headwall and concrete pedestrian crossing.				
Wetted width and depth	1.50 m, 0.07 m				
Bankful width and depth	2.20 m, 0.60 m				
% substrate type	10 boulders, 70 cobbles, 20 fine				
In-stream Cover	None.				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.60	8.03	221.00	158.00	104.00
Barriers	None.				

Healy Creek	
Proposed Enhancement	In-stream features sure as boulders, LWD and bank cover should be added here to improve habitat quality, as well as appropriate riparian plantings to improve shade and provide habitat.
Photos	 

Healy Creek					
Station ID	**56**				
Easting	510394				
Northing	5446151				
Comments	Upstream of pedestrian bridge crossing within BC Hydro ROW. Channel appears constructed and banks are lined with sand bags.				
Wetted width and depth	1.50 m, 0.15 m				
Bankful width and depth	1.50 m, 0.60 m				
% substrate type	5 boulders, 30 cobbles, 65 fines				
In-stream Cover	None.				
Water Quality	Temp	pH	Cond	TDS	salinity
	14.00	8.32	236.00	167.00	109.00
Barriers	None.				
Proposed Enhancement	In-stream features sure as boulders and LWD should be added here to				

Healy Creek	
	improve habitat quality, as well as appropriate riparian plantings to improve habitat.
Photos	 

Unnamed Tributary to Healy Creek					
Station ID	**57**				
Easting	510171				
Northing	5445962				
Comments	Garbage and debris located upstream of Queen Mary Boulevard.				
Wetted widd depth	2.20 m, 0.15 m				
Bankful width and depth	3.10 m, 0.70 m				
% substrate type	20 boulders, 80 fines				
In-stream Cover	None.				
Water Quality	Temp	pH	Cond	TDS	salinity
	14.00	8.28	202.00	161.00	106.00
Barriers	None.				
Proposed Enhancement	In-stream features sure as boulders and LWD should be added here to				

Unnamed Tributary to Healy Creek	
	improve habitat quality. Garbage debris should be removed and regularly maintained.
Photos	 

Bear Creek					
Station ID	**71**				
Easting	509592				
Northing	5444826				
Comments	Several log jams exist in this reach of the stream.				
Wetted width and depth	2.70 m, 0.15 m				
Bankful width and depth	4.60 m, 1.50 m				
% substrate type	20 boulders, 40 cobbles, 40 fines				
In-stream Cover	Some bank erosion, and LWD.				
Water Quality	Temp	pH	Cond	TDS	salinity
	12.80	8.77	252.00	180.00	117.00
Barriers	Log jams may impede and garbage debris may impede passage of fish.				

Bear Creek	
Proposed Enhancement	Garbage debris within the reach should be removed, and replaced with appropriate LWD properly anchored. Install trash rack on culvert west of 128 Street; regular maintenance to remove debris within creek and at trash rack.
Photos	  

Bear Creek					
Station ID	**72**				
Easting	509833				
Northing	5444826				
Comments	East of 128 Street is large deep pool then low weir comprised of large boulders. Detention pond located northwest of the Station.				
Wetted width and depth	3.10 m, 0.20 m				
Bankful width and depth	5.50 m, 1.50 m				
% substrate type	20 boulders, 40 cobbles, 40 fines				
In-stream Cover	Undercut banks, large boulders and garbage debris (tires within pool).				
Water Quality	Temp	pH	Cond	TDS	salinity
	13.00	8.43	237.00	174.00	110.00
Barriers	None; fish observed within pool.				
Proposed Enhancement	Removal of garbage within pool and installation of properly anchored LWD.				

Bear Creek	
Photos	  

Appendix C - Surficial Geological Observation Sites

Surficial Geological Observation Sites

Site	Northing	Easting	Surficial Sediment	Comments
1	5447820	509409	0.5 silt and alluvium over 0.3 glaciomarine	Staff plates, dug ditch from BC Hydro yard enters
2	5444804	509485	3 m glaciomarine	Dug ditch with bottom rip rap from BC Hydro yard, LWD pile did not collect sediment wedge
3	5444771	509208	4 m glaciomarine	Dug ditch through powerline ROW, no soil piles
4	5444850	509024	Estimate 2 m glaciomarine	Culverts under railway ROW
5	5444854	5089863	Channelized route along W side of railway ROW, est. 1 m glaciomarine	Dug, then eroded and enlarged
6	5444923	508893	Channelized route along W side Rwy ROW	Concrete culverts below rail spur
7	5444835	508825	Unknown	Surface ditches must connect to storms
8	5445081	508595	Unknown	Outlet of storm sewer, degraded gabions spilling cobbles.
9	5445065	508571	Unknown	Collection basin above storm sewer
10	5445548	511322	Unknown, assume alluvium over glaciomarine	Very large box culvert takes Quest Creek below 88 Avenue
11	5445476	511367	Alluvium over glaciomarine	Northern park walking trail bridge
12	5445351	511351	Alluvium over glaciomarine	Quest Creek above confluence with Bear Creek
13	5445350	511343	Alluvium over glaciomarine	Bear Creek above confluence with Quest
14	5445345	511257	Alluvium over glaciomarine	King George crossing over Bear Creek, wood bridge, piles, failed concrete bag wall, eroded concrete protection, displaced rip rap
15	5445269	511215	Alluvium over glaciomarine	Bear Creek above King George, erosion, partly failed boulder rip rap
16	5445226	511123	Alluvium over glaciomarine	Bear Creek above King George,
17	5445155	511099	Alluvium over glaciomarine	Tree fall, bank failure, sediment wedge behind LWD obstruction,

City of Surrey Integrated Stormwater Management Plan - Surface Soil and Creek Bank Observation Sites

Site	Northing	Easting	Surficial Sediment	Comments
18	n/a		Alluvium over glaciomarine	7 m high, 10 m long bank from undercut, groundwater table intersected, seepage out at 3 m below sfc.
19	n/a		Glaciomarine	8 m high, 15 m long bank from undercut, groundwater table intersected, seepage out at 5 m below sfc.
20	n/a		Glaciomarine	Channel bank receeded 5 m N since about 100 years, bouldery channel section from erosion of bouldery glaciomarine or till
21	n/a		Glaciomarine, organic deposits	Low north bank, groundwater outflow zone, wet loving veg., stream avulsions evident, flood berms of gravel
22	5444753	510556	Glaciomarine	Old concrete culverts under 84 ave
23	5445107	511418	Alluvium over glaciomarine	Southern walking trail bridge over Quest Creek in Bear Creek park., anchored logs for fish, rip rap displaced
24	5443860	509183	Oxidized beach sand and gravel, probably over glaciomarine	Hydro ROW, soil test pit in groundwater outflow zone
25	5443712	509165	Beach sand, probably over glaciomarine	Old ditchwater retention pond, concrete v notch weir as outlet
26	5443352	509185	Oxidized beach sand and gravel, probably over glaciomarine	Soil test pit in flat area with high water table
27	5443916	509140	Not observed, likely oxidized beach sand and gravel, probably over glaciomarine	Inlet 24 inch storm sewer
28	5443144	510421	Not observed	Inlet for concrete storm sewer pipes
29	5443370	510130	Oxidized sl silty med coarse sand, moist	Cedar forest, flat, high water table, stading water at surface seasonally, test hole fills with water to 35 cm below surface
30	5445937	510159	Clayey silt glaciomarine deposit	Creek ravine with large concrete pipe, evidence previous erosion repair and rip rap, now displaced

City of Surrey Integrated Stormwater Management Plan - Surface Soil and Creek Bank Observation Sites

Site	Northing	Easting	Surficial Sediment	Comments
31	5445753	510179	Orange red, silty fine sand,no stonees, soft	Flat shoulder above stream gully, large live and dead maple trees
32	5445869	510149	Beige white silty clay, dense, homog., oxidized iron on fractures	Creek bank downstream of 31, log blocks stream, erosion packet above
33	5445634	510420	Unknown	3 to 4 m H concrete bag wall, and poured concrete wall, bag wall sags out 0.4 m upper half, local back yards right to top of ravine
34	5445685	510419	Unknown	Storm sewer outlet, 24 inch concrete pipe, outlet rack dislodged
35	5446773	510242	Topsoil over gleyed sandy silt, red brown, mosit, cobbles at depth	Park and school ground with large rd surface boulder grouped after land development.
36	5446136	508404	Soil over 20 - 70 cm loose, red brown, sl moist, cobbly and pebblyy sand, roots to depth Capilano	Just north of dog park in forested area, below windfall tree
37	5446119	508417	40 cm soil and rd cobs, water table near surface	Low, seasonally inundated, large cottonwood, alder, salmonberry, 1 - 3 m lower than 36
38	5445336	511785	Alluvium over fine grained silt	On King Creek, east of Bear Creek swimming pool, creek ravine had erosion repair on east slope - on-contour logs, fibre mat, now rotted.
39	5445265	511738	1.5 m gravelly alluvium over beige silt to 3 m depth	Eroded creek area, vertical banks, above garden bridge
40	5444993	511637	Beige silty fine sand	Miniature rail bridge, 6 foot concrete culvert, lock blocks, large mossy bloulder rip rap
41	5444993	511637	Beige silty fine sand	Eroded ravine below road drainage pipe, took out about 120 - 200 m3 of sediment into creek, now some bld rip rap on base
42	5444746	511628	Unknown	Man made debris accumulation, holds back large pond in gully, under footbridge to 140 st parking lot, many fish, pond more than 1 m deep

City of Surrey Integrated Stormwater Management Plan - Surface Soil and Creek Bank Observation Sites

Site	Northing	Easting	Surficial Sediment	Comments
43	5444701	511661	Silt and sand, cobble base	Creek through hydro ROW, likely channelized then later erosion, no stumps
44	5444592	511701	Silt and sand	Farthest downstream part of channel, near property line of park, outer edge hydro ROW
58	5445125	510249	Alluvium over dense silty sand,no stone, mottled	Beside Hydro ROW, fill on top soil section
59	5444952	509953	Bouldery alluvium over silty fine sand	Eroded channel beside commercial park
60	5444648	510017	Dense, mottled silt, no stone	Channelized, white cloudiness in water
61	5444434	508456	Topsoil over red brown, loose peb sand	Park
62	5444666	508878	Topsoil over beige dense silty sand w/ cobs, mottled	Park
63	5443338	508789	Loose soil over beige dense silty fn sand, cob peb, mottled	Park
64	5443244	509509	Soil over red brown sandy silt, rd cob, over tan red si sal, dense, cobs	Park/unused
65	5442820	510746	Soil over grey silty sand rd pebs, mottled	Unused land, wet species
66	5444291	510632	Soil over dense grey sandy silt, moist, gley	Unused land beside school
67	5445786	509369	Soil over dense fine sand tr pebs, moist, mottled	Hydro row, likely bulldozed and spoiled
68	5446273	509390	Soil over beige dense silty fn sand, pebs cobs, mottled	Park
69	5443903	511501	Beige sandy silt w pebs cobs, beside stream: fluvial gravels, sands, Fe cement	Park, top of gully
70	5444803	511345	Sandy silt, pebs, cobs, blds lag	Park

Surface Soil and Creek Bank Photos

Photo 3-1: Vertical exposure of glaciomarine cobbly silty sand, part of Capilano Sediments unit. Groundwater seeps out at about 3 m below surface, at elevation of top of shovel. At base, a layer of silt forms part of glaciomarine unit. The shovel is about 1 m long. Site 18. See also cover photo.

Photo 3-2: Vertical exposure of glaciomarine cobbly silty Sand created by accentuated erosion at channel bend. Groundwater seeps out about 5 m below surface, with some oxidized iron precipitated on face. Deciduous brush grows on sloughed sediment in top half of face. Channel lag boulders and cobbles are present in the stream. Site 19.

Photo 3-3: Bouldery fluvial deposit over glaciomarine silty sand with pebbles and cobbles. Plant and tree roots only penetrate to the top of the glaciomarine unit. Site 59.

Photo 3-4: Oxidized medium and coarse sand with rounded pebbles and cobbles, part of Salish Sediments Unit. Roots and water penetrate to depth. Site 36.

Photo 3-5: Bear Creek above King George Boulevard, where wood debris obstructs the channel, which has caused buildup of a wedge of sand and gravel, nearly filling the channel. Site 17.

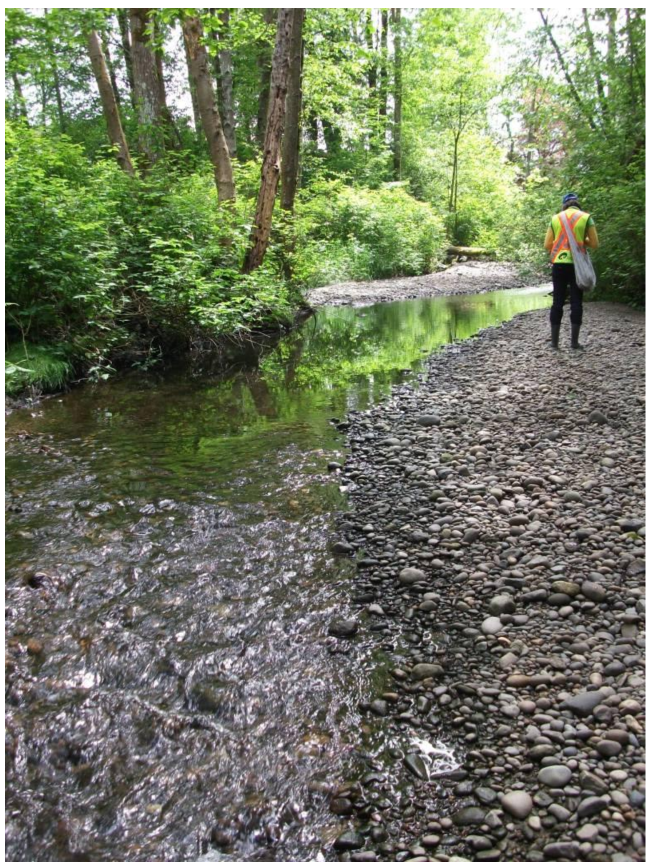

Photo 3-6: Bear Creek with lateral bars of cobbles and pebbles formed during high flood conditions. Location between sites.

Photo 3-7: Typical stream reach with lag cobbles and pebbles as lateral bars, some woody debris mainly from deciduous trees, and riparian vegetation to the waterline. Site 58.

Photo 3-8: Channelized reach of Bear Creek, with evidence of lateral channel erosion since installation of concrete block wall, and growth of pioneer deciduous trees on new banks with spoils. Shovel is about 1 m long. Glaciomarine silty sands form channel bank. Site 6.

Appendix D - Cost Estimates

STORM SEWER AND CULVERT UPGRADES - TO SERVICE FUTURE DEVELOPMENT CONDITIONS

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
C-12614	Map 6-3C	82 Avenue	Culvert	5	450	600	600	$850	$850	$4,250	$4,250
C-12617	Map 6-3C	82 Avenue	Culvert	5	450	600	600	$850	$850	$4,250	$4,250
C-12636	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$950	$950	$4,750	$4,750
C-12639	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$950	$950	$4,750	$4,750
C-12642	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$950	$950	$4,750	$4,750
Pipe-10475-2	Map 6-3D	130 Street	Culvert	27	-	1200 x 1500	1200 x 1500	$2,000	$2,000	$54,000	$54,000
Pipe-10487	Map 6-3A	Prince Charles Blvd.	Storm Sewer	37	525	675	675	$900	$900	$33,300	$33,300
Pipe-10508	Map 3-6B	128 Street	Storm Sewer	42	750	900	900	$1,040	$1,040	$43,680	$43,680
Pipe-10509	Map 6-3D	84 Avenue	Storm Sewer	55	1200	1350	1350	$1,280	$1,280	$70,400	$70,400
Pipe-10518	Map 6-3A	92 Avenue	Storm Sewer	50	900	1200	1200	$1,200	$1,200	$60,000	$60,000
Pipe-10539	Map 6-3E	132 Street	Storm Sewer	12	525	1050	1050	$1,130	$1,130	$13,560	$13,560
Pipe-10569	Map 3-6B	88 Avenue	Storm Sewer	13	1050		1200		$1,200		$15,600
Pipe-10570	Map 6-3A	132 Street	Storm Sewer	14	750	900	1050	$1,040	$1,130	$14,560	$15,820
Pipe-10596	Map 6-3D	130 Street	Storm Sewer	110	750	900	900	$1,040	$1,040	$114,400	$114,400
Pipe-10608	Map 6-3D	132 Street	Storm Sewer	62	1050	1200	1200	$1,200	$1,200	$74,400	$74,400
Pipe-10624	Map 6-3D	128 Street	Storm Sewer	22	900	1200	1200	$1,200	$1,200	$26,400	$26,400
Pipe-10658	Map 6-3A	132 Street	Storm Sewer	65	750	825	900	$1,000	$1,040	$65,000	$67,600
Pipe-10680	Map 6-3C	122A Street	Storm Sewer	148	1350	1500	1800	$1,350	$1,470	$199,800	$217,560
Pipe-10688	Map 3-6B	88 Avenue	Storm Sewer	77	1050		1200		$1,200		$92,400
Pipe-10710	Map 6-3A	92 Avenue	Storm Sewer	76	750	1200	1200	$1,200	$1,200	$91,200	$91,200
Pipe-10712	Map 6-3C	122A Street	Storm Sewer	90	1350	1500	1800	$1,350	$1,470	$121,500	$132,300
Pipe-10723	Map 6-3A	Applehill Cresent	Storm Sewer	93	900	1200	1200	$1,200	$1,200	$111,600	$111,600
Pipe-10727	Map 6-3D	84 Avenue	Storm Sewer	57	675	900	900	$1,040	$1,040	$59,280	$59,280
Pipe-10757	Map 6-3E	128 Street	Storm Sewer	105	750		825		$1,000		$105,000
Pipe-10761	Map 6-3E	132 Street	Storm Sewer	76	675	1050	1050	$1,130	$1,130	$85,880	$85,880
Pipe-10771	Map 6-3D	80 Avenue	Storm Sewer	36	600		675		$900		$32,400
Pipe-10783	Map 6-3A	132 Street	Storm Sewer	52	900	1050	1200	$1,130	$1,200	$58,760	$62,400
Pipe-10788	Map 6-3E	132 Street	Storm Sewer	132	900	1050	1050	$1,130	$1,130	$149,160	$149,160
Pipe-10798	Map 6-3E	King George Blvd.	Storm Sewer	54	750	900	900	$1,040	$1,040	$56,160	$56,160
Pipe-10801	Map 6-3F	88 Avenue	Storm Sewer	94	600		675		$900		$84,600
Pipe-10803	Map 6-3D	130 Street	Storm Sewer	102	750	900	900	$1,040	$1,040	$106,080	$106,080
Pipe-10828	Map 6-3D	128 Street	Storm Sewer	93	900	1200	1200	$1,200	$1,200	$111,600	$111,600
Pipe-10842	Map 6-3A	132 Street	Storm Sewer	55	750	825	900	$1,000	$1,040	$55,000	$57,200
Pipe-10846	Map 6-3D	130 Street	Storm Sewer	37	600	750	750	$950	$950	$35,150	$35,150
Pipe-10850	Map 6-3E	King George Blvd.	Storm Sewer	143	750	900	900	$1,040	$1,040	$148,720	$148,720
Pipe-10866	Map 6-3A	Prince Charles Blvd.	Storm Sewer	25	525	675	675	$900	$900	$22,500	$22,500
Pipe-10868	Map 6-3D	132 Street	Storm Sewer	103	1050	1200	1200	$1,200	$1,200	$123,600	$123,600
Pipe-10881	Map 6-3D	84 Avenue	Storm Sewer	73	675	900	900	$1,040	$1,040	$75,920	$75,920
Pipe-10882	Map 3-6B	88 Avenue	Storm Sewer	98	1050	1350	1350	$1,280	$1,280	$125,440	$125,440
Pipe-10891	Map 3-6B	88 Avenue	Storm Sewer	110	900	1350	1350	$1,280	$1,280	$140,800	$140,800

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-10892	Map 6-3A	92 Avenue	Storm Sewer	103	600	825	825	$1,000	$1,000	$103,000	$103,000
Pipe-10912	Map 6-3A	Prince Charles Blvd.	Storm Sewer	58	900	1200	1200	$1,200	$1,200	$69,600	$69,600
Pipe-10913	Map 6-3E	76 Avenue	Storm Sewer	16	750	900	900	$1,040	$1,040	$16,640	$16,640
Pipe-10914	Map 6-3E	76 Avenue	Storm Sewer	40	750	900	900	$1,040	$1,040	$41,600	$41,600
Pipe-10924	Map 6-3D	128 Street	Storm Sewer	166	1200	1350	1350	$1,280	$1,280	$212,480	$212,480
Pipe-10929	Map 6-3D	134 Street	Storm Sewer	6	750	900	900	$1,040	$1,040	$6,240	$6,240
Pipe-10939	Map 6-3C	82 Avenue	Storm Sewer	72	900	1050	1050	$1,130	$1,130	$81,360	$81,360
Pipe-10966	Map 6-3A	92 Avenue	Storm Sewer	83	525	675	675	$900	$900	$74,700	$74,700
Pipe-10973	Map 6-3E	128 Street	Storm Sewer	123	600	675	675	$900	$900	$110,700	$110,700
Pipe-10979	Map 6-3A	Applehill Cres.	Storm Sewer	44	1200	1350	1500	$1,280	$1,350	$56,320	$59,400
Pipe-10984	Map 6-3D	130 Street	Storm Sewer	70	600	750	750	$950	$950	$66,500	$66,500
Pipe-10990	Map 6-3A	92 Avenue	Storm Sewer	17	900	1200	1200	$1,200	$1,200	$20,400	$20,400
Pipe-11013	Map 6-3A	92 Avenue	Storm Sewer	30	900	1200	1200	$1,200	$1,200	$36,000	$36,000
Pipe-11018	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	525	675	675	$900	$900	$74,700	$74,700
Pipe-11019	Map 6-3D	132 Street	Storm Sewer	22	1050	1200	1200	$1,200	$1,200	$26,400	$26,400
Pipe-11021	Map 6-3D	134 Street	Storm Sewer	100	900	1050	1050	$1,130	$1,130	$113,000	$113,000
Pipe-11033	Map 3-6B	88 Avenue	Storm Sewer	162	1050		1200		$1,200		$194,400
Pipe-11035	Map 3-6B	88 Avenue	Storm Sewer	95	1050	1350	1350	$1,280	$1,280	$121,600	$121,600
Pipe-11075	Map 6-3E	132 Street	Storm Sewer	56	900	1050	1050	$1,130	$1,130	$63,280	$63,280
Pipe-11077	Map 6-3D	128 Street	Storm Sewer	23	1200		1350		$1,280		$29,440
Pipe-11084	Map 6-3E	76 Avenue	Storm Sewer	58	750	900	900	$1,040	$1,040	$60,320	$60,320
Pipe-11090	Map 6-3E	128 Street	Storm Sewer	55	750	825	1050	$1,000	$1,130	$55,000	$62,150
Pipe-11100	Map 6-3D	133A Street	Storm Sewer	143	1050	1200	1200	$1,200	$1,200	$171,600	$171,600
Pipe-11118	Map 6-3A	92 Avenue	Storm Sewer	89	750	1200	1200	$1,200	$1,200	$106,800	$106,800
Pipe-11137	Map 6-3D	82B Avenue	Storm Sewer	93	1050	1200	1200	$1,200	$1,200	$111,600	$111,600
Pipe-11152	Map 6-3D	128 Street	Storm Sewer	13	1050	1200	1200	$1,200	$1,200	$15,600	$15,600
Pipe-11161	Map 6-3E	128 Street	Storm Sewer	118	900	1050	1200	$1,130	$1,200	$133,340	$141,600
Pipe-11168	Map 6-3D	132 Street	Storm Sewer	55	1050	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11169	Map 6-3D	134 Street	Storm Sewer	105	900	1050	1050	$1,130	$1,130	$118,650	$118,650
Pipe-11190	Map 6-3E	128 Street	Storm Sewer	91	750	900	900	$1,040	$1,040	$94,640	$94,640
Pipe-11195	Map 6-3E	132 Street	Storm Sewer	145	750	1050	1050	$1,130	$1,130	$163,850	$163,850
Pipe-11198	Map 6-3D	128 Street	Storm Sewer	74	900	1200	1200	$1,200	$1,200	$88,800	$88,800
Pipe-11202	Map 6-3D	80 Avenue	Storm Sewer	14	900	1050	1200	$1,130	$1,200	$15,820	$16,800
Pipe-11261	Map 6-3A	Prince Charles Blvd.	Storm Sewer	103	675	900	900	$1,040	$1,040	$107,120	$107,120
Pipe-11284	Map 6-3A	131A Street	Storm Sewer	98	600		675		$900		$88,200
Pipe-11317	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	600	675	675	$900	$900	$74,700	$74,700
Pipe-11345	Map 6-3C	122A Street	Storm Sewer	5	1350	1500	1800	$1,350	$1,470	$6,750	$7,350
Pipe-11351	Map 6-3A	132 Street	Storm Sewer	100	750	900	1050	$1,040	$1,130	$104,000	$113,000
Pipe-11357	Map 3-6B	88 Avenue	Storm Sewer	108	900	1350	1350	$1,280	$1,280	$138,240	$138,240
Pipe-11371	Map 6-3A	92 Avenue	Storm Sewer	55	675	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11379	Map 6-3A	92 Avenue	Storm Sewer	94	750	1200	1200	$1,200	$1,200	$112,800	$112,800
Pipe-11404	Map 6-3A	132 Street	Storm Sewer	20	900	1050	1050	$1,130	$1,130	$22,600	$22,600

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-11405	Map 6-3A	Prince Charles Blvd.	Storm Sewer	99	675	825	825	$1,000	$1,000	$99,000	$99,000
Pipe-11414	Map 6-3D	84 Avenue	Storm Sewer	12	675	900	1050	$1,040	$1,130	$12,480	$13,560
Pipe-11456	Map 6-3A	Huntley Avenue	Storm Sewer	99	750		825		$1,000		$99,000
Pipe-11458	Map 6-3E	134 Street	Storm Sewer	99	600	675	675	$900	$900	$89,100	$89,100
Pipe-11459	Map 3-6B	88A Avenue	Storm Sewer	108	900	1050	1050	$1,130	$1,130	$122,040	$122,040
Pipe-11483	Map 6-3E	76 Avenue	Storm Sewer	15	600	900	900	$1,040	$1,040	$15,600	$15,600
Pipe-11500	Map 6-3D	84 Avenue	Storm Sewer	113	600	675	675	$900	$900	$101,700	$101,700
Pipe-11504	Map 6-3E	King George Blvd.	Storm Sewer	94	750	900	900	$1,040	$1,040	$97,760	$97,760
Pipe-11508	Map 3-6B	88 Avenue	Storm Sewer	104	1200	1500	1500	$1,350	$1,350	$140,400	$140,400
Pipe-11518	Map 3-6B	128 Street	Storm Sewer	46	750	900	1050	$1,040	$1,130	$47,840	$51,980
Pipe-11522	Map 6-3D	132 Street	Storm Sewer	122	1050	1200	1200	$1,200	$1,200	$146,400	$146,400
Pipe-11543	Map 6-3A	Prince Charles Blvd.	Storm Sewer	98	675	900	900	$1,040	$1,040	$101,920	$101,920
Pipe-11558	Map 6-3E	134 Street	Storm Sewer	59	600	675	675	$900	$900	$53,100	$53,100
Pipe-11562	Map 6-3A	90 Avenue	Storm Sewer	88	675		750		$950		$83,600
Pipe-11569	Map 6-3D	132 Street	Storm Sewer	7	1050	1200	1200	$1,200	$1,200	$8,400	$8,400
Pipe-11601	Map 6-3A	132 Street	Storm Sewer	9	900	1050	1200	$1,130	$1,200	$10,170	$10,800
Pipe-11610	Map 6-3D	134 Street	Storm Sewer	13	900		1050		$1,130		$14,690
Pipe-11621	Map 6-3A	Prince Charles Blvd.	Storm Sewer	55	900	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11641	Map 6-3A	92 Avenue	Storm Sewer	103	750	1200	1200	$1,200	$1,200	$123,600	$123,600
Pipe-11653	Map 6-3F	88 Avenue	Storm Sewer	104	600		675		$900		$93,600
Pipe-11660	Map 6-3A	Prince Charles Blvd.	Storm Sewer	91	525	675	675	$900	$900	$81,900	$81,900
Pipe-11701	Map 6-3D	132 Street	Storm Sewer	104	1050	1200	1200	$1,200	$1,200	$124,800	$124,800
Pipe-11706	Map 6-3E	132 Street	Storm Sewer	99	900	1050	1050	$1,130	$1,130	$111,870	$111,870
Pipe-11708	Map 6-3D	80 Avenue	Storm Sewer	25	600		675		$900		$22,500
Pipe-11732	Map 6-3D	132 Street	Storm Sewer	25	1050	1200	1200	$1,200	$1,200	$30,000	$30,000
Pipe-11739	Map 6-3A	132 Street	Storm Sewer	36	750	900	900	$1,040	$1,040	$37,440	$37,440
Pipe-11765	Map 6-3A	92 Avenue	Storm Sewer	93	600	825	825	$1,000	$1,000	$93,000	$93,000
Pipe-11773	Map 3-6B	88 Avenue	Storm Sewer	64	1050	1350	1350	$1,280	$1,280	$81,920	$81,920
Pipe-11779	Map 6-3D	80 Avenue	Storm Sewer	74	600		675		$900		$66,600
Pipe-11806	Map 6-3E	128 Street	Storm Sewer	178	750	1050	1200	$1,130	$1,200	$201,140	$213,600
Pipe-11815	Map 3-6B	88 Avenue	Storm Sewer	15	900	1500	1500	$1,350	$1,350	$20,250	$20,250
Pipe-11836	Map 6-3E	76 Avenue	Storm Sewer	14	750	900	900	$1,040	$1,040	$14,560	$14,560
Pipe-11854	Map 6-3A	Prince Charles Blvd.	Storm Sewer	82	600	675	675	$900	$900	$73,800	$73,800
Pipe-11856	Map 6-3A	Prince Charles Blvd.	Storm Sewer	97	600	675	675	$900	$900	$87,300	$87,300
Pipe-11868	Map 6-3A	Prince Charles Blvd.	Storm Sewer	91	600	675	675	$900	$900	$81,900	$81,900
Pipe-11898	Map 6-3E	132 Street	Storm Sewer	12	750	1050	1050	$1,130	$1,130	$13,560	$13,560
Pipe-11901	Map 6-3A	92 Avenue	Storm Sewer	89	750	1200	1200	$1,200	$1,200	$106,800	$106,800
Pipe-11910	Map 6-3E	132 Street	Storm Sewer	59	675	1050	1050	$1,130	$1,130	$66,670	$66,670
Pipe-11912	Map 6-3E	128 Street	Storm Sewer	133	750	900	900	$1,040	$1,040	$138,320	$138,320
Pipe-11927	Map 6-3E	76 Avenue	Storm Sewer	118	750	900	900	$1,040	$1,040	$122,720	$122,720
Pipe-11954	Map 6-3E	King George Blvd.	Storm Sewer	145	750	900	900	$1,040	$1,040	$150,800	$150,800
Pipe-11971	Map 6-3E	132 Street	Storm Sewer	19	1050	1200	1200	$1,200	$1,200	$22,800	$22,800

