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BON ACCORD - NORTH SLOPE (EAST) INTEGRATED STORMWATER MANAGEMENT PLAN

REPORT

MAY 2015

Associated Engineering

CANADA'S BEST MANAGED COMPANIES

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date 12 MAY 2015

#04-15-068

Executive Summary

1 INTEGRATED STORMWATER MANAGEMENT PLANNING

An Integrated Stormwater Management Plan (ISMP) is a comprehensive plan that links drainage servicing, land use planning, sustainability principles, and environmental protection and enhancement. Its purpose is to guide economic development in a way that maintains or enhances overall watershed health. A healthy watershed supports biodiversity and fish and stream health while protecting public property and safety through mitigation of erosion and flooding. This is accomplished by promoting sustainable rainwater management for the full spectrum of rainfall events and attempting to mimic the natural hydrologic processes of an undisturbed watershed. In an urban context, replicating an untouched watershed is not practical; however, this approach provides a significant improvement over historic urban stormwater management practices, and therefore is of great value.

2 STUDY AREA DESCRIPTION

The Bon Accord – North Slope (East) study area consists of seven watersheds: Bon Accord, 157 Street, 160 Street, Fraser Heights, Big Bend, Port Kells and Surrey Bend Regional Park.

The major watercourses in the study area include Bon Accord Creek, East Bon Accord Creek, Landfill Creek, 157 Street Creek, 160 Street Creek, Centre Creek, Lyncean Creek (East and West), Leoran Brook, and 184 Street Creek. Several minor, unnamed tributaries also drain down the north slope, discharging either to major watercourses or the lowlands.

Current Land Use and Development Plans

With the exception of Surrey Bend and ravine areas with generally steep topography, the watersheds are mostly built out with a mixture of residential, industrial and major transportation corridors comprising the primary land uses. The lowlands are not protected by a dyke system, and it is unlikely that any such system will be constructed in the future.

Very little new development is planned, with the exception of the Anniedale-Tynehead neighbourhood in Port Kells, which will see the conversion of a residentially zoned area to light-impact industrial. Approximately one-third of the Anniedale-Tynehead neighbourhood concept plan is located within the study area. Within the study area, the remainder of development is expected to be in the form of the redevelopment and densification of existing lots dispersed throughout the watersheds, as housing demand increases and businesses expand.

Environmental Conditions

A significant portion of the study area is intact green space. These areas are primarily located in deeply cut ravines along the north slope, and are not likely to be encroached upon by development due to topographic limitations. Surrey Bend Regional Park accounts for another considerable proportion of green space, and is protected under a joint initiative between the City of Surrey and Metro Vancouver, and identified as an area of ecological significance.

The City's Biodiversity Conservation Strategy (BCS) outlines several terrestrial hubs, sites, and movement corridors that support terrestrial biodiversity, and outlines recommendations for enhancing the ecology of the study area. The recommendations in the BCS directly support the enhancement of watershed health, and should be pursued in support of the objectives of this ISMP.

The watercourses in the study area range from highly modified, disturbed, and degraded channels and riparian areas, to undeveloped, high-value natural corridors and stream habitats. Historical development has resulted in the loss of open channels and headwater tributaries through piping or infilling, and habitat degradation through channel realignment, the alteration of flow regimes, and water quality degradation. Remnant natural sections of some watercourses are preserved as part of City parks or stream setback areas. Other natural stream sections are present in undeveloped areas along the steep north-facing slopes and in Surrey Bend Regional Park.

Hydrogeological Conditions

The surficial and subsurface soil characteristics and local physiography are generally not conducive to the successful infiltration of runoff. While much of the upland areas in Bon Accord, Fraser Heights, and Big Bend have moderate infiltration potential at the surface, impervious strata approximately 1.3 m below the surface restricts further infiltration. This can result in a perched water table and the promotion of lateral subsurface flow, which can translate into undesirable impacts to down-gradient infrastructure, or the destabilization of steep ravine banks. Infiltration-based source controls must therefore be approached with caution. In eastern Port Kells, the soils are well-drained and suitable for infiltration-based source controls, provided the influence of the Fraser River on groundwater levels is assessed.

Overall Watershed Health

The watersheds, although degraded by historical development, are in reasonable health in comparison to typical developed watersheds. This is due in part to the intact ravine areas. Limited testing of benthic invertebrate communities by the City indicates that Bon Accord Creek and Leoran Brook (the two watercourses tested in the study area) show scores exceeding the mean B-IBI score across the city for each sampling period, although they are still within the category of 'poor' health. Surrey Bend, although relatively undeveloped is fragmented and encroached upon by CN rail, the South Fraser Perimeter Road, and an operating sawmill; it also receives direct hydrologic input from the developed upland areas, and therefore is not wholly undisturbed.

Drainage and Erosion Concerns

Previous studies have discerned severe drainage limitations and erosion concerns in the East Bon Accord subwatershed, and proposed a peak flow diversion project to address this.

Our analysis of trunk systems in the minor drainage network (pipes receiving runoff from urban catchments of 20 ha or greater) indicate that the present development condition in eastern Port Kells is placing considerable strain on the system, with the potential for pipe surcharging and localized flooding.

Drainage through natural watercourses and the associated culverts appears to function adequately and without causing flooding to nearby properties.

Absent of mitigative measures, the Anniedale-Tynehead development poses the risk of accelerating erosion in downstream watercourses, particularly in Leoran Brook.

3 WATERSHED GOALS AND OBJECTIVES

Developed based on our assessment of the existing state of the watershed, the primary objectives of this ISMP are outlined in Table E-1.

Table E-1
Goals and Objectives for the Bon Accord – North Slope (East) ISMP

	Goals and Objectives
1.	Proactively address the implications of climate change on the drainage system to prevent flooding and promote the protection of public property and health.
2.	Direct long-term redevelopment and economic activity towards sustainable practices and support community initiatives set to accomplish this.
3.	Preserve existing green space and undeveloped lands.
4.	Protect Surrey Bend Regional Park by restricting further encroachment of development into the area and tempering development in the Big Bend watershed.
5.	Improve biodiversity by supporting the maintenance and enhancement of the Green Infrastructure Network described in the City's Biodiversity Conservation Strategy.
6.	Enhance watershed health through specific environmental enhancement projects, ravine restoration projects, enforcement of riparian setbacks and by including responsible stormwater management in all infrastructure projects, including road rehabilitation projects.
7.	Enhance aquatic habitat through the removal of historic constraints, and the restoration of degraded habitat, considering fish presence, fish potential, and inputs to downstream habitat.

4 IMPLEMENTATION, ENFORCEMENT, AND FUNDING

Improvement Projects
To address the identified drainage concerns, the following drainage projects should be pursued:

- Proceed with the current plans for the East Bon Accord peak flow diversion and incorporate environmental enhancement projects in the scope.
- Upgrade the relief sewer along the 194 Street alignment north of 96 Avenue to 1050 mm diameter.

Watershed health enhancement should be supported by undertaking 19 recommended environmental enhancement projects. Some of these projects may be incorporated with currently planned projects, while others must be undertaken as independent projects. The two environmental enhancement projects with the greatest urgency are:

- The removal of the old timber dam on Bon Accord Creek and associated stream corridor restoration, and
- The removal of a concrete flume on Bon Accord Creek upstream of Surrey Road.

These projects are listed as high priority as they would maximize the positive impacts of recent enhancement works completed on Bon Accord Creek as part of the South Fraser Perimeter Road.

The cost breakdown for the recommended drainage and environmental enhancement projects is provided in Table E-2.

Table E-2
Cost for Recommended Drainage and Environmental Enhancement Projects

Project Location	Drainage Project Cost	Environmental Project Cost(2)	Total Cost
Bon Accord Watershed	$22,790,000(1)	$755,000	$23,545,000
157 Street Watershed	$ -	$35,000	$35,000
160 Street Watershed	$ -	$35,000	$35,000
Fraser Heights Watershed	$ -	$105,000	$105,000
Big Bend Watershed	$ -	$25,000	$25,000
Port Kells Watershed	$444,600(3)	$380,000	$824,600
Surrey Bend Regional Park(4)	$ -	$ -	$ -
Total Study Area	$23,234,600	$1,335,000	$24,569,600
		Total + Contingency(5)	**$25,103,480**

Notes: 1) City-estimated cost for East Bon Accord peak flow diversion project, presently underway – refer to Appendix A for project definition reports.
2) Refer to Table 7-1 at the end of this section for a breakdown of environmental projects and their associated cost estimates by watershed.
3) Proposed Port Kells Trunk Relief – refer to Map 7-1 at the end of this section for project details.
4) Surrey Bend Regional Park conservation efforts are assumed to be paid jointly between the City of Surrey and Metro Vancouver and in line with the park's management plan; costs have therefore been excluded in this ISMP.
5) Contingency is applied as [(Total Drainage Cost + Total Environmental Cost – East Bon Accord Diversion Cost) x 1.3]. The diversion project is assumed to include its own contingency.

Source Control Implementation

Development in the Anniedale-Tynehead area must consciously incorporate source controls into the stormwater management efforts to manage the full spectrum of rainfall events and mitigate adverse impacts to receiving watercourses downstream. Redevelopment and densification of existing lots across the study area should be encouraged to incorporate source controls into landscaping and site plans, and should aim to meet relevant performance targets.

Table E-3 lists the most applicable source controls for each of the prominent land use types in the study area.

Table E-3
Applicable Source Controls by Land Use

Land Use	Applicable Source Controls
Residential	• Absorbent soils to capture and attenuate runoff. • Disconnection of roof leaders from the storm drains (for older houses being redeveloped). • Pervious pavements used for walkways, driveways and patios.
Industrial / Commercial	• Absorbent soils to capture and attenuate runoff. • Pervious pavements for walkways, parking areas and storage pads. • Bioswales, rather than below-grade piped systems to drain parking lots. • Green roofs to attenuate runoff. • Rain gardens to collect, treat and attenuate runoff.
Roadways	• Absorbent soils and landscaping trees to intercept, capture and attenuate runoff. • Pervious pavements for sidewalks and low-traffic parking areas. • Rain gardens to capture, treat and attenuate runoff. • Bioswales / enhanced ditches.

Funding Strategy

Successful implementation of the ISMP's recommendations will rely on the ability of the City to secure the necessary funding, and for private land owners, community groups, and environmental groups to become involved. Table E-4 lists options to cover the financial aspects of the ISMP recommendations.

Table E-4
Funding Strategy Summary

Funding Recommendations	
1.	Incorporate source controls and stormwater Best-Management Practices in all municipal road projects to maximize cost-effectiveness.
2.	Confirm the DCC criteria for the Anniedale-Tynehead area adequately covers the City's costs.
3.	Revise the Drainage Parcel Tax fee structure to reflect the relative impact of developments, including parcel area and impervious coverage.
4.	Encourage land owners and private developers who undertake source controls in support of watershed health through recognition and incentive programs, specifically: • A Stormwater Management Rebate Program offering one-time rebates through the City of Surrey Planning and Development Department. • Property and Drainage Parcel Tax rebates based on reduction in burden on the drainage system through proper rainwater management. • Salmon Marshall Certification Program (existing program).
5.	Incorporate source controls and stormwater Best-Management Practices in major infrastructure projects sponsored by the New Building Canada Plan.
6.	Encourage community and environmental groups to undertake identified environmental enhancement projects and facilitate application for funding by the EcoAction Community Funding Program.
7.	Apply for funding through the Green Municipal Fund for projects with a significant rainwater management component.
8.	Apply for funding through the Infrastructure Planning Grant Program for further studies recommended in this ISMP.

Enforcement Strategy

Improvement of the health of the Bon Accord – North Slope (East) watersheds is most effectively accomplished through community involvement that encourages land owners and developers to incorporate source controls into their property. However, the City also must have a sufficient regulatory framework to enforce certain recommendations in the ISMP.

A summary of the ISMP's recommended regulatory amendments are presented in Table E-5.

Table E-5
Enforcement Strategy Summary

Regulatory Amendment Recommendations	
1.	Update the City of Surrey Engineering Design Criteria Manual: ● Define design criteria to account for the impacts of climate change. ● Include maximum acceptable runoff rates by land use. ● Define source control design criteria.
2.	Amend the City of Surrey Zoning Bylaw: ● Include the Industrial Park Zone Two I-P(2) classification. ● Refine special building setbacks to include watercourses, GIN hubs and corridors, wetlands, ponds, and areas of environmental significance. ● Explicitly reference source control requirements for parking areas, residential and industrial sections.
3.	Amend the Drainage Parcel Tax Bylaw to reflect the fee structure discussed in the funding strategy.
4.	Amend the Stormwater Drainage Regulation and Charges Bylaw: ● Revise the requirements for stormwater management facilities to include redeveloped parcels. ● Prescribe specific consequences for discharge of pollutants of concern to the stormwater drainage system, ditches, watercourses or other water bodies, and specifically reference ISMP stormwater quality and quantity targets.
5.	Expand Schedule B of the Erosion and Sediment Control Bylaw to include provisions for common components of source control stormwater best management facilities.
6.	Develop specifications and standard drawings for this ISMP's recommended source control strategies for incorporation into the City's Supplementary Master Municipal Construction Documents.
7.	Develop and pass a formal Riparian Bylaw.
8.	Require the following for residential development and building permit applications: ● Landscaping and site plans showing the location and extent of source controls. ● Summary of hydrologic calculations used to prove that source control measures meet the performance targets described in this ISMP.
9.	Require the following for industrial / commercial development and building permit applications: ● Landscaping and site plans showing the location and extent of source controls. ● Summary of hydrologic calculations used to prove that source control measures meet the performance targets described in this ISMP. ● Summary of calculations and methodology used to design and locate any detention/retention storage facilities to meet the performance targets described in this ISMP.

5 MONITORING AND ASSESSMENT

Performance indicators and targets are required to evaluate whether the goals and objectives of the ISMP are being achieved. The hydrometric monitoring, water quality monitoring, and benthic invertebrates monitoring components should generally adhere to Metro Vancouver's Monitoring and Adaptive Management Framework (AMF). We recommend additional metrics to be monitored, should resources allow. These metrics have the capability to improve proactive identification of potential problems across the watershed.

Primary performance metrics to be monitored are listed in Table E-6.

Table E-6
Recommended Performance Indicators

	Performance Indicator	Estimated Cost	Monitoring Program
Land Use Metrics			
Metric 1	**Percent Tree Cover**	$500 per investigation	Supplemental
Metric 2	**Percent Total Impervious Area**	$2,000 per investigation	Supplemental
Metric 3	**Percent Effective Impervious Area**	$5,000 per investigation (where flow monitoring data is available)	Supplemental
Metric 4	**Percent Riparian Forest Integrity**	$4,000 per investigation	Supplemental
Flow Regime Metrics			
Metric 5	**Number and Condition of Erosion Sites**	Part of the City's overall Ravine Stability Assessment budget	Ravine Stability Assessments
Metric 6	**Hydrometric Monitoring (Water Level and Flow)**	$30,000 for setup (per site) $5,000 annually for data collection (per site)	AMF
Environmental Metrics			
Metric 7	**Water Quality Monitoring**	$8,000 per site per sampling period	AMF
Metric 8	**Benthic Invertebrates (B-IBI)**	$3,500 per site	AMF
Metric 9	**Fisheries Habitat Assessment**	$8,000 per watercourse	Supplemental
Metric 10	**Spill Reporting**	$500 per incident Additional costs to analyze and remediate problem areas	Supplemental

The timing and triggers of each performance indicator vary, and for maximized value should be integrated into existing City programs where feasible.

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1 Introduction

1.1 PROJECT DESCRIPTION

Associated Engineering was retained by the City of Surrey to develop an Integrated Stormwater Management Plan (ISMP) for the Bon Accord – North Slope (East) watersheds, located along the northeast boundary of Surrey.

An ISMP is a comprehensive plan to guide land use planning decisions such that they integrate components of responsible rainwater management, flood and erosion protection, aquatic habitat protection and enhancement, and terrestrial habitat protection and enhancement into the overall planning process. Integration of these components into a consolidated planning document provides a proactive way to maintain and enhance watershed health and the values of the community while still allowing development and economic growth to occur.

For the development of this ISMP, we issued four draft stage reports to the City of Surrey:

- Stage 1: Inventory – March 2014
- Stage 2: Vision for Future Development – July 2014
- Stage 3: Implementation, Funding and Enforcement – December 2014
- Stage 4: Monitoring and Assessment Plan – February 2015

At each stage, we received comments and input from the City to align the ISMP with the City's objectives. This final ISMP incorporates the main findings from the previous four stages into one comprehensive plan. The recommendations presented in this document are based on the stage reports and incorporate the feedback received from the City, superseding the previous draft stage reports. The final ISMP should therefore be viewed as a standalone document.

1.2 PROJECT PARTICIPANTS

Key team members from Associated Engineering involved in the development of the Bon Accord – North Slope (East) ISMP are:

- Jamie Fitzgerald, AScT, P.Eng. — Project Manager
- Michael MacLatchy, Ph.D., P.Eng. — Technical Leader
- Jason Kindrachuk, EIT — Lead Project Engineer
- Rob Hoogendoorn, R.P.Bio. — Aquatic Biologist
- Cole Basaraba, M.Sc., P.Ag. — Terrestrial Biologist
- Christopher Homes, P.Geo. — Hydrogeologist
- Aaron Deane, GIS(PG) — GIS Specialist

City of Surrey staff critical to the project's success include:

- Jeannie Lee, *City's Project Manager*
- Carrie Baron, *Drainage and Environment Manager*
- Stephen Godwin, *Environmental Coordinator*

1.3 BACKGROUND INFORMATION

A number of previous and current studies have assessed, or are assessing, facets of the major catchments, storm drainage trunks, watercourses, ravines, and environmental conditions of the Bon Accord – North Slope (East) study area.

These documents (listed in Table 1-1) contribute to a base of understanding of the study area watersheds, and were reviewed and incorporated into the ISMP development.

Table 1-1
Background Documentation

Document Title	Author	Date
East Bon Accord Sub-Watershed Updated Functional Plan	Associated Engineering	November 2011
East Bon Accord Creek Sub-Watershed Storm Drainage Functional / Feasibility Plan	CitiWest Consulting Ltd.	December 1999
Surrey Bend Regional Park Management Plan	City of Surrey / Metro Vancouver	June 2010
North Slope Study	City of Surrey	January 1994
2014 – 2023 Ten-Year Servicing Plan (Draft)	City of Surrey	January 2014
Plan Surrey 2013: Official Community Plan	City of Surrey	October 2014
Anniedale-Tynehead – Stage 2 Engineering Corporate Report	City of Surrey	April 2012
Biodiversity Conservation Strategy	Diamond Head Consulting	January 2014
Stormwater Management Review – North Bluff Drainage and Slope Stability Assessment	ECL Envirowest Consultants Ltd.	February 1999
Watercourse Bioinventories – North Bluff Drainage and Slope Stability Assessment	ECL Envirowest Consultants Ltd.	March 2000
City of Surrey Ecosystem Management Study	HB Lanarc / Raincoast	April 2011
Bon Accord West Functional and Remediation Plan	McElhanney Consulting Services Ltd.	October 2002

Document Title	Author	Date
2012 City of Surrey Benthic Invertebrate Sampling Program: Methods and Results	Raincoast Applied Ecology	2012
Bon Accord Creek Master Drainage Plan	Reid Crowther Consulting	August 1999
North Bluff Drainage and Slope Stability Assessments	Stantec	March 2000
North Bluff Functional Review of Existing Drainage Concerns	Stantec	November 1999
South Fraser Perimeter Road Project Stormwater Management Review, Segment 8	Stantec	March 2011
South Fraser Perimeter Road Project – Segment 8 Issued for Construction Drawings	Stantec	March 2011
2009 City of Surrey Ravine Stability Assessment	WEB Engineering, Ltd.	June 2009
2011 City of Surrey Ravine Stability Assessment (Draft)	WEB Engineering, Ltd.	June 2011

2 ISMP Framework

The framework for the Bon Accord – North Slope (East) ISMP is broken into four stages, in general adherence with Metro Vancouver's ISMP Template. Table 2-1 summarizes these stages and indicates the sections of this report which apply to each stage.

Table 2-1
Bon Accord – North Slope (East) ISMP Framework

ISMP Stages	Section Summary	Report Section
Part 1 – What do we have?	**Study Area Overview**: summarizes the current state of the watersheds, including descriptions of the physiography and climate, the drainage system, the condition of the natural environment, hydrogeological conditions, and current and planned future land use. **Watershed Health Assessment:** assesses the overall health of the watersheds under present conditions. **Hydrologic and Hydraulic Assessment**: describes the results of the hydrologic and hydraulic modelling exercise used in identifying drainage problems and those areas most at risk to the impacts of development and redevelopment.	3, 4, 5
Part 2 – What do we want?	**Goals and Objectives**: establishes specific goals for the ISMSP based on the understanding of the current and anticipated conditions of the watersheds.	6
Part 3 – How do we get there?	**Recommended Improvement Projects**: identifies tangible drainage projects, environmental enhancement projects, and rainwater management strategies to address any deficiencies and enhance the overall health of the watershed. **Funding Strategy**: outlines the most promising funding sources available for the City to use towards projects to enhance watershed health and achieve the objectives of the ISMP. **Enforcement Strategy**: identifies the critical amendments to the City's regulatory framework necessary for achieving the goals and objectives of the ISMP.	7, 8, 9
Part 4 – How do we stay on track?	**Monitoring and Assessment Plan**: describes a series of metrics the City can monitor that will serve as reliable indicators of whether the goals and objectives of the ISMP are being achieved, or whether modifications or additional effort is required.	10

3 Study Area Overview

3.1 LOCATION, PHYSIOGRAPHY AND CLIMATE

3.1.1 Study Area Location

The Bon Accord – North Slope (East) study area lies in northeast Surrey. It is bound by the Fraser River to the north, the Township of Langley to the east, and the North Slope (West), Quibble Creek, Upper and Lower Serpentine, Tynehead, and Latimer watersheds to the west and south.

The total study area is 2,131 ha, divided into seven watersheds as outlined in Table 3-1 and illustrated in Map 3-1. We discuss each of these watersheds in greater detail in Section 3.2. Previous studies have grouped the 157 Street Creek, 160 Street Creek, Fraser Heights, and Big Bend watersheds together and collectively refer to them as the North Bluff (Central) region. Further, previous studies have referred to the Port Kells watershed as the North Bluff (East) region. To better assess each watershed in the context of an ISMP, this study does not use this grouping.

Table 3-1
Watershed Areas within the Study Area

Major Catchment	Catchment Area
Bon Accord Watershed	542 ha
157 Street Creek Watershed	94 ha
160 Street Creek Watershed	26 ha
Fraser Heights Watershed	273 ha
Big Bend Watershed	230 ha
Port Kells Watershed	579 ha
Surrey Bend Regional Park	388 ha
Total Area	**2,131 ha**

We confirmed the watershed boundaries referenced above based on the City of Surrey's GIS data, and made minor adjustments based on topography and the drainage network layout as required.

3.1.2 Physiography

In general, the watersheds west of Port Kells are characterized by highly developed, gently sloped upland areas ranging in elevation between 20 m and 120 m, sloping to the north and to the east. Lowland areas at the base of the escarpment range between sea level and 20 m.

A steep escarpment (known variously as the Surrey escarpment, north slope, or north bluff) creates the transition between the upland and lowland areas, and drains north to the Fraser River. Watercourses descend the escarpment in ravines, and tend to form dendritic (branched) drainage patterns. Many of the watercourses along the north slope, specifically in the Fraser Heights and Big Bend area are ephemeral and unnamed, with slopes as steep as 50%.

Within the lowlands west of Port Kells, watercourses discharge to the Fraser River through culverts beneath the South Fraser Perimeter Road (SFPR) and CN railway facilities. Portions of the lowlands, particularly at the base of the escarpment near the Fraser Heights and Big Bend watersheds are comprised of a complex wetland, with relatively ill-defined and discontinuous lowland channels. This results in patches of stagnant water in these regions.

Towards the eastern side of the study area in the Port Kells watershed, the drastic elevation differences created by the Surrey escarpment are less pronounced, and elevations range from sea level to 55 m. At the eastern limit of the study area, the slope towards the Fraser River is significantly less, with maximum elevations of less than 20 m.

The lowlands in the study area are located within the Fraser River floodplain. These areas are not dyked, and it is unlikely that any dykes will be implemented in the future.

3.1.3 Climate

As with much of Metro Vancouver, the climate of the study area is relatively warm and averages approximately 1530 mm of rainfall per year. The largest rainfall events tend to occur between November and January as a result of cyclonic, frontal storms that often last as long as three days. During the summer, short-duration convective storms are common. July and August tend to be the driest months, often presenting prolonged periods without rain.

The nearest long-term climate station is Surrey Kwantlen Park, which lies approximately 2 km west of the study area. The 1971 to 2000 climatic normal data (precipitation) at this station is summarized in Table 3-2. There is an additional climate station in Port Kells (Port Kells Pump Station), but it has a significantly shorter period of record (11 years). In the future, when additional data has been collected, it may be used to assess the variability of rainfall from west to east across the study area.

Table 3-2
Canadian Climate Normals Station Data, 1971 – 2000; Surrey Kwantlen Park

Surrey Kwantlen Park	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
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**
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**

3.2 DRAINAGE

3.2.1 Bon Accord Watershed

The westernmost watershed in the study area is Bon Accord (Map 3-2), and contains the following major watercourses:

- Bon Accord Creek,
- East Bon Accord Creek,
- Wallace Creek (tributary to East Bon Accord Creek), and
- Landfill Creek.

The upland areas are primarily residential, interspersed with small-scale commercial developments. These areas are drained via trunk storm systems to one of the aforementioned watercourses before draining down the escarpment to the Fraser River.

Within Hawthorne Park, runoff from the upland areas is attenuated in a large lake before being released to Bon Accord Creek. This water feature was constructed following a major rainfall event (estimated to be a 1 in 50-year return period event) that occurred on January 29, 1997, leading to the identification of significant deficiencies in the existing drainage system. The residential areas upstream of the park are subject to flooding due to existing basements constructed below the Minimum Building Elevations (MBE), but these impacts have been partly addressed through modifications to Bon Accord Lake (Hawthorne Park detention pond).