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-11974	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	525	675	675	$900	$900	$74,700	$74,700
Pipe-11998	Map 6-3A	92 Avenue	Storm Sewer	67	750	1050	1050	$1,130	$1,130	$75,710	$75,710
Pipe-11999	Map 6-3A	92 Avenue	Storm Sewer	24	750	1050	1050	$1,130	$1,130	$27,120	$27,120
Pipe-12004	Map 3-6B	88A Avenue	Storm Sewer	45	900	1050	1200	$1,130	$1,200	$50,850	$54,000
Pipe-12026	Map 6-3E	128 Street	Storm Sewer	92	750		825		$1,000		$92,000
Pipe-12039	Map 6-3D	132 Street	Storm Sewer	82	1050	1200	1200	$1,200	$1,200	$98,400	$98,400
Pipe-12104	Map 6-3E	132 Street	Storm Sewer	116	900	1050	1050	$1,130	$1,130	$131,080	$131,080
Pipe-12129	Map 3-6B	128 Street	Storm Sewer	14	900		1050		$1,130		$15,820
Pipe-12160	Map 6-3F	88 Avenue	Storm Sewer	81	600		675		$900		$72,900
Pipe-12161	Map 6-3E	128 Street	Storm Sewer	18	750	900	900	$1,040	$1,040	$18,720	$18,720
Pipe-12176	Map 6-3F	88 Avenue	Storm Sewer	16	600		675		$900		$14,400
Pipe-12182	Map 6-3D	128 Street	Storm Sewer	12	900	1200	1200	$1,200	$1,200	$14,400	$14,400
Pipe-12184	Map 6-3E	128 Street	Storm Sewer	27	750	900	900	$1,040	$1,040	$28,080	$28,080
Pipe-12185	Map 6-3D	84 Avenue	Storm Sewer	49	1200	1350	1350	$1,280	$1,280	$62,720	$62,720
Pipe-12193	Map 6-3E	128 Street	Storm Sewer	116	900	1050	1200	$1,130	$1,200	$131,080	$139,200
Pipe-12212	Map 6-3E	128 Street	Storm Sewer	91	900	1050	1050	$1,130	$1,130	$102,830	$102,830
Pipe-12221-2	Map 6-3D	128 Street	Culvert	21	-	1000 x 1500	1000 x 1500	$1,800	$1,800	$37,800	$37,800
Pipe-12266	Map 6-3D	134 Street	Storm Sewer	130	750	900	900	$1,040	$1,040	$135,200	$135,200
Pipe-12281	Map 6-3E	King George Blvd.	Storm Sewer	10	750	900	900	$1,040	$1,040	$10,400	$10,400
Pipe-12287	Map 6-3D	80 Avenue	Storm Sewer	13	600		675		$900		$11,700
Pipe-12291	Map 6-3E	76 Avenue	Storm Sewer	105	750	900	900	$1,040	$1,040	$109,200	$109,200
Pipe-12315	Map 3-6B	88 Avenue	Storm Sewer	76	1050	1350	1350	$1,280	$1,280	$97,280	$97,280
Pipe-12337	Map 6-3E	132 Street	Storm Sewer	72	900	1050	1050	$1,130	$1,130	$81,360	$81,360
Pipe-12338	Map 6-3E	132 Street	Storm Sewer	30	900	1050	1050	$1,130	$1,130	$33,900	$33,900
Pipe-12341	Map 6-3A	92 Avenue	Storm Sewer	63	675	1200	1200	$1,200	$1,200	$75,600	$75,600
Pipe-12370	Map 3-6B	88A Avenue	Storm Sewer	50	900	1050	1200	$1,130	$1,200	$56,500	$60,000
Pipe-12379	Map 6-3D	134 Street	Storm Sewer	93	750	900	900	$1,040	$1,040	$96,720	$96,720
Pipe-12380	Map 6-3D	132 Street	Storm Sewer	32	1050	1200	1200	$1,200	$1,200	$38,400	$38,400
Pipe-12387	Map 6-3D	80 Avenue	Storm Sewer	57	600		675		$900		$51,300
Pipe-12388	Map 6-3D	128 Street	Storm Sewer	19	1050	1200	1200	$1,200	$1,200	$22,800	$22,800
Pipe-12400	Map 6-3A	92 Avenue	Storm Sewer	91	900	1200	1200	$1,200	$1,200	$109,200	$109,200
Pipe-12446-2	Map 6-3D	84 Avenue	Culvert	33	-	1500 x 2000	1500 x 2000	$2,500	$2,500	$82,500	$82,500
Pipe-12448	Map 6-3A	92 Avenue	Storm Sewer	110	675	1050	1050	$1,130	$1,130	$124,300	$124,300
Pipe-12450	Map 6-3C	82 Avenue	Storm Sewer	5	750	825	825	$1,000	$1,000	$5,000	$5,000
Pipe-12453	Map 6-3A	92 Avenue	Storm Sewer	91	750	1200	1200	$1,200	$1,200	$109,200	$109,200
Pipe-12465	Map 6-3D	132 Street	Storm Sewer	71	1050	1200	1200	$1,200	$1,200	$85,200	$85,200
Pipe-12467	Map 3-6B	88 Avenue	Storm Sewer	40	900	1500	1500	$1,350	$1,350	$54,000	$54,000
Pipe-12468	Map 6-3D	132 Street	Storm Sewer	86	1050	1200	1200	$1,200	$1,200	$103,200	$103,200
Pipe-12469	Map 6-3D	132 Street	Storm Sewer	1	1050	1200	1200	$1,200	$1,200	$1,200	$1,200
Pipe-12484	Map 6-3D	128 Street	Storm Sewer	6	1200	1350	1350	$1,280	$1,280	$7,680	$7,680
Pipe-12505	Map 6-3A	Applehill Cres.	Storm Sewer	143	750	1200	1200	$1,200	$1,200	$171,600	$171,600
Pipe-12507	Map 6-3A	92 Avenue	Storm Sewer	5	750	900	900	$1,040	$1,040	$5,200	$5,200

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-12508	Map 6-3A	92 Avenue	Storm Sewer	9	750	900	1050	$1,040	$1,130	$9,360	$10,170
Pipe-12521	Map 3-6B	88 Avenue	Storm Sewer	70	1050		1200		$1,200		$84,000
Pipe-12527	Map 6-3D	134 Street	Storm Sewer	165	750	900	1050	$1,040	$1,130	$171,600	$186,450
Pipe-12531	Map 3-6B	88 Avenue	Storm Sewer	97	900	1350	1350	$1,280	$1,280	$124,160	$124,160
Pipe-12562	Map 6-3A	92 Avenue	Storm Sewer	79	525	675	675	$900	$900	$71,100	$71,100
									Total:	$11,341,760	$12,821,980

APPPENDIX D: COST ESTIMATES
Cruikshank & Grenville ISMP
Stormwater Management Ponds
December 2012

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

STORMWATER MANAGEMENT POND No. 1				
ITEM	**UNITS**	**QUANTITY**	**UNIT PRICE**	**PRICE**
Equipment Mobilization	lump sum	1	$10,000.00	$10,000.00
Land Aqusition	ha	1.53	$2,500,000.00	$3,825,000.00
Clearing, Grubbing, & Stripping	ha	1.53	$20,000.00	$30,600.00
Excavation	m^3	36,738	$80.00	$2,939,040.00
Supply & Install Inlet Pipe	m	50	$165.00	$8,250.00
Supply & Install Outlet Pipe	m	50	$100.00	$5,000.00
Trenching and Native Backfill	m	100	$200.00	$20,000.00
Supply & Install Inlet Headwall	each	1	$8,500.00	$8,500.00
Supply & Install Outlet Headwall	each	1	$5,500.00	$5,500.00
Landscaping	ha	0.75	$20,000.00	$15,000.00
3.0m Wide Access Road	m	350	$50.00	$17,500.00
Engineering/ Contingencies/ Traffic Control/ Quality Management	lump sum	18%	$1,239,190.20	$223,054.24
			COST:	**$7,107,444**

STORMWATER MANAGEMENT POND No. 2				
ITEM	**UNITS**	**QUANTITY**	**UNIT PRICE**	**PRICE**
Equipment Mobilization	lump sum	1	$10,000.00	$10,000.00
Land Aqusition	ha	1.10	$2,500,000.00	$2,750,000.00
Clearing, Grubbing, & Stripping	ha	1.10	$20,000.00	$22,000.00
Excavation	m^3	23,267	$80.00	$1,861,360.00
Supply & Install Inlet Pipe	m	50	$165.00	$8,250.00
Supply & Install Outlet Pipe	m	50	$100.00	$5,000.00
Trenching and Native Backfill	m	100	$200.00	$20,000.00
Supply & Install Inlet Headwall	each	1	$8,500.00	$8,500.00
Supply & Install Outlet Headwall	each	1	$5,500.00	$5,500.00
Landscaping	ha	0.55	$20,000.00	$11,000.00
3.0m Wide Access Road	m	250	$50.00	$12,500.00
Engineering/ Contingencies/ Traffic Control/ Quality Management	lump sum	18%	$848,539.80	$152,737.16
			COST:	**$4,866,847**

STORMWATER MANAGEMENT POND No. 3				
ITEM	UNITS	QUANTITY	UNIT PRICE	PRICE
Equipment Mobilization	lump sum	1	$10,000.00	$10,000.00
Land Aqusition	ha	0.98	$2,500,000.00	$2,450,000.00
Clearing, Grubbing, & Stripping	ha	0.98	$20,000.00	$19,600.00
Excavation	m³	21,172	$80.00	$1,693,760.00
Supply & Install Inlet Pipe	m	50	$165.00	$8,250.00
Supply & Install Outlet Pipe	m	50	$100.00	$5,000.00
Trenching and Native Backfill	m	100	$200.00	$20,000.00
Supply & Install Inlet Headwall	each	1	$8,500.00	$8,500.00
Supply & Install Outlet Headwall	each	1	$5,500.00	$5,500.00
Landscaping	ha	0.5	$20,000.00	$10,000.00
3.0m Wide Access Road	m	280	$50.00	$14,000.00
Engineering/ Contingencies/ Traffic Control/ Quality Management	lump sum	18%	$764,029.80	$137,525.36
			COST:	**$4,382,135**

STORMWATER MANAGEMENT POND No. 4				
ITEM	UNITS	QUANTITY	UNIT PRICE	PRICE
Equipment Mobilization	lump sum	1	$10,000.00	$10,000.00
Land Aqusition	ha	1.23	$2,500,000.00	$3,075,000.00
Clearing, Grubbing, & Stripping	ha	1.23	$20,000.00	$24,600.00
Excavation	m³	15,228	$80.00	$1,218,240.00
Supply & Install Inlet Pipe	m	50	$165.00	$8,250.00
Supply & Install Outlet Pipe	m	50	$100.00	$5,000.00
Trenching and Native Backfill	m	100	$200.00	$20,000.00
Supply & Install Inlet Headwall	each	1	$8,500.00	$8,500.00
Supply & Install Outlet Headwall	each	1	$5,500.00	$5,500.00
Landscaping	ha	0.5	$20,000.00	$10,000.00
3.0m Wide Access Road	m	280	$50.00	$14,000.00
Engineering/ Contingencies/ Traffic Control/ Quality Management	lump sum	18%	$791,836.20	$142,530.52
			COST:	**$4,541,621**

STORMWATER MANAGEMENT POND No. 5				
ITEM	UNITS	QUANTITY	UNIT PRICE	PRICE
Equipment Mobilization	lump sum	1	$10,000.00	$10,000.00
Land Aqusition	ha	0.64	$2,500,000.00	$1,600,000.00
Clearing, Grubbing, & Stripping	ha	0.64	$20,000.00	$12,800.00
Excavation	m³	10,933	$80.00	$874,640.00
Supply & Install Inlet Pipe	m	50	$165.00	$8,250.00
Supply & Install Outlet Pipe	m	50	$100.00	$5,000.00
Trenching and Native Backfill	m	100	$200.00	$20,000.00
Supply & Install Inlet Headwall	each	1	$8,500.00	$8,500.00
Supply & Install Outlet Headwall	each	1	$5,500.00	$5,500.00
Landscaping	ha	0.5	$20,000.00	$10,000.00
3.0m Wide Access Road	m	280	$50.00	$14,000.00
Engineering/ Contingencies/ Traffic Control/ Quality Management	lump sum	18%	$462,364.20	$83,225.56
			COST:	**$2,651,916**

URBAN RESIDENTIAL SOURCE CONTROLS				
ITEM	**DESCRIPTION**	**UNITS**	**UNIT PRICE**	**TOTAL PRICE**
Shrubs and/or Tree Planting with Minimum 450mm Growing Medium	Shrubs or Trees	m^2	$10.00	
	450mm Growing Medium	m^2	$20.00	$30.00
Enhanced Growing Medium	Enhanced Growing Medium	m^2	$15.00	$15.00
Pervious Pavement	Pavers	m^2	$50.00	
	50mm Aggregate Bedding	m^2	$10.00	
	150mm Open Graded Base	m^2	$15.00	
	450mm Open Graded Sub-Base	m^2	$25.00	
	Geotextile	m^2	$5.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	$115.00

COMMERICAL, INDUSTRIAL, AND MULTIPLE RESIDENTIAL SOURCE CONTROLS				
ITEM	**DESCRIPTION**	**UNITS**	**UNIT PRICE**	**PRICE**
Shrubs and/or Tree Planting with Minimum 450mm Growing Medium	Shrubs or Trees	m^2	$10.00	
	450mm Growing Medium	m^2	$20.00	$30.00
Pervious Pavement	Pavers	m^2	$50.00	
	50mm Aggregate Bedding	m^2	$10.00	
	150mm Open Graded Base	m^2	$15.00	
	450mm Open Graded Sub-Base	m^2	$25.00	
	Geotextile	m^2	$5.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	
	Reinforcing Grid (Optional)*	m^2	$50.00	$160.00
Green Roof / Detention Roof	Vegetation	m^2	$10.00	
	Detention Chamber	lump sum	$52,500.00	
	75mm Growing Medium	m^2	$5.00	
	Geotextile	m^2	$5.00	
	Root Barrier	m^2	$5.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	$75.00 / $110.00
Enhanced Growing Medium	Enhanced Growing Medium	m^2	$15.00	$15.00
Bioswale / Infiltration Trench	Vegetation	m^2	$10.00	
	300mm Growing Medium	m^2	$15.00	
	100mm Sand	m^2	$5.00	
	Geotextile	m^2	$10.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	
	Overflow Standpipe System	lump sum	$2,000.00	$60.00
Rain Garden	Vegetation	m^2	$10.00	
	450mm Growing Medium	m^2	$20.00	
	Geotextile	m^2	$8.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	
	Overflow Standpipe System	lump sum	$1,500.00	$50.00

* Cost of reinforcing grid included in total cost

LOCAL AND COLLECTOR RIGHTS-OF-WAY SOURCE CONTROLS				
ITEM	**DESCRIPTION**	**UNITS**	**UNIT PRICE**	**PRICE**
Enhanced Growing Medium	600mm Growing Medium	m^2	$30.00	$30.00
Tree Planting	Trees	m^2	$10.00	
	600mm Growing Medium	m^2	$30.00	$40.00
Shrub Planting in Boulevards	Shrubs	m^2	$10.00	
	600mm Growing Medium	m^2	$30.00	$40.00
Pervious Parking Lanes	Pavers	m^2	$50.00	
	50mm Aggregate Bedding	m^2	$10.00	
	150mm Open Graded Base	m^2	$15.00	
	450mm Open Graded Sub-Base	m^2	$25.00	
	Geotextile	m^2	$5.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	l.m.	$50.00	
	Reinforcing Grid (Optional)*	m^2	$50.00	$160.00
Infiltration / Retention Systems	Vegetation	m^2	$10.00	
	450mm Growing Medium	m^2	$20.00	
	Geotextile	m^2	$10.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	
	Overflow Standpipe System	lump sum	$2,000.00	$60.00

* Cost of reinforcing grid included in total cost

ARTERIAL RIGHTS-OF-WAY SOURCE CONTROLS				
ITEM	**DESCRIPTION**	**UNITS**	**UNIT PRICE**	**PRICE**
Enhanced Growing Medium in Medians	900mm Growing Medium	m^2	$45.00	$45.00
Tree / Shrub Planting in Medians	Trees	m^2	$10.00	
	600mm Growing Medium	m^2	$30.00	$40.00
Enhanced Growing Medium in Boulevards	600mm Growing Medium	m^2	$30.00	$30.00
Tree / Shrub Planting in Boulevards	Shrubs	m^2	$10.00	
	600mm Growing Medium	m^2	$30.00	$40.00
Infiltration / Retention in Boulevards	Vegetation	m^2	$10.00	
	300mm Growing Medium	m^2	$15.00	
	100mm Sand	m^2	$10.00	
	Geotextile	m^2	$5.00	
	Overflow Standpipe System	lump sum	$2,000.00	
	150mm Ø Perforated Drain Pipe with Drain Rock	m	$50.00	$60.00

Table D-1: Identified Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

STORM SEWER AND CULVERT UPGRADES - EXISTING AND FUTURE DEVELOPMENT CONDITIONS - NO MITIGATION

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
C-12614	Map 6-3C	82 Avenue	Culvert	5	450	600	600	$8,500	$8,500	$43,000	$43,000
C-12617	Map 6-3C	82 Avenue	Culvert	5	450	600	600	$8,500	$8,500	$43,000	$43,000
C-12636	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$9,500	$9,500	$48,000	$48,000
C-12639	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$9,500	$9,500	$48,000	$48,000
C-12642	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$9,500	$9,500	$48,000	$48,000
Pipe-10475-2	Map 6-3D	130 Street	Culvert	27	-	1200 x 1500	1200 x 1500	$20,000	$20,000	$540,000	$540,000
Pipe-12221-2	Map 6-3D	128 Street	Culvert	21	-	1000 x 1500	1000 x 1500	$18,000	$18,000	$378,000	$378,000
Pipe-12446-2	Map 6-3D	84 Avenue	Culvert	33	-	1500 x 2000	1500 x 2000	$25,000	$25,000	$825,000	$825,000
Pipe-10487	Map 6-3A	Prince Charles Blvd.	Storm Sewer	37	525	675	675	$900	$900	$34,000	$34,000
Pipe-10508	Map 3-6B	128 Street	Storm Sewer	42	750	900	900	$1,040	$1,040	$44,000	$44,000
Pipe-10509	Map 6-3D	84 Avenue	Storm Sewer	55	1200	1350	1350	$1,280	$1,280	$71,000	$71,000
Pipe-10518	Map 6-3A	92 Avenue	Storm Sewer	50	900	1200	1200	$1,200	$1,200	$60,000	$60,000
Pipe-10539	Map 6-3E	132 Street	Storm Sewer	12	525	1050	1050	$1,130	$1,130	$14,000	$14,000
Pipe-10569	Map 3-6B	88 Avenue	Storm Sewer	13	1050		1200		$1,200		$16,000
Pipe-10570	Map 6-3A	132 Street	Storm Sewer	14	750	900	1050	$1,040	$1,130	$15,000	$16,000
Pipe-10596	Map 6-3D	130 Street	Storm Sewer	110	750	900	900	$1,040	$1,040	$115,000	$115,000
Pipe-10608	Map 6-3D	132 Street	Storm Sewer	62	1050	1200	1200	$1,200	$1,200	$75,000	$75,000
Pipe-10624	Map 6-3D	128 Street	Storm Sewer	22	900	1200	1200	$1,200	$1,200	$27,000	$27,000
Pipe-10658	Map 6-3A	132 Street	Storm Sewer	65	750	825	900	$1,000	$1,040	$65,000	$68,000
Pipe-10680	Map 6-3C	122A Street	Storm Sewer	148	1350	1500	1800	$1,350	$1,470	$200,000	$218,000
Pipe-10688	Map 3-6B	88 Avenue	Storm Sewer	77	1050		1200		$1,200		$93,000
Pipe-10710	Map 6-3A	92 Avenue	Storm Sewer	76	750	1200	1200	$1,200	$1,200	$92,000	$92,000
Pipe-10712	Map 6-3C	122A Street	Storm Sewer	90	1350	1500	1800	$1,350	$1,470	$122,000	$133,000
Pipe-10723	Map 6-3A	Applehill Cresent	Storm Sewer	93	900	1200	1200	$1,200	$1,200	$112,000	$112,000
Pipe-10727	Map 6-3D	84 Avenue	Storm Sewer	57	675	900	900	$1,040	$1,040	$60,000	$60,000
Pipe-10757	Map 6-3E	128 Street	Storm Sewer	105	750		825		$1,000		$105,000
Pipe-10761	Map 6-3E	132 Street	Storm Sewer	76	675	1050	1050	$1,130	$1,130	$86,000	$86,000
Pipe-10771	Map 6-3D	80 Avenue	Storm Sewer	36	600		675		$900		$33,000
Pipe-10783	Map 6-3A	132 Street	Storm Sewer	52	900	1050	1200	$1,130	$1,200	$59,000	$63,000
Pipe-10788	Map 6-3E	132 Street	Storm Sewer	132	900	1050	1050	$1,130	$1,130	$150,000	$150,000
Pipe-10798	Map 6-3E	King George Blvd.	Storm Sewer	54	750	900	900	$1,040	$1,040	$57,000	$57,000
Pipe-10801	Map 6-3F	88 Avenue	Storm Sewer	94	600		675		$900		$85,000
Pipe-10803	Map 6-3D	130 Street	Storm Sewer	102	750	900	900	$1,040	$1,040	$107,000	$107,000
Pipe-10828	Map 6-3D	128 Street	Storm Sewer	93	900	1200	1200	$1,200	$1,200	$112,000	$112,000
Pipe-10842	Map 6-3A	132 Street	Storm Sewer	55	750	825	900	$1,000	$1,040	$55,000	$58,000
Pipe-10846	Map 6-3D	130 Street	Storm Sewer	37	600	750	750	$950	$950	$36,000	$36,000

Table D-1: Identified Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

STORM SEWER AND CULVERT UPGRADES - EXISTING AND FUTURE DEVELOPMENT CONDITIONS - NO MITIGATION

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-10850	Map 6-3E	King George Blvd.	Storm Sewer	143	750	900	900	$1,040	$1,040	$149,000	$149,000
Pipe-10866	Map 6-3A	Prince Charles Blvd.	Storm Sewer	25	525	675	675	$900	$900	$23,000	$23,000
Pipe-10868	Map 6-3D	132 Street	Storm Sewer	103	1050	1200	1200	$1,200	$1,200	$124,000	$124,000
Pipe-10881	Map 6-3D	84 Avenue	Storm Sewer	73	675	900	900	$1,040	$1,040	$76,000	$76,000
Pipe-10882	Map 3-6B	88 Avenue	Storm Sewer	98	1050	1350	1350	$1,280	$1,280	$126,000	$126,000
Pipe-10891	Map 3-6B	88 Avenue	Storm Sewer	110	900	1350	1350	$1,280	$1,280	$141,000	$141,000
Pipe-10892	Map 6-3A	92 Avenue	Storm Sewer	103	600	825	825	$1,000	$1,000	$103,000	$103,000
Pipe-10912	Map 6-3A	Prince Charles Blvd.	Storm Sewer	58	900	1200	1200	$1,200	$1,200	$70,000	$70,000
Pipe-10913	Map 6-3E	76 Avenue	Storm Sewer	16	750	900	900	$1,040	$1,040	$17,000	$17,000
Pipe-10914	Map 6-3E	76 Avenue	Storm Sewer	40	750	900	900	$1,040	$1,040	$42,000	$42,000
Pipe-10924	Map 6-3D	128 Street	Storm Sewer	166	1200	1350	1350	$1,280	$1,280	$213,000	$213,000
Pipe-10929	Map 6-3D	134 Street	Storm Sewer	6	750	900	900	$1,040	$1,040	$7,000	$7,000
Pipe-10939	Map 6-3C	82 Avenue	Storm Sewer	72	900	1050	1050	$1,130	$1,130	$82,000	$82,000
Pipe-10966	Map 6-3A	92 Avenue	Storm Sewer	83	525	675	675	$900	$900	$75,000	$75,000
Pipe-10973	Map 6-3E	128 Street	Storm Sewer	123	600	675	675	$900	$900	$111,000	$111,000
Pipe-10979	Map 6-3A	Applehill Cres.	Storm Sewer	44	1200	1350	1500	$1,280	$1,350	$57,000	$60,000
Pipe-10984	Map 6-3D	130 Street	Storm Sewer	70	600	750	750	$950	$950	$67,000	$67,000
Pipe-10990	Map 6-3A	92 Avenue	Storm Sewer	17	900	1200	1200	$1,200	$1,200	$21,000	$21,000
Pipe-11013	Map 6-3A	92 Avenue	Storm Sewer	30	900	1200	1200	$1,200	$1,200	$36,000	$36,000
Pipe-11018	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	525	675	675	$900	$900	$75,000	$75,000
Pipe-11019	Map 6-3D	132 Street	Storm Sewer	22	1050	1200	1200	$1,200	$1,200	$27,000	$27,000
Pipe-11021	Map 6-3D	134 Street	Storm Sewer	100	900	1050	1050	$1,130	$1,130	$113,000	$113,000
Pipe-11033	Map 3-6B	88 Avenue	Storm Sewer	162	1050		1200		$1,200		$195,000
Pipe-11035	Map 3-6B	88 Avenue	Storm Sewer	95	1050	1350	1350	$1,280	$1,280	$122,000	$122,000
Pipe-11075	Map 6-3E	132 Street	Storm Sewer	56	900	1050	1050	$1,130	$1,130	$64,000	$64,000
Pipe-11077	Map 6-3D	128 Street	Storm Sewer	23	1200		1350		$1,280		$30,000
Pipe-11084	Map 6-3E	76 Avenue	Storm Sewer	58	750	900	900	$1,040	$1,040	$61,000	$61,000
Pipe-11090	Map 6-3E	128 Street	Storm Sewer	55	750	825	1050	$1,000	$1,130	$55,000	$63,000
Pipe-11100	Map 6-3D	133A Street	Storm Sewer	143	1050	1200	1200	$1,200	$1,200	$172,000	$172,000
Pipe-11118	Map 6-3A	92 Avenue	Storm Sewer	89	750	1200	1200	$1,200	$1,200	$107,000	$107,000
Pipe-11137	Map 6-3D	82B Avenue	Storm Sewer	93	1050	1200	1200	$1,200	$1,200	$112,000	$112,000
Pipe-11152	Map 6-3D	128 Street	Storm Sewer	13	1050	1200	1200	$1,200	$1,200	$16,000	$16,000
Pipe-11161	Map 6-3E	128 Street	Storm Sewer	118	900	1050	1200	$1,130	$1,200	$134,000	$142,000
Pipe-11168	Map 6-3D	132 Street	Storm Sewer	55	1050	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11169	Map 6-3D	134 Street	Storm Sewer	105	900	1050	1050	$1,130	$1,130	$119,000	$119,000
Pipe-11190	Map 6-3E	128 Street	Storm Sewer	91	750	900	900	$1,040	$1,040	$95,000	$95,000