In 2011, Associated Engineering developed an updated functional plan for the East Bon Accord subwatershed that covers the catchments draining to Wallace Creek and East Bon Accord Creek. As a result of the study, a peak flow diversion system was proposed to manage the full spectrum of rainfall events. The proposed diversion provides safe conveyance of both minor and major storm events, up to and including the 100-year return period design storm. The City of Surrey has developed Project Definition Reports for this project that divide it into six phases. Presently, design of the first phase is underway. The level of detail of the updated functional plan is greater than is allowed in an ISMP context, and therefore the functional plan is directly referenced, and the assessment not reproduced for the purpose of this document. For details regarding the diversion, refer to the East Bon Accord Subwatershed Updated Functional Plan (Associated Engineering, 2011). The City's project definition reports detailing the phasing and cost estimate are included in Appendix A.

3.2.2 157 and 160 Street Watersheds

The 157 and 160 Street watersheds (Map 3-2) are comprised of multiple ravines along the slope of the Surrey escarpment and include the following major drainage courses:

- 157 Street Creek, and
- 160 Street Creek.

We note that the City of Surrey Ravine Stability Assessments refer to 157 Street Creek as 158 Street Creek. For consistency with the City of Surrey's major catchment divisions, we refer to this creek as 157 Street Creek throughout this report.

Both 157 Street Creek and 160 Street Creek receive runoff from relatively small upland areas, and discharge via culverts beneath the SFPR and CN railway.

3.2.3 Fraser Heights Watershed

The Fraser Heights watershed (Map 3-3) is comprised primarily of urban and suburban residential developments drained to the east by several small drainage trunks discharging to the lowlands along the SFPR via multiple unnamed tributaries.

Drainage originating in the upland areas is isolated from Surrey Bend Regional Park by the CN railway and the SFPR. Within the lowland wetland complex, several large, ill-defined channels at very low slopes convey drainage northwest, ultimately discharging to the Fraser River beneath the SFPR and CN railway.

3.2.4 Big Bend Watershed

Similar to the Fraser Heights watershed, the Big Bend watershed (Map 3-3) is comprised primarily of urban and suburban residential developments that drain eastward. The piped system discharges to multiple tributaries along the north slope, which concentrate in the lowlands and drain into Surrey Bend Regional Park via Centre Creek.

3.2.5 Surrey Bend Regional Park

Surrey Bend Regional Park (Map 3-3) is a lowland bog and is the subject of a joint initiative by the City of Surrey and Metro Vancouver. Surrey Bend Regional Park receives runoff originating in the uplands of the Big Bend watershed, yet functions as a distinct watershed due to its unique drainage and environmental characteristics.

Surrey Bend Regional Park is not dyked. Due to its location in the Fraser River floodplain, the entire park is subject to wetting from the Fraser River during spring freshet, and also from year-round tidal influence. A number of small, lowland drainage channels drain various subareas of the park to the Fraser River. Two major watercourses convey the majority of the flow from the Big Bend watershed to the Fraser River:

- Centre Creek, and
- A large drainage ditch along the 176 Street alignment.

3.2.6 Port Kells Watershed

The eastern and western halves of the Port Kells watershed (Map 3-4) are distinctly different. The western half is somewhat sparsely developed with residential and light-industrial land uses. Runoff from these areas drains north to the Fraser River (Parsons Channel) via one of the following major watercourses:

- Lyncean Creek West.
- Lyncean Creek East.
- Leoran Brook,
- 184 Street Creek.

The eastern half of Port Kells is densely developed with light-industrial and commercial land uses and drains north to the Fraser River (Parsons Channel) entirely by way of piped drainage systems. The drainage pipes in this area are typically large diameter (> 600 mm) and the slopes are severely limited by the topography.

3.3 LAND USE

3.3.1 Current Land Use and Anticipated Development Trends

The Bon Accord – North Slope (East) watersheds are extensively developed.

The majority of industrial developments are concentrated in the eastern half of Port Kells. The CN rail and intermodal yard and the SFPR run along the base of the north slope through each watershed, and the TransCanada Highway passes through Big Bend and Port Kells. Residential developments make up most of the remainder of the study area.

Although the southern boundary is formed by the SFPR and CN railway, Surrey Bend Regional Park is mostly undeveloped. Future modifications are expected to be limited to infrastructure supporting its operation as a protected area of ecological significance, and will not likely impact the hydrology significantly.

The City's 2013 Official Community Plan (OCP) includes development permit guidelines for Hazard Lands (DP2). These guidelines set stricter requirements for proponents wanting to develop lots in City-designated 'hazardous' areas, as defined by their proximity to steep slopes or flood prone lands. The location and physiography of the Bon Accord – North Slope (East) study is such that 48% of the total area is within designated hazard lands. For this reason, new development is expected to be limited in the study area.

When development activities do occur, they will mostly be confined to already-developed areas in the form of densification and redevelopment.

3.3.2 Development by Land Use Change

To assess the degree of future development planned for the study area we reviewed the City's OCP and Neighbourhood Concept Plans (NCP), as well as current approved or in-progress rezoning applications.

The development plan anticipated to have the greatest effect on the study area is the Anniedale-Tynehead development proposed for the South Port Kells region. The Anniedale-Tynehead NCP details the land use plans for the development. Approximately one-third of the Anniedale-Tynehead NCP area is within the Port Kells watershed as defined in this ISMP. Current land use plans show a substantial change in zoning from residential to industrial in support of this development, which, if unmitigated will have a significant impact on some or all of the receiving watercourses (Lyncean Creek West, Lyncean Creek East, Leoran Brook, 183 Street Creek and 184 Street Creek).

Aside from the Anniedale-Tynehead NCP, only minor dispersed rezoning is anticipated. The remainder of development is anticipated to be through densification and redevelopment with only minor changes to zoning class.

Map 3-5 presents the current and projected future land use by zoning classification in the Bon Accord – North Slope (East) study area. Table 3-3 outlines the prominent zoning classifications across the study area. For the purposes of this ISMP, we simplified the zoning classification into agricultural, commercial, green space, industrial, institutional, residential (standard, acre and half-acre), transportation corridor, and utility right-of-way (representing BC Hydro right-of-way, primarily quasi-green space). This provides an adequate breakdown for the context of this ISMP and is used in support of assessing the impacts of land use changes as they relate to rainwater management.

The general development trend noted from Table 3-3 is the increase in industrial land use at the expense of large lot residential zones.

Table 3-3
Existing and Future Land Use Coverage

Land Use Type[1]	Coverage as a Percent of Total Study Area		Future Change
	Existing Conditions	Future Conditions	
Residential (Acre)	11.5%	6.8%	Significant Decrease
Industrial	12.4%	14.9%	Significant Increase
Residential (General)	23.6%	25.7%	Moderate Increase
Residential (Half-Acre)	3.9%	4.0%	Small Increase
Commercial	2.9%	3.0%	Small Increase
Agricultural	0.1%	0.0%	Eliminated
Transportation Corridor[2]	12.8%	12.7%	Negligible Change
Green Space	31.8%	31.9%	Negligible Change
Utility Right-of-Way[3]	0.5%	0.5%	Negligible Change
Institutional	0.4%	0.4%	Negligible Change

1) Sorted by greatest-to-least adverse impact on the study area.

2) Represents South Fraser Perimeter Road, TransCanada Highway, Golden Ears Connector and CN rail – see land use map.

3) Represents BC Hydro Right-of-Way in west Bon Accord, disturbed green space.

3.3.3 Redevelopment and Densification

For the reasons stated above, the primary changes to the Bon Accord – North Slope (East) watersheds will be due to redevelopment and densification of existing lots.

The most prominent uses of land in the study area other than green space are residential, industrial and major transportation corridors.

In the context of stormwater management, the impervious coverage of each lot type is the critical factor influencing the hydrological response of the watersheds. We present some of the most common redevelopment activities that result in increased impervious areas (and thus increased peak runoff rates and volumes) by land use in Table 3-4.

Table 3-4
Typical Redevelopment Activities Resulting in Increased Impervious Area

Land Use Designation	Typical Activity
Commercial / Industrial	• Construction of storage sheds / pads • Renovations to accommodate greater store space • Construction of patios • Paving or expansion of parking areas / loading bays
Residential	• Construction of garages, patios, sheds • Expansion of driveways • Paving of gravel driveways • Densification of residential dwellings to accommodate additional families.

3.4 TERRESTRIAL ECOLOGY AND AQUATIC HABITAT

The City of Surrey has invested substantial resources into understanding the city's terrestrial and aquatic ecological conditions. The intent of this ISMP is not to reproduce this work, but to summarize the key findings of these investigations as they pertain to the integration of stormwater management, land development, and ecology.

Our analysis includes an assessment of the existing terrestrial ecology and aquatic habitat across the study area, as discerned from existing studies and documentation, and supplemented by field reconnaissance on December 16 and 17, 2013. The sections below summarize the key findings pertaining to this ISMP. Appendix B presents the site assessments contributing to the understanding of the environmental conditions across the study area.

3.4.1 Terrestrial Overview

The City of Surrey engaged Diamond Head Consulting to develop a city-wide Biodiversity Conservation Strategy (BCS). The BCS (January 2014) builds upon the findings of the City's earlier Ecosystem Management Study (EMS) to develop a practical and implementable strategy for preserving and enhancing the condition of the terrestrial ecosystem across the city.

The study provides great detail on the present terrestrial condition and includes the Bon Accord – North Slope (East) areas. One of the key recommendations of the BCS is the creation of an interconnected Green Infrastructure Network (GIN) that aims to maintain the connectivity between ecological hubs and sites through the use of movement corridors. The City's EMS initially defined hubs, sites and corridors as follows:

Hubs – large areas of complex ecological processes.
Sites – smaller sites of less complex ecological activity.
Corridors – pathways that offer species and ecological process connection between hubs.

Map 3-6 shows the location of hubs, sites, and corridors within the study area. In support of the GIN, the BCS proposes hubs in several locations across the city, but no new hubs are proposed for the Bon Accord – North Slope (East) area. Thus, the existing GIN features should be maintained by ensuring development does not encroach on these areas. Many corridors are located within riparian areas, and are therefore relatively protected from the encroachment of development; however, we note that the BC Hydro right-of-way in the Bon Accord watershed is identified as a wildlife corridor, and maintenance activities must consider this.

In addition to the recommendations regarding the maintenance and enhancement of the GIN, the BCS also outlines a series of management objectives, opportunities, and constraints for management areas that cover our study area. The management areas within the bounds of our study area are Fleetwood, Fraser River Industrial, Green Timbers, Surrey Bend, and Tynehead. Given the enhanced level of detail of the BCS, we stress the importance of the document in supporting the objectives of this ISMP.

3.4.2 Aquatic Overview

3.4.2.1 Aquatic Habitat Condition

The watercourses in the study area range from highly modified, disturbed, and degraded channels and riparian areas, to undeveloped, high-value natural corridors and stream habitats. Historical development has resulted in the loss of open channels and headwater tributaries through piping or infilling, and habitat degradation through channel realignment, the alteration of flow regimes, and water quality degradation. Remnant natural sections of some watercourses are preserved as part of City parks or stream setback areas. Other natural stream sections are present in undeveloped areas along the steep north-facing slopes and in Surrey Bend Regional Park.

Our review of available background information was supplemented by field visits of major watercourses to identify constraints and enhancement opportunities. Some constraints identified in previous reports have been addressed as part of recent projects, including the construction of the SFPR. The recommended aquatic enhancement projects discussed in Section 7 of this report reflect the noted constraints in the study area, and are not presented here, to avoid duplication.

3.4.2.2 Watercourse Classification

In 1995, the City of Surrey developed a classification system for watercourses, tributaries, and ditches in each watershed within the city. The classification provides an overall fish habitat value rating based on fish presence, the duration of water flow and water source, and surrounding vegetation potential. Four classifications were established, and are summarized in Table 3-5.

Table 3-5
City of Surrey Watercourse Classification System

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 salmonids or regionally significant fish present
Class C	Solid green line	Insignificant food and/or nutrient value or road-side ditches

Note: "Potential habitation" includes stream reaches that could support salmonids or other regionally significant fish with adequate enhancement projects, including the removal of barriers to fish passage.

Map 3-7 shows the watercourse classifications for the Bon Accord – North Slope (East) study area. Most major streams in the study area are classified as fish-bearing/potentially fish-bearing (Class A or A(O)), with several other minor watercourses and tributaries classified as providing significant food and nutrient value for downstream fish populations (Class B). Table 3-6 summarizes the classification of the major watercourses in the study area.