Table D-1: Identified Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

STORM SEWER AND CULVERT UPGRADES - EXISTING AND FUTURE DEVELOPMENT CONDITIONS - NO MITIGATION

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-11195	Map 6-3E	132 Street	Storm Sewer	145	750	1050	1050	$1,130	$1,130	$164,000	$164,000
Pipe-11198	Map 6-3D	128 Street	Storm Sewer	74	900	1200	1200	$1,200	$1,200	$89,000	$89,000
Pipe-11202	Map 6-3D	80 Avenue	Storm Sewer	14	900	1050	1200	$1,130	$1,200	$16,000	$17,000
Pipe-11261	Map 6-3A	Prince Charles Blvd.	Storm Sewer	103	675	900	900	$1,040	$1,040	$108,000	$108,000
Pipe-11284	Map 6-3A	131A Street	Storm Sewer	98	600		675		$900		$89,000
Pipe-11317	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	600	675	675	$900	$900	$75,000	$75,000
Pipe-11345	Map 6-3C	122A Street	Storm Sewer	5	1350	1500	1800	$1,350	$1,470	$7,000	$8,000
Pipe-11351	Map 6-3A	132 Street	Storm Sewer	100	750	900	1050	$1,040	$1,130	$104,000	$113,000
Pipe-11357	Map 3-6B	88 Avenue	Storm Sewer	108	900	1350	1350	$1,280	$1,280	$139,000	$139,000
Pipe-11371	Map 6-3A	92 Avenue	Storm Sewer	55	675	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11379	Map 6-3A	92 Avenue	Storm Sewer	94	750	1200	1200	$1,200	$1,200	$113,000	$113,000
Pipe-11404	Map 6-3A	132 Street	Storm Sewer	20	900	1050	1050	$1,130	$1,130	$23,000	$23,000
Pipe-11405	Map 6-3A	Prince Charles Blvd.	Storm Sewer	99	675	825	825	$1,000	$1,000	$99,000	$99,000
Pipe-11414	Map 6-3D	84 Avenue	Storm Sewer	12	675	900	1050	$1,040	$1,130	$13,000	$14,000
Pipe-11456	Map 6-3A	Huntley Avenue	Storm Sewer	99	750		825		$1,000		$99,000
Pipe-11458	Map 6-3E	134 Street	Storm Sewer	99	600	675	675	$900	$900	$90,000	$90,000
Pipe-11459	Map 3-6B	88A Avenue	Storm Sewer	108	900	1050	1050	$1,130	$1,130	$123,000	$123,000
Pipe-11483	Map 6-3E	76 Avenue	Storm Sewer	15	600	900	900	$1,040	$1,040	$16,000	$16,000
Pipe-11500	Map 6-3D	84 Avenue	Storm Sewer	113	600	675	675	$900	$900	$102,000	$102,000
Pipe-11504	Map 6-3E	King George Blvd.	Storm Sewer	94	750	900	900	$1,040	$1,040	$98,000	$98,000
Pipe-11508	Map 3-6B	88 Avenue	Storm Sewer	104	1200	1500	1500	$1,350	$1,350	$141,000	$141,000
Pipe-11518	Map 3-6B	128 Street	Storm Sewer	46	750	900	1050	$1,040	$1,130	$48,000	$52,000
Pipe-11522	Map 6-3D	132 Street	Storm Sewer	122	1050	1200	1200	$1,200	$1,200	$147,000	$147,000
Pipe-11543	Map 6-3A	Prince Charles Blvd.	Storm Sewer	98	675	900	900	$1,040	$1,040	$102,000	$102,000
Pipe-11558	Map 6-3E	134 Street	Storm Sewer	59	600	675	675	$900	$900	$54,000	$54,000
Pipe-11562	Map 6-3A	90 Avenue	Storm Sewer	88	675		750		$950		$84,000
Pipe-11569	Map 6-3D	132 Street	Storm Sewer	7	1050	1200	1200	$1,200	$1,200	$9,000	$9,000
Pipe-11601	Map 6-3A	132 Street	Storm Sewer	9	900	1050	1200	$1,130	$1,200	$11,000	$11,000
Pipe-11610	Map 6-3D	134 Street	Storm Sewer	13	900		1050		$1,130		$15,000
Pipe-11621	Map 6-3A	Prince Charles Blvd.	Storm Sewer	55	900	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11641	Map 6-3A	92 Avenue	Storm Sewer	103	750	1200	1200	$1,200	$1,200	$124,000	$124,000
Pipe-11653	Map 6-3F	88 Avenue	Storm Sewer	104	600		675		$900		$94,000
Pipe-11660	Map 6-3A	Prince Charles Blvd.	Storm Sewer	91	525	675	675	$900	$900	$82,000	$82,000
Pipe-11701	Map 6-3D	132 Street	Storm Sewer	104	1050	1200	1200	$1,200	$1,200	$125,000	$125,000
Pipe-11706	Map 6-3E	132 Street	Storm Sewer	99	900	1050	1050	$1,130	$1,130	$112,000	$112,000
Pipe-11708	Map 6-3D	80 Avenue	Storm Sewer	25	600		675		$900		$23,000

Table D-1: Identified Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

STORM SEWER AND CULVERT UPGRADES - EXISTING AND FUTURE DEVELOPMENT CONDITIONS - NO MITIGATION

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-11732	Map 6-3D	132 Street	Storm Sewer	25	1050	1200	1200	$1,200	$1,200	$30,000	$30,000
Pipe-11739	Map 6-3A	132 Street	Storm Sewer	36	750	900	900	$1,040	$1,040	$38,000	$38,000
Pipe-11765	Map 6-3A	92 Avenue	Storm Sewer	93	600	825	825	$1,000	$1,000	$93,000	$93,000
Pipe-11773	Map 3-6B	88 Avenue	Storm Sewer	64	1050	1350	1350	$1,280	$1,280	$82,000	$82,000
Pipe-11779	Map 6-3D	80 Avenue	Storm Sewer	74	600		675		$900		$67,000
Pipe-11806	Map 6-3E	128 Street	Storm Sewer	178	750	1050	1200	$1,130	$1,200	$202,000	$214,000
Pipe-11815	Map 3-6B	88 Avenue	Storm Sewer	15	900	1500	1500	$1,350	$1,350	$21,000	$21,000
Pipe-11836	Map 6-3E	76 Avenue	Storm Sewer	14	750	900	900	$1,040	$1,040	$15,000	$15,000
Pipe-11854	Map 6-3A	Prince Charles Blvd.	Storm Sewer	82	600	675	675	$900	$900	$74,000	$74,000
Pipe-11856	Map 6-3A	Prince Charles Blvd.	Storm Sewer	97	600	675	675	$900	$900	$88,000	$88,000
Pipe-11868	Map 6-3A	Prince Charles Blvd.	Storm Sewer	91	600	675	675	$900	$900	$82,000	$82,000
Pipe-11898	Map 6-3E	132 Street	Storm Sewer	12	750	1050	1050	$1,130	$1,130	$14,000	$14,000
Pipe-11901	Map 6-3A	92 Avenue	Storm Sewer	89	750	1200	1200	$1,200	$1,200	$107,000	$107,000
Pipe-11910	Map 6-3E	132 Street	Storm Sewer	59	675	1050	1050	$1,130	$1,130	$67,000	$67,000
Pipe-11912	Map 6-3E	128 Street	Storm Sewer	133	750	900	900	$1,040	$1,040	$139,000	$139,000
Pipe-11927	Map 6-3E	76 Avenue	Storm Sewer	118	750	900	900	$1,040	$1,040	$123,000	$123,000
Pipe-11954	Map 6-3E	King George Blvd.	Storm Sewer	145	750	900	900	$1,040	$1,040	$151,000	$151,000
Pipe-11971	Map 6-3E	132 Street	Storm Sewer	19	1050	1200	1200	$1,200	$1,200	$23,000	$23,000
Pipe-11974	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	525	675	675	$900	$900	$75,000	$75,000
Pipe-11998	Map 6-3A	92 Avenue	Storm Sewer	67	750	1050	1050	$1,130	$1,130	$76,000	$76,000
Pipe-11999	Map 6-3A	92 Avenue	Storm Sewer	24	750	1050	1050	$1,130	$1,130	$28,000	$28,000
Pipe-12004	Map 3-6B	88A Avenue	Storm Sewer	45	900	1050	1200	$1,130	$1,200	$51,000	$54,000
Pipe-12026	Map 6-3E	128 Street	Storm Sewer	92	750		825		$1,000		$92,000
Pipe-12039	Map 6-3D	132 Street	Storm Sewer	82	1050	1200	1200	$1,200	$1,200	$99,000	$99,000
Pipe-12104	Map 6-3E	132 Street	Storm Sewer	116	900	1050	1050	$1,130	$1,130	$132,000	$132,000
Pipe-12129	Map 3-6B	128 Street	Storm Sewer	14	900		1050		$1,130		$16,000
Pipe-12160	Map 6-3F	88 Avenue	Storm Sewer	81	600		675		$900		$73,000
Pipe-12161	Map 6-3E	128 Street	Storm Sewer	18	750	900	900	$1,040	$1,040	$19,000	$19,000
Pipe-12176	Map 6-3F	88 Avenue	Storm Sewer	16	600		675		$900		$15,000
Pipe-12182	Map 6-3D	128 Street	Storm Sewer	12	900	1200	1200	$1,200	$1,200	$15,000	$15,000
Pipe-12184	Map 6-3E	128 Street	Storm Sewer	27	750	900	900	$1,040	$1,040	$29,000	$29,000
Pipe-12185	Map 6-3D	84 Avenue	Storm Sewer	49	1200	1350	1350	$1,280	$1,280	$63,000	$63,000
Pipe-12193	Map 6-3E	128 Street	Storm Sewer	116	900	1050	1200	$1,130	$1,200	$132,000	$140,000
Pipe-12212	Map 6-3E	128 Street	Storm Sewer	91	900	1050	1050	$1,130	$1,130	$103,000	$103,000
Pipe-12266	Map 6-3D	134 Street	Storm Sewer	130	750	900	900	$1,040	$1,040	$136,000	$136,000
Pipe-12281	Map 6-3E	King George Blvd.	Storm Sewer	10	750	900	900	$1,040	$1,040	$11,000	$11,000

Table D-1: Identified Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

STORM SEWER AND CULVERT UPGRADES - EXISTING AND FUTURE DEVELOPMENT CONDITIONS - NO MITIGATION

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Recom		Unit Cost ($/m)		Total Estimated Cost ($)	
						Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions	Existing Development Conditions	Future Development Conditions
Pipe-12287	Map 6-3D	80 Avenue	Storm Sewer	13	600		675		$900		$12,000
Pipe-12291	Map 6-3E	76 Avenue	Storm Sewer	105	750	900	900	$1,040	$1,040	$110,000	$110,000
Pipe-12315	Map 3-6B	88 Avenue	Storm Sewer	76	1050	1350	1350	$1,280	$1,280	$98,000	$98,000
Pipe-12337	Map 6-3E	132 Street	Storm Sewer	72	900	1050	1050	$1,130	$1,130	$82,000	$82,000
Pipe-12338	Map 6-3E	132 Street	Storm Sewer	30	900	1050	1050	$1,130	$1,130	$34,000	$34,000
Pipe-12341	Map 6-3A	92 Avenue	Storm Sewer	63	675	1200	1200	$1,200	$1,200	$76,000	$76,000
Pipe-12370	Map 3-6B	88A Avenue	Storm Sewer	50	900	1050	1200	$1,130	$1,200	$57,000	$60,000
Pipe-12379	Map 6-3D	134 Street	Storm Sewer	93	750	900	900	$1,040	$1,040	$97,000	$97,000
Pipe-12380	Map 6-3D	132 Street	Storm Sewer	32	1050	1200	1200	$1,200	$1,200	$39,000	$39,000
Pipe-12387	Map 6-3D	80 Avenue	Storm Sewer	57	600		675		$900		$52,000
Pipe-12388	Map 6-3D	128 Street	Storm Sewer	19	1050	1200	1200	$1,200	$1,200	$23,000	$23,000
Pipe-12400	Map 6-3A	92 Avenue	Storm Sewer	91	900	1200	1200	$1,200	$1,200	$110,000	$110,000
Pipe-12448	Map 6-3A	92 Avenue	Storm Sewer	110	675	1050	1050	$1,130	$1,130	$125,000	$125,000
Pipe-12450	Map 6-3C	82 Avenue	Storm Sewer	5	750	825	825	$1,000	$1,000	$5,000	$5,000
Pipe-12453	Map 6-3A	92 Avenue	Storm Sewer	91	750	1200	1200	$1,200	$1,200	$110,000	$110,000
Pipe-12465	Map 6-3D	132 Street	Storm Sewer	71	1050	1200	1200	$1,200	$1,200	$86,000	$86,000
Pipe-12467	Map 3-6B	88 Avenue	Storm Sewer	40	900	1500	1500	$1,350	$1,350	$54,000	$54,000
Pipe-12468	Map 6-3D	132 Street	Storm Sewer	86	1050	1200	1200	$1,200	$1,200	$104,000	$104,000
Pipe-12469	Map 6-3D	132 Street	Storm Sewer	1	1050	1200	1200	$1,200	$1,200	$2,000	$2,000
Pipe-12484	Map 6-3D	128 Street	Storm Sewer	6	1200	1350	1350	$1,280	$1,280	$8,000	$8,000
Pipe-12505	Map 6-3A	Applehill Cres.	Storm Sewer	143	750	1200	1200	$1,200	$1,200	$172,000	$172,000
Pipe-12507	Map 6-3A	92 Avenue	Storm Sewer	5	750	900	900	$1,040	$1,040	$6,000	$6,000
Pipe-12508	Map 6-3A	92 Avenue	Storm Sewer	9	750	900	1050	$1,040	$1,130	$10,000	$11,000
Pipe-12521	Map 3-6B	88 Avenue	Storm Sewer	70	1050		1200		$1,200		$84,000
Pipe-12527	Map 6-3D	134 Street	Storm Sewer	165	750	900	1050	$1,040	$1,130	$172,000	$187,000
Pipe-12531	Map 3-6B	88 Avenue	Storm Sewer	97	900	1350	1350	$1,280	$1,280	$125,000	$125,000
Pipe-12562	Map 6-3A	92 Avenue	Storm Sewer	79	525	675	675	$900	$900	$72,000	$72,000
									Total:	$13,180,000	$14,669,000

P:\20112781\00_ISMP\Engineering\03.02_Conceptual_Feasibility_Report\ISMP Final\Appendix D - Cost Estimates\[Pipe_Upgrades_20140327_mm.xlsx]Upgrades by Pipes Future

Table D-2: Recommended Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

STORM SEWER AND CULVERT UPGRADES - TO SERVICE FUTURE DEVELOPMENT CONDITIONS

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Upgrades for Future Development Conditions	Recommended Upgrades for Future Development with BMPs	Unit Cost ($/m)		Estimated Cost	Estimated Cost Upgrades for Future Development with BMPs
								Existing Development Conditions	Future Development Conditions	Future Development Conditions	
C-12614	Map 6-3C	82 Avenue	Culvert	5	450	600	600	$8,500	$8,500	$43,000	$43,000
C-12617	Map 6-3C	82 Avenue	Culvert	5	450	600	600	$8,500	$8,500	$43,000	$43,000
C-12636	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$9,500	$9,500	$48,000	$48,000
C-12639	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$9,500	$9,500	$48,000	$48,000
C-12642	Map 3-6B	85 Avenue	Culvert	5	450	750	750	$9,500	$9,500	$48,000	$48,000
Pipe-10475-2	Map 6-3D	130 Street	Culvert	27	-	1200 x 1500		$20,000		$540,000	
Pipe-12221-2	Map 6-3D	128 Street	Culvert	21	-	1000 x 1500	1000 x 1500	$18,000	$18,000	$378,000	$378,000
Pipe-12446-2	Map 6-3D	84 Avenue	Culvert	33	-	1500 x 2000	1500 x 2000	$25,000	$25,000	$825,000	$825,000
Pipe-10487	Map 6-3A	Prince Charles Blvd.	Storm Sewer	37	525	675	675	$900	$900	$34,000	$34,000
Pipe-10508	Map 3-6B	128 Street	Storm Sewer	42	750	900	900	$1,040	$1,040	$44,000	$44,000
Pipe-10509	Map 6-3D	84 Avenue	Storm Sewer	55	1200	1350	1350	$1,280	$1,280	$71,000	$71,000
Pipe-10518	Map 6-3A	92 Avenue	Storm Sewer	50	900	1200	1200	$1,200	$1,200	$60,000	$60,000
Pipe-10539	Map 6-3E	132 Street	Storm Sewer	12	525	1050	900	$1,130	$1,040	$14,000	$13,000
Pipe-10569	Map 3-6B	88 Avenue	Storm Sewer	13	1050	1200	1200	$1,200	$1,200	$16,000	$16,000
Pipe-10570	Map 6-3A	132 Street	Storm Sewer	14	750	1050	1050	$1,130	$1,130	$16,000	$16,000
Pipe-10596	Map 6-3D	130 Street	Storm Sewer	110	750	900		$1,040		$115,000	
Pipe-10608	Map 6-3D	132 Street	Storm Sewer	62	1050	1200		$1,200		$75,000	
Pipe-10624	Map 6-3D	128 Street	Storm Sewer	22	900	1200	1200	$1,200	$1,200	$27,000	$27,000
Pipe-10658	Map 6-3A	132 Street	Storm Sewer	65	750	900	900	$1,040	$1,040	$68,000	$68,000
Pipe-10680	Map 6-3C	122A Street	Storm Sewer	148	1350	1800	1800	$1,470	$1,470	$218,000	$218,000
Pipe-10688	Map 3-6B	88 Avenue	Storm Sewer	77	1050	1200		$1,200		$93,000	
Pipe-10710	Map 6-3A	92 Avenue	Storm Sewer	76	750	1200	1200	$1,200	$1,200	$92,000	$92,000
Pipe-10712	Map 6-3C	122A Street	Storm Sewer	90	1350	1800	1800	$1,470	$1,470	$133,000	$133,000
Pipe-10723	Map 6-3A	Applehill Cresent	Storm Sewer	93	900	1200	1200	$1,200	$1,200	$112,000	$112,000
Pipe-10727	Map 6-3D	84 Avenue	Storm Sewer	57	675	900		$1,040		$60,000	
Pipe-10757	Map 6-3E	128 Street	Storm Sewer	105	750	825	825	$1,000	$1,000	$105,000	$105,000
Pipe-10761	Map 6-3E	132 Street	Storm Sewer	76	675	1050	900	$1,130	$1,040	$86,000	$80,000
Pipe-10771	Map 6-3D	80 Avenue	Storm Sewer	36	600	675	675	$900	$900	$33,000	$33,000
Pipe-10783	Map 6-3A	132 Street	Storm Sewer	52	900	1200	1200	$1,200	$1,200	$63,000	$63,000
Pipe-10788	Map 6-3E	132 Street	Storm Sewer	132	900	1050		$1,130		$150,000	
Pipe-10798	Map 6-3E	King George Blvd.	Storm Sewer	54	750	900	900	$1,040	$1,040	$57,000	$57,000
Pipe-10801	Map 6-3F	88 Avenue	Storm Sewer	94	600	675	675	$900	$900	$85,000	$85,000
Pipe-10803	Map 6-3D	130 Street	Storm Sewer	102	750	900		$1,040		$107,000	
Pipe-10828	Map 6-3D	128 Street	Storm Sewer	93	900	1200	1200	$1,200	$1,200	$112,000	$112,000
Pipe-10842	Map 6-3A	132 Street	Storm Sewer	55	750	900	900	$1,040	$1,040	$58,000	$58,000

Table D-2: Recommended Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

STORM SEWER AND CULVERT UPGRADES - TO SERVICE FUTURE DEVELOPMENT CONDITIONS

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Upgrades for Future Development Conditions	Recommended Upgrades for Future Development with BMPs	Unit Cost ($/m)		Estimated Cost	Estimated Cost Upgrades for Future Development with BMPs
								Existing Development Conditions	Future Development Conditions	Future Development Conditions	
Pipe-10846	Map 6-3D	130 Street	Storm Sewer	37	600	750		$950		$36,000	
Pipe-10850	Map 6-3E	King George Blvd.	Storm Sewer	143	750	900	900	$1,040	$1,040	$149,000	$149,000
Pipe-10866	Map 6-3A	Prince Charles Blvd.	Storm Sewer	25	525	675	675	$900	$900	$23,000	$23,000
Pipe-10868	Map 6-3D	132 Street	Storm Sewer	103	1050	1200		$1,200		$124,000	
Pipe-10881	Map 6-3D	84 Avenue	Storm Sewer	73	675	900		$1,040		$76,000	
Pipe-10882	Map 3-6B	88 Avenue	Storm Sewer	98	1050	1350	1350	$1,280	$1,280	$126,000	$126,000
Pipe-10891	Map 3-6B	88 Avenue	Storm Sewer	110	900	1350	1350	$1,280	$1,280	$141,000	$141,000
Pipe-10892	Map 6-3A	92 Avenue	Storm Sewer	103	600	825	825	$1,000	$1,000	$103,000	$103,000
Pipe-10912	Map 6-3A	Prince Charles Blvd.	Storm Sewer	58	900	1200	1200	$1,200	$1,200	$70,000	$70,000
Pipe-10913	Map 6-3E	76 Avenue	Storm Sewer	16	750	900	825	$1,040	$1,000	$17,000	$16,000
Pipe-10914	Map 6-3E	76 Avenue	Storm Sewer	40	750	900	825	$1,040	$1,000	$42,000	$40,000
Pipe-10924	Map 6-3D	128 Street	Storm Sewer	166	1200	1350	1350	$1,280	$1,280	$213,000	$213,000
Pipe-10929	Map 6-3D	134 Street	Storm Sewer	6	750	900	825	$1,040	$1,000	$7,000	$6,000
Pipe-10939	Map 6-3C	82 Avenue	Storm Sewer	72	900	1050		$1,130		$82,000	
Pipe-10966	Map 6-3A	92 Avenue	Storm Sewer	83	525	675	675	$900	$900	$75,000	$75,000
Pipe-10973	Map 6-3E	128 Street	Storm Sewer	123	600	675	675	$900	$900	$111,000	$111,000
Pipe-10979	Map 6-3A	Applehill Cres.	Storm Sewer	44	1200	1500	1350	$1,350	$1,280	$60,000	$57,000
Pipe-10984	Map 6-3D	130 Street	Storm Sewer	70	600	750		$950		$67,000	
Pipe-10990	Map 6-3A	92 Avenue	Storm Sewer	17	900	1200	1200	$1,200	$1,200	$21,000	$21,000
Pipe-11013	Map 6-3A	92 Avenue	Storm Sewer	30	900	1200	1200	$1,200	$1,200	$36,000	$36,000
Pipe-11018	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	525	675	675	$900	$900	$75,000	$75,000
Pipe-11019	Map 6-3D	132 Street	Storm Sewer	22	1050	1200		$1,200		$27,000	
Pipe-11021	Map 6-3D	134 Street	Storm Sewer	100	900	1050		$1,130		$113,000	
Pipe-11033	Map 3-6B	88 Avenue	Storm Sewer	162	1050	1200		$1,200		$195,000	
Pipe-11035	Map 3-6B	88 Avenue	Storm Sewer	95	1050	1350	1350	$1,280	$1,280	$122,000	$122,000
Pipe-11075	Map 6-3E	132 Street	Storm Sewer	56	900	1050		$1,130		$64,000	
Pipe-11077	Map 6-3D	128 Street	Storm Sewer	23	1200	1350	1350	$1,280	$1,280	$30,000	$30,000
Pipe-11084	Map 6-3E	76 Avenue	Storm Sewer	58	750	900	825	$1,040	$1,000	$61,000	$58,000
Pipe-11090	Map 6-3E	128 Street	Storm Sewer	55	750	1050	1050	$1,130	$1,130	$63,000	$63,000
Pipe-11100	Map 6-3D	133A Street	Storm Sewer	143	1050	1200		$1,200		$172,000	
Pipe-11118	Map 6-3A	92 Avenue	Storm Sewer	89	750	1200	1200	$1,200	$1,200	$107,000	$107,000
Pipe-11137	Map 6-3D	82B Avenue	Storm Sewer	93	1050	1200		$1,200		$112,000	
Pipe-11152	Map 6-3D	128 Street	Storm Sewer	13	1050	1200	1200	$1,200	$1,200	$16,000	$16,000
Pipe-11161	Map 6-3E	128 Street	Storm Sewer	118	900	1200	1200	$1,200	$1,200	$142,000	$142,000
Pipe-11168	Map 6-3D	132 Street	Storm Sewer	55	1050	1200		$1,200		$66,000	

Table D-2: Recommended Pipe Upgrades - Details and Cost Estimates
Cruikshank & Grenville ISMP

Associated Engineering
GLOBAL PERSPECTIVE. LOCAL FOCUS.

STORM SEWER AND CULVERT UPGRADES - TO SERVICE FUTURE DEVELOPMENT CONDITIONS

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Upgrades for Future Development Conditions	Recommended Upgrades for Future Development with BMPs	Unit Cost ($/m)		Estimated Cost	Estimated Cost Upgrades for Future Development with BMPs
								Existing Development Conditions	Future Development Conditions	Future Development Conditions	
Pipe-11169	Map 6-3D	134 Street	Storm Sewer	105	900	1050	1050	$1,130	$1,130	$119,000	$119,000
Pipe-11190	Map 6-3E	128 Street	Storm Sewer	91	750	900	900	$1,040	$1,040	$95,000	$95,000
Pipe-11195	Map 6-3E	132 Street	Storm Sewer	145	750	1050	900	$1,130	$1,040	$164,000	$151,000
Pipe-11198	Map 6-3D	128 Street	Storm Sewer	74	900	1200	1200	$1,200	$1,200	$89,000	$89,000
Pipe-11202	Map 6-3D	80 Avenue	Storm Sewer	14	900	1200	1200	$1,200	$1,200	$17,000	$17,000
Pipe-11261	Map 6-3A	Prince Charles Blvd.	Storm Sewer	103	675	900	900	$1,040	$1,040	$108,000	$108,000
Pipe-11284	Map 6-3A	131A Street	Storm Sewer	98	600	675	675	$900	$900	$89,000	$89,000
Pipe-11317	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	600	675	675	$900	$900	$75,000	$75,000
Pipe-11345	Map 6-3C	122A Street	Storm Sewer	5	1350	1800	1800	$1,470	$1,470	$8,000	$8,000
Pipe-11351	Map 6-3A	132 Street	Storm Sewer	100	750	1050	1050	$1,130	$1,130	$113,000	$113,000
Pipe-11357	Map 3-6B	88 Avenue	Storm Sewer	108	900	1350	1350	$1,280	$1,280	$139,000	$139,000
Pipe-11371	Map 6-3A	92 Avenue	Storm Sewer	55	675	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11379	Map 6-3A	92 Avenue	Storm Sewer	94	750	1200	1200	$1,200	$1,200	$113,000	$113,000
Pipe-11404	Map 6-3A	132 Street	Storm Sewer	20	900	1050	1050	$1,130	$1,130	$23,000	$23,000
Pipe-11405	Map 6-3A	Prince Charles Blvd.	Storm Sewer	99	675	825	825	$1,000	$1,000	$99,000	$99,000
Pipe-11414	Map 6-3D	84 Avenue	Storm Sewer	12	675	1050		$1,130		$14,000	
Pipe-11456	Map 6-3A	Huntley Avenue	Storm Sewer	99	750	825	825	$1,000	$1,000	$99,000	$99,000
Pipe-11458	Map 6-3E	134 Street	Storm Sewer	99	600	675		$900		$90,000	
Pipe-11459	Map 3-6B	88A Avenue	Storm Sewer	108	900	1050		$1,130		$123,000	
Pipe-11483	Map 6-3E	76 Avenue	Storm Sewer	15	600	900	900	$1,040	$1,040	$16,000	$16,000
Pipe-11500	Map 6-3D	84 Avenue	Storm Sewer	113	600	675		$900		$102,000	
Pipe-11504	Map 6-3E	King George Blvd.	Storm Sewer	94	750	900	900	$1,040	$1,040	$98,000	$98,000
Pipe-11508	Map 3-6B	88 Avenue	Storm Sewer	104	1200	1500	1350	$1,350	$1,280	$141,000	$134,000
Pipe-11518	Map 3-6B	128 Street	Storm Sewer	46	750	1050	900	$1,130	$1,040	$52,000	$48,000
Pipe-11522	Map 6-3D	132 Street	Storm Sewer	122	1050	1200		$1,200		$147,000	
Pipe-11543	Map 6-3A	Prince Charles Blvd.	Storm Sewer	98	675	900	900	$1,040	$1,040	$102,000	$102,000
Pipe-11558	Map 6-3E	134 Street	Storm Sewer	59	600	675		$900		$54,000	
Pipe-11562	Map 6-3A	90 Avenue	Storm Sewer	88	675	750	750	$950	$950	$84,000	$84,000
Pipe-11569	Map 6-3D	132 Street	Storm Sewer	7	1050	1200		$1,200		$9,000	
Pipe-11601	Map 6-3A	132 Street	Storm Sewer	9	900	1200	1200	$1,200	$1,200	$11,000	$11,000
Pipe-11610	Map 6-3D	134 Street	Storm Sewer	13	900	1050		$1,130		$15,000	
Pipe-11621	Map 6-3A	Prince Charles Blvd.	Storm Sewer	55	900	1200	1200	$1,200	$1,200	$66,000	$66,000
Pipe-11641	Map 6-3A	92 Avenue	Storm Sewer	103	750	1200	1200	$1,200	$1,200	$124,000	$124,000
Pipe-11653	Map 6-3F	88 Avenue	Storm Sewer	104	600	675	675	$900	$900	$94,000	$94,000
Pipe-11660	Map 6-3A	Prince Charles Blvd.	Storm Sewer	91	525	675	675	$900	$900	$82,000	$82,000