Table 3-6
Study Area Major Watercourse Classifications

Watershed	Watercourse Name	Classification
Bon Accord	Bon Accord Creek	Class A
Bon Accord	East Bon Accord Creek	Class A
Bon Accord	Wallace Creek	Class B
Bon Accord	Landfill Creek	Class B
157 Street	157 Street Creek	Class B
160 Street	160 Street Creek	Class B
Port Kells	Lyncean Creek West	Class B
Port Kells	Lyncean Creek East (lower reaches)	Class A
Port Kells	Lyncean Creek East (upper reaches)	Class B
Port Kells	Leoran Brook	Class A
Port Kells	184 Street Creek	Class A

3.5 HYDROGEOLOGY

The purpose of our hydrogeological assessment of the study area was primarily to identify key features relevant to the ISMP. This section summarizes the areas where infiltration or partial-infiltration source controls are most feasible, and identifies those areas where poor infiltration, the development of perched water tables, or substantial lateral seepage may preclude the use of certain source controls.

The key conclusions of our hydrogeological assessment pertaining to integrated stormwater management are presented here. Appendix B provides additional information from the hydrogeological assessment completed in support of this ISMP.

The soils across the Lower Mainland, including in the study area, were mapped in 1939 at a general scale when the land was still mostly undeveloped; the soil types are described in the Soil Survey of the Lower Fraser Valley (Kelley and Spilsbury, 1939). A more detailed assessment of the soils east of 160 Street was completed in the early 1980s and described in the Soils of the Langley-Vancouver Map Area (Luttmerding, 1980 and 1984).

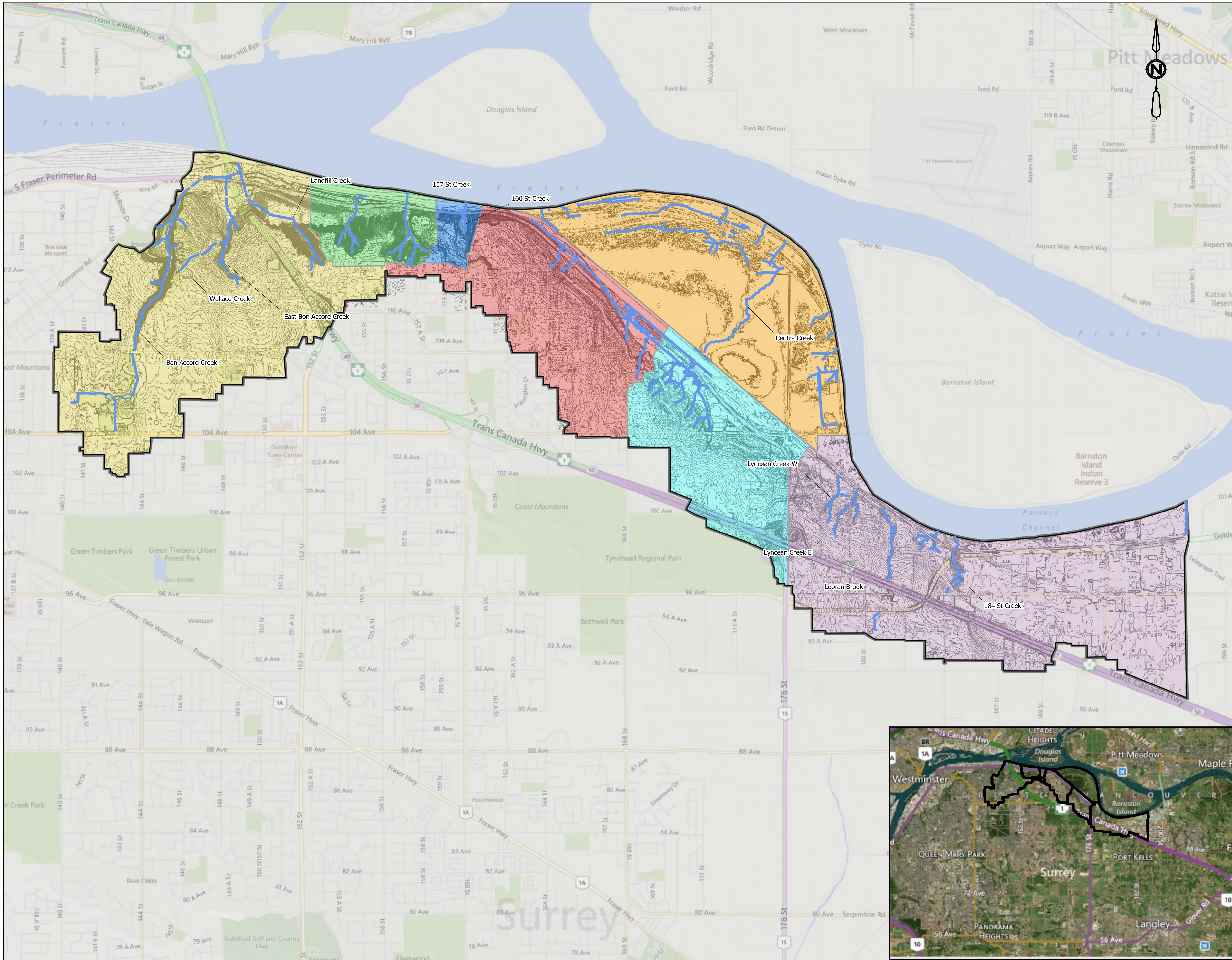
The purpose of these historic soil assessments was to assess agricultural capability, although these reports describe the soil moisture characteristics of each soil type, and therefore are relevant to the objectives of the ISMP. By analyzing the soil moisture characteristics, we can identify those areas where infiltration-based source controls are the most feasible.

Map 3-8 summarizes infiltration suitability, based on our assessment of the soil types found in the study area.

In general, the study area is poorly suited to infiltration-based source controls. Those areas identified as having moderate suitability may be acceptable for infiltration, but detailed site assessments should be completed to assess the risks. Those soil classes showing moderate suitability are typically prone to at least some ponding during periods of prolonged rainfall, and may also have adverse impacts on down-gradient infrastructure due to subsurface lateral seepage. Infiltration in these areas should therefore be approached with caution.

The areas showing the greatest suitability for infiltration-based source controls include:

- A gravel pit area in the western part of Fraser Heights north of 112 Avenue; excessive infiltration in this area may have adverse impacts on the stability of the north slope and should be investigated prior to planning extensive source controls.
- The northeastern quadrant of Port Kells, comprised of a gravel pit area and Cloverdale Soils; the northern extent may be subject to restrictive influence from the Fraser River (Parsons Channel) during freshet and high tide.



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Legend

- Creek
- Major Catchment Boundary
- Surface Contours (1 m)

Study Area Watersheds

- Bon Accord
- 157 Street
- 160 Street
- Fraser Heights
- Surrey Bend
- Big Bend
- Port Kells

0 2 km

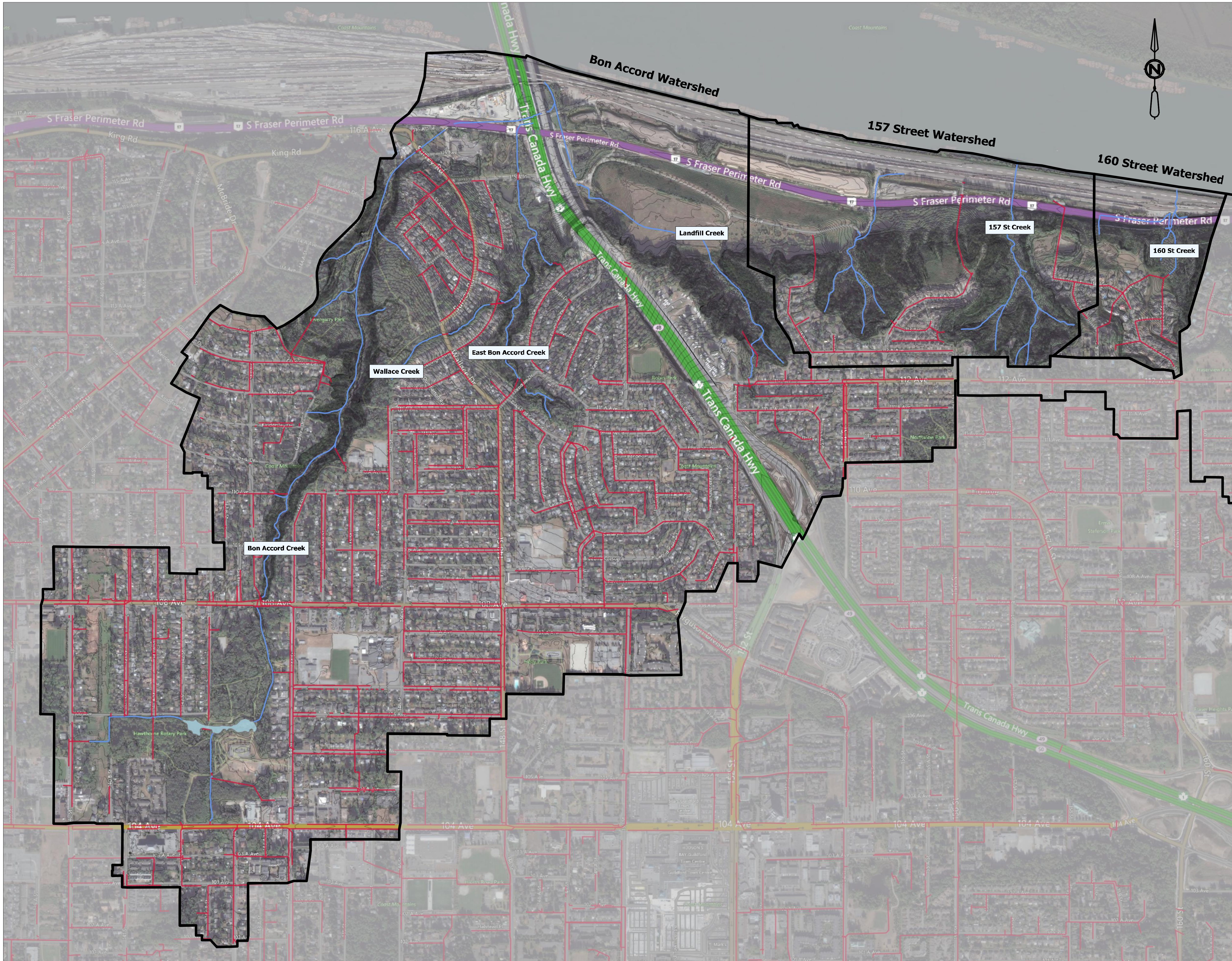
Map 3-1: Study Area Overview

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:55,000

DATE: May 2015



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Legend

- Watershed Boundary
- Existing Piped Drainage Network
- Watercourse
- Surface Contours (1 m)

0 — 1 km

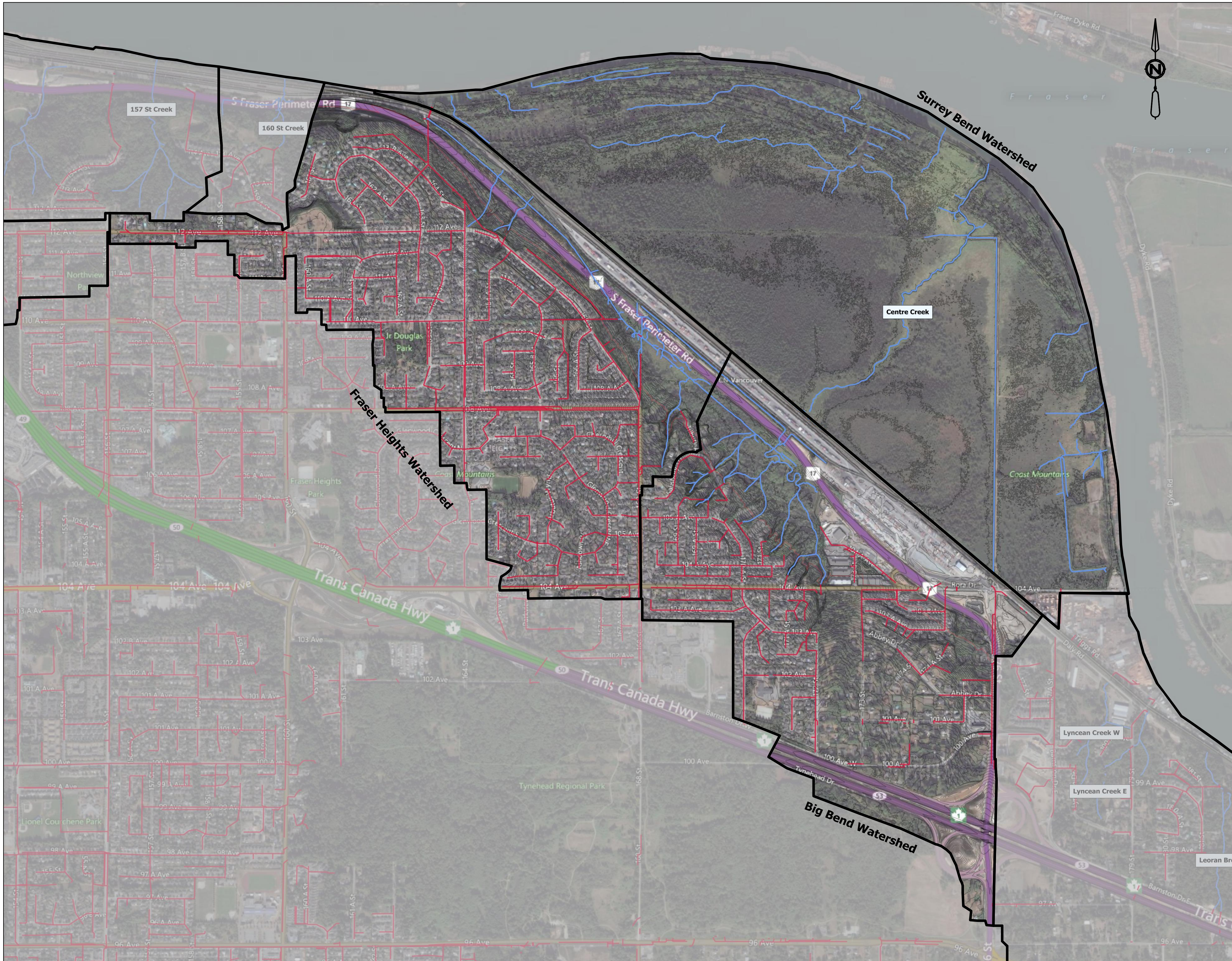
Map 3-2: Bon Accord, 157 Street and 160 Street Watersheds

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:20,000

DATE: May 2015



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Legend

Watershed Boundary
Existing Piped Drainage Network
Watercourse
Surface Contours (1 m)

0 1 km

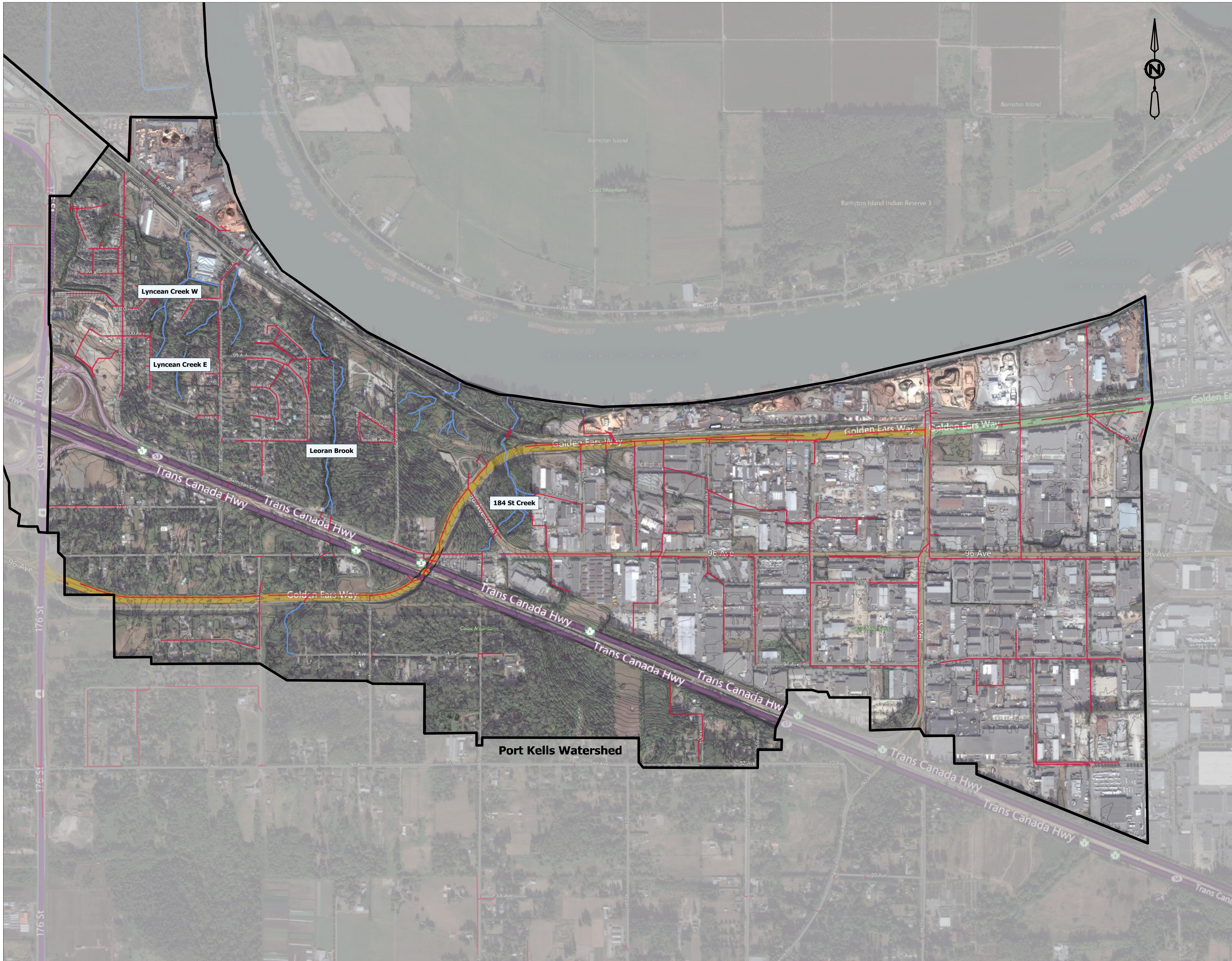
Map 3-3: Fraser Heights, Big Bend, and Surrey Bend Watersheds

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:25,000

DATE: May 2015



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Legend

Watershed Boundary
Existing Piped Drainage Network
Watercourse
Surface Contours (1 m)

0 1 km

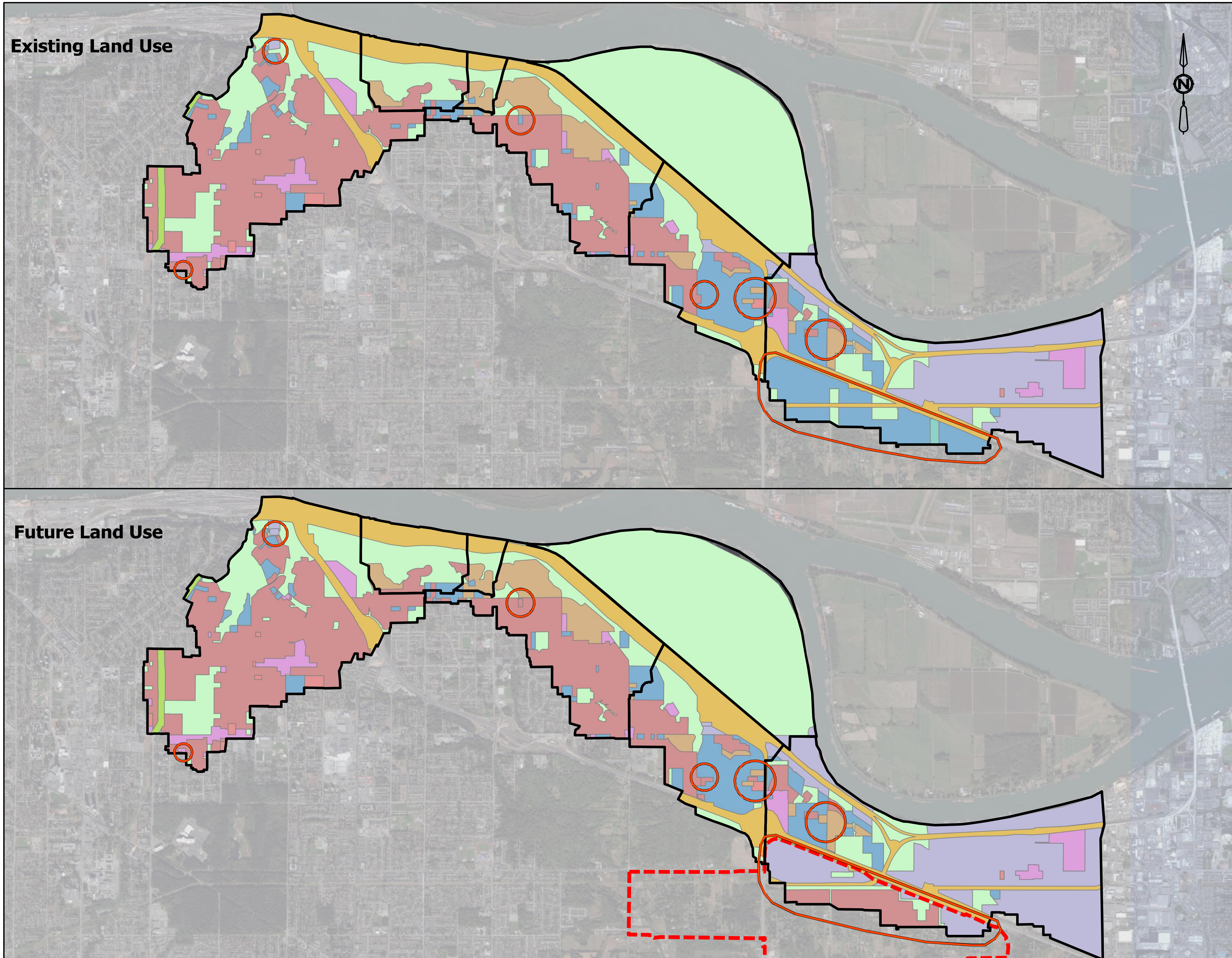
Map 3-4: Port Kells Watershed

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:20,000

DATE: May 2015



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Legend

Major Catchment Boundary

Anniedale-Tynehead NCP Boundary

Changes in Land Use Classification

Land Use Class

- Commercial
- Green Space
- Industrial
- Institutional
- Residential
- Residential (Acre)
- Residential (Half-Acre)
- Transportation Corridor
- Utility Right of Way