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STORM SEWER AND CULVERT UPGRADES - TO SERVICE FUTURE DEVELOPMENT CONDITIONS

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Upgrades for Future Development Conditions	Recommended Upgrades for Future Development with BMPs	Unit Cost ($/m)		Estimated Cost	Estimated Cost Upgrades for Future Development with BMPs
								Existing Development Conditions	Future Development Conditions	Future Development Conditions	
Pipe-11701	Map 6-3D	132 Street	Storm Sewer	104	1050	1200		$1,200		$125,000	
Pipe-11706	Map 6-3E	132 Street	Storm Sewer	99	900	1050		$1,130		$112,000	
Pipe-11708	Map 6-3D	80 Avenue	Storm Sewer	25	600	675	675	$900	$900	$23,000	$23,000
Pipe-11732	Map 6-3D	132 Street	Storm Sewer	25	1050	1200		$1,200		$30,000	
Pipe-11739	Map 6-3A	132 Street	Storm Sewer	36	750	900	900	$1,040	$1,040	$38,000	$38,000
Pipe-11765	Map 6-3A	92 Avenue	Storm Sewer	93	600	825	825	$1,000	$1,000	$93,000	$93,000
Pipe-11773	Map 3-6B	88 Avenue	Storm Sewer	64	1050	1350	1350	$1,280	$1,280	$82,000	$82,000
Pipe-11779	Map 6-3D	80 Avenue	Storm Sewer	74	600	675	675	$900	$900	$67,000	$67,000
Pipe-11806	Map 6-3E	128 Street	Storm Sewer	178	750	1200	1200	$1,200	$1,200	$214,000	$214,000
Pipe-11815	Map 3-6B	88 Avenue	Storm Sewer	15	900	1500	1350	$1,350	$1,280	$21,000	$20,000
Pipe-11836	Map 6-3E	76 Avenue	Storm Sewer	14	750	900	825	$1,040	$1,000	$15,000	$14,000
Pipe-11854	Map 6-3A	Prince Charles Blvd.	Storm Sewer	82	600	675	675	$900	$900	$74,000	$74,000
Pipe-11856	Map 6-3A	Prince Charles Blvd.	Storm Sewer	97	600	675	675	$900	$900	$88,000	$88,000
Pipe-11868	Map 6-3A	Prince Charles Blvd.	Storm Sewer	91	600	675	675	$900	$900	$82,000	$82,000
Pipe-11898	Map 6-3E	132 Street	Storm Sewer	12	750	1050	900	$1,130	$1,040	$14,000	$13,000
Pipe-11901	Map 6-3A	92 Avenue	Storm Sewer	89	750	1200	1200	$1,200	$1,200	$107,000	$107,000
Pipe-11910	Map 6-3E	132 Street	Storm Sewer	59	675	1050	900	$1,130	$1,040	$67,000	$62,000
Pipe-11912	Map 6-3E	128 Street	Storm Sewer	133	750	900	900	$1,040	$1,040	$139,000	$139,000
Pipe-11927	Map 6-3E	76 Avenue	Storm Sewer	118	750	900	825	$1,040	$1,000	$123,000	$118,000
Pipe-11954	Map 6-3E	King George Blvd.	Storm Sewer	145	750	900	900	$1,040	$1,040	$151,000	$151,000
Pipe-11971	Map 6-3E	132 Street	Storm Sewer	19	1050	1200		$1,200		$23,000	
Pipe-11974	Map 6-3A	Prince Charles Blvd.	Storm Sewer	83	525	675	675	$900	$900	$75,000	$75,000
Pipe-11998	Map 6-3A	92 Avenue	Storm Sewer	67	750	1050	1050	$1,130	$1,130	$76,000	$76,000
Pipe-11999	Map 6-3A	92 Avenue	Storm Sewer	24	750	1050	1050	$1,130	$1,130	$28,000	$28,000
Pipe-12004	Map 3-6B	88A Avenue	Storm Sewer	45	900	1200		$1,200		$54,000	
Pipe-12026	Map 6-3E	128 Street	Storm Sewer	92	750	825	825	$1,000	$1,000	$92,000	$92,000
Pipe-12039	Map 6-3D	132 Street	Storm Sewer	82	1050	1200		$1,200		$99,000	
Pipe-12104	Map 6-3E	132 Street	Storm Sewer	116	900	1050		$1,130		$132,000	
Pipe-12129	Map 3-6B	128 Street	Storm Sewer	14	900	1050		$1,130		$16,000	
Pipe-12160	Map 6-3F	88 Avenue	Storm Sewer	81	600	675	675	$900	$900	$73,000	$73,000
Pipe-12161	Map 6-3E	128 Street	Storm Sewer	18	750	900	900	$1,040	$1,040	$19,000	$19,000
Pipe-12176	Map 6-3F	88 Avenue	Storm Sewer	16	600	675	675	$900	$900	$15,000	$15,000
Pipe-12182	Map 6-3D	128 Street	Storm Sewer	12	900	1200	1200	$1,200	$1,200	$15,000	$15,000
Pipe-12184	Map 6-3E	128 Street	Storm Sewer	27	750	900	900	$1,040	$1,040	$29,000	$29,000
Pipe-12185	Map 6-3D	84 Avenue	Storm Sewer	49	1200	1350	1350	$1,280	$1,280	$63,000	$63,000

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Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

STORM SEWER AND CULVERT UPGRADES - TO SERVICE FUTURE DEVELOPMENT CONDITIONS

Conduit Name	Map Number	Street	Conduit Type	Conduit Length (m)	Existing Conduit Diameter or Height (mm)	Upgrades for Future Development Conditions	Recommended Upgrades for Future Development with BMPs	Unit Cost ($/m) Existing Development Conditions	Unit Cost ($/m) Future Development Conditions	Estimated Cost Future Development Conditions	Estimated Cost Upgrades for Future Development with BMPs
Pipe-12193	Map 6-3E	128 Street	Storm Sewer	116	900	1200	1200	$1,200	$1,200	$140,000	$140,000
Pipe-12212	Map 6-3E	128 Street	Storm Sewer	91	900	1050	1050	$1,130	$1,130	$103,000	$103,000
Pipe-12266	Map 6-3D	134 Street	Storm Sewer	130	750	900	825	$1,040	$1,000	$136,000	$130,000
Pipe-12281	Map 6-3E	King George Blvd.	Storm Sewer	10	750	900	900	$1,040	$1,040	$11,000	$11,000
Pipe-12287	Map 6-3D	80 Avenue	Storm Sewer	13	600	675	675	$900	$900	$12,000	$12,000
Pipe-12291	Map 6-3E	76 Avenue	Storm Sewer	105	750	900	825	$1,040	$1,000	$110,000	$105,000
Pipe-12315	Map 3-6B	88 Avenue	Storm Sewer	76	1050	1350	1350	$1,280	$1,280	$98,000	$98,000
Pipe-12337	Map 6-3E	132 Street	Storm Sewer	72	900	1050		$1,130		$82,000	
Pipe-12338	Map 6-3E	132 Street	Storm Sewer	30	900	1050		$1,130		$34,000	
Pipe-12341	Map 6-3A	92 Avenue	Storm Sewer	63	675	1200	1200	$1,200	$1,200	$76,000	$76,000
Pipe-12370	Map 3-6B	88A Avenue	Storm Sewer	50	900	1200		$1,200		$60,000	
Pipe-12379	Map 6-3D	134 Street	Storm Sewer	93	750	900	825	$1,040	$1,000	$97,000	$93,000
Pipe-12380	Map 6-3D	132 Street	Storm Sewer	32	1050	1200		$1,200		$39,000	
Pipe-12387	Map 6-3D	80 Avenue	Storm Sewer	57	600	675	675	$900	$900	$52,000	$52,000
Pipe-12388	Map 6-3D	128 Street	Storm Sewer	19	1050	1200	1200	$1,200	$1,200	$23,000	$23,000
Pipe-12400	Map 6-3A	92 Avenue	Storm Sewer	91	900	1200	1200	$1,200	$1,200	$110,000	$110,000
Pipe-12448	Map 6-3A	92 Avenue	Storm Sewer	110	675	1050	1050	$1,130	$1,130	$125,000	$125,000
Pipe-12450	Map 6-3C	82 Avenue	Storm Sewer	5	750	825	825	$1,000	$1,000	$5,000	$5,000
Pipe-12453	Map 6-3A	92 Avenue	Storm Sewer	91	750	1200	1200	$1,200	$1,200	$110,000	$110,000
Pipe-12465	Map 6-3D	132 Street	Storm Sewer	71	1050	1200		$1,200		$86,000	
Pipe-12467	Map 3-6B	88 Avenue	Storm Sewer	40	900	1500	1350	$1,350	$1,280	$54,000	$52,000
Pipe-12468	Map 6-3D	132 Street	Storm Sewer	86	1050	1200		$1,200		$104,000	
Pipe-12469	Map 6-3D	132 Street	Storm Sewer	1	1050	1200		$1,200		$2,000	
Pipe-12484	Map 6-3D	128 Street	Storm Sewer	6	1200	1350	1350	$1,280	$1,280	$8,000	$8,000
Pipe-12505	Map 6-3A	Applehill Cres.	Storm Sewer	143	750	1200	1200	$1,200	$1,200	$172,000	$172,000
Pipe-12507	Map 6-3A	92 Avenue	Storm Sewer	5	750	900	900	$1,040	$1,040	$6,000	$6,000
Pipe-12508	Map 6-3A	92 Avenue	Storm Sewer	9	750	1050	1050	$1,130	$1,130	$11,000	$11,000
Pipe-12521	Map 3-6B	88 Avenue	Storm Sewer	70	1050	1200		$1,200		$84,000	
Pipe-12527	Map 6-3D	134 Street	Storm Sewer	165	750	1050	825	$1,130	$1,000	$187,000	$165,000
Pipe-12531	Map 3-6B	88 Avenue	Storm Sewer	97	900	1350	1350	$1,280	$1,280	$125,000	$125,000
Pipe-12562	Map 6-3A	92 Avenue	Storm Sewer	79	525	675	675	$900	$900	$72,000	$72,000
									Total:	$14,669,000	$10,666,000

P:\20112781\00_ISMP\Engineering\03.02_Conceptual_Feasibility_Report\ISMP Final\Appendix D - Cost Estimates\[Pipe_Upgrades_20140327_mm.xlsx]Upgrades by Pipes with BMPs

Appendix E – PCSWMM Model Data

City of Surrey
Table E-1: Subcatchment Hydrological Parameters - Existing Conditions
Cruikshank & Grenville ISMP

Subcatchment ID	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Slope (%)	Impervious (%)	N Impervious	N Pervious	D Store Impervious (mm)	D Store Pervious (mm)	Zero Impervious (%)	Sub-Area Routing	% Routed	Curb Length	Max Infiltration Rate (mm/h)	Min Infiltration Rate (mm/h)	Decay Constant	Drying Time (d)	Max Volume (mm)
Delta_1	507723	5445467	N-1738	48.1	176.8	2720.0	37.4	0.025	0.175	2.44	4.89	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Delta_2	507723	5444724	N-1566	36.6	140.7	2600.0	37.3	0.025	0.175	2.44	4.89	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Quibble	511703	5447456	N-3004	656.6	2499.6	2626.7	55.5	0.025	0.175	2.15	5.35	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_1	509674	5447119	N-852	5.6	167.6	334.6	81.0	0.025	0.175	1.61	3.21	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_10	510258	5446465	N-483	7.5	182.2	409.3	52.3	0.025	0.175	1.90	3.79	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_100	509241	5444303	N-1278	0.6	86.9	67.2	31.4	0.025	0.175	2.94	11.48	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_101	509096	5444544	N-172	19.6	321.8	607.5	91.2	0.025	0.175	1.36	2.74	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_102	511110	5444223	N-841	5.4	94.0	577.4	61.3	0.025	0.175	1.90	4.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_103	509963	5443782	N-1789	17.7	209.3	844.6	92.3	0.025	0.175	1.14	2.29	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_104	511725	5444783	N-3002	67.3	737.8	912.2	31.8	0.025	0.175	2.91	11.33	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_105	509212	5444121	N-178	3.2	110.1	291.5	88.0	0.025	0.175	1.63	3.46	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_106	511917	5444270	N-3002	0.1	13.2	87.1	25.0	0.025	0.175	3.13	12.50	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_107	509074	5444105	N-1434	4.4	152.4	288.4	91.6	0.025	0.175	1.23	2.50	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_108	511468	5443756	N-3003	31.4	297.7	1053.4	63.0	0.025	0.175	1.98	4.60	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_109	511052	5444061	N-2237	7.7	118.9	649.7	61.7	0.025	0.175	1.73	3.45	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_11	509147	5446466	N-1064	7.2	114.1	632.6	54.6	0.025	0.175	1.81	3.64	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_110	509721	5444072	N-1476	0.4	45.6	92.9	89.4	0.025	0.175	2.39	4.79	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_111	509699	5444033	N-1060	1.7	101.1	163.7	90.6	0.025	0.175	1.35	2.69	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_112	510691	5444056	N-302	7.7	149.3	514.3	56.5	0.025	0.175	1.76	3.51	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_113	510468	5444009	N-1222	0.9	24.4	374.6	60.3	0.025	0.175	1.69	3.38	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_114	511298	5444061	N-871	0.7	40.1	176.0	79.4	0.025	0.175	1.56	4.34	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_115	511018	5443882	N-1514	5.3	62.2	852.3	57.9	0.025	0.175	1.80	3.59	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_116	509658	5443984	N-704	0.6	33.5	170.8	88.9	0.025	0.175	1.23	2.44	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_117	508912	5443960	N-1183	5.1	90.6	564.9	69.8	0.025	0.175	1.60	3.21	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_118	508718	5443809	N-1155	7.7	133.4	574.2	59.6	0.025	0.175	1.71	3.38	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_119	511045	5443530	N-1427	22.5	217.2	1037.7	75.9	0.025	0.175	1.48	3.13	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_12	509330	5446434	N-264	1.7	74.4	232.2	53.6	0.025	0.175	1.85	3.70	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_120	509331	5443841	N-645	9.6	242.4	396.2	60.7	0.025	0.175	1.83	3.66	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_121	510343	5443801	N-734	7.9	170.7	461.5	87.0	0.025	0.175	1.10	2.31	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_122	510624	5443762	N-263	10.2	175.2	581.8	57.1	0.025	0.175	1.76	3.54	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_123	510790	5443923	N-1180	0.4	30.3	127.0	57.9	0.025	0.175	1.73	3.45	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_124	509603	5443756	N-661	11.8	328.6	360.6	83.6	0.025	0.175	1.35	3.19	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_125	510074	5443818	N-901	7.5	198.1	376.3	92.1	0.025	0.175	1.09	2.19	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_126	510819	5443827	N-705	1.5	50.7	300.7	55.9	0.025	0.175	1.79	3.58	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_127	509078	5443515	N-911	32.2	577.4	558.4	45.8	0.025	0.175	2.18	5.53	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_128	511334	5443640	N-1845	2.2	50.0	445.0	74.8	0.025	0.175	1.80	3.60	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_129	510322	5443477	N-842	10.6	290.7	363.2	91.9	0.025	0.175	1.14	2.28	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_13	509374	5446748	N-560	27.1	401.1	676.7	53.4	0.025	0.175	1.86	3.74	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_130	510663	5443386	N-249	19.4	306.6	632.8	88.3	0.025	0.175	1.15	2.31	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_131	511266	5443354	N-968	0.9	17.7	481.8	74.1	0.025	0.175	1.66	3.33	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_132	509790	5443314	N-1694	18.0	366.8	490.6	87.2	0.025	0.175	1.31	2.63	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_133	509469	5443356	N-827	13.4	257.2	519.4	63.5	0.025	0.175	1.71	4.23	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_134	511214	5443478	N-311	0.8	60.1	134.6	91.4	0.025	0.175	0.96	1.93	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_135	511193	5443278	N-801	3.8	130.0	291.7	91.7	0.025	0.175	1.10	2.19	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_136	510453	5443251	N-1408	0.1	9.4	112.9	84.8	0.025	0.175	1.40	2.80	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_137	509431	5442970	N-641	13.9	287.3	482.7	35.3	0.025	0.175	2.70	9.94	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_138	510158	5443280	N-1541	5.5	215.6	252.9	91.8	0.025	0.175	1.33	2.64	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_139	510950	5442925	N-862	27.2	403.5	673.7	91.5	0.025	0.175	1.29	2.66	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_14	509722	5446360	N-893	0.8	23.3	340.2	35.0	0.025	0.175	2.50	5.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_140	510292	5443043	N-500	13.9	412.1	337.3	92.3	0.025	0.175	1.16	2.34	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_141	509851	5443027	N-821	1.7	95.4	176.6	55.4	0.025	0.175	1.79	3.58	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_142	510610	5443047	N-551	3.4	116.0	291.1	90.9	0.025	0.175	1.19	2.39	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_143	509942	5443012	N-385	7.6	267.8	285.2	72.2	0.025	0.175	1.51	3.01	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_144	511271	5442840	N-975	1.0	51.0	196.0	83.9	0.025	0.175	1.38	2.74	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_145	510931	5442696	N-694	4.8	126.9	377.3	90.3	0.025	0.175	1.40	2.80	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_15	510107	5446243	N-1254	0.1	8.7	71.8	57.8	0.025	0.175	1.70	3.40	25	PERVIOUS	100	0	1.6	0.9	4	7	0

City of Surrey
Table E-1: Subcatchment Hydrological Parameters - Existing Conditions
Cruikshank & Grenville ISMP

Subcatchment ID	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Slope (%)	Impervious (%)	N Impervious	N Pervious	D Store Impervious (mm)	D Store Pervious (mm)	Zero Impervious (%)	Sub-Area Routing	% Routed	Curb Length	Max Infiltration Rate (mm/h)	Min Infiltration Rate (mm/h)	Decay Constant	Drying Time (d)	Max Volume (mm)
Sub-Catchment_16	510227	5446159	N-2375	0.0	5.0	45.9	41.7	0.025	0.175	2.24	4.49	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_17	509916	5446217	N-391	19.8	284.8	696.1	49.6	0.025	0.175	2.00	3.99	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_18	509530	5446292	N-989	3.9	90.5	425.9	53.6	0.025	0.175	1.88	3.75	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_19	508420	5446068	N-524	13.1	177.4	737.8	53.4	0.025	0.175	1.98	4.30	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_2	510224	5447005	N-477	8.4	154.4	547.1	56.6	0.025	0.175	1.86	3.71	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_20	508842	5446062	N-1010	3.4	127.3	267.4	58.6	0.025	0.175	1.78	3.54	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_21	510339	5446200	N-1828	4.9	111.9	437.9	50.7	0.025	0.175	2.03	4.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_22	510128	5446066	N-1834	5.8	137.1	422.0	39.7	0.025	0.175	2.35	4.69	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_23	509112	5445981	N-894	1.2	73.3	158.9	55.1	0.025	0.175	1.79	3.56	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_24	510377	5445911	N-12	0.5	47.9	106.5	49.6	0.025	0.175	1.94	3.88	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_25	510095	5445803	N-2356	0.1	10.4	50.0	35.0	0.025	0.175	2.50	5.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_26	509913	5445874	N-213	11.9	150.8	790.8	47.0	0.025	0.175	2.11	4.23	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_27	510385	5445838	N-9	0.7	59.6	121.6	42.8	0.025	0.175	2.20	4.40	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_28	511094	5445709	N-446	0.0	7.6	45.5	35.0	0.025	0.175	2.50	5.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_29	510306	5445929	N-1836	3.8	71.0	538.7	49.2	0.025	0.175	2.01	4.04	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_3	509909	5446996	N-242	5.6	148.1	378.3	72.3	0.025	0.175	1.65	3.30	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_30	508693	5445790	N-604	27.0	301.2	896.1	90.9	0.025	0.175	1.49	2.99	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_31	509221	5446095	N-269	37.9	335.6	1128.1	52.9	0.025	0.175	1.90	3.91	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_32	508120	5445792	N-111	2.2	55.9	397.1	89.2	0.025	0.175	1.56	3.11	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_33	510154	5445707	N-1502	4.7	116.8	400.1	48.3	0.025	0.175	2.04	4.09	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_34	508055	5445799	N-1460	2.0	71.0	275.0	84.6	0.025	0.175	1.83	3.51	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_35	510349	5445777	N-141	4.0	68.0	581.2	55.5	0.025	0.175	1.84	3.69	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_36	510508	5446261	N-1339	16.7	150.5	1110.2	53.2	0.025	0.175	1.88	3.75	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_37	511129	5445654	N-51	1.3	71.5	175.3	37.3	0.025	0.175	2.54	8.50	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_38	509273	5445574	N-1066	0.1	8.3	160.7	66.0	0.025	0.175	1.64	3.28	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_39	510685	5445742	N-297	12.6	179.5	703.1	57.2	0.025	0.175	1.70	3.41	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_4	510334	5446824	N-798	16.7	235.6	709.2	51.7	0.025	0.175	1.95	3.90	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_40	510892	5445877	N-764	19.1	136.0	1403.6	52.8	0.025	0.175	1.90	4.19	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_41	510183	5445405	N-497	10.7	299.2	356.9	88.5	0.025	0.175	1.34	2.66	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_42	509236	5445502	N-1153	10.1	152.5	663.9	72.3	0.025	0.175	1.90	5.45	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_43	509960	5445526	N-953	1.3	17.6	747.3	74.1	0.025	0.175	1.55	3.10	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_44	509925	5445634	N-457	11.3	112.4	1003.0	57.8	0.025	0.175	1.80	3.56	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_45	508282	5445649	N-1843	11.7	261.3	449.5	90.0	0.025	0.175	1.29	2.56	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_46	509261	5445745	N-292	14.5	188.2	769.2	60.9	0.025	0.175	2.00	4.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_47	508243	5445547	N-102	0.3	32.6	85.1	90.0	0.025	0.175	1.56	3.13	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_48	508122	5445542	N-224	2.1	100.7	203.9	92.6	0.025	0.175	1.50	3.00	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_49	511181	5445488	N-1220	2.4	45.2	539.0	70.4	0.025	0.175	1.70	3.75	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_5	509811	5446692	N-1006	25.8	309.2	833.7	57.0	0.025	0.175	1.86	3.74	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_50	508479	5445425	N-80	4.3	272.2	158.9	90.5	0.025	0.175	1.48	2.96	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_51	508316	5445414	N-125	0.6	51.3	123.0	94.0	0.025	0.175	1.44	2.86	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_52	511383	5445459	N-114	4.5	142.3	317.0	25.0	0.025	0.175	3.13	12.50	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_53	510853	5445384	N-65	19.8	162.9	1215.7	55.3	0.025	0.175	1.81	3.63	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_54	511180	5445306	N-64	0.6	35.4	158.9	53.3	0.025	0.175	2.33	4.66	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_55	509529	5445356	N-570	3.2	93.6	336.6	83.0	0.025	0.175	1.68	3.96	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_57	511150	5444951	N-62	17.3	285.5	606.0	58.5	0.025	0.175	2.14	5.30	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_58	509095	5445328	N-2200	12.5	209.5	597.1	90.2	0.025	0.175	1.53	3.06	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_59	510524	5445330	N-46	4.1	171.4	237.2	42.0	0.025	0.175	2.26	5.30	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_6	508457	5446366	N-1258	8.7	208.7	415.7	65.2	0.025	0.175	1.78	3.65	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_60	508251	5445292	N-555	12.9	323.2	399.4	91.0	0.025	0.175	1.29	2.74	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_61	508337	5445163	N-554	0.2	22.8	76.1	91.2	0.025	0.175	1.38	2.75	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_62	510863	5445116	N-218	3.5	177.2	196.5	39.7	0.025	0.175	2.59	6.90	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_63	511046	5445112	N-60	0.5	49.1	95.1	52.5	0.025	0.175	2.36	4.73	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_64	510011	5445231	N-168	28.9	299.2	967.1	82.2	0.025	0.175	1.43	2.98	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_65	508577	5445066	N-2584	0.6	28.2	220.8	66.5	0.025	0.175	1.66	3.31	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_66	508573	5445043	N-1081	0.1	10.7	58.6	51.4	0.025	0.175	2.04	4.09	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_67	509963	5444947	N-68	13.9	263.1	529.1	91.4	0.025	0.175	1.15	2.20	25	OUTLET	100	0	1.6	0.9	4	7	0

City of Surrey
Table E-1: Subcatchment Hydrological Parameters - Existing Conditions
Cruikshank & Grenville ISMP

Subcatchment ID	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Slope (%)	Impervious (%)	N Impervious	N Pervious	D Store Imprevious (mm)	D Store Pervious (mm)	Zero Impervious (%)	Sub-Area Routing	% Routed	Curb Length	Max Infiltration Rate (mm/h)	Min Infiltration Rate (mm/h)	Decay Constant	Drying Time (d)	Max Volume (mm)
Sub-Catchment_68	508296	5444991	N-386	19.6	468.5	418.4	62.5	0.025	0.175	1.69	3.38	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_69	509526	5445087	N-813	7.8	193.1	403.6	89.5	0.025	0.175	1.53	3.04	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_7	508606	5446586	N-531	9.1	176.4	515.1	58.3	0.025	0.175	1.83	3.84	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_70	510664	5445086	N-134	3.8	190.5	201.8	34.3	0.025	0.175	2.85	10.43	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_71	510674	5444893	N-57	3.1	131.5	238.7	33.9	0.025	0.175	2.63	7.51	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_72	509718	5445009	N-1404	2.2	91.6	240.8	91.2	0.025	0.175	1.13	2.24	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_73	510520	5444979	N-83	6.3	262.9	239.6	46.3	0.025	0.175	2.60	9.08	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_74	508716	5445303	N-38	15.5	443.5	349.9	89.8	0.025	0.175	1.28	2.55	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_75	510263	5444392	N-157	33.7	318.3	1058.5	87.4	0.025	0.175	1.30	3.05	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_76	508696	5444683	N-40	22.4	343.6	652.4	77.1	0.025	0.175	1.46	3.59	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_77	508915	5444996	N-143	2.4	78.8	310.7	90.2	0.025	0.175	1.54	3.08	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_78	511494	5445203	N-16	24.8	406.3	610.0	25.5	0.025	0.175	3.10	12.41	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_79	509495	5444755	N-1520	6.5	167.3	387.2	90.4	0.025	0.175	1.45	2.91	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_8	508897	5446599	N-511	13.3	253.8	524.5	52.8	0.025	0.175	1.88	3.75	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_80	509691	5444841	N-94	1.9	87.9	215.3	93.7	0.025	0.175	1.19	2.39	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_81	508041	5444860	N-597	0.8	58.3	135.2	89.5	0.025	0.175	1.21	2.44	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_82	508250	5444607	N-1093	19.2	399.2	482.0	62.8	0.025	0.175	1.84	5.43	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_83	509196	5444994	N-129	23.5	287.2	819.3	90.1	0.025	0.175	1.54	3.09	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_84	509768	5444595	N-833	10.3	218.8	470.5	92.5	0.025	0.175	1.15	2.30	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_85	510583	5444636	N-921	4.0	84.8	475.7	35.0	0.025	0.175	2.71	9.88	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_86	510970	5444618	N-1758	28.1	304.8	923.0	67.1	0.025	0.175	1.69	3.34	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_87	510498	5444707	N-1517	0.8	54.1	148.2	30.6	0.025	0.175	2.94	11.49	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_88	510069	5444707	N-158	3.7	145.9	255.1	91.1	0.025	0.175	1.13	2.25	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_89	510464	5444585	N-312	0.6	27.0	212.8	43.8	0.025	0.175	2.48	8.90	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_9	510411	5446518	N-1684	0.8	36.0	210.8	55.6	0.025	0.175	1.83	3.66	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_90	509536	5444481	N-339	7.8	299.3	260.9	91.8	0.025	0.175	1.13	2.25	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_91	509861	5444318	N-159	14.9	224.5	664.8	93.3	0.025	0.175	1.29	2.56	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_92	511454	5444625	N-2456	0.0	5.8	44.2	58.4	0.025	0.175	2.58	6.26	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_93	510660	5444327	N-319	16.6	200.1	827.9	51.7	0.025	0.175	1.93	3.85	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_94	510450	5444314	N-330	0.3	12.2	274.9	56.9	0.025	0.175	1.85	3.70	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_95	508109	5444243	N-329	6.5	293.0	220.9	88.6	0.025	0.175	1.24	2.46	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_96	508499	5444194	N-326	16.0	381.0	420.1	56.1	0.025	0.175	1.93	4.63	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_97	508753	5444339	N-1015	0.5	37.4	143.6	53.5	0.025	0.175	1.85	3.71	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_98	509170	5444191	N-1166	24.1	228.0	1056.8	84.7	0.025	0.175	1.29	2.86	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_99	509282	5444605	N-24	0.9	56.5	165.6	90.0	0.025	0.175	1.56	3.13	25	OUTLET	100	0	1.6	0.9	4	7	0