Reference Table 3-3

0 2 km

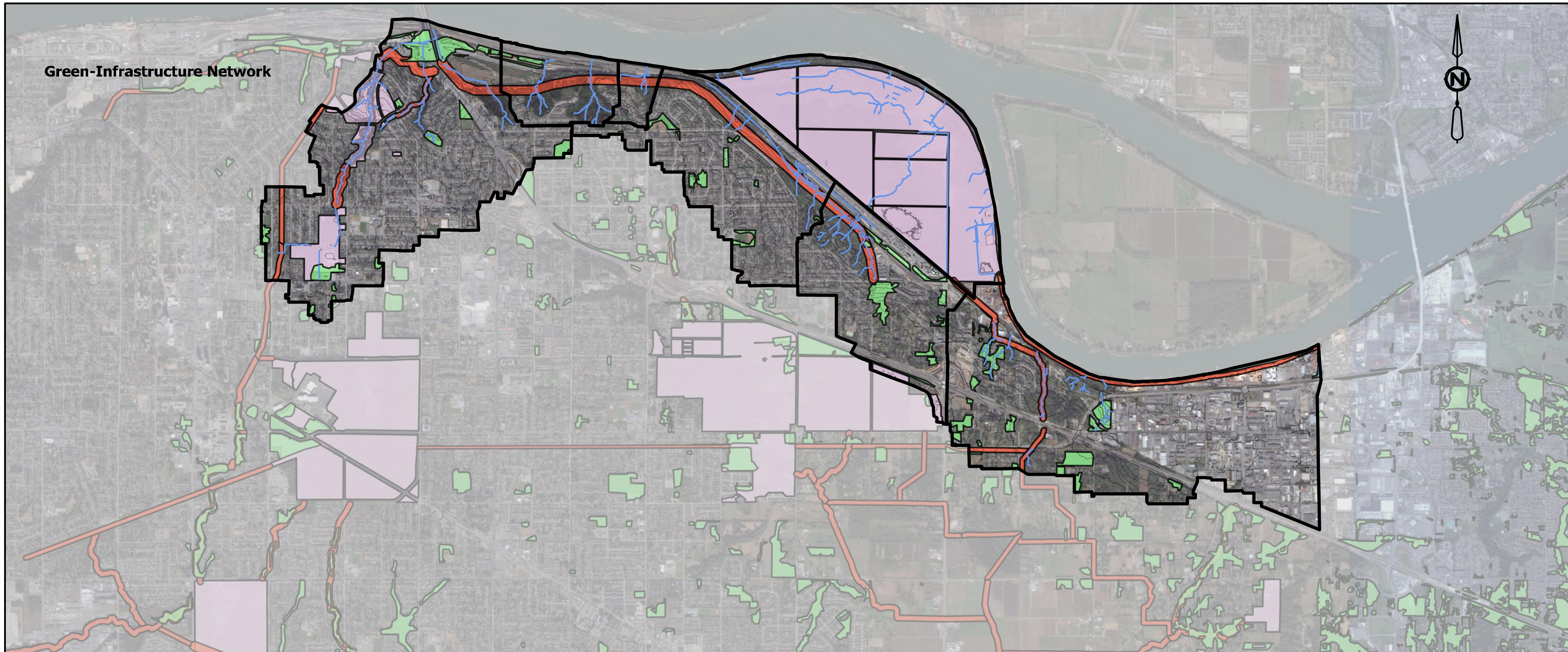
Map 3-5: Existing and Future Land Use

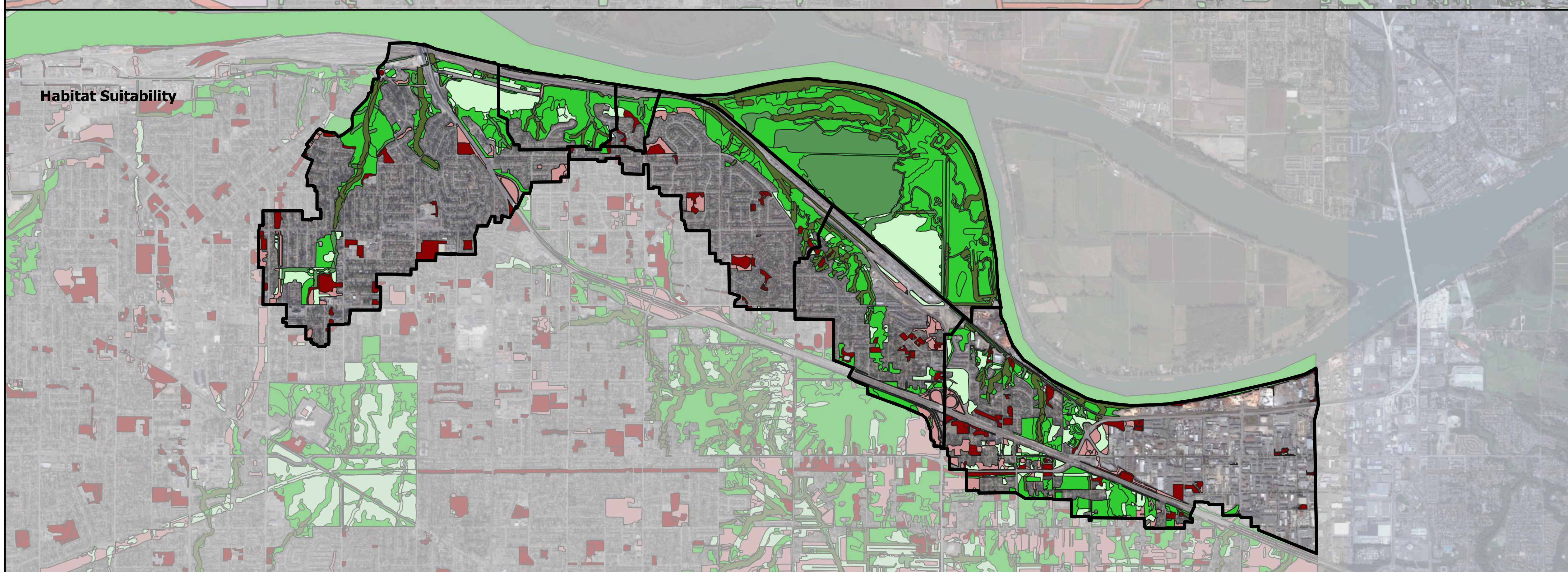
Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:65,000

DATE: May 2015





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Legend

Watercourse
Watershed Boundary
Surface Contours (5 m)

Green Infrastructure Network*
Hubs
Sites
Corridors

Habitat Suitability*
Very High
High
Moderate High
Moderate
Low
Very Low

* Adapted from the City's Biodiversity Conservation Strategy

0 2 km

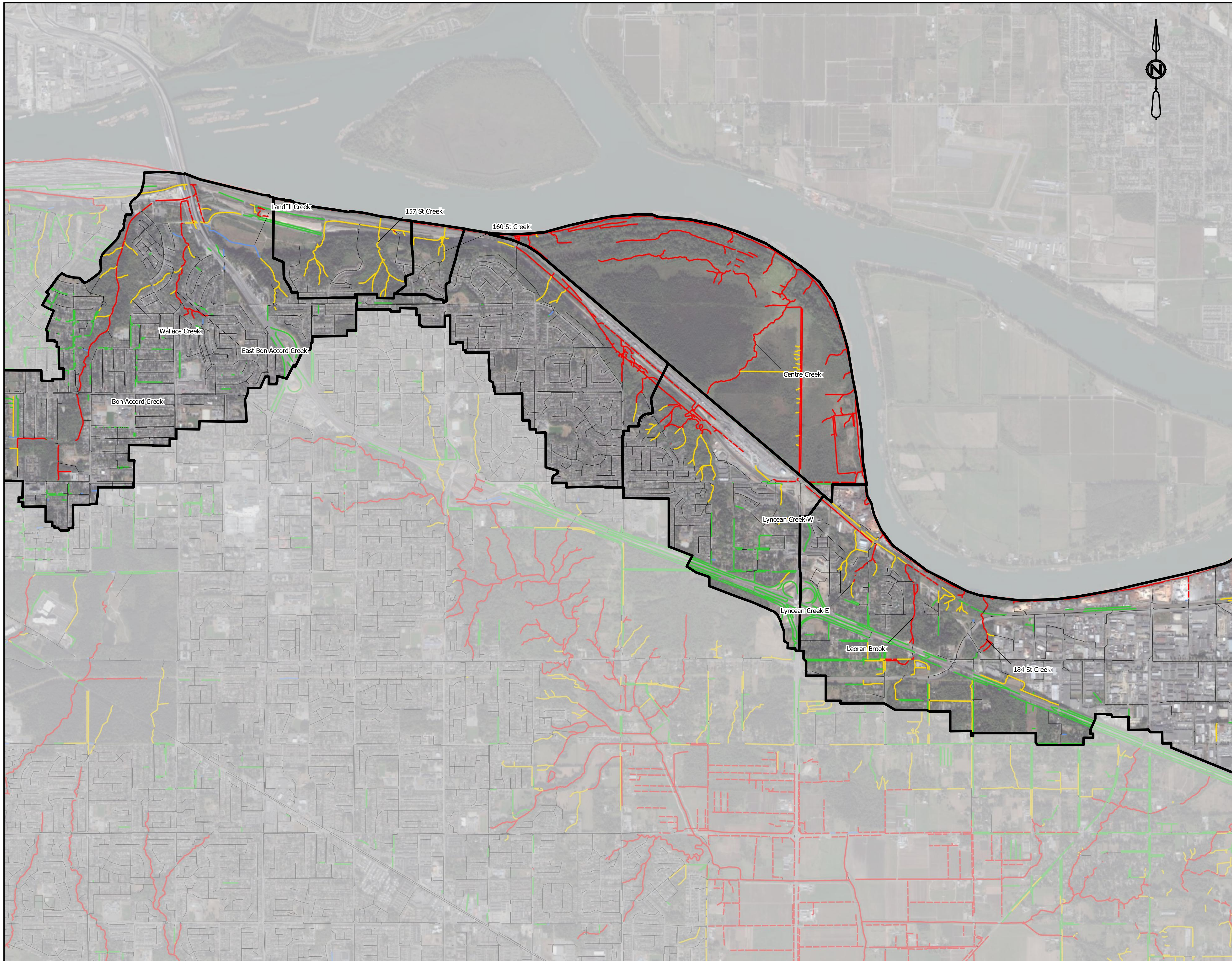
Map 3-6 - Terrestrial Habitat Inventory

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:75,000

DATE: May 2015



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Legend

Watershed Boundary

Watercourse Classification

Class A

Class A(O)

Class B

Class C

Unknown

Reference Table 3-5 for Class Definitions

0 2 km

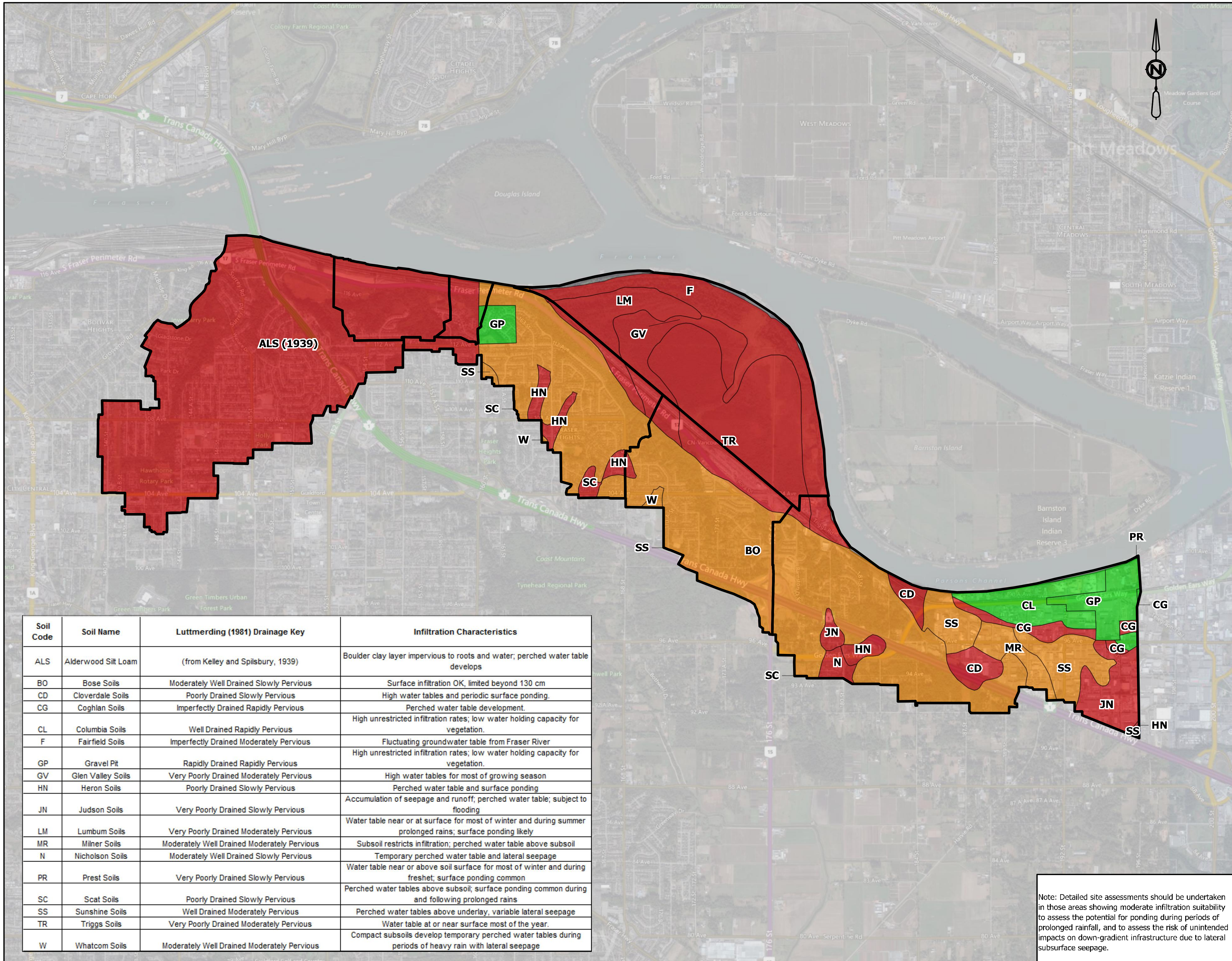
Map 3-7: Watercourse Classification

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:50,000

DATE: May 2015



Soil Code	Soil Name	Luttmerding (1981) Drainage Key	Infiltration Characteristics
ALS	Alderwood Silt Loam	(from Kelley and Spilsbury, 1939)	Boulder clay layer impervious to roots and water; perched water table develops
BO	Bose Soils	Moderately Well Drained Slowly Pervious	Surface infiltration OK, limited beyond 130 cm
CD	Cloverdale Soils	Poorly Drained Slowly Pervious	High water tables and periodic surface ponding.
CG	Coghlan Soils	Imperfectly Drained Rapidly Pervious	Perched water table development.
CL	Columbia Soils	Well Drained Rapidly Pervious	High unrestricted infiltration rates; low water holding capacity for vegetation.
F	Fairfield Soils	Imperfectly Drained Moderately Pervious	Fluctuating groundwater table from Fraser River
GP	Gravel Pit	Rapidly Drained Rapidly Pervious	High unrestricted infiltration rates; low water holding capacity for vegetation.
GV	Glen Valley Soils	Very Poorly Drained Moderately Pervious	High water tables for most of growing season
HN	Heron Soils	Poorly Drained Slowly Pervious	Perched water table and surface ponding
JN	Judson Soils	Very Poorly Drained Slowly Pervious	Accumulation of seepage and runoff; perched water table; subject to flooding
LM	Lumbum Soils	Very Poorly Drained Moderately Pervious	Water table near or at surface for most of winter and during summer prolonged rains; surface ponding likely
MR	Milner Soils	Moderately Well Drained Moderately Pervious	Subsoil restricts infiltration; perched water table above subsoil
N	Nicholson Soils	Moderately Well Drained Slowly Pervious	Temporary perched water table and lateral seepage
PR	Prest Soils	Very Poorly Drained Slowly Pervious	Water table near or above soil surface for most of winter and during freshet; surface ponding common
SC	Scat Soils	Poorly Drained Slowly Pervious	Perched water tables above subsoil; surface ponding common during and following prolonged rains
SS	Sunshine Soils	Well Drained Moderately Pervious	Perched water tables above underlay, variable lateral seepage
TR	Triggs Soils	Very Poorly Drained Moderately Pervious	Water table at or near surface most of the year.
W	Whatcom Soils	Moderately Well Drained Moderately Pervious	Compact subsoils develop temporary perched water tables during periods of heavy rain with lateral seepage

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Map 3-8: Soil Types and Infiltration Suitability

Bon Accord - North Slope (East) ISMP

Note: Detailed site assessments should be undertaken in those areas showing moderate infiltration suitability to assess the potential for ponding during periods of prolonged rainfall, and to assess the risk of unintended impacts on down-gradient infrastructure due to lateral subsurface seepage.

PROJECT No: 20132512

SCALE: 1:60,000

DATE: May 2015

4 Watershed Health Assessment

The Template for Integrated Stormwater Management Planning (Metro Vancouver, 2005) provides guidance on assessing the health of a watershed by using two physical characteristics: total impervious area and percent riparian forest integrity. Also, the Benthic Index of Biotic Integrity (B-IBI), if available, can provide further information on watershed health from a biological perspective.

Total Impervious Area (TIA) provides an estimate of the fraction of paved and hard surface areas within a watershed. The more developed a watershed, the higher a percentage of impervious areas, such as roads, buildings and parking lots. These restrict the amount of land available to support natural infiltration and evapotranspiration of rainfall. The result is a significant change to a watershed's hydrology compared to natural, undeveloped conditions, which often results in changes to stream hydrology (higher peak flows, lower base flows) and has been correlated to degradation of stream health and the availability of suitable fish habitat.

TIA calculations assume that impervious surfaces have a direct hydraulic connection to the drainage system, which is not necessarily the case if source controls are implemented. As such, a common supplement to TIA is the Effective Impervious Area (EIA), which assumes the disconnection of a portion of impervious surfaces from watercourses. Source controls can effectively lower the TIA of a watershed, allowing for improved watershed health. EIA refers to this lowered value of impervious area, and is important when considering long-term watershed health planning.

Riparian Forest Integrity (RFI) describes the fraction of riparian forest that remains intact within a buffer zone 30 m to either side of the stream, comprising a stream "corridor." It is well understood that intact natural vegetation within this corridor supports stream health by providing shade, supporting nutrient cycling, stabilizing erodible banks, promoting hydrologic processes (such as interception and infiltration), and supporting terrestrial biodiversity.

For the assessment of watershed health, we omitted Surrey Bend Regional Park from our analysis based on RFI and TIA/EIA. Surrey Bend Regional Park is a wetland system and watershed health assessments based on RFI and TIA/EIA are most relevant for forested watersheds.

4.1 IMPERVIOUS AREA ASSESSMENT

To establish the existing TIA and EIA of the watersheds within the study area, we assigned TIA and EIA values based on land use characteristics within the study area, supplemented by a review of aerial imagery.

The values used for TIA were adapted in part from the City of Surrey's Engineering Design Criteria Manual (2004). A detailed evaluation of EIA was not undertaken for the study area, rather EIA was estimated as 10% lower than TIA. While explicit source controls are not widely applied across the study area at present, roof leader discharge to pervious surfaces (on more recent developments), and various routing of driveways and sidewalks to grassed areas are assumed to have some effect. The resulting values used in the assessment of watershed TIA and EIA are presented in Table 4-1.

Table 4-1
Assumed Total and Effective Impervious Areas by Land Use

Land-Use Classification	Total Impervious Area (%)	Effective Impervious Area (%)
Commercial, Industrial, Transportation Corridor	90%	80%
Residential - Acreage	50%	40%
Residential – Half-Acreage	55%	45%
Residential - Other	65%	55%
Institutional (Schools, Churches)	80%	70%
Parks, Agricultural, Cemeteries	20%	10%

We calculated area-weighted TIA and EIA values for each watershed in the study area based on zoning in tandem with the TIA and EIA values for each land use classification. The results of this analysis are presented in Table 4-2.

Table 4-2
Calculated Total and Effective Impervious Area by Watershed

Watershed Name	Total Impervious Area (%)	Effective Impervious Area (%)
Bon Accord	58%	48%
157 Street	50%	40%
160 Street	54%	44%
Fraser Heights	60%	50%
Big Bend	62%	52%
Port Kells	72%	62%

4.2 RIPARIAN FOREST INTEGRITY

Percent Riparian Forest Integrity (RFI) is a key factor used in establishing overall watershed health. In the context of watershed health, natural watercourses (excluding lowland watercourses) should maintain an appropriate buffer on either side of the watercourse such that the riparian forest remains intact. This supports riparian functions that contribute to terrestrial and aquatic health, mitigates erosion, and helps to maintain natural flow regimes in the watercourses.

The desired riparian corridor for the watercourses in the Bon Accord – North Slope (East) study area is based on a total width of 64 m. This represents a 4 m stream width plus 30 m buffer to either side of the watercourse.

Table 4-3 presents our calculation of RFI for the study area watersheds. The assessment is based on the March 2014 orthophoto and includes the significant non-lowland natural watercourses in the study area and their tributaries, as illustrated on Map 4-1.

Table 4-3
Riparian Forest Integrity by Watershed

Watershed	Intact Riparian Area (ha)	Target Riparian Area (ha)	% RFI
Bon Accord	31.9	52.7	61%
157 Street	12.1	15.8	77%
160 Street	1.8	2.9	62%
Fraser Heights	5.1	8.8	58%
Big Bend	13.1	20.3	65%
Port Kells	14.7	25.8	57%
Surrey Bend	n/a	n/a	n/a

4.3 BENTHIC INVERTEBRATE COMMUNITIES

Metro Vancouver's ISMP Template (2005) suggests monitoring of benthic invertebrate communities to add further detail to watershed health assessments.

Measuring the presence of benthic invertebrates via the Benthic Index of Biotic Integrity (B-IBI) provides an estimate of the population and species of streambed insects present within a watercourse. Benthic invertebrates are considered 'indicator species,' meaning that by monitoring their presence, we can (in theory) discern the general health of a given watershed.

In the context of Metro Vancouver's proposed Watershed Health Tracking System, B-IBI scores determined through field sampling can be compared to the theoretical B-IBI scores, calculated as a function of a watershed's total impervious area. A field B-IBI score greater than that predicted based on TIA suggests that the watershed is in a better health than the level of development would suggest. Conversely, a lower score suggests that development has severely degraded the health of the watershed (more than would be expected on average).

To date, the City of Surrey has completed benthic invertebrate sampling on Bon Accord Creek and Leoran Brook in 2012, 2013 and 2014. The B-IBI scores for each sampling period are presented in Table 4-4.

Table 4-4
B-IBI Scores for Bon Accord Creek and Leoran Brook

Watercourse	Spring 2012	Fall 2012	Spring 2013	Fall 2013	Spring 2014
Bon Accord Creek	22.7	15.3	21.3	N/A	15.3
Leoran Brook	24.0	N/A	18.7	N/A	22.0
City-Wide Mean Score	16.1	14.3	15.9	18.4	16.5

For each sampling period, the scores exceeded the mean B-IBI score for the entire city, suggesting that the watercourses are in relatively good health, compared to other watercourses across the city.

Metro Vancouver provides guidance on the meaning of B-IBI scores as they relate to stream health (reproduced in Table 4-5 below). We note that Metro Vancouver's qualitative ranking is not particularly representative of streams of the type found in our study area, and the categorical results should be interpreted with this in mind. Based on the qualitative ranking, the B-IBI scores for both Bon Accord and Leoran Brook, despite being the highest ranking in the city, indicate 'poor' condition, with certain samples showing 'very poor' rankings.

Table 4-5
Values and Rankings for B-IBI Scores

B-IBI Score	Rank	Comments
46 – 50	Excellent	Pristine, no habitat degradation
38 – 44	Good	
28 – 36	Fair	
18 – 26	Poor	
10 – 16	Very Poor	Impacted watershed, heavily urbanized

Reproduced from Metro Vancouver's Monitoring and Adaptive Management Framework for Stormwater (September 2014).

Our watershed health assessment cannot be properly compared to these B-IBI scores, due to the limited data currently available. The Bon Accord watershed health assessment includes Bon Accord Creek, East Bon Accord Creek and Landfill Creek, but a B-IBI score is only available for the mainstem of Bon Accord Creek. Similarly, the Port Kells watershed assessment includes Lyncean Creek West and East, Leoran Brook, 183 Street Creek and 184 Street Creek, but a B-IBI score is only available for Leoran Brook. The relatively high B-IBI score for Leoran Brook does not adequately represent the eastern area of Port Kells that is potentially severely degraded due to the extensive impervious area.

4.4 WATERSHED HEALTH

The health of each watershed in the study area (excluding Surrey Bend Regional Park) is plotted on Metro Vancouver's Watershed Health Tracking System template in Figure 4-1.