P:\20112781\00_ISMP\Engineering\03.02_Conceptual_Feasibility_Report\ISMP Final\[dnt_final_model_data_20140403_mm.xlsx]Table E-1

City of Surrey
Table E-2: Subcatchment Hydrological Parameters - Future Conditions (no source controls)
Cruikshank & Grenville ISMP

Subcatchment ID	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Slope (%)	Impervious (%)	N Impervious	N Pervious	D Store Imprevious (mm)	D Store Pervious (mm)	Zero Impervious (%)	Sub-Area Routing	% Routed	Curb Length	Max Infiltration Rate (mm/h)	Min Infiltration Rate (mm/h)	Decay Constant	Drying Time (d)	Max Volume (mm)
Delta_1	507723	5445467	N-1738	48.1	176.8	3.5	37.4	0.025	0.175	2.44	4.89	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Delta_2	507723	5444724	N-1566	36.6	140.7	3.5	37.3	0.025	0.175	2.45	4.89	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Quibble	511703	5447456	N-3004	656.6	2499.6	5.9	55.5	0.025	0.175	2.48	5.44	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_1	509674	5447119	N-852	5.6	167.6	4.3	73.0	0.025	0.175	1.44	2.88	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_10	510258	5446465	N-483	7.5	182.2	4.6	65.0	0.025	0.175	1.90	3.80	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_100	509241	5444303	N-1278	0.6	86.9	9.6	74.5	0.025	0.175	1.55	3.09	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_101	509096	5444544	Ind-Stor-1	19.6	321.8	4.4	75.0	0.025	0.175	1.36	2.74	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_102	511110	5444223	N-841	5.4	94.0	5.4	64.9	0.025	0.175	1.89	3.83	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_103	509963	5443782	Ind-Stor-23	17.7	209.3	4.9	74.6	0.025	0.175	1.14	2.26	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_104	511725	5444783	N-3002	67.3	737.8	7.6	32.0	0.025	0.175	2.91	11.33	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_105	509212	5444121	Ind-Stor-2	3.2	110.1	3.0	75.0	0.025	0.175	1.54	3.08	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_106	511917	5444270	N-3002	0.1	13.2	3.0	25.0	0.025	0.175	3.13	12.50	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_107	509074	5444105	Ind-Stor-3	4.4	152.4	4.6	75.0	0.025	0.175	1.20	2.40	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_108	511468	5443756	N-3003	31.4	297.7	9.7	63.9	0.025	0.175	1.98	4.31	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_109	511052	5444061	N-2237	7.7	118.9	4.9	65.0	0.025	0.175	1.74	3.48	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_11	509147	5446466	N-1064	7.2	114.1	2.7	65.0	0.025	0.175	1.81	3.64	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_110	509721	5444072	N-1476	0.4	45.6	7.7	74.4	0.025	0.175	1.55	3.09	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_111	509699	5444033	N-1060	1.7	101.1	6.2	74.3	0.025	0.175	1.34	2.69	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_112	510691	5444056	N-302	7.7	149.3	3.9	65.0	0.025	0.175	1.78	3.54	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_113	510468	5444009	N-1222	0.9	24.4	3.3	65.0	0.025	0.175	1.70	3.41	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_114	511298	5444061	N-871	0.7	40.1	7.1	66.8	0.025	0.175	1.56	4.34	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_115	511018	5443882	N-1514	5.3	62.2	4.2	65.0	0.025	0.175	1.84	3.68	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_116	509658	5443984	N-704	0.6	33.5	2.6	72.3	0.025	0.175	1.23	2.44	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_117	508912	5443960	N-1183	5.1	90.6	3.9	68.4	0.025	0.175	1.60	3.21	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_118	508718	5443809	N-1155	7.7	133.4	2.8	65.0	0.025	0.175	1.89	3.76	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_119	511045	5443530	N-1427	22.5	217.2	4.1	70.1	0.025	0.175	1.40	2.80	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_12	509330	5446434	N-264	1.7	74.4	3.1	65.0	0.025	0.175	1.85	3.70	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_120	509331	5443841	N-645	9.6	242.4	3.7	67.4	0.025	0.175	1.71	3.44	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_121	510343	5443801	Ind-Stor-21	7.9	170.7	4.3	72.9	0.025	0.175	1.09	2.18	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_122	510624	5443762	N-263	10.2	175.2	3.9	65.4	0.025	0.175	1.76	3.54	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_123	510790	5443923	N-1180	0.4	30.3	2.6	65.0	0.025	0.175	1.73	3.45	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_124	509603	5443756	N-661	11.8	328.6	3.1	73.1	0.025	0.175	1.11	2.23	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_125	510074	5443818	Ind-Stor-22	7.5	198.1	4.6	74.3	0.025	0.175	1.09	2.19	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_126	510819	5443827	N-705	1.5	50.7	3.7	65.0	0.025	0.175	1.79	3.58	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_127	509078	5443515	N-911	32.2	577.4	3.9	65.0	0.025	0.175	2.06	4.11	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_128	511334	5443640	N-1845	2.2	50.0	4.8	65.0	0.025	0.175	1.80	3.60	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_129	510322	5443477	Ind-Stor-20	10.6	290.7	3.7	74.3	0.025	0.175	1.14	2.28	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_13	509374	5446748	N-560	27.1	401.1	3.6	65.4	0.025	0.175	1.90	3.80	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_130	510663	5443386	Ind-Stor-19	19.4	306.6	3.6	73.5	0.025	0.175	1.15	2.31	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_131	511266	5443354	N-968	0.9	17.7	3.3	65.1	0.025	0.175	1.66	3.33	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_132	509790	5443314	N-1694	18.0	366.8	2.7	73.0	0.025	0.175	1.15	2.30	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_133	509469	5443356	N-827	13.4	257.2	4.1	69.1	0.025	0.175	1.49	2.98	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_134	511214	5443478	N-311	0.8	60.1	4.7	73.0	0.025	0.175	0.96	1.93	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_135	511193	5443278	N-801	3.8	130.0	4.1	73.6	0.025	0.175	1.04	2.08	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_136	510453	5443251	N-1408	0.1	9.4	2.3	69.8	0.025	0.175	1.40	2.80	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_137	509431	5442970	N-641	13.9	287.3	3.3	65.0	0.025	0.175	2.25	4.51	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_138	510158	5443280	Ind-Stor-4	5.5	215.6	4.2	75.0	0.025	0.175	1.28	2.55	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_139	510950	5442925	N-862	27.2	403.5	3.5	74.2	0.025	0.175	1.10	2.20	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_14	509722	5446360	N-893	0.8	23.3	3.0	65.0	0.025	0.175	2.50	5.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_140	510292	5443043	N-500	13.9	412.1	3.1	74.4	0.025	0.175	1.09	2.19	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_141	509851	5443027	N-821	1.7	95.4	2.4	65.0	0.025	0.175	1.79	3.58	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_142	510610	5443047	N-551	3.4	116.0	3.0	73.7	0.025	0.175	1.19	2.39	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_143	509942	5443012	N-385	7.6	267.8	3.1	68.8	0.025	0.175	1.54	3.08	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_144	511271	5442840	N-975	1.0	51.0	2.9	68.6	0.025	0.175	1.38	2.74	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_145	510931	5442696	N-694	4.8	126.9	3.7	74.4	0.025	0.175	1.40	2.80	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_15	510107	5446243	N-1254	0.1	8.7	4.5	65.0	0.025	0.175	1.70	3.40	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_16	510227	5446159	N-2375	0.0	5.0	6.4	65.0	0.025	0.175	2.24	4.49	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_17	509916	5446217	N-391	19.8	284.8	4.5	65.0	0.025	0.175	2.00	3.99	25	PERVIOUS	100	0	1.6	0.9	4	7	0

Sub-Catchment_18	509530	5446292	N-989	3.9	90.5	3.9	65.0	0.025	0.175	1.88	3.75	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_19	508420	5446068	N-524	13.1	177.4	5.3	67.1	0.025	0.175	1.89	3.78	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_2	510224	5447005	N-477	8.4	154.4	5.4	65.7	0.025	0.175	1.88	3.74	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_20	508842	5446062	N-1010	3.4	127.3	3.3	65.7	0.025	0.175	1.73	3.45	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_21	510339	5446200	N-1828	4.9	111.9	4.9	65.0	0.025	0.175	2.10	4.19	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_22	510128	5446066	N-1834	5.8	137.1	4.9	65.0	0.025	0.175	2.38	4.74	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_23	509112	5445981	N-894	1.2	73.3	2.5	65.0	0.025	0.175	1.79	3.56	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_24	510377	5445911	N-12	0.5	47.9	7.8	65.0	0.025	0.175	1.94	3.88	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_25	510095	5445803	N-2356	0.1	10.4	9.6	65.0	0.025	0.175	2.50	5.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_26	509913	5445874	N-213	11.9	150.8	5.0	65.0	0.025	0.175	2.11	4.23	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_27	510385	5445838	N-9	0.7	59.6	8.6	65.0	0.025	0.175	2.20	4.40	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_28	511094	5445709	N-446	0.0	7.6	15.6	65.0	0.025	0.175	2.50	5.00	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_29	510306	5445929	N-1836	3.8	71.0	4.4	65.0	0.025	0.175	2.01	4.04	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_3	509909	5446996	N-242	5.6	148.1	4.1	74.5	0.025	0.175	1.58	3.16	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_30	508693	5445790	N-604	27.0	301.2	4.8	74.5	0.025	0.175	1.31	2.63	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_31	509221	5446095	N-269	37.9	335.6	3.3	65.0	0.025	0.175	1.89	3.78	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_32	508120	5445792	N-111	2.2	55.9	6.0	73.8	0.025	0.175	1.44	2.86	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_33	510154	5445707	N-1502	4.7	116.8	6.5	65.0	0.025	0.175	2.04	4.09	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_34	508055	5445799	N-1460	2.0	71.0	7.3	74.2	0.025	0.175	1.44	2.86	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_35	510349	5445777	N-141	4.0	68.0	5.6	65.0	0.025	0.175	1.85	3.70	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_36	510508	5446261	N-1339	16.7	150.5	3.6	65.0	0.025	0.175	1.90	3.81	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_37	511129	5445654	N-51	1.3	71.5	10.8	65.0	0.025	0.175	2.20	4.40	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_38	509273	5445574	N-1066	0.1	8.3	5.2	65.0	0.025	0.175	1.64	3.28	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_39	510685	5445742	N-297	12.6	179.5	5.2	65.0	0.025	0.175	1.70	3.41	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_4	510334	5446824	N-798	16.7	235.6	3.9	65.1	0.025	0.175	1.95	3.90	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_40	510892	5445877	N-764	19.1	136.0	5.3	65.0	0.025	0.175	1.90	3.81	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_41	510183	5445405	Ind-Stor-29	10.7	299.2	5.8	74.1	0.025	0.175	1.34	2.66	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_42	509236	5445502	Ind-Stor-31	10.1	152.5	4.7	74.1	0.025	0.175	1.49	2.98	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_43	509960	5445526	N-953	1.3	17.6	3.6	68.8	0.025	0.175	1.55	3.10	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_44	509925	5445634	N-457	11.3	112.4	3.9	65.0	0.025	0.175	1.84	3.68	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_45	508282	5445649	Ind-Stor-32	11.7	261.3	5.3	73.3	0.025	0.175	1.24	2.46	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_46	509261	5445745	N-292	14.5	188.2	4.3	67.2	0.025	0.175	1.84	3.68	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_47	508243	5445547	Ind-Stor-5	0.3	32.6	13.4	75.0	0.025	0.175	1.56	3.13	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_48	508122	5445542	Ind-Stor-6	2.1	100.7	8.3	75.0	0.025	0.175	1.15	2.31	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_49	511181	5445488	N-1220	2.4	45.2	5.2	62.7	0.025	0.175	1.80	3.96	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_5	509811	5446692	N-1006	25.8	309.2	4.2	68.7	0.025	0.175	1.86	3.73	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_50	508479	5445425	Ind-Stor-7	4.3	272.2	4.2	75.0	0.025	0.175	1.48	2.96	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_51	508316	5445414	Ind-Stor-8	0.6	51.3	5.7	75.0	0.025	0.175	0.95	1.89	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_52	511383	5445459	N-114	4.5	142.3	8.9	25.0	0.025	0.175	3.13	12.50	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_53	510853	5445384	N-65	19.8	162.9	4.8	65.0	0.025	0.175	1.81	3.63	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_54	511180	5445306	N-64	0.6	35.4	12.3	65.0	0.025	0.175	2.33	4.66	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_55	509529	5445356	Ind-Stor-30	3.2	93.6	4.0	74.3	0.025	0.175	1.53	3.05	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_57	511150	5444951	N-62	17.3	285.5	6.0	65.5	0.025	0.175	2.06	4.26	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_58	509095	5445328	Ind-Stor-9	12.5	209.5	4.0	75.0	0.025	0.175	1.53	3.06	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_59	510524	5445330	N-46	4.1	171.4	13.4	65.0	0.025	0.175	2.19	4.38	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_6	508457	5446366	N-1258	8.7	208.7	5.9	65.6	0.025	0.175	1.78	3.55	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_60	508251	5445292	Ind-Stor-15	12.9	323.2	3.8	74.5	0.025	0.175	1.05	2.11	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_61	508337	5445163	N-554	0.2	22.8	3.3	75.0	0.025	0.175	1.38	2.75	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_62	510863	5445116	N-218	3.5	177.2	14.9	65.0	0.025	0.175	2.41	4.84	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_63	511046	5445112	N-60	0.5	49.1	22.0	65.0	0.025	0.175	2.36	4.73	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_64	510011	5445231	Ind-Stor-28	28.9	299.2	5.8	72.3	0.025	0.175	1.34	2.66	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_65	508577	5445066	N-2584	0.6	28.2	4.1	67.0	0.025	0.175	1.66	3.31	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_66	508573	5445043	N-1081	0.1	10.7	2.1	65.0	0.025	0.175	2.04	4.09	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_67	509963	5444947	Ind-Stor-10	13.9	263.1	7.1	75.0	0.025	0.175	1.10	2.20	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_68	508296	5444991	N-386	19.6	468.5	3.6	67.1	0.025	0.175	1.69	3.38	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_69	509526	5445087	N-813	7.8	193.1	6.0	74.3	0.025	0.175	1.53	3.04	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_7	508606	5446586	N-531	9.1	176.4	4.5	65.0	0.025	0.175	1.91	3.83	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_70	510664	5445086	N-134	3.8	190.5	13.4	65.0	0.025	0.175	2.45	4.90	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_71	510674	5444893	N-57	3.1	131.5	10.6	65.0	0.025	0.175	2.40	4.81	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_72	509718	5445009	N-1404	2.2	91.6	5.2	73.6	0.025	0.175	1.13	2.24	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_73	510520	5444979	N-83	6.3	262.9	12.2	65.0	0.025	0.175	2.34	4.69	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_74	508716	5445303	Ind-Stor-16	15.5	443.5	5.2	73.9	0.025	0.175	1.28	2.55	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_75	510263	5444392	Ind-Stor-18	33.7	318.3	5.1	74.6	0.025	0.175	1.15	2.29	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_76	508696	5444683	Ind-Stor-17	22.4	343.6	4.0	71.6	0.025	0.175	1.38	2.74	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_77	508915	5444996	Ind-Stor-11	2.4	78.8	5.5	75.0	0.025	0.175	1.54	3.08	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_78	511494	5445203	N-16	24.8	406.3	7.5	25.5	0.025	0.175	3.10	12.41	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_79	509495	5444755	Ind-Stor-27	6.5	167.3	6.3	74.0	0.025	0.175	1.31	2.61	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_8	508897	5446599	N-511	13.3	253.8	3.8	65.0	0.025	0.175	1.91	3.83	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_80	509691	5444841	Ind-Stor-12	1.9	87.9	7.9	75.0	0.025	0.175	0.99	1.98	25	OUTLET	100	0	1.6	0.9	4	7	0

Sub-Catchment_81	508041	5444860	N-597	0.8	58.3	5.7	73.3	0.025	0.175	1.21	2.44	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_82	508250	5444607	N-1093	19.2	399.2	3.7	73.4	0.025	0.175	1.66	3.34	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_83	509196	5444994	Ind-Stor-13	23.5	287.2	3.9	75.0	0.025	0.175	1.54	3.09	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_84	509768	5444595	Ind-Stor-25	10.3	218.8	4.7	74.0	0.025	0.175	0.98	1.95	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_85	510583	5444636	N-921	4.0	84.8	4.1	65.0	0.025	0.175	2.26	4.53	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_86	510970	5444618	N-1758	28.1	304.8	4.5	65.6	0.025	0.175	1.73	3.44	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_87	510498	5444707	N-1517	0.8	54.1	12.7	65.0	0.025	0.175	2.38	4.75	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_88	510069	5444707	N-158	3.7	145.9	5.6	73.6	0.025	0.175	1.13	2.25	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_89	510464	5444585	N-312	0.6	27.0	5.2	65.0	0.025	0.175	2.08	4.15	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_9	510411	5446518	N-1684	0.8	36.0	3.5	65.0	0.025	0.175	1.83	3.66	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_90	509536	5444481	Ind-Stor-26	7.8	299.3	4.7	74.1	0.025	0.175	1.11	2.21	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_91	509861	5444318	Ind-Stor-24	14.9	224.5	6.1	74.8	0.025	0.175	1.01	2.03	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_92	511454	5444625	N-2456	0.0	5.8	11.4	66.2	0.025	0.175	2.58	6.26	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_93	510660	5444327	N-319	16.6	200.1	4.6	65.0	0.025	0.175	1.91	3.84	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_94	510450	5444314	N-330	0.3	12.2	3.2	65.0	0.025	0.175	1.85	3.70	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_95	508109	5444243	N-329	6.5	293.0	3.3	74.1	0.025	0.175	1.24	2.46	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_96	508499	5444194	N-326	16.0	381.0	3.1	68.7	0.025	0.175	1.89	3.76	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_97	508753	5444339	N-1015	0.5	37.4	2.6	65.0	0.025	0.175	1.85	3.71	25	PERVIOUS	100	0	1.6	0.9	4	7	0
Sub-Catchment_98	509170	5444191	N-1166	24.1	228.0	3.8	72.7	0.025	0.175	1.19	2.38	25	OUTLET	100	0	1.6	0.9	4	7	0
Sub-Catchment_99	509282	5444605	Ind-Stor-14	0.9	56.5	9.1	75.0	0.025	0.175	1.56	3.13	25	OUTLET	100	0	1.6	0.9	4	7	0

P:\20112781\00_ISMP\Engineering\03.02_Conceptual_Feasibility_Report\ISMP Final\[dnt_final_model_data_20140403_mm.xlsx]Table E-2

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
C-10001	N-111	N-1443	Culvert	Round	61.5	0.022	0	0	0.7	0	0	NO	CIRCULAR	0.45	0	0	0	1
C-11786	N-226	N-960	Culvert	Round	16.8	0.022	0	0	0.7	0	0	NO	CIRCULAR	0.9	0	0	0	1
C-12211	N-102	N-1161	Culvert	Round	51.2	0.013	0	0	0.5	0	0	NO	CIRCULAR	0.6	0	0	0	1
C-12486	N-132	N-1307	Culvert	Round	15.6	0.022	0	0	0.7	0	0	NO	CIRCULAR	0.9	0	0	0	1
C-12558	N-1828	N-1822	Culvert	Round	33.0	0.013	0	0	0.9	0	0	NO	CIRCULAR	1.25	0	0	0	1
C-12614	N-1425	N-1367	Culvert	Round	5.0	0.022	0	0	0.9	0	0	NO	CIRCULAR	0.45	0	0	0	1
C-12617	N-178	N-1369	Culvert	Round	5.2	0.022	0	0	0.9	0	0	NO	CIRCULAR	0.45	0	0	0	1
C-12621	N-1564	N-1853	Culvert	Round	5.0	0.022	0	0	0.9	0	0	NO	CIRCULAR	0.45	0	0	0	1
C-12636	N-33	N-1381	Culvert	Round	5.0	0.022	0	0	0.9	0	0	NO	CIRCULAR	0.45	0	0	0	1
C-12639	N-34	N-1384	Culvert	Round	5.0	0.022	0	0	0.9	0	0	NO	CIRCULAR	0.45	0	0	0	1
C-12642	N-35	N-1387	Culvert	Round	5.0	0.022	0	0	0.9	0	0	NO	CIRCULAR	0.45	0	0	0	1
D-10043	N-880	N-18	Ditch	Natural_Channel_261	10.8	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	0.5	1.5	1.5	1
D-10083	N-2465	N-33	Ditch	Natural_Channel_261	42.7	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	0.5	1.5	1.5	1
D-10084	N-1387	N-1404	Ditch	Natural_Channel_261	98.4	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	0.5	1.5	1.5	1
D-10085	N-1381	N-34	Ditch	Natural_Channel_261	23.2	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	0.5	1.5	1.5	1
D-10086	N-1384	N-35	Ditch	Natural_Channel_261	25.0	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	0.5	1.5	1.5	1
D-10176	N-940	N-78	Ditch	Natural_Channel_261	59.7	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	0.5	1.5	1.5	1
D-10182	N-101	N-80	Ditch	Natural_Channel_232	18.4	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	1.5	1	6	1.5	1
D-10222	N-912	N-101	Ditch	Natural_Channel_257	33.4	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	3	2	2	1
D-10223	N-1161	N-101	Ditch	Natural_Channel_232	20.7	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	1.5	1	6	1.5	1
D-10224	N-1443	N-102	Ditch	Natural_Channel_232	116.7	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	1.5	1	6	1.5	1
D-10236	N-24	N-109	Ditch	Natural_Channel_223	3.4	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10270	N-156	N-125	Ditch	Natural_Channel_231	18.6	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	2	2	3	1
D-10276	N-130	N-129	Ditch	Natural_Channel_201	45.7	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	5	1.25	1.5	1
D-10277	N-1523	N-130	Ditch	Natural_Channel_201	120.9	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	5	1.25	1.5	1
D-10278	N-1852	N-1523	Ditch	Natural_Channel_201	141.5	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	5	1.25	1.5	1
D-10279	N-1853	N-1852	Ditch	Natural_Channel_201	4.1	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	5	1.25	1.5	1
D-10280	N-2200	N-1564	Ditch	Natural_Channel_201	143.4	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	5	1.25	1.5	1
D-10298	N-1215	N-1093	Ditch	Natural_Channel_122	36.2	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	1.5	1.5	2	2	1
D-10319	N-281	N-156	Ditch	Natural_Channel_231	53.3	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	2	2	3	1
D-10321	N-267	N-24	Ditch	Natural_Channel_223	2.8	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10353	N-1338	N-170	Ditch	Natural_Channel_231	87.5	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	2	2	3	1
D-10357	N-515	N-172	Ditch	Natural_Channel_223	10.9	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10358	N-172	N-173	Ditch	Natural_Channel_223	2.7	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10369	N-1948	N-1434	Ditch	Natural_Channel_223	146.8	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10371	N-179	N-177	Ditch	Natural_Channel_223	71.0	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10372	N-1434	N-1425	Ditch	Natural_Channel_223	2.6	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10373	N-1367	N-178	Ditch	Natural_Channel_223	67.8	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10374	N-1369	N-179	Ditch	Natural_Channel_223	1.3	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.3	2	2	1
D-10464	N-170	N-224	Ditch	Natural_Channel_231	58.4	0.045	0	0	0	0	0	NO	TRAPEZOIDAL	3	2	2	3	1
Pipe-10474	N-232	N-231	Gravity	Rectangular	13.4	0.022	0	0	0	0	0	NO	RECT_CLOSED	1.2	1.5	0	0	1
Pipe-10475	N-159	N-232	Gravity	Rectangular	13.7	0.022	0	0	0.7	0	0	NO	RECT_CLOSED	1.2	1.5	0	0	1
Pipe-10487	N-900	N-242	Gravity	Round	36.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-10500	N-453	N-251	Gravity	Round	37.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1

City of Surrey
Table E-3: Current Condition Model Drainage Components
Cruikshank & Grenville ISMP

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-10507	N-901	N-255	Gravity	Round	152.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10508	N-269	N-256	Gravity	Round	41.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10509	N-921	N-257	Gravity	Round	54.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10518	N-1263	N-261	Gravity	Round	49.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10519	N-1612	N-804	Gravity	Round	48.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10534	N-173	N-267	Gravity	Round	9.3	0.022	0	0	0	0	0	NO	CIRCULAR	1	0	0	0	1
Pipe-10535	N-813	N-2465	Gravity	Round	45.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10536	N-1142	N-269	Gravity	Round	80.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10539	N-1656	N-1577	Gravity	Round	12.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-10544	N-975	N-1578	Gravity	Round	44.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10556	N-1187	N-281	Gravity	Round	17.9	0.013	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10567	N-836	N-290	Gravity	Rectangular	23.7	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.675	0.8	0	0	1
Pipe-10569	N-572	N-292	Gravity	Round	13.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10570	N-1684	N-483	Gravity	Round	14.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10579	N-555	N-298	Gravity	Rectangular	12.3	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.8	1.8	0	0	1
Pipe-10583	N-306	N-300	Gravity	Round	17.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.375	0	0	0	1
Pipe-10587	N-1710	N-1583	Gravity	Round	100.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10592	N-2456	N-306	Gravity	Round	4.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.375	0	0	0	1
Pipe-10596	N-1629	N-309	Gravity	Round	110.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10597	N-298	N-554	Gravity	Round	3.8	0.022	0	0	0	0	0	NO	CIRCULAR	1.5	0	0	0	1
Pipe-10607	N-568	N-316	Gravity	Round	65.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10608	N-1159	N-1040	Gravity	Round	61.8	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10610	N-1578	N-1585	Gravity	Round	89.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10615	N-768	N-322	Gravity	Round	45.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10616	N-551	N-323	Gravity	Round	93.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-10624	N-1150	N-1060	Gravity	Round	21.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10626	N-824	N-329	Gravity	Round	50.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10628	N-1834	N-1586	Gravity	Round	27.1	0.013	0	0	0.9	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-10630	N-1514	N-332	Gravity	Round	23.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10634	N-1110	N-336	Gravity	Round	2.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10636	N-39	N-338	Gravity	Round	29.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10643	N-846	N-342	Gravity	Round	80.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10657	N-51	N-349	Gravity	Round	9.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10658	N-798	N-1588	Gravity	Round	64.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10670	N-1017	N-2223	Gravity	Round	89.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10678	N-339	N-853	Gravity	Round	91.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10680	N-733	N-465	Gravity	Round	148.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.35	0	0	0	1
Pipe-10684	N-1090	N-365	Gravity	Round	48.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10687	N-1585	N-1592	Gravity	Round	90.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-10688	N-1320	N-367	Gravity	Round	77.4	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10690	N-709	N-369	Gravity	Round	35.7	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-10707	N-154	N-381	Gravity	Round	24.5	0.022	0	0	0.5	0	0	NO	CIRCULAR	1.5	0	0	0	2
Pipe-10710	N-1290	N-384	Gravity	Round	76.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10711	N-660	N-385	Gravity	Round	87.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1

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Table E-3: Current Condition Model Drainage Components
Cruikshank & Grenville ISMP

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-10712	N-465	N-386	Gravity	Round	90.0	0.022	0	0	0	0	0	NO	CIRCULAR	1.35	0	0	0	1
Pipe-10720	N-1092	N-1220	Gravity	Round	28.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10723	N-1254	N-391	Gravity	Round	93.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10727	N-479	N-395	Gravity	Round	56.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-10740	N-371	N-503	Gravity	Round	69.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.5	0	0	0	1
Pipe-10743	N-349	N-406	Gravity	Round	14.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10754	N-863	N-412	Gravity	Round	34.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10757	N-936	N-466	Gravity	Round	105.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10761	N-1744	N-1847	Gravity	Round	76.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-10771	N-920	N-420	Gravity	Round	35.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10782	N-1846	N-1607	Gravity	Round	52.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10783	N-1690	N-892	Gravity	Round	51.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10788	N-842	N-358	Gravity	Round	131.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10790	N-1674	N-1609	Gravity	Round	66.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-10792	N-368	N-1467	Gravity	Round	67.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10798	N-311	N-669	Gravity	Round	54.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10801	N-898	N-349	Gravity	Round	94.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10803	N-309	N-232	Gravity	Round	102.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10808	N-2237	N-1612	Gravity	Round	90.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10811	N-1030	N-1017	Gravity	Round	68.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10828	N-704	N-942	Gravity	Round	92.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10834	N-1212	N-1180	Gravity	Round	18.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.45	0	0	0	1
Pipe-10840	N-553	N-371	Gravity	Round	77.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.5	0	0	0	1
Pipe-10842	N-1588	N-1615	Gravity	Round	55.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10843	N-1304	N-457	Gravity	Rectangular	1.4	0.022	0	0	0	0	0	NO	RECT_CLOSED	1.35	2.155	0	0	1
Pipe-10846	N-1789	N-456	Gravity	Round	36.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10847	N-694	N-1469	Gravity	Round	89.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10848	N-332	N-460	Gravity	Round	35.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10850	N-1041	N-801	Gravity	Round	142.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10866	N-564	N-471	Gravity	Round	25.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-10868	N-1222	N-472	Gravity	Round	103.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10881	N-823	N-479	Gravity	Round	73.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-10882	N-574	N-480	Gravity	Round	98.2	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10886	N-764	N-1092	Gravity	Round	33.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-10891	N-1326	N-355	Gravity	Round	110.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10892	N-531	N-486	Gravity	Round	103.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10893	N-894	N-493	Gravity	Round	42.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10900	N-908	N-488	Gravity	Round	148.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10912	N-1714	N-391	Gravity	Round	58.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10913	N-601	N-500	Gravity	Round	15.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10914	N-986	N-501	Gravity	Round	40.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10924	N-1476	N-1398	Gravity	Round	165.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10929	N-1495	N-302	Gravity	Round	6.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10936	N-503	N-386	Gravity	Round	8.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.35	0	0	0	1

City of Surrey
Table E-3: Current Condition Model Drainage Components
Cruikshank & Grenville ISMP

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-10938	N-1836	N-1143	Gravity	Round	10.9	0.013	0	0	0.5	0	0	NO	CIRCULAR	1.5	0	0	0	1
Pipe-10939	N-1227	N-515	Gravity	Round	71.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10945	N-255	N-520	Gravity	Round	67.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10946	N-520	N-521	Gravity	Round	25.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10948	N-1712	N-1623	Gravity	Round	115.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-10966	N-348	N-531	Gravity	Round	83.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-10973	N-641	N-1626	Gravity	Round	123.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10977	N-1592	N-1627	Gravity	Round	106.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-10979	N-391	N-538	Gravity	Round	44.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10983	N-1482	N-1845	Gravity	Round	4.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-10984	N-456	N-1629	Gravity	Round	69.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-10989	N-263	N-541	Gravity	Round	56.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-10990	N-560	N-542	Gravity	Round	17.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11005	N-554	N-553	Gravity	Round	2.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.5	0	0	0	1
Pipe-11006	N-342	N-554	Gravity	Round	63.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11013	N-384	N-560	Gravity	Round	29.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11018	N-1049	N-564	Gravity	Round	83.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-11019	N-472	N-321	Gravity	Round	21.7	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11020	N-460	N-565	Gravity	Round	18.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11021	N-879	N-1632	Gravity	Round	99.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11022	N-1404	N-566	Gravity	Round	24.5	0.022	0	0	0.7	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11028	N-1758	N-569	Gravity	Round	31.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11033	N-367	N-572	Gravity	Round	162.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11035	N-292	N-574	Gravity	Round	94.8	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11067	N-1067	N-1183	Gravity	Round	13.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11069	N-1433	N-1948	Gravity	Round	187.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11075	N-358	N-596	Gravity	Round	55.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11077	N-1060	N-1476	Gravity	Round	22.7	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11078	N-488	N-568	Gravity	Round	89.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11083	N-329	N-1057	Gravity	Round	158.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11084	N-501	N-601	Gravity	Round	58.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11090	N-711	N-827	Gravity	Round	55.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11100	N-319	N-1641	Gravity	Round	142.7	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11101	N-968	N-610	Gravity	Round	16.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11118	N-542	N-622	Gravity	Round	88.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11137	N-1567	N-319	Gravity	Round	93.2	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11143	N-750	N-637	Gravity	Round	61.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11147	N-253	N-249	Gravity	Round	97.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11150	N-1258	N-642	Gravity	Round	44.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11152	N-1496	N-1974	Gravity	Round	13.0	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11159	N-1627	N-1649	Gravity	Round	90.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11161	N-1784	N-758	Gravity	Round	117.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11168	N-741	N-1652	Gravity	Round	55.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11169	N-1632	N-1567	Gravity	Round	104.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-11178	N-1957	N-555	Gravity	Rectangular	5.3	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.8	1.8	0	0	1
Pipe-11181	N-1935	N-1706	Gravity	Round	134.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11190	N-1573	N-1654	Gravity	Round	90.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11195	N-1408	N-1656	Gravity	Round	145.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11198	N-1974	N-704	Gravity	Round	74.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11201	N-365	N-660	Gravity	Round	55.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11202	N-955	N-661	Gravity	Round	13.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11232	N-1143	N-674	Gravity	Round	7.3	0.013	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11261	N-844	N-688	Gravity	Round	102.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11264	N-1081	N-690	Gravity	Round	22.4	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-11268	N-2584	N-690	Gravity	Rectangular	23.6	0.022	0	0	0.7	0	0	NO	RECT_CLOSED	1.65	2.255	0	0	1
Pipe-11281	N-952	N-701	Gravity	Round	76.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11284	N-1741	N-1674	Gravity	Round	97.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11290	N-1212	N-705	Gravity	Round	14.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11293	N-388	N-706	Gravity	Round	98.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11295	N-2223	N-1676	Gravity	Round	37.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11300	N-386	N-709	Gravity	Round	2.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-11313	N-1015	N-714	Gravity	Round	12.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11317	N-998	N-717	Gravity	Round	83.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11327	N-251	N-724	Gravity	Round	51.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11335	N-672	N-727	Gravity	Round	7.4	0.013	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11339	N-1271	N-1846	Gravity	Round	61.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11345	N-1093	N-733	Gravity	Round	5.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.35	0	0	0	1
Pipe-11348	N-1295	N-734	Gravity	Round	12.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11350	N-1010	N-736	Gravity	Round	90.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11351	N-1726	N-1684	Gravity	Round	100.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11357	N-355	N-740	Gravity	Round	108.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11360	N-1623	N-743	Gravity	Round	91.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11369	N-1153	N-750	Gravity	Round	82.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11371	N-1025	N-752	Gravity	Round	55.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11379	N-893	N-755	Gravity	Round	93.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11383	N-1843	N-1686	Gravity	Round	24.0	0.013	0	0	0.5	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11395	N-406	N-764	Gravity	Round	27.4	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11401	N-1641	N-768	Gravity	Round	17.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11404	N-483	N-1690	Gravity	Round	20.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11405	N-1006	N-770	Gravity	Round	98.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11414	N-395	N-776	Gravity	Round	12.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11418	N-336	N-1693	Gravity	Round	19.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11425	N-1583	N-253	Gravity	Round	90.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11436	N-369	N-676	Gravity	Round	11.8	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-11444	N-841	N-1696	Gravity	Round	36.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11445	N-804	N-841	Gravity	Round	5.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11456	N-1609	N-798	Gravity	Round	99.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11458	N-938	N-1697	Gravity	Round	98.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1

City of Surrey
Table E-3: Current Condition Model Drainage Components
Cruikshank & Grenville ISMP

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-11459	N-604	N-799	Gravity	Round	107.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11464	N-1649	N-968	Gravity	Round	89.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11478	N-724	N-813	Gravity	Round	31.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11483	N-1541	N-815	Gravity	Round	15.0	0.013	0	0	0.7	0	0	NO	CIRCULAR	0.6	0	0	0	2
Pipe-11495	N-80	N-156	Gravity	Round	21.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11500	N-833	N-823	Gravity	Round	113.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11502	N-1144	N-824	Gravity	Round	47.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11504	N-1931	N-311	Gravity	Round	94.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11508	N-1214	N-826	Gravity	Round	103.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11516	N-1607	N-1482	Gravity	Round	46.7	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11518	N-256	N-832	Gravity	Round	45.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11522	N-321	N-834	Gravity	Round	121.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11526	N-1845	N-836	Gravity	Rectangular	6.5	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.8	1.2	0	0	1
Pipe-11543	N-770	N-844	Gravity	Round	98.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11545	N-412	N-846	Gravity	Round	65.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11558	N-1640	N-938	Gravity	Round	58.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11559	N-249	N-1640	Gravity	Round	45.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11562	N-524	N-855	Gravity	Round	87.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11569	N-1040	N-696	Gravity	Round	7.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11575	N-1427	N-1935	Gravity	Round	165.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11577	N-706	N-604	Gravity	Round	90.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11578	N-1217	N-863	Gravity	Round	83.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11591	N-565	N-871	Gravity	Round	32.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11601	N-892	N-1826	Gravity	Round	9.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11605	N-323	N-1710	Gravity	Round	108.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-11609	N-1655	N-1211	Gravity	Round	62.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11610	N-1819	N-879	Gravity	Round	13.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11612	N-979	N-880	Gravity	Round	12.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.375	0	0	0	1
Pipe-11615	N-1157	N-705	Gravity	Round	12.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11616	N-1696	N-1712	Gravity	Round	64.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11621	N-688	N-1714	Gravity	Round	54.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11635	N-322	N-1717	Gravity	Round	50.0	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11641	N-622	N-893	Gravity	Round	103.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11644	N-736	N-894	Gravity	Round	100.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11653	N-351	N-898	Gravity	Round	104.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11660	N-471	N-900	Gravity	Round	90.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-11673	N-570	N-368	Gravity	Round	54.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11675	N-1467	N-453	Gravity	Round	3.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11676	N-714	N-908	Gravity	Round	86.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11680	N-1686	N-912	Gravity	Round	18.5	0.013	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11692	N-1936	N-1180	Gravity	Round	4.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11694	N-1124	N-572	Gravity	Round	3.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11701	N-1652	N-1222	Gravity	Round	103.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11706	N-596	N-734	Gravity	Round	98.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1

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Table E-3: Current Condition Model Drainage Components
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Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-11708	N-1257	N-920	Gravity	Round	24.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11715	N-1693	N-718	Gravity	Round	19.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11720	N-326	N-927	Gravity	Round	72.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11730	N-637	N-292	Gravity	Round	19.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11732	N-834	N-330	Gravity	Round	24.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11739	N-1615	N-1726	Gravity	Round	36.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11746	N-566	N-940	Gravity	Round	33.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11755	N-1586	N-1728	Gravity	Round	13.3	0.013	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-11765	N-486	N-511	Gravity	Round	93.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11771	N-1155	N-952	Gravity	Round	94.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11773	N-740	N-953	Gravity	Round	64.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11779	N-420	N-955	Gravity	Round	73.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11803	N-669	N-968	Gravity	Round	25.2	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-11805	N-853	N-969	Gravity	Round	31.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11806	N-758	N-955	Gravity	Round	178.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11808	N-385	N-930	Gravity	Round	4.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11815	N-1299	N-457	Gravity	Round	14.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11816	N-1676	N-975	Gravity	Round	45.3	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11821	N-300	N-979	Gravity	Round	61.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.375	0	0	0	1
Pipe-11836	N-1199	N-986	Gravity	Round	14.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11854	N-983	N-998	Gravity	Round	82.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11856	N-242	N-983	Gravity	Round	97.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11866	N-477	N-1741	Gravity	Round	98.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11868	N-717	N-1006	Gravity	Round	91.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11875	N-855	N-1010	Gravity	Round	134.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11884	N-927	N-1015	Gravity	Round	85.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-11888	N-871	N-1018	Gravity	Round	30.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11893	N-1057	N-1655	Gravity	Round	177.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11898	N-1847	N-1408	Gravity	Round	12.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11901	N-1064	N-1025	Gravity	Round	89.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11905	N-1626	N-936	Gravity	Round	17.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11910	N-815	N-1744	Gravity	Round	59.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-11912	N-1779	N-1745	Gravity	Round	132.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11922	N-1247	N-1030	Gravity	Round	21.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11927	N-930	N-878	Gravity	Round	117.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11933	N-493	N-388	Gravity	Round	56.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-11954	N-862	N-1041	Gravity	Round	145.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11971	N-734	N-1755	Gravity	Round	18.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-11974	N-852	N-1049	Gravity	Round	82.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
Pipe-11998	N-1286	N-1063	Gravity	Round	66.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-11999	N-1063	N-1064	Gravity	Round	24.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12004	N-270	N-1066	Gravity	Round	44.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12005	N-701	N-1067	Gravity	Round	15.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12011	N-1469	N-1247	Gravity	Round	90.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1

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Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-12013	N-107	N-1071	Gravity	Round	33.4	0.022	0	0	0.7	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12019	N-743	N-1758	Gravity	Round	91.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12021	N-897	N-352	Gravity	Round	12.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12022	N-1220	N-1075	Gravity	Round	37.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12026	N-466	N-711	Gravity	Round	92.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12037	N-911	N-701	Gravity	Round	45.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12039	N-902	N-312	Gravity	Round	81.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12056	N-821	N-1090	Gravity	Round	52.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12085	N-125	N-1957	Gravity	Round	192.9	0.013	0	0	0.7	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12100	N-969	N-1110	Gravity	Round	86.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12104	N-1569	N-842	Gravity	Round	115.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12122	N-312	N-1122	Gravity	Round	5.6	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12125	N-989	N-828	Gravity	Round	118.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12129	N-832	N-1124	Gravity	Round	14.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12133	N-718	N-94	Gravity	Round	25.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12160	N-352	N-1138	Gravity	Round	80.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12161	N-1694	N-1573	Gravity	Round	18.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12167	N-597	N-1141	Gravity	Round	20.8	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12171	N-1213	N-1142	Gravity	Round	121.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12173	N-1566	N-1144	Gravity	Round	39.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12176	N-1138	N-351	Gravity	Round	15.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12182	N-942	N-1150	Gravity	Round	11.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12184	N-1654	N-1779	Gravity	Round	27.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12185	N-1717	N-921	Gravity	Round	49.4	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12193	N-1745	N-661	Gravity	Round	116.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12212	N-827	N-1784	Gravity	Round	91.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12221	N-1283	N-1166	Gravity	Rectangular	20.9	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.6	1.8	0	0	1
Pipe-12250	N-541	N-1180	Gravity	Round	31.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12266	N-1180	N-1794	Gravity	Round	129.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12272	N-1697	N-1493	Gravity	Round	86.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12281	N-801	N-1931	Gravity	Round	10.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12287	N-645	N-1196	Gravity	Round	12.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12291	N-878	N-1199	Gravity	Round	105.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12299	N-1183	N-1433	Gravity	Round	22.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12312	N-1493	N-1212	Gravity	Round	3.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12313	N-828	N-1213	Gravity	Round	88.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12315	N-953	N-1214	Gravity	Round	75.7	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12317	N-1141	N-1215	Gravity	Round	167.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12318	N-705	N-1936	Gravity	Round	12.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12322	N-1738	N-1217	Gravity	Round	35.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12337	N-1577	N-1802	Gravity	Round	72.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12338	N-1802	N-1569	Gravity	Round	30.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12340	N-1279	N-1227	Gravity	Round	54.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12341	N-752	N-264	Gravity	Round	62.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-12348	N-297	N-897	Gravity	Round	43.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12351	N-1706	N-1157	Gravity	Round	86.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12370	N-799	N-270	Gravity	Round	50.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12379	N-1794	N-1495	Gravity	Round	92.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12380	N-1755	N-741	Gravity	Round	31.8	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12387	N-1196	N-1257	Gravity	Round	57.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12388	N-661	N-1496	Gravity	Round	19.4	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12400	N-755	N-1263	Gravity	Round	91.4	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12413	N-610	N-1271	Gravity	Round	102.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12430	N-1211	N-597	Gravity	Round	12.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12432	N-168	N-789	Gravity	Rectangular	5.5	0.013	0	0	0.7	0	0	NO	RECT_CLOSED	2.1	2.5	0	0	1
Pipe-12433	N-315	N-1277	Gravity	Rectangular	93.2	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.9	1.8	0	0	1
Pipe-12434	N-316	N-1278	Gravity	Round	65.5	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12435	N-1278	N-1279	Gravity	Round	81.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12442	N-1277	N-1283	Gravity	Rectangular	55.6	0.022	0	0	0	0	0	NO	RECT_CLOSED	0.9	1.8	0	0	1
Pipe-12443	N-776	N-1497	Gravity	Rectangular	11.1	0.013	0	0	0	0	0	NO	RECT_CLOSED	1	2	0	0	1
Pipe-12444	N-108	N-1284	Gravity	Round	33.1	0.022	0	0	0.7	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12446	N-158	N-776	Gravity	Rectangular	21.5	0.013	0	0	0	0	0	NO	RECT_CLOSED	1	2	0	0	1
Pipe-12448	N-1285	N-1286	Gravity	Round	109.8	0.022	0	0	0	0	0	NO	CIRCULAR	0.675	0	0	0	1
Pipe-12450	N-177	N-1278	Gravity	Round	5.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12453	N-264	N-1290	Gravity	Round	91.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12458	N-109	N-315	Gravity	Round	5.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12461	N-521	N-1295	Gravity	Round	60.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12465	N-330	N-1159	Gravity	Round	70.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12467	N-826	N-1299	Gravity	Round	40.2	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12468	N-1812	N-902	Gravity	Round	86.4	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12469	N-696	N-1812	Gravity	Round	1.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12471	N-497	N-672	Gravity	Round	13.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.6	0	0	0	1
Pipe-12474	N-500	N-1541	Gravity	Round	6.2	0.013	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12475	N-157	N-1301	Gravity	Rectangular	25.8	0.013	0	0	0	0	0	NO	RECT_CLOSED	1.2	1.8	0	0	1
Pipe-12476	N-789	N-1302	Gravity	Rectangular	16.3	0.013	0	0	0	0	0	NO	RECT_CLOSED	2.1	2.5	0	0	1
Pipe-12477	N-457	N-1303	Gravity	Rectangular	30.0	0.022	0	0	0	0	0	NO	RECT_CLOSED	1.35	2.155	0	0	1
Pipe-12478	N-1339	N-1304	Gravity	Rectangular	56.6	0.022	0	0	0	0	0	NO	RECT_CLOSED	1.35	1.8	0	0	1
Pipe-12484	N-1398	N-1166	Gravity	Round	6.0	0.022	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12505	N-261	N-1254	Gravity	Round	142.9	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12507	N-511	N-1316	Gravity	Round	5.0	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12508	N-1316	N-1285	Gravity	Round	9.3	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12518	N-224	N-1318	Gravity	Round	3.5	0.013	0	0	0.5	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12519	N-1318	N-1187	Gravity	Round	23.1	0.013	0	0	0	0	0	NO	CIRCULAR	1.2	0	0	0	1
Pipe-12521	N-1066	N-1320	Gravity	Round	70.1	0.022	0	0	0	0	0	NO	CIRCULAR	1.05	0	0	0	1
Pipe-12527	N-302	N-1819	Gravity	Round	165.1	0.022	0	0	0	0	0	NO	CIRCULAR	0.75	0	0	0	1
Pipe-12531	N-480	N-1326	Gravity	Round	96.6	0.022	0	0	0	0	0	NO	CIRCULAR	0.9	0	0	0	1
Pipe-12546	N-676	N-1334	Gravity	Round	40.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-12547	N-1334	N-1335	Gravity	Round	0.5	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1

City of Surrey
Table E-3: Current Condition Model Drainage Components
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Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
Pipe-12553	N-1031	N-1338	Gravity	Round	12.2	0.013	0	0	0	0	0	NO	CIRCULAR	0.45	0	0	0	1
Pipe-12555	N-141	N-1339	Gravity	Rectangular	21.4	0.022	0	0	0.7	0	0	NO	RECT_CLOSED	1.35	1.8	0	0	1
Pipe-12559	N-1460	N-1031	Gravity	Round	24.1	0.013	0	0	0	0	0	NO	CIRCULAR	0.45	0	0	0	1
Pipe-12560	N-1335	N-1081	Gravity	Round	139.9	0.022	0	0	0	0	0	NO	CIRCULAR	1.8	0	0	0	1
Pipe-12562	N-642	N-348	Gravity	Round	78.7	0.022	0	0	0	0	0	NO	CIRCULAR	0.525	0	0	0	1
WC-10023	N-1075	N-8	Watercourse	Natural_Channel_601	108.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10024	N-213	N-1502	Watercourse	Natural_Channel_210	192.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10025	N-1502	N-1503	Watercourse	Natural_Channel_210	173.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10026	N-674	N-1503	Watercourse	Natural_Channel_251	62.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10027	N-10	N-1836	Watercourse	Natural_Channel_251	54.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10028	N-13	N-9	Watercourse	Natural_Channel_212	33.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10029	N-9	N-10	Watercourse	Natural_Channel_251	39.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10032	N-1822	N-12	Watercourse	Natural_Channel_212	59.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10033	N-12	N-19	Watercourse	Natural_Channel_212	57.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10034	N-19	N-13	Watercourse	Natural_Channel_212	22.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10036	N-219	N-8	Watercourse	Natural_Channel_602	104.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10037	N-114	N-14	Watercourse	Natural_Channel_601	212.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10038	N-14	N-15	Watercourse	Natural_Channel_601	176.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10039	N-15	N-1842	Watercourse	Natural_Channel_601	216.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10040	N-1842	N-16	Watercourse	Natural_Channel_601	84.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10041	N-17	N-16	Watercourse	Natural_Channel_524	70.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	1.5	4	4	1
WC-10042	N-569	N-17	Watercourse	Natural_Channel_524	100.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	1.5	4	4	1
WC-10044	N-18	N-1512	Watercourse	Natural_Channel_601	220.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10045	N-1827	N-272	Watercourse	Natural_Channel_212	44.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10050	N-1829	N-1828	Watercourse	Natural_Channel_212	121.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10051	N-1830	N-1829	Watercourse	Natural_Channel_212	112.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10052	N-1401	N-20	Watercourse	Natural_Channel_212	20.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10054	N-2374	N-1830	Watercourse	Natural_Channel_212	1.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10055	N-20	N-2374	Watercourse	Natural_Channel_212	8.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10056	N-272	N-2152	Watercourse	Natural_Channel_212	44.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10057	N-2152	N-1401	Watercourse	Natural_Channel_212	3.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10088	N-211	N-37	Watercourse	Natural_Channel_203	214.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10091	N-37	N-38	Watercourse	Natural_Channel_203	10.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10092	N-38	N-39	Watercourse	Natural_Channel_203	95.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10093	N-338	N-40	Watercourse	Natural_Channel_203	51.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10096	N-131	N-1851	Watercourse	Natural_Channel_235	133.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-10113	N-74	N-46	Watercourse	Natural_Channel_521	41.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	0.5	2	3	1
WC-10114	N-1504	N-46	Watercourse	Natural_Channel_251	122.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10122	N-202	N-51	Watercourse	Natural_Channel_520	6.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.5	1.5	1.5	1
WC-10128	N-46	N-55	Watercourse	Natural_Channel_251	68.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10129	N-1558	N-56	Watercourse	Natural_Channel_251	34.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10130	N-55	N-1558	Watercourse	Natural_Channel_251	6.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10131	N-56	N-1509	Watercourse	Natural_Channel_251	20.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10132	N-181	N-57	Watercourse	Natural_Channel_235	151.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1

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Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
WC-10133	N-57	N-1510	Watercourse	Natural_Channel_602	161.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10134	N-1510	N-1511	Watercourse	Natural_Channel_602	133.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10135	N-218	N-58	Watercourse	Natural_Channel_602	86.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10136	N-60	N-59	Watercourse	Natural_Channel_602	82.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10137	N-58	N-60	Watercourse	Natural_Channel_602	23.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10138	N-59	N-61	Watercourse	Natural_Channel_602	56.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10139	N-61	N-62	Watercourse	Natural_Channel_602	53.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10140	N-64	N-63	Watercourse	Natural_Channel_602	15.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10145	N-70	N-65	Watercourse	Natural_Channel_602	6.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10166	N-727	N-1506	Watercourse	Natural_Channel_521	113.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	0.5	2	3	1
WC-10167	N-1506	N-74	Watercourse	Natural_Channel_521	24.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	0.5	2	3	1
WC-10168	N-182	N-57	Watercourse	Natural_Channel_602	13.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10169	N-62	N-64	Watercourse	Natural_Channel_602	66.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10174	N-1507	N-78	Watercourse	Natural_Channel_216	65.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10175	N-78	N-79	Watercourse	Natural_Channel_216	69.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10177	N-16	N-1513	Watercourse	Natural_Channel_601	204.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10189	N-1403	N-1504	Watercourse	Natural_Channel_251	129.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10190	N-1505	N-1403	Watercourse	Natural_Channel_251	6.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10191	N-63	N-70	Watercourse	Natural_Channel_602	10.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10192	N-105	N-83	Watercourse	Natural_Channel_253	43.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	3	2	2	1
WC-10193	N-97	N-68	Watercourse	Natural_Channel_216	147.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10196	N-67	N-85	Watercourse	Natural_Channel_216	52.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10203	N-85	N-90	Watercourse	Natural_Channel_216	12.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10208	N-1303	N-1505	Watercourse	Natural_Channel_251	85.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10209	N-96	N-94	Watercourse	Natural_Channel_216	86.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10213	N-94	N-1507	Watercourse	Natural_Channel_216	128.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10214	N-79	N-97	Watercourse	Natural_Channel_216	129.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10216	N-90	N-98	Watercourse	Natural_Channel_253	170.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	3	2	2	1
WC-10217	N-1851	N-1519	Watercourse	Natural_Channel_235	48.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-10230	N-1302	N-105	Watercourse	Natural_Channel_253	143.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	3	2	2	1
WC-10231	N-1284	N-106	Watercourse	Natural_Channel_216	2.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10232	N-1071	N-106	Watercourse	Natural_Channel_216	3.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10233	N-129	N-1520	Watercourse	Natural_Channel_216	181.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10234	N-1520	N-107	Watercourse	Natural_Channel_216	7.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10235	N-1520	N-108	Watercourse	Natural_Channel_216	5.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10237	N-1501	N-184	Watercourse	Natural_Channel_210	14.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10243	N-8	N-114	Watercourse	Natural_Channel_601	63.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10244	N-1513	N-18	Watercourse	Natural_Channel_601	94.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-10253	N-538	N-121	Watercourse	Natural_Channel_210	57.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10257	N-1826	N-1827	Watercourse	Natural_Channel_212	3.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	1	4	4	1
WC-10269	N-1509	N-124	Watercourse	Natural_Channel_251	39.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10274	N-155	N-1521	Watercourse	Natural_Channel_102	104.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	1.5	5	1
WC-10275	N-1521	N-129	Watercourse	Natural_Channel_102	129.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	1.5	5	1
WC-10281	N-1307	N-131	Watercourse	Natural_Channel_235	4.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
WC-10282	N-960	N-131	Watercourse	Natural_Channel_235	4.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-10283	N-1517	N-132	Watercourse	Natural_Channel_235	3.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-10284	N-1122	N-1517	Watercourse	Natural_Channel_235	116.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-10285	N-124	N-133	Watercourse	Natural_Channel_251	52.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10286	N-91	N-134	Watercourse	Natural_Channel_602	2.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10297	N-1503	N-141	Watercourse	Natural_Channel_251	16.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10313	N-1497	N-152	Watercourse	Natural_Channel_217	132.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10314	N-152	N-153	Watercourse	Natural_Channel_217	137.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10315	N-40	N-154	Watercourse	Natural_Channel_203	64.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10316	N-381	N-143	Watercourse	Natural_Channel_203	10.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10317	N-143	N-1522	Watercourse	Natural_Channel_203	105.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10318	N-1522	N-155	Watercourse	Natural_Channel_102	89.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	1.5	5	1
WC-10322	N-153	N-157	Watercourse	Natural_Channel_217	55.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10323	N-231	N-158	Watercourse	Natural_Channel_217	173.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10324	N-1518	N-159	Watercourse	Natural_Channel_217	305.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10325	N-1166	N-1518	Watercourse	Natural_Channel_217	347.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10347	N-98	N-168	Watercourse	Natural_Channel_253	88.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	8	3	2	2	1
WC-10348	N-1519	N-83	Watercourse	Natural_Channel_602	107.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10349	N-83	N-1508	Watercourse	Natural_Channel_602	119.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10376	N-133	N-134	Watercourse	Natural_Channel_251	62.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	3	1.5	1.5	1
WC-10377	N-257	N-181	Watercourse	Natural_Channel_235	151.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-10378	N-1508	N-91	Watercourse	Natural_Channel_602	68.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10379	N-134	N-182	Watercourse	Natural_Channel_602	63.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10382	N-2375	N-1832	Watercourse	Natural_Channel_210	62.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10383	N-1832	N-121	Watercourse	Natural_Channel_210	26.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10384	N-121	N-1501	Watercourse	Natural_Channel_210	38.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10385	N-184	N-1833	Watercourse	Natural_Channel_210	42.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10410	N-446	N-1557	Watercourse	Natural_Channel_520	73.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.5	1.5	1.5	1
WC-10411	N-1557	N-202	Watercourse	Natural_Channel_520	90.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	2	0.5	1.5	1.5	1
WC-10420	N-1301	N-1519	Watercourse	Natural_Channel_217	88.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	3.5	2.5	2	2	1
WC-10425	N-106	N-96	Watercourse	Natural_Channel_216	28.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10439	N-691	N-211	Watercourse	Natural_Channel_203	41.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-10440	N-1833	N-1834	Watercourse	Natural_Channel_210	37.6	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10441	N-1728	N-1835	Watercourse	Natural_Channel_210	94.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10442	N-1835	N-212	Watercourse	Natural_Channel_210	29.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10443	N-212	N-213	Watercourse	Natural_Channel_210	23.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10444	N-2356	N-214	Watercourse	Natural_Channel_210	26.3	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10445	N-214	N-213	Watercourse	Natural_Channel_210	63.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	4	4	1
WC-10455	N-1511	N-218	Watercourse	Natural_Channel_602	35.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10456	N-65	N-219	Watercourse	Natural_Channel_602	12.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	10	5	2	2	1
WC-10458	N-68	N-67	Watercourse	Natural_Channel_216	52.4	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	6	4	2	2	1
WC-10468	N-1517	N-226	Watercourse	Natural_Channel_235	5.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	4	2	2	1
WC-11265	N-690	N-691	Watercourse	Natural_Channel_203	4.0	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	4	2	2	2	1
WC-20001	N-3001	N-3002	Watercourse	Natural_Channel_601	48.9	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1