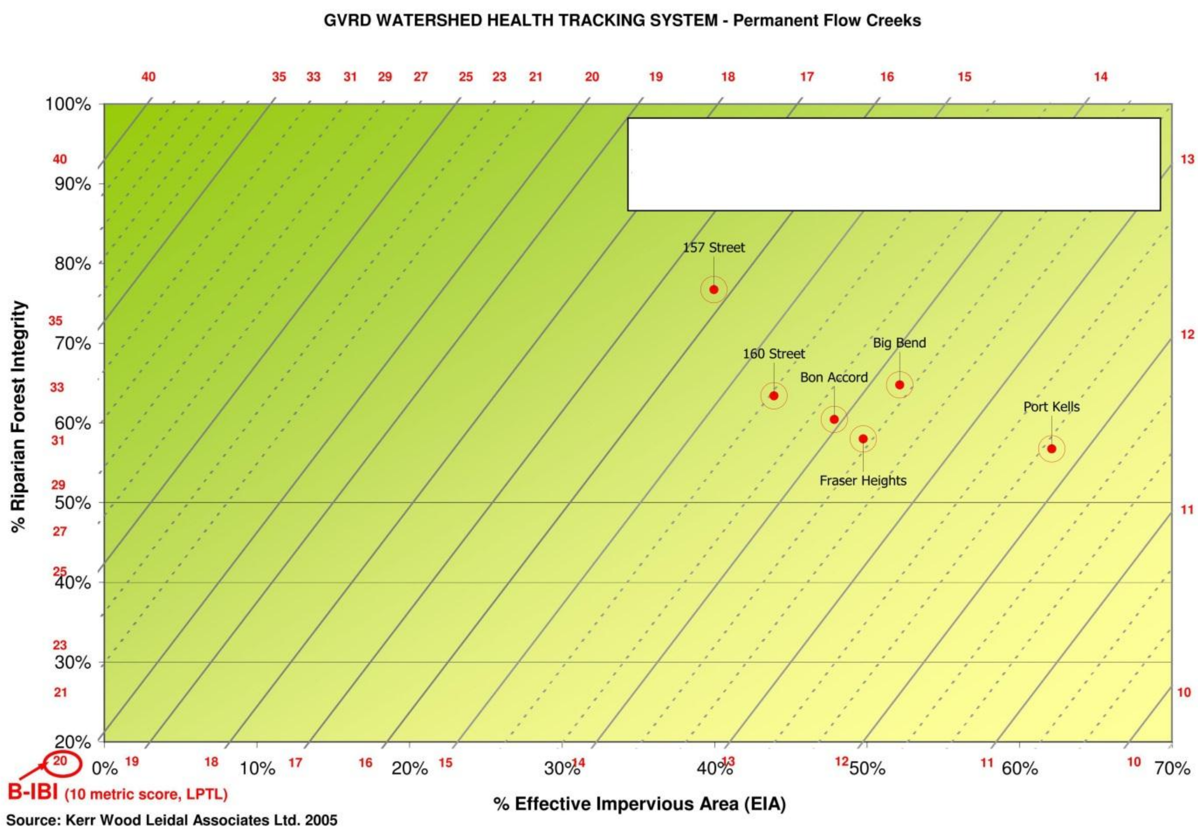


Figure 4-1

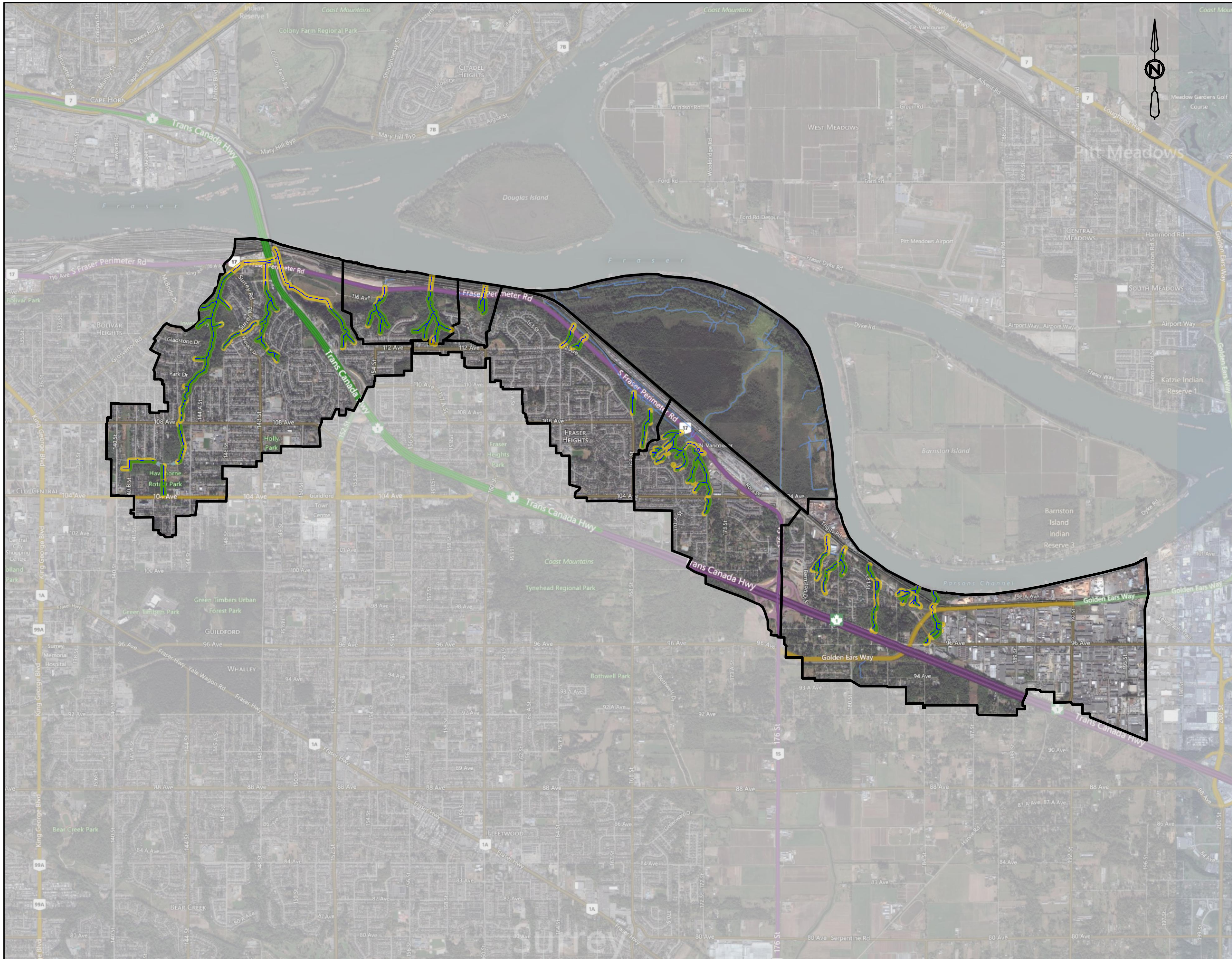
Watershed Health

The Watershed Health Tracking System provides a qualitative indicator of watershed health. A fully healthy watershed would have very high (>90%) RFI, and very low (<5%) EIA, and therefore would plot in the upper left-hand corner of the Health Tracking System figure. As RFI decreases and EIA increases, the watershed health degrades and the plotting position moves toward the bottom right-hand corner of the figure. Overall, the Watershed Health Assessment ranks the watersheds in the study area as follows (from most- to least-healthy):

1. 157 Street
2. 160 Street
3. Bon Accord
4. Big Bend
5. Fraser Heights
6. Port Kells

In general, the plotting position indicates all the watersheds within the study area are significantly impacted; however, the 157 Street, 160 Street, and Bon Accord watersheds should retain a reasonable level of watershed health. The (apparently) most heavily impacted watershed is Port Kells, which is intuitively expected, given its highly-developed, industrialized state.

We note that although Surrey Bend Regional Park was excluded from the Watershed Health Assessment for reasons discussed in the preceding sections, the portion of the Surrey Bend north of the CN railway has a low degree of disturbance, and is anticipated to be well-protected into the future given the City of Surrey and Metro Vancouver's management plan.



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Legend

- Intact Riparian Forest
- Recommended Riparian Forest
- Watershed Boundary

0 — 2 km

Map 4-1: Riparian Forest Integrity

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:60,000

DATE: May 2015

5 Hydrologic and Hydraulic Assessment

To assess the study area drainage system, we developed a hydrologic and hydraulic model of the existing network using PCSWMM software (SWMM 5.0.022).

The modelled drainage network is presented in Map 5-1. We note that the development of the model has been substantially refined from earlier stages based on discussions with the City, and this section supersedes previous work, except where explicitly referenced.

5.1 MODEL APPROACH

The primary purpose of our modelling effort is threefold:

1) Assess the degree to which the existing drainage system meets the City of Surrey's Design Criteria as defined in the City's 2004 Design Criteria Manual for the minor drainage system (piped drainage trunks receiving runoff from urban catchments of 20 ha or greater) and the major drainage system (natural watercourses and culverts).
2) To determine any reduction in the level of service of the minor and major drainage systems as a result of anticipated future development.
3) To identify natural watercourses most prone to accelerated erosion given current and future development and to assess the effectiveness of addressing these issues through the use of widespread source controls.

To accomplish these objectives, we developed two design storm scenarios and one extended period simulation, each comparing existing and future conditions. The purpose of each scenario is described in Table 5-1.

Table 5-1
Model Scenarios

Scenario Number	Return Period	Development Indicator	Development Condition	Analysis Purpose
1	5-year	A	Existing	Identify surcharged pipes in minor system drainage trunks
		B	Future	
2	100-year	A	Existing	Identify culverts causing flooding concerns for property or public safety
		B	Future	
3	Extended Period Simulation	A	Existing	Assess erosion potential in natural watercourses
		B	Future	
		C	Future with Source Controls	

5.2 MODEL DEVELOPMENT

Based on discussions with the City and a review of the City's criteria for planning-level studies, our model of the minor drainage system is limited to those pipes receiving runoff from urban catchments of 20 ha or greater. This generally results in the exclusion of pipes smaller than 600 mm in diameter. For a planning level of study, this provides sufficient detail to assess the primary deficiencies in the minor system. We delineated urban subcatchments based on a review of aerial imagery, topography and the overall layout of the piped drainage system.

The major system for the purposes of this model is limited to major flow routes through natural watercourses, lowland ditches, and culverts, and does not include overland flow paths through the urban environment (i.e. along roadways).

Our model is set up such that where the hydraulic grade line (HGL) in the piped system exceeds the ground elevation, the excess water ponds and is reintroduced into the system as capacity becomes available. This approach ensures that no water is lost from the model, but also results in slightly exaggerated HGLs at these locations. Our interpretation of all results considers this approach.

5.2.1 Base Model Assembly

The City of Surrey has undertaken a number of studies within the area, and maintains a digital GIS database of the below-ground storm pipe network and major watercourses and ditches. We supplemented this with information from several additional sources, including:

- South Fraser Perimeter Road Segment 8 Issued for Construction Drawings (Stantec, 2011);
- PCSWMM models created by Associated Engineering for previous projects including,
  - Port Mann Highway 1,
  - Golden Ears Connector,
  - East Bon Accord Subwatershed Functional Plan;
- Record drawings of detention ponds retrieved through the City of Surrey's online database;
- Field reconnaissance as part of this ISMP; and
- The City's Ravine Stability Assessments.

5.2.2 Modelled Subcatchments

We refined the watershed boundaries into subcatchments with tributary areas of approximately 20 ha to define the minor system's drainage trunks. Where necessary, subcatchments were further divided to develop realistic hydrologic responses in areas with unique characteristics. For example, along Bon Accord Creek, subcatchments of substantially smaller size were used to differentiate ravine areas from upstream urban catchments. We used a similar approach for lowland catchments around the major transportation corridors.

One of the key parameters required for hydrologic modelling is the impervious percentage of each subcatchment. We established these parameters for individual subcatchments based on the land use classifications discussed in Section 3.3, for three development scenarios:

1) Existing conditions (development indicator ‘A’),
2) Future conditions without mitigative source controls (development indicator ‘B’), and
3) Future conditions with mitigative source controls (development indicator ‘C’).

Existing Conditions (A)
Our cursory review of aerial imagery suggested total impervious coverages roughly in line with the values suggested in the City’s 2004 Design Criteria Manual for each land use, and these were applied to our subcatchment based on area-weighting routines.

Future Conditions (No Mitigation, B)
As discussed in Section 3.3, newer developments tend to have greater impervious coverage than older lots, due to increased use of available lot space by the buildings and the inclusion of garages, larger driveways, patios and sheds. Further, we expect that as the residential housing stock in the area ages, more and more of the older houses will be replaced, as properties undergo densification, redevelopment, or renovation that will ultimately lead to increased impervious coverage. We expect that as a result of this, the overall impervious coverage of the watersheds will increase in the future, absent of community-based redevelopment strategies. To account for this, our future development scenarios use slightly increased impervious values. Our assumption is that over the ultimate time horizon assessed in this ISMP, 35% of industrial, commercial and residential lots will undergo modifications that increase their impervious coverage (if unmitigated by source controls).

Future Conditions (With Source Controls, C)
Based on our analysis of the most applicable source controls to residential, commercial and industrial lots, we recognize that the opportunity exists to significantly reduce the effective impervious coverage of each lot. We adjusted the impervious coverage values to reflect this. We note that this scenario is only used to assess erosion potential in the natural watercourses, as it should not be relied on to relieve the strain on the drainage system during design storms.

Table 5-2 provides the impervious coverages applied to our subcatchments for each of the conditions mentioned above.

Table 5-2
Impervious Coverage by Land Use

Land Use Designation	Percent Impervious Coverage		
	Existing Conditions	Future Conditions (No Mitigation)	Future Conditions with Source Controls
Agricultural	20%	20%	20%
Commercial / Industrial	90%	92%	65%
Parks / Green Space	20%	20%	20%
Institutional	80%	80%	80%
Residential – Acreage	50%	54%	40%
Residential – Half-Acreage	55%	59%	40%
Residential – Urban/Suburban	65%	70%	40%
Transportation Corridor	90%	90%	90%
Utility Right-of-Way	20%	20%	20%

5.2.3 Modelling Parameters

Subcatchment parameters used in the model, including Horton infiltration rates, average slope, Manning's roughness coefficients for overland flow and depression storage were established based on aerial imagery, LiDAR data, site visits and previous modelling efforts of the region.

Manning's roughness coefficients for piped and open channel flows were determined based on pipe material, as defined in the City's GIS database and confirmed through record drawings, existing studies, previous modelling efforts and field investigations. Entry and exit losses vary based on material type and inlet/outlet configuration. Exit losses also vary based on the projected velocity difference between the conduit and the receiving channel or reservoir.

The various model parameters used for subcatchments and conduits are provided in Appendix C.

5.2.4 Rainfall Data

Rainfall data used in the modelling effort is based on data from Environment Canada for the Surrey Kwantlen Park rain gauge. This rain gauge was selected due to the proximity to the study area, its relatively unbroken period of record, and its suggested use in the City's 2004 Engineering Design Criteria Manual.

The rain gauge is located approximately 2 km west of the study area, at an elevation of 78 m. We note that an additional rain gauge (Port Kells Pump Station) is located within the study area, but the data was not used in this ISMP due to the limited period of record of 11 years.

5.2.4.1 Design Storm Scenarios

To establish a design storm to for use in assessing the drainage system, we used IDF data from Environment Canada for the Kwantlen Park rain gauge dated February 2, 2012. The IDF data includes 37 years of data (from 1962 to 1999). We note that the IDF data referenced in the City's Design Criteria Manual is from an earlier analysis than that used for our study, and therefore the values differ slightly.

Table 5-3 provides the Coefficient A and Exponent B values from the IDF curve for both the 5-year and 100-year return periods.

Table 5-3
Coefficient A and Exponent B for Surrey Kwantlen Park IDF Curve

	5-Year Return Period	100-Year Return Period
Coefficient A	15.500	25.700
Exponent B	-0.493	-0.534

The rainfall intensity data was used to create an All-Duration Storm (ADS) for the 5-year and 100-year return period events used to assess the City's minor and major drainage systems, respectively.

The ADS is an effective screening tool that can be used to efficiently identify problem areas within the storm drainage network. The ADS includes all durations on an IDF curve and therefore allows for the distribution of the 24-hour duration rainfall depth with intensities matching those seen during shorter-duration storms. This allows the analysis of drainage system hydraulics based on intensities representative of both winter and summer conditions.

As discussed, our modelling approach covers those minor system trunks receiving runoff from catchments of 20 ha or greater, and is appropriate for a planning level study. With catchments of this size, however, using a minimum time step (representing a short-duration rainfall intensity) of 5-, or even 30-minutes, can result in a short burst of intense rainfall arriving at the upstream end of the drainage trunk, indicating a deficiency not representative of reality. To moderate this effect, we used a minimum time step of 80 minutes. This attenuates the peak slightly, providing a realistic response, and hence more reliable results.

The 5-year and 100-year ADS distributions used in our models are presented in Appendix C.

For comparison purposes, we ran a sensitivity analysis using the SCS storm distribution recommended in the City's Design Criteria Manual and found that the use of the ADS results in slightly more conservative, but similar, results.

5.2.4.2 Extended Period Simulation

To assess the erosion risk in natural watercourses across the study area, we developed an extended period simulation (EPS) based on historical rainfall for a three year period (January 1, 2009 to January 1, 2012) as recorded at the Kwantlen Park rain gauge.

The Canadian Climate Normals entry for Surrey Kwantlen Park indicates an average annual rainfall of approximately 1530 mm. The period we selected for the EPS has an average annual