City of Surrey
Table E-3: Current Condition Model Drainage Components
Cruikshank & Grenville ISMP

Conduit ID	Upstream Node	Downstream Node	Description	Conduit Shape	Length (m)	Manning's "n"	Inlet Offset	Outlet Offset	Inlet Loss Coefficient	Outlet Loss Coefficient	Avg. Loss Coefficient	Flap Gate	Type	Geom 1 (m)	Geom 2 (m)	Geom 3	Geom 4	No. Barrels
WC-20002	N-3004	N-114	Watercourse	Natural_Channel_601	233.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-20003	N-1512	N-3001	Watercourse	Natural_Channel_601	348.8	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-20004	N-1018	N-3003	Watercourse	Natural_Channel_601	540.2	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-20005	N-3003	N-3001	Watercourse	Natural_Channel_601	135.5	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-20006	N-655	N-3003	Watercourse	Natural_Channel_601	259.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-20007	N-290	N-738	Watercourse	Natural_Channel_601	202.7	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1
WC-20008	N-738	N-655	Watercourse	Natural_Channel_601	267.1	0.04	0	0	0	0	0	NO	TRAPEZOIDAL	5	8	2	2	1

P:\20112781\00_ISMP\Engineering\03.02_Conceptual_Feasibility_Report\ISMP Final\[dnt_final_model_data_20140403_mm.xlsx]Table E-3

City of Surrey
Table E-4: Model Junction and Node Data
Cruikshank & Grenville ISMP

Node ID	X Cooridinate	Y Coordinate	Description	Conduit Shape	Invert Elev. (m)	Rim Elev. (m)	Depth (m)	Surchage Depth (m)	Ponded Area (m2)
N-10	510409	5445754	Model Node	Watercourse	55.7	61.7	6.0	0	0
N-1006	510100	5446512	Manhole	Gravity	71.6	75.5	3.9	0	0
N-101	508340	5445459	Model Node	Ditch	89.4	90.9	1.5	0	0
N-1010	509018	5445972	Manhole	Gravity	83.6	85.9	2.4	0	0
N-1015	508810	5444358	Manhole	Gravity	88.6	89.9	1.3	0	0
N-1017	511248	5442922	Manhole	Gravity	70.9	72.7	1.8	0	0
N-1018	511352	5444145	Manhole	Watercourse	46.3	48.0	1.7	0	0
N-102	508284	5445504	Manhole	Culvert	89.6	91.1	1.5	0	0
N-1025	509304	5446350	Manhole	Gravity	83.4	86.1	2.8	0	0
N-1030	511249	5442853	Manhole	Gravity	71.5	73.0	1.5	0	0
N-1031	508151	5445598	Manhole	Gravity	92.9	95.8	3.0	0	0
N-1040	510446	5444547	Manhole	Gravity	54.2	56.5	2.3	0	0
N-1041	511246	5443284	Manhole	Gravity	67.7	69.7	2.0	0	0
N-1049	509910	5447067	Manhole	Gravity	82.2	84.8	2.6	0	0
N-105	510550	5445028	Model Node	Watercourse	41.3	49.3	8.0	0	0
N-1057	508122	5444551	Manhole	Gravity	92.5	93.8	1.3	0	0
N-106	509644	5444836	Model Node	Watercourse	67.3	73.3	6.0	0	0
N-1060	509633	5444162	Manhole	Gravity	73.4	77.6	4.2	0	0
N-1063	509190	5446359	Manhole	Gravity	84.0	87.6	3.6	0	0
N-1064	509215	5446358	Manhole	Gravity	83.8	87.4	3.5	0	0
N-1066	509321	5445569	Manhole	Gravity	76.9	79.4	2.5	0	0
N-1067	509096	5443943	Manhole	Gravity	83.2	84.6	1.3	0	0
N-107	509609	5444826	Manhole	Gravity	68.8	70.5	1.7	0	0
N-1071	509642	5444835	Manhole	Gravity	67.3	70.3	3.0	0	0
N-1075	511260	5445473	Manhole	Gravity	29.1	32.1	3.0	0	0
N-108	509609	5444830	Manhole	Gravity	68.8	71.0	2.2	0	0
N-1081	508575	5445064	Manhole	Gravity	86.5	90.3	3.8	0	0
N-109	509510	5444350	Manhole	Gravity	75.1	78.1	3.0	0	0
N-1090	509887	5443134	Manhole	Gravity	84.0	85.7	1.7	0	0
N-1092	511228	5445522	Manhole	Gravity	29.8	33.0	3.2	0	0
N-1093	508345	5444797	Manhole	Gravity	87.8	89.7	2.0	0	0
N-111	508160	5445630	Model Node	Culvert	94.1	96.6	2.5	0	0
N-1110	509734	5444752	Manhole	Gravity	66.5	68.3	1.8	0	0
N-1122	510451	5444722	Manhole	Gravity	49.4	52.4	3.0	0	0
N-1124	509629	5445545	Manhole	Gravity	70.6	72.0	1.4	0	0
N-1138	510980	5445562	Manhole	Gravity	42.1	43.3	1.3	0	0
N-114	511354	5445348	Model Node	Watercourse	25.9	30.9	5.0	0	0
N-1141	508142	5444803	Manhole	Gravity	89.5	92.2	2.7	0	0
N-1142	509616	5445717	Manhole	Gravity	72.6	74.4	1.8	0	0
N-1143	510409	5445690	Manhole	Gravity	54.5	57.2	2.6	0	0
N-1144	508025	5444398	Manhole	Gravity	94.6	96.6	2.0	0	0
N-1150	509633	5444140	Manhole	Gravity	74.0	77.5	3.5	0	0
N-1153	509471	5445544	Manhole	Gravity	75.0	76.2	1.2	0	0
N-1155	508910	5443948	Manhole	Gravity	87.3	88.6	1.3	0	0
N-1157	510854	5443943	Manhole	Gravity	63.9	65.2	1.3	0	0
N-1159	510447	5444486	Manhole	Gravity	55.4	57.4	2.0	0	0
N-1161	508323	5445470	Model Node	Culvert	89.4	90.4	1.0	0	0
N-1166	509638	5444353	Manhole	Gravity	71.5	74.5	3.0	0	0
N-1180	510836	5443931	Manhole	Gravity	63.1	65.2	2.1	0	0

Node ID	X Cooridinate	Y Coordinate	Description	Conduit Shape	Invert Elev. (m)	Rim Elev. (m)	Depth (m)	Surchage Depth (m)	Ponded Area (m2)
N-219	511233	5445344	Model Node	Watercourse	28.0	38.0	10.0	0	0
N-2200	509410	5445252	Model Node	Ditch	74.9	76.9	2.0	0	0
N-2223	511248	5443011	Manhole	Gravity	70.8	72.1	1.2	0	0
N-2237	511239	5444194	Manhole	Gravity	47.9	49.8	1.8	0	0
N-224	508263	5445491	Manhole	Gravity	89.6	92.6	3.0	0	0
N-226	510554	5444735	Manhole	Culvert	45.9	47.3	1.4	0	0
N-231	510053	5444643	Manhole	Gravity	59.0	62.0	3.0	0	0
N-232	510040	5444643	Manhole	Gravity	59.1	60.9	1.8	0	0
N-2356	510097	5445799	Model Node	Watercourse	60.7	64.7	4.0	0	0
N-2374	510403	5446174	Model Node	Watercourse	65.4	69.4	4.0	0	0
N-2375	510230	5446157	Model Node	Watercourse	66.1	70.1	4.0	0	0
N-24	509508	5444348	Model Node	Ditch	75.7	77.7	2.0	0	0
N-242	509972	5446842	Manhole	Gravity	78.9	82.0	3.1	0	0
N-2456	511456	5444628	Manhole	Gravity	29.6	35.4	5.7	0	0
N-2465	509662	5445049	Model Node	Gravity	67.4	70.6	3.3	0	0
N-249	510848	5443624	Manhole	Gravity	68.7	70.6	1.9	0	0
N-251	509617	5445123	Manhole	Gravity	68.0	70.1	2.2	0	0
N-253	510848	5443527	Manhole	Gravity	70.4	72.1	1.7	0	0
N-255	510283	5443932	Manhole	Gravity	70.1	72.8	2.7	0	0
N-256	509616	5445595	Manhole	Gravity	71.3	72.7	1.3	0	0
N-257	510642	5444792	Manhole	Gravity	44.2	47.2	3.0	0	0
N-2584	508572	5445067	Manhole	Gravity	87.1	89.0	2.0	0	0
N-261	510057	5446366	Manhole	Gravity	70.4	73.2	2.8	0	0
N-263	510747	5443932	Manhole	Gravity	64.3	65.8	1.5	0	0
N-264	509422	5446344	Manhole	Gravity	81.5	84.1	2.6	0	0
N-267	509505	5444346	Manhole	Gravity	75.8	78.8	3.0	0	0
N-269	509616	5445637	Manhole	Gravity	71.8	73.4	1.7	0	0
N-270	509320	5445614	Manhole	Gravity	77.7	79.4	1.7	0	0
N-272	510388	5446244	Manhole	Gravity	65.9	68.9	3.0	0	0
N-281	508296	5445462	Manhole	Gravity	88.9	91.3	2.4	0	0
N-290	511402	5443790	Manhole	Watercourse	47.3	50.3	3.0	0	0
N-292	509634	5445529	Manhole	Gravity	69.8	71.7	1.8	0	0
N-297	510845	5445559	Manhole	Gravity	44.2	45.8	1.7	0	0
N-298	508342	5445201	Manhole	Gravity	88.0	89.5	1.5	0	0
N-300	511476	5444619	Manhole	Gravity	27.0	29.7	2.7	0	0
N-3001	511938	5444292	Model Node	Watercourse	16.7	21.7	5.0	0	0
N-3003	511844	5444249	Model Node	Watercourse	19.2	24.2	5.0	0	0
N-3004	511319	5445549	Model Node	Watercourse	29.8	34.8	5.0	0	0
N-302	510835	5444160	Manhole	Gravity	57.6	60.2	2.6	0	0
N-306	511460	5444626	Manhole	Gravity	29.1	34.9	5.8	0	0
N-309	510041	5444541	Manhole	Gravity	59.9	61.7	1.9	0	0
N-311	511246	5443532	Manhole	Gravity	63.5	65.4	2.0	0	0
N-312	510446	5444722	Manhole	Gravity	49.4	53.9	4.5	0	0
N-315	509514	5444355	Manhole	Gravity	75.1	76.4	1.3	0	0
N-316	509212	5444346	Manhole	Gravity	80.0	82.1	2.2	0	0
N-319	510739	5444533	Manhole	Gravity	47.9	50.6	2.7	0	0
N-321	510447	5444268	Manhole	Gravity	59.7	61.6	2.0	0	0
N-322	510738	5444739	Manhole	Gravity	44.4	47.9	3.5	0	0
N-323	510850	5443227	Manhole	Gravity	74.7	76.8	2.1	0	0

N-1183	509092	5443956	Manhole	Gravity	83.1	84.5	1.5	0	0
N-1187	508283	5445473	Manhole	Gravity	89.1	91.9	2.7	0	0
N-1196	509429	5443934	Manhole	Gravity	81.1	82.5	1.4	0	0
N-1199	510307	5443128	Manhole	Gravity	81.4	83.1	1.8	0	0
N-12	510380	5445879	Model Node	Watercourse	58.2	62.2	4.0	0	0
N-121	510201	5446078	Model Node	Watercourse	62.6	66.6	4.0	0	0
N-1211	508121	5444791	Manhole	Gravity	90.2	92.4	2.2	0	0
N-1212	510847	5443917	Manhole	Gravity	64.0	65.3	1.3	0	0
N-1213	509616	5445839	Manhole	Gravity	73.9	75.3	1.4	0	0
N-1214	510282	5445537	Manhole	Gravity	55.0	57.6	2.7	0	0
N-1215	508309	5444797	Manhole	Gravity	87.9	89.9	1.9	0	0
N-1217	508016	5445196	Manhole	Gravity	92.2	94.5	2.4	0	0
N-1220	511228	5445493	Manhole	Gravity	29.3	32.9	3.6	0	0
N-1222	510447	5444143	Manhole	Gravity	62.1	64.4	2.3	0	0
N-1227	509413	5444343	Manhole	Gravity	77.0	78.8	1.8	0	0
N-124	510672	5445120	Model Node	Watercourse	40.0	46.0	6.0	0	0
N-1247	511249	5442832	Manhole	Gravity	71.6	73.1	1.5	0	0
N-125	508342	5445411	Manhole	Gravity	88.4	90.2	1.8	0	0
N-1254	510104	5446231	Manhole	Gravity	66.4	69.7	3.2	0	0
N-1257	509486	5443932	Manhole	Gravity	80.6	81.9	1.4	0	0
N-1258	508598	5446386	Manhole	Gravity	90.2	93.2	3.0	0	0
N-1263	510011	5446348	Manhole	Gravity	71.2	73.7	2.5	0	0
N-1271	511384	5443604	Manhole	Gravity	57.8	60.1	2.2	0	0
N-1277	509567	5444358	Manhole	Gravity	72.9	74.5	1.5	0	0
N-1278	509277	5444345	Manhole	Gravity	79.2	81.2	2.1	0	0
N-1279	509359	5444342	Manhole	Gravity	77.2	79.6	2.4	0	0
N-1283	509618	5444359	Manhole	Gravity	71.5	73.8	2.4	0	0
N-1284	509642	5444838	Manhole	Gravity	67.3	70.3	3.0	0	0
N-1285	509014	5446369	Manhole	Gravity	85.4	88.3	2.9	0	0
N-1286	509124	5446363	Manhole	Gravity	84.5	87.7	3.2	0	0
N-129	509428	5444798	Model Node	Watercourse	70.9	72.9	2.0	0	0
N-1290	509513	5446339	Manhole	Gravity	80.3	83.2	2.9	0	0
N-1295	510436	5443932	Manhole	Gravity	67.5	69.0	1.5	0	0
N-1299	510426	5445539	Manhole	Gravity	53.3	55.9	2.7	0	0
N-13	510384	5445816	Model Node	Watercourse	56.8	60.8	4.0	0	0
N-130	509411	5444838	Model Node	Ditch	74.5	76.5	2.0	0	0
N-1301	510455	5444922	Manhole	Gravity	46.1	49.1	3.0	0	0
N-1302	510445	5445088	Manhole	Gravity	44.8	47.8	3.0	0	0
N-1303	510450	5445511	Manhole	Gravity	51.8	54.8	3.0	0	0
N-1304	510441	5445540	Manhole	Gravity	52.0	55.8	3.8	0	0
N-1307	510553	5444752	Model Node	Culvert	45.8	48.1	2.3	0	0
N-131	510555	5444756	Model Node	Watercourse	45.8	49.8	4.0	0	0
N-1316	509005	5446370	Manhole	Gravity	85.5	88.3	2.8	0	0
N-1318	508266	5445489	Manhole	Gravity	89.6	92.6	3.0	0	0
N-132	510552	5444736	Manhole	Culvert	45.9	48.9	3.0	0	0
N-1320	509391	5445563	Manhole	Gravity	75.9	77.5	1.5	0	0
N-1326	509924	5445533	Manhole	Gravity	64.5	66.4	1.9	0	0
N-133	510705	5445081	Model Node	Watercourse	39.2	45.2	6.0	0	0
N-1334	508437	5445041	Manhole	Gravity	86.9	88.9	2.0	0	0
N-1335	508438	5445041	Manhole	Gravity	86.9	88.9	2.0	0	0
N-1338	508161	5445591	Manhole	Gravity	92.7	93.8	1.1	0	0
N-1339	510438	5445597	Manhole	Gravity	52.5	56.2	3.7	0	0
N-134	510734	5445033	Model Node	Watercourse	37.3	47.3	10.0	0	0
N-1367	509195	5444251	Model Node	Culvert	82.7	85.7	3.0	0	0
N-1369	509264	5444271	Model Node	Culvert	81.5	83.2	1.7	0	0
N-1381	509708	5445062	Model Node	Culvert	66.1	69.1	3.0	0	0
N-1384	509736	5445067	Model Node	Culvert	66.0	69.0	3.0	0	0
N-1387	509766	5445070	Model Node	Culvert	65.8	68.8	3.0	0	0
N-1398	509633	5444350	Manhole	Gravity	71.5	73.9	2.4	0	0
N-14	511430	5445194	Model Node	Watercourse	24.8	29.8	5.0	0	0

N-326	508652	5444364	Manhole	Gravity	89.1	91.5	2.4	0	0
N-329	508123	5444393	Manhole	Gravity	93.3	95.1	1.9	0	0
N-33	509703	5445061	Model Node	Culvert	66.1	69.2	3.1	0	0
N-330	510447	5444415	Manhole	Gravity	56.8	58.7	1.9	0	0
N-332	511264	5444097	Manhole	Gravity	50.0	52.6	2.6	0	0
N-336	509736	5444754	Manhole	Gravity	66.4	68.2	1.9	0	0
N-338	508909	5444915	Manhole	Gravity	84.7	87.7	3.0	0	0
N-339	509619	5444649	Manhole	Gravity	70.8	72.6	1.8	0	0
N-34	509731	5445066	Model Node	Culvert	66.0	69.4	3.5	0	0
N-342	508280	5445199	Manhole	Gravity	87.8	89.6	1.8	0	0
N-348	508720	5446383	Manhole	Gravity	88.6	90.5	1.9	0	0
N-349	511194	5445567	Manhole	Gravity	31.2	34.0	2.8	0	0
N-35	509761	5445069	Model Node	Culvert	65.9	69.3	3.5	0	0
N-351	510996	5445562	Manhole	Gravity	41.8	43.0	1.2	0	0
N-352	510900	5445560	Manhole	Gravity	43.3	44.8	1.4	0	0
N-355	510034	5445536	Manhole	Gravity	60.7	62.9	2.2	0	0
N-358	510437	5443782	Manhole	Gravity	71.2	73.5	2.3	0	0
N-365	509936	5443134	Manhole	Gravity	83.8	85.6	1.8	0	0
N-367	509468	5445556	Manhole	Gravity	74.4	76.3	1.9	0	0
N-368	509617	5445230	Manhole	Gravity	68.6	70.6	1.9	0	0
N-369	508385	5445040	Manhole	Gravity	87.0	88.8	1.8	0	0
N-37	508802	5444998	Model Node	Watercourse	85.2	89.2	4.0	0	0
N-371	508342	5445117	Manhole	Gravity	87.6	89.1	1.5	0	0
N-38	508812	5444994	Model Node	Watercourse	85.2	89.2	4.0	0	0
N-381	509025	5444852	Manhole	Gravity	81.4	84.4	3.0	0	0
N-384	509589	5446335	Manhole	Gravity	79.3	82.1	2.8	0	0
N-385	510079	5443130	Manhole	Gravity	82.0	84.1	2.2	0	0
N-386	508347	5445040	Manhole	Gravity	87.4	88.9	1.5	0	0
N-388	509208	5445860	Manhole	Gravity	81.7	83.2	1.5	0	0
N-39	508886	5444934	Manhole	Gravity	84.7	87.7	3.0	0	0
N-391	510135	5446143	Manhole	Gravity	64.5	67.8	3.3	0	0
N-395	510169	5444746	Manhole	Gravity	56.8	59.0	2.2	0	0
N-40	508948	5444882	Model Node	Watercourse	82.0	86.0	4.0	0	0
N-406	511201	5445555	Manhole	Gravity	30.8	33.8	3.0	0	0
N-412	508134	5445198	Manhole	Gravity	89.8	91.3	1.5	0	0
N-420	509547	5443930	Manhole	Gravity	79.6	81.0	1.4	0	0
N-446	511099	5445709	Manhole	Gravity	40.9	43.9	3.0	0	0
N-453	509617	5445160	Manhole	Gravity	68.2	70.2	2.0	0	0
N-456	510040	5444361	Manhole	Gravity	61.7	64.3	2.6	0	0
N-457	510441	5445539	Manhole	Gravity	51.9	55.8	3.9	0	0
N-46	510599	5445240	Model Node	Gravity	41.8	49.8	8.0	0	0
N-460	511299	5444100	Manhole	Gravity	49.0	51.3	2.3	0	0
N-465	508346	5444950	Manhole	Gravity	87.6	89.1	1.5	0	0
N-466	509626	5443394	Manhole	Gravity	81.9	83.4	1.5	0	0
N-471	509926	5446961	Manhole	Gravity	81.8	83.6	1.8	0	0
N-472	510447	5444247	Manhole	Gravity	60.0	62.1	2.1	0	0
N-477	510331	5446889	Manhole	Gravity	71.3	74.1	2.8	0	0
N-479	510112	5444745	Manhole	Gravity	57.0	59.2	2.2	0	0
N-480	509828	5445532	Manhole	Gravity	66.4	68.4	2.0	0	0
N-483	510413	5446361	Manhole	Gravity	66.3	68.4	2.1	0	0
N-486	508907	5446375	Manhole	Gravity	86.7	88.3	1.6	0	0
N-488	509057	5444351	Manhole	Gravity	81.0	83.1	2.1	0	0
N-493	509208	5445916	Manhole	Gravity	82.0	83.7	1.7	0	0
N-497	510428	5445270	Manhole	Gravity	50.0	52.4	2.4	0	0
N-500	510429	5443137	Manhole	Gravity	80.5	82.0	1.5	0	0
N-501	510355	5443138	Manhole	Gravity	81.0	82.5	1.5	0	0
N-503	508342	5445048	Manhole	Gravity	87.5	88.9	1.5	0	0
N-51	511190	5445575	Manhole	Gravity	32.0	37.1	5.1	0	0
N-511	509000	5446370	Manhole	Gravity	85.6	88.3	2.7	0	0
N-515	509485	5444341	Manhole	Gravity	76.0	77.6	1.6	0	0

N-1401	510404	5446203	Model Node	Watercourse	65.8	69.8	4.0	0	0
N-1403	510473	5445434	Model Node	Watercourse	50.6	56.6	6.0	0	0
N-1404	509803	5445000	Manhole	Gravity	64.0	65.2	1.2	0	0
N-1408	510452	5443287	Manhole	Gravity	77.7	79.8	2.1	0	0
N-141	510422	5445610	Manhole	Gravity	52.7	55.1	2.4	0	0
N-1425	509190	5444252	Model Node	Culvert	82.7	85.0	2.3	0	0
N-1427	511240	5443942	Manhole	Gravity	65.9	67.4	1.6	0	0
N-143	509035	5444854	Model Node	Watercourse	80.9	83.9	3.0	0	0
N-1433	509114	5443955	Manhole	Gravity	82.9	84.6	1.6	0	0
N-1434	509188	5444253	Model Node	Ditch	82.7	84.7	2.0	0	0
N-1443	508203	5445586	Model Node	Culvert	92.9	94.4	1.5	0	0
N-1460	508142	5445621	Manhole	Gravity	93.1	96.1	3.0	0	0
N-1467	509617	5445163	Manhole	Gravity	68.2	70.2	2.1	0	0
N-1469	511249	5442741	Manhole	Gravity	72.1	73.3	1.2	0	0
N-1476	509633	5444185	Manhole	Gravity	73.2	77.2	4.1	0	0
N-1482	511384	5443764	Manhole	Gravity	56.2	57.9	1.7	0	0
N-1493	510846	5443914	Manhole	Gravity	64.0	65.3	1.3	0	0
N-1495	510835	5444154	Manhole	Gravity	57.8	60.3	2.5	0	0
N-1496	509634	5443948	Manhole	Gravity	78.0	79.7	1.6	0	0
N-1497	510181	5444757	Manhole	Gravity	56.4	59.4	3.0	0	0
N-15	511451	5445032	Model Node	Watercourse	23.4	28.4	5.0	0	0
N-1501	510202	5446043	Model Node	Watercourse	62.5	66.5	4.0	0	0
N-1502	510246	5445630	Model Node	Gravity	55.1	59.1	4.0	0	0
N-1503	510410	5445623	Model Node	Watercourse	53.1	57.1	4.0	0	0
N-1504	510549	5445333	Model Node	Watercourse	46.8	52.8	6.0	0	0
N-1505	510470	5445439	Model Node	Watercourse	50.8	56.8	6.0	0	0
N-1506	510537	5445253	Model Node	Watercourse	45.7	53.7	8.0	0	0
N-1507	509826	5444876	Model Node	Watercourse	61.9	67.9	6.0	0	0
N-1508	510668	5445014	Model Node	Watercourse	37.9	47.9	10.0	0	0
N-1509	510648	5445140	Model Node	Watercourse	40.6	46.6	6.0	0	0
N-1510	510913	5445126	Model Node	Watercourse	34.8	44.8	10.0	0	0
N-1511	510983	5445184	Model Node	Watercourse	33.1	43.1	10.0	0	0
N-1512	511728	5444534	Model Node	Watercourse	18.1	21.1	3.0	0	0
N-1513	511475	5444674	Model Node	Watercourse	20.3	25.3	5.0	0	0
N-1514	511240	5444097	Manhole	Gravity	50.9	52.6	1.7	0	0
N-1517	510549	5444734	Model Node	Watercourse	45.9	49.9	4.0	0	0
N-1518	509900	5444445	Model Node	Watercourse	66.7	70.2	3.5	0	0
N-1519	510542	5444914	Model Node	Watercourse	41.8	45.3	3.5	0	0
N-152	510271	5444844	Model Node	Watercourse	55.8	59.3	3.5	0	0
N-1520	509604	5444830	Model Node	Watercourse	68.9	74.9	6.0	0	0
N-1521	509303	5444777	Model Node	Watercourse	73.4	77.4	4.0	0	0
N-1522	509119	5444797	Model Node	Watercourse	78.1	82.1	4.0	0	0
N-1523	509411	5444958	Model Node	Ditch	74.6	76.6	2.0	0	0
N-153	510373	5444930	Model Node	Watercourse	51.3	54.8	3.5	0	0
N-154	509000	5444849	Manhole	Gravity	81.6	84.6	3.0	0	0
N-1541	510429	5443143	Manhole	Gravity	80.3	82.1	1.7	0	0
N-155	509203	5444773	Model Node	Watercourse	75.8	79.8	4.0	0	0
N-1557	511144	5445657	Model Node	Watercourse	34.6	36.6	2.0	0	0
N-1558	510631	5445184	Model Node	Watercourse	41.7	47.7	6.0	0	0
N-156	508338	5445429	Model Node	Gravity	88.4	93.3	4.8	0	0
N-1564	509410	5445109	Model Node	Culvert	74.8	78.3	3.6	0	0
N-1566	507986	5444396	Manhole	Gravity	95.7	98.7	3.0	0	0
N-1567	510832	5444533	Manhole	Gravity	48.7	51.2	2.5	0	0
N-1569	510439	5443535	Manhole	Gravity	75.3	77.2	1.9	0	0
N-157	510427	5444926	Manhole	Gravity	46.4	50.7	4.3	0	0
N-1573	509637	5443562	Manhole	Gravity	80.7	82.5	1.8	0	0
N-1577	510439	5443432	Manhole	Gravity	76.3	78.4	2.1	0	0
N-1578	511271	5443132	Manhole	Gravity	69.8	71.6	1.8	0	0
N-158	510181	5444724	Manhole	Gravity	56.6	58.4	1.7	0	0
N-1583	510848	5443436	Manhole	Gravity	71.8	74.1	2.3	0	0

N-520	510350	5443932	Manhole	Gravity	68.1	70.7	2.6	0	0
N-521	510376	5443932	Manhole	Gravity	68.0	69.7	1.8	0	0
N-524	508799	5446006	Manhole	Gravity	84.6	87.4	2.8	0	0
N-531	508804	5446380	Manhole	Gravity	87.6	88.8	1.2	0	0
N-538	510151	5446101	Manhole	Gravity	64.3	67.3	3.0	0	0
N-541	510804	5443931	Manhole	Gravity	64.0	65.5	1.5	0	0
N-542	509634	5446347	Manhole	Gravity	78.8	81.6	2.8	0	0
N-55	510629	5445190	Model Node	Watercourse	41.8	47.8	6.0	0	0
N-551	510850	5443134	Manhole	Gravity	75.7	78.2	2.5	0	0
N-553	508342	5445195	Manhole	Gravity	87.7	89.9	2.2	0	0
N-554	508342	5445197	Manhole	Gravity	87.7	89.7	2.0	0	0
N-555	508342	5445213	Manhole	Gravity	88.1	89.3	1.2	0	0
N-56	510643	5445155	Model Node	Watercourse	40.8	46.8	6.0	0	0
N-560	509617	5446345	Manhole	Gravity	79.1	81.8	2.6	0	0
N-564	509916	5446984	Manhole	Gravity	81.9	83.9	1.9	0	0
N-565	511317	5444101	Manhole	Gravity	48.8	50.8	2.1	0	0
N-566	509823	5444985	Manhole	Gravity	63.5	65.7	2.1	0	0
N-568	509147	5444348	Manhole	Gravity	80.3	82.4	2.1	0	0
N-569	511264	5444750	Manhole	Gravity	33.9	36.9	3.0	0	0
N-57	510802	5445023	Model Node	Gravity	37.0	41.0	4.0	0	0
N-570	509617	5445285	Manhole	Gravity	69.0	70.9	2.0	0	0
N-572	509629	5445542	Manhole	Gravity	70.1	71.9	1.8	0	0
N-574	509729	5445530	Manhole	Gravity	67.8	69.9	2.1	0	0
N-58	511064	5445118	Model Node	Watercourse	31.9	41.9	10.0	0	0
N-59	511114	5445202	Model Node	Watercourse	30.1	40.1	10.0	0	0
N-596	510449	5443835	Manhole	Gravity	71.2	74.2	3.0	0	0
N-597	508121	5444804	Manhole	Gravity	90.1	91.9	1.8	0	0
N-60	511085	5445126	Model Node	Gravity	31.3	41.3	10.0	0	0
N-601	510413	5443137	Manhole	Gravity	80.6	81.9	1.3	0	0
N-604	509212	5445670	Manhole	Gravity	79.2	82.2	3.0	0	0
N-61	511150	5445245	Model Node	Watercourse	29.3	39.3	10.0	0	0
N-610	511282	5443603	Manhole	Gravity	60.8	63.0	2.3	0	0
N-62	511201	5445259	Model Node	Watercourse	29.1	39.1	10.0	0	0
N-622	509722	5446344	Manhole	Gravity	77.1	78.9	1.8	0	0
N-63	511214	5445331	Model Node	Watercourse	28.6	38.9	10.3	0	0
N-637	509615	5445531	Manhole	Gravity	71.3	72.4	1.1	0	0
N-64	511213	5445316	Model Node	Watercourse	28.8	31.8	3.0	0	0
N-641	509628	5443148	Manhole	Gravity	84.1	86.0	1.8	0	0
N-642	508642	5446385	Manhole	Gravity	89.4	90.9	1.5	0	0
N-645	509417	5443935	Manhole	Gravity	81.3	82.6	1.2	0	0
N-65	511220	5445345	Model Node	Watercourse	28.1	38.1	10.0	0	0
N-655	511634	5444146	Manhole	Watercourse	25.1	28.1	3.0	0	0
N-660	509991	5443133	Manhole	Gravity	83.5	84.9	1.4	0	0
N-661	509634	5443929	Manhole	Gravity	78.3	79.8	1.5	0	0
N-669	511245	5443586	Manhole	Gravity	62.6	64.5	1.9	0	0
N-67	510163	5445077	Model Node	Watercourse	51.3	54.3	3.0	0	0
N-672	510440	5445264	Manhole	Gravity	49.8	52.2	2.4	0	0
N-674	510410	5445682	Manhole	Gravity	54.5	57.5	3.0	0	0
N-676	508397	5445040	Manhole	Gravity	87.0	89.1	2.2	0	0
N-68	510120	5445048	Model Node	Watercourse	51.7	54.7	3.0	0	0
N-688	510200	5446230	Manhole	Gravity	65.5	68.3	2.7	0	0
N-690	508593	5445077	Manhole	Gravity	86.4	89.8	3.4	0	0
N-691	508597	5445079	Model Node	Watercourse	86.4	90.4	4.0	0	0
N-694	511249	5442651	Manhole	Gravity	72.7	75.7	3.0	0	0
N-696	510446	5444554	Manhole	Gravity	52.3	55.1	2.8	0	0
N-70	511215	5445341	Model Node	Watercourse	28.3	31.3	3.0	0	0
N-701	509081	5443945	Manhole	Gravity	83.3	84.6	1.3	0	0
N-704	509634	5444036	Manhole	Gravity	75.5	78.2	2.8	0	0
N-705	510853	5443931	Manhole	Gravity	63.9	65.1	1.2	0	0
N-706	509210	5445761	Manhole	Gravity	80.8	82.9	2.1	0	0

N-1585	511270	5443222	Manhole	Gravity	68.4	70.7	2.3	0	0
N-1586	510168	5445934	Manhole	Gravity	60.8	63.1	2.3	0	0
N-1588	510427	5446553	Manhole	Gravity	68.2	71.5	3.3	0	0
N-159	510026	5444643	Manhole	Gravity	60.0	62.8	2.8	0	0
N-1592	511269	5443312	Manhole	Gravity	66.7	69.3	2.6	0	0
N-16	511402	5444841	Model Node	Watercourse	21.3	27.3	6.0	0	0
N-1607	511384	5443718	Manhole	Gravity	56.7	58.8	2.2	0	0
N-1609	510328	5446628	Manhole	Gravity	69.1	71.4	2.4	0	0
N-1612	511239	5444284	Manhole	Gravity	45.1	46.9	1.8	0	0
N-1615	510427	5446498	Manhole	Gravity	67.3	71.0	3.7	0	0
N-1623	511237	5444554	Manhole	Gravity	37.5	39.2	1.7	0	0
N-1626	509627	5443272	Manhole	Gravity	82.4	84.0	1.6	0	0
N-1627	511268	5443418	Manhole	Gravity	65.2	67.5	2.2	0	0
N-1629	510039	5444431	Manhole	Gravity	60.6	62.9	2.3	0	0
N-1632	510843	5444434	Manhole	Gravity	50.7	52.9	2.2	0	0
N-1640	510848	5443670	Manhole	Gravity	68.3	70.3	2.1	0	0
N-1641	510738	5444676	Manhole	Gravity	46.3	48.3	2.0	0	0
N-1649	511268	5443509	Manhole	Gravity	63.8	65.7	2.0	0	0
N-1652	510447	5444039	Manhole	Gravity	64.0	66.3	2.2	0	0
N-1654	509636	5443653	Manhole	Gravity	80.2	82.2	2.0	0	0
N-1655	508121	5444729	Manhole	Gravity	90.9	92.6	1.7	0	0
N-1656	510451	5443432	Manhole	Gravity	76.4	78.3	2.0	0	0
N-1674	510330	5446693	Manhole	Gravity	69.6	72.2	2.6	0	0
N-1676	511248	5443049	Manhole	Gravity	70.5	72.2	1.7	0	0
N-168	510423	5445093	Manhole	Gravity	44.9	48.2	3.2	0	0
N-1684	510427	5446361	Manhole	Gravity	66.5	69.0	2.5	0	0
N-1686	508344	5445509	Manhole	Gravity	89.4	92.3	2.8	0	0
N-1690	510413	5446341	Manhole	Gravity	66.2	67.8	1.6	0	0
N-1693	509736	5444773	Manhole	Gravity	65.9	67.8	1.9	0	0
N-1694	509637	5443544	Manhole	Gravity	81.1	82.5	1.4	0	0
N-1696	511238	5444375	Manhole	Gravity	42.4	44.3	1.9	0	0
N-1697	510846	5443828	Manhole	Gravity	64.9	67.3	2.4	0	0
N-17	511346	5444805	Model Node	Watercourse	27.6	33.6	6.0	0	0
N-170	508225	5445533	Model Node	Ditch	92.3	95.3	3.0	0	0
N-1706	510941	5443943	Manhole	Gravity	64.4	67.4	3.0	0	0
N-1710	510849	5443336	Manhole	Gravity	72.8	75.1	2.3	0	0
N-1712	511238	5444439	Manhole	Gravity	40.7	42.4	1.7	0	0
N-1714	510181	5446178	Manhole	Gravity	65.2	68.0	2.8	0	0
N-1717	510688	5444739	Manhole	Gravity	44.3	48.3	3.9	0	0
N-172	509495	5444340	Model Node	Ditch	75.9	77.9	2.0	0	0
N-1726	510427	5446461	Manhole	Gravity	67.3	70.6	3.4	0	0
N-1728	510166	5445921	Manhole	Gravity	60.7	63.7	3.0	0	0
N-173	509498	5444341	Manhole	Gravity	75.9	78.9	3.0	0	0
N-1738	507983	5445185	Manhole	Gravity	93.3	96.3	3.0	0	0
N-1741	510331	5446791	Manhole	Gravity	70.3	73.3	3.0	0	0
N-1744	510441	5443211	Manhole	Gravity	79.4	80.7	1.3	0	0
N-1745	509633	5443813	Manhole	Gravity	78.5	81.0	2.5	0	0
N-1755	510448	5443952	Manhole	Gravity	66.5	68.7	2.3	0	0
N-1758	511235	5444737	Manhole	Gravity	34.0	36.5	2.4	0	0
N-177	509275	5444340	Manhole	Gravity	79.7	82.7	3.0	0	0
N-1779	509636	5443680	Manhole	Gravity	80.0	81.9	1.9	0	0
N-178	509260	5444268	Model Node	Gravity	81.5	85.9	4.3	0	0
N-1784	509624	5443633	Manhole	Gravity	80.8	82.2	1.4	0	0
N-1789	510040	5444324	Manhole	Gravity	62.0	64.7	2.7	0	0
N-179	509265	5444272	Model Node	Ditch	81.5	83.5	2.0	0	0
N-1794	510835	5444061	Manhole	Gravity	59.5	62.8	3.3	0	0
N-18	511551	5444638	Model Node	Watercourse	19.4	22.4	3.0	0	0
N-1802	510439	5443504	Manhole	Gravity	75.6	77.5	1.9	0	0
N-181	510691	5444931	Model Node	Watercourse	40.4	44.4	4.0	0	0
N-1812	510446	5444556	Manhole	Gravity	52.2	57.3	5.0	0	0
N-709	508349	5445040	Manhole	Gravity	87.1	88.8	1.7	0	0
N-711	509626	5443486	Manhole	Gravity	81.4	82.7	1.4	0	0
N-714	508822	5444358	Manhole	Gravity	88.4	89.8	1.4	0	0
N-717	510067	5446597	Manhole	Gravity	74.5	77.3	2.8	0	0
N-718	509727	5444790	Manhole	Gravity	65.5	67.9	2.4	0	0
N-724	509618	5445072	Manhole	Gravity	67.6	69.7	2.1	0	0
N-727	510447	5445262	Manhole	Gravity	49.7	52.7	3.0	0	0
N-733	508346	5444802	Manhole	Gravity	87.7	89.4	1.7	0	0
N-734	510449	5443933	Manhole	Gravity	67.0	69.2	2.2	0	0
N-736	509108	5445966	Manhole	Gravity	83.1	84.8	1.7	0	0
N-738	511497	5443938	Manhole	Watercourse	37.2	40.2	3.0	0	0
N-74	510560	5445246	Model Node	Watercourse	44.9	52.9	8.0	0	0
N-740	510142	5445536	Manhole	Gravity	57.6	59.4	1.7	0	0
N-741	510448	5443984	Manhole	Gravity	66.3	69.3	3.0	0	0
N-743	511237	5444645	Manhole	Gravity	36.0	37.9	1.8	0	0
N-750	509554	5445536	Manhole	Gravity	73.2	74.4	1.1	0	0
N-752	509359	5446348	Manhole	Gravity	82.2	84.8	2.6	0	0
N-755	509919	5446345	Manhole	Gravity	72.0	74.1	2.1	0	0
N-758	509624	5443751	Manhole	Gravity	80.4	81.6	1.2	0	0
N-764	511228	5445555	Manhole	Gravity	29.8	33.0	3.1	0	0
N-768	510738	5444694	Manhole	Gravity	45.9	48.0	2.1	0	0
N-770	510136	5446420	Manhole	Gravity	69.7	73.4	3.7	0	0
N-776	510181	5444746	Manhole	Gravity	56.5	59.0	2.5	0	0
N-78	509879	5444914	Model Node	Watercourse	59.9	65.9	6.0	0	0
N-789	510429	5445091	Manhole	Gravity	44.9	48.7	3.8	0	0
N-79	509939	5444947	Model Node	Watercourse	58.2	64.2	6.0	0	0
N-798	510427	5446617	Manhole	Gravity	68.8	72.1	3.3	0	0
N-799	509320	5445664	Manhole	Gravity	78.2	79.7	1.5	0	0
N-8	511305	5445386	Model Node	Watercourse	26.8	31.8	5.0	0	0
N-80	508352	5445445	Manhole	Gravity	89.3	92.3	3.0	0	0
N-801	511247	5443427	Manhole	Gravity	65.2	67.2	2.0	0	0
N-804	511239	5444333	Manhole	Gravity	43.5	45.8	2.3	0	0
N-813	509618	5445040	Manhole	Gravity	67.5	69.8	2.3	0	0
N-815	510441	5443152	Manhole	Gravity	80.1	82.0	1.8	0	0
N-821	509835	5443135	Manhole	Gravity	84.2	86.1	2.0	0	0
N-823	510039	5444745	Manhole	Gravity	57.4	59.9	2.5	0	0
N-824	508073	5444394	Manhole	Gravity	94.1	95.4	1.3	0	0
N-826	510386	5445538	Manhole	Gravity	54.0	56.8	2.9	0	0
N-827	509625	5443542	Manhole	Gravity	81.1	82.5	1.4	0	0
N-828	509615	5445928	Manhole	Gravity	74.4	76.2	1.8	0	0
N-83	510579	5444997	Model Node	Watercourse	39.4	47.4	8.0	0	0
N-832	509616	5445549	Manhole	Gravity	70.9	72.3	1.4	0	0
N-833	509926	5444743	Manhole	Gravity	59.3	62.8	3.6	0	0
N-834	510447	5444390	Manhole	Gravity	57.3	59.1	1.8	0	0
N-836	511385	5443775	Manhole	Gravity	52.4	56.8	4.4	0	0
N-841	511239	5444338	Manhole	Gravity	43.5	45.1	1.7	0	0
N-842	510438	5443650	Manhole	Gravity	73.7	75.6	1.9	0	0
N-844	510172	5446328	Manhole	Gravity	66.9	70.3	3.4	0	0
N-846	508199	5445199	Manhole	Gravity	88.6	90.2	1.6	0	0
N-85	510211	5445098	Model Node	Gravity	49.6	55.6	6.0	0	0
N-852	509909	5447150	Manhole	Gravity	82.4	84.9	2.4	0	0
N-853	509619	5444740	Manhole	Gravity	70.4	72.0	1.6	0	0
N-855	508885	5445991	Manhole	Gravity	83.8	87.0	3.2	0	0
N-862	511244	5443139	Manhole	Gravity	69.5	71.6	2.1	0	0
N-863	508100	5445198	Manhole	Gravity	90.5	92.2	1.7	0	0
N-871	511324	5444133	Manhole	Gravity	47.1	49.8	2.7	0	0
N-878	510201	5443129	Manhole	Gravity	81.7	83.5	1.8	0	0
N-879	510844	5444334	Manhole	Gravity	52.8	54.8	2.0	0	0
N-880	511545	5444629	Manhole	Gravity	20.6	23.6	3.0	0	0
N-892	510389	5446295	Manhole	Gravity	66.0	67.3	1.3	0	0

N-1819	510834	5444325	Manhole	Gravity	53.0	55.2	2.2	0	0
N-182	510793	5445031	Model Node	Watercourse	37.1	47.1	10.0	0	0
N-1822	510365	5445935	Model Node	Culvert	59.7	62.7	3.0	0	0
N-1826	510385	5446286	Manhole	Gravity	65.9	68.9	3.0	0	0
N-1827	510384	5446283	Model Node	Watercourse	65.9	69.9	4.0	0	0
N-1828	510375	5445966	Manhole	Culvert	59.8	62.8	3.0	0	0
N-1829	510376	5446073	Model Node	Watercourse	62.4	66.4	4.0	0	0
N-1830	510403	5446172	Model Node	Watercourse	65.4	69.4	4.0	0	0
N-1832	510201	5446104	Model Node	Watercourse	64.6	68.6	4.0	0	0
N-1833	510178	5445997	Model Node	Watercourse	61.5	65.5	4.0	0	0
N-1834	510172	5445961	Manhole	Gravity	61.3	64.3	3.0	0	0
N-1835	510149	5445837	Model Node	Watercourse	59.1	63.1	4.0	0	0
N-1836	510409	5445700	Manhole	Gravity	54.8	56.8	1.9	0	0
N-184	510203	5446030	Model Node	Watercourse	61.7	64.7	3.0	0	0
N-1842	511387	5444913	Model Node	Watercourse	22.0	27.0	5.0	0	0
N-1843	508344	5445533	Manhole	Gravity	89.5	91.8	2.3	0	0
N-1845	511383	5443769	Manhole	Gravity	55.7	58.1	2.4	0	0
N-1846	511384	5443665	Manhole	Gravity	57.2	59.4	2.2	0	0
N-1847	510440	5443287	Manhole	Gravity	78.9	80.0	1.1	0	0
N-1851	510554	5444870	Model Node	Watercourse	43.1	47.1	4.0	0	0
N-1852	509410	5445100	Model Node	Ditch	74.7	76.7	2.0	0	0
N-1853	509410	5445104	Model Node	Culvert	74.7	76.2	1.5	0	0
N-19	510369	5445832	Model Node	Watercourse	57.4	60.4	3.0	0	0
N-1931	511247	5443438	Manhole	Gravity	65.0	67.1	2.1	0	0
N-1935	511075	5443942	Manhole	Gravity	65.0	68.0	3.0	0	0
N-1936	510841	5443931	Manhole	Gravity	63.8	65.2	1.4	0	0
N-1948	509114	5444142	Manhole	Gravity	82.8	84.1	1.3	0	0
N-1957	508342	5445218	Manhole	Gravity	88.1	89.8	1.7	0	0
N-1974	509634	5443961	Manhole	Gravity	77.9	79.4	1.5	0	0
N-20	510404	5446183	Model Node	Watercourse	65.5	68.5	3.0	0	0
N-202	511184	5445578	Model Node	Watercourse	33.7	35.7	2.0	0	0
N-211	508637	5445085	Model Node	Gravity	86.4	90.4	4.0	0	0
N-212	510165	5445813	Model Node	Gravity	57.6	61.6	4.0	0	0
N-213	510181	5445796	Model Node	Watercourse	57.2	61.2	4.0	0	0
N-214	510121	5445791	Model Node	Gravity	59.7	63.7	4.0	0	0
N-2152	510404	5446206	Model Node	Watercourse	65.8	69.8	4.0	0	0
N-218	510997	5445155	Model Node	Gravity	32.4	42.4	10.0	0	0
N-893	509826	5446343	Manhole	Gravity	74.0	77.3	3.3	0	0
N-894	509208	5445959	Manhole	Gravity	82.4	84.4	2.0	0	0
N-897	510888	5445560	Manhole	Gravity	43.5	44.9	1.4	0	0
N-898	511100	5445564	Manhole	Gravity	37.8	39.3	1.5	0	0
N-9	510407	5445792	Model Node	Watercourse	56.3	60.3	4.0	0	0
N-90	510223	5445102	Model Node	Watercourse	49.6	55.6	6.0	0	0
N-900	509958	5446876	Manhole	Gravity	80.2	82.7	2.5	0	0
N-901	510131	5443931	Manhole	Gravity	71.7	73.5	1.8	0	0
N-902	510444	5444642	Manhole	Gravity	51.4	55.4	4.1	0	0
N-908	508909	5444355	Manhole	Gravity	84.6	87.1	2.5	0	0
N-91	510731	5445032	Model Node	Watercourse	37.3	40.3	3.0	0	0
N-911	509081	5443900	Manhole	Gravity	83.5	84.6	1.1	0	0
N-912	508344	5445491	Manhole	Gravity	89.4	92.4	3.0	0	0
N-920	509511	5443932	Manhole	Gravity	80.3	81.5	1.2	0	0
N-921	510639	5444738	Manhole	Gravity	44.3	47.0	2.7	0	0
N-927	508725	5444361	Manhole	Gravity	88.9	91.0	2.1	0	0
N-930	510083	5443130	Manhole	Gravity	81.9	84.0	2.1	0	0
N-936	509627	5443289	Manhole	Gravity	82.3	83.9	1.6	0	0
N-938	510848	5443729	Manhole	Gravity	67.0	70.2	3.2	0	0
N-94	509739	5444810	Model Node	Gravity	64.8	70.8	6.0	0	0
N-940	509849	5444965	Manhole	Gravity	63.1	66.1	3.0	0	0
N-942	509633	5444128	Manhole	Gravity	74.1	77.5	3.4	0	0
N-952	509005	5443946	Manhole	Gravity	83.7	85.3	1.6	0	0
N-953	510207	5445537	Manhole	Gravity	56.4	58.0	1.6	0	0
N-955	509620	5443929	Manhole	Gravity	78.7	80.0	1.3	0	0
N-96	509672	5444842	Model Node	Watercourse	65.7	68.7	3.0	0	0
N-960	510556	5444752	Model Node	Culvert	45.8	47.7	1.9	0	0
N-968	511267	5443599	Manhole	Gravity	61.9	64.2	2.3	0	0
N-969	509648	5444751	Manhole	Gravity	69.7	70.9	1.2	0	0
N-97	510058	5444930	Model Node	Watercourse	54.3	60.3	6.0	0	0
N-975	511272	5443087	Manhole	Gravity	70.1	71.9	1.8	0	0
N-979	511537	5444620	Manhole	Gravity	23.1	24.7	1.6	0	0
N-98	510366	5445140	Model Node	Watercourse	47.3	55.3	8.0	0	0
N-983	510007	5446751	Manhole	Gravity	77.8	80.9	3.1	0	0
N-986	510315	5443139	Manhole	Gravity	81.2	82.9	1.7	0	0
N-989	509615	5446046	Manhole	Gravity	74.9	78.0	3.1	0	0
N-998	510037	5446675	Manhole	Gravity	76.2	78.9	2.7	0	0

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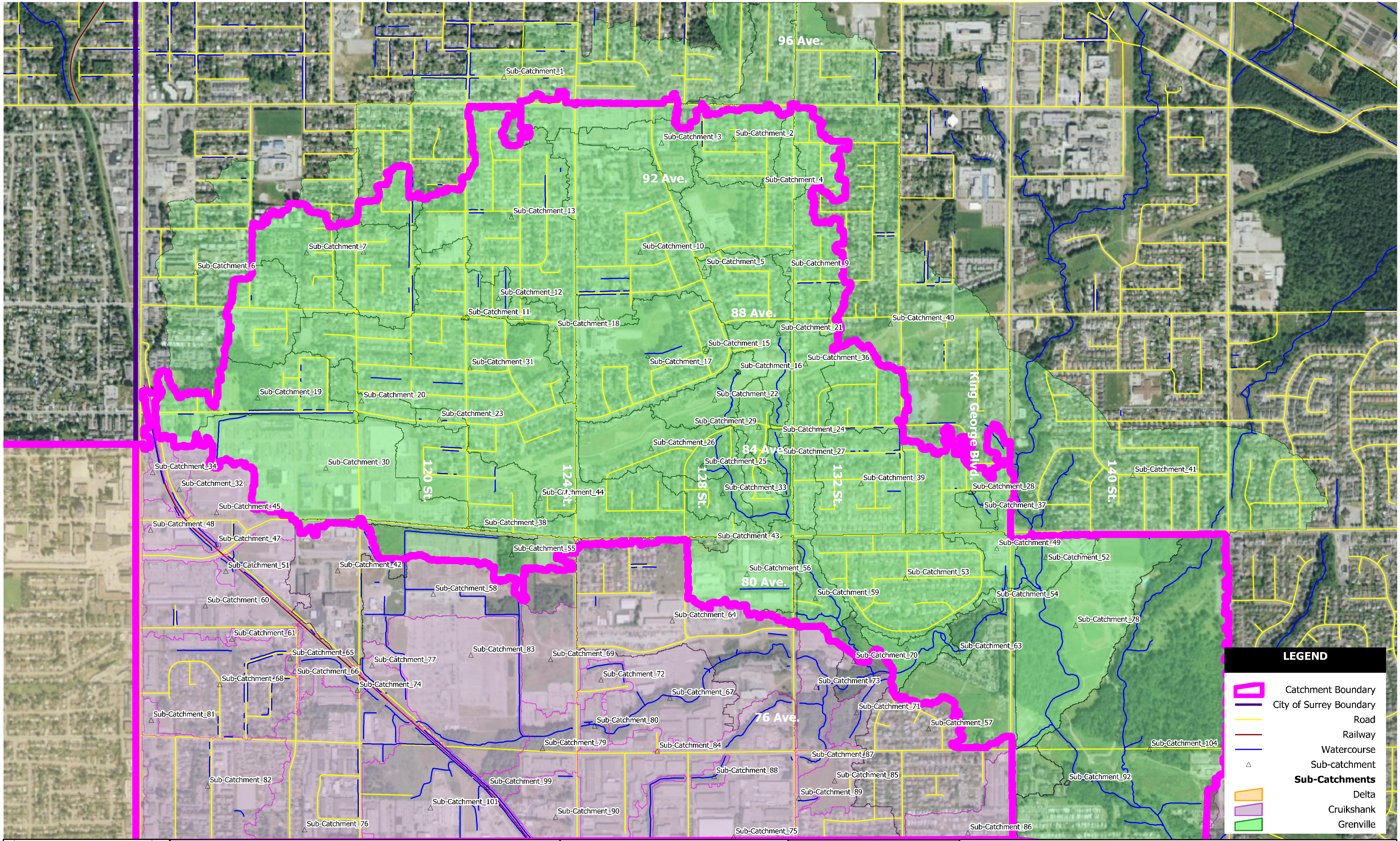

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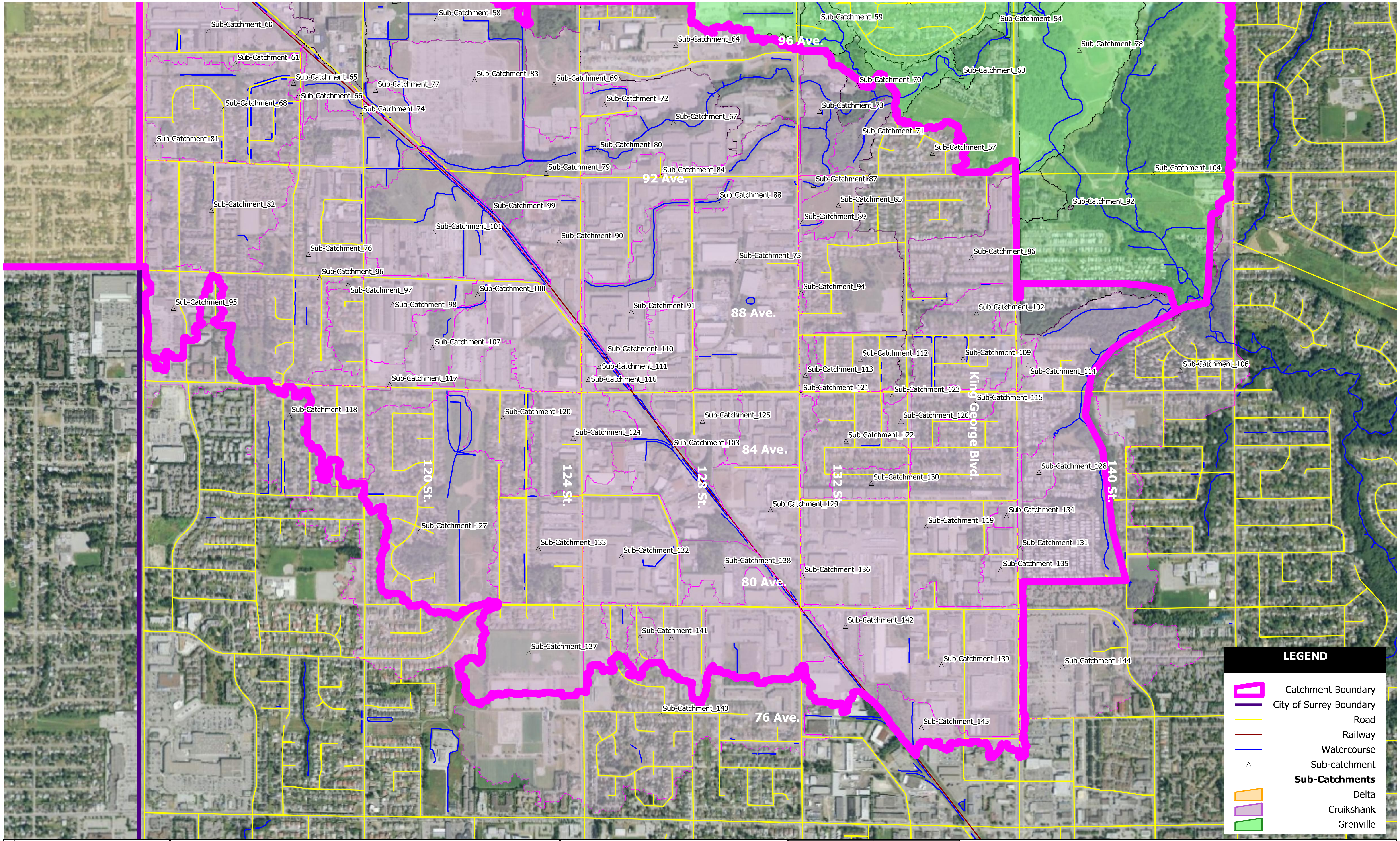
Map E-1: Sub-Catchment Delineation



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Map E-2: Sub-Catchment Delineation

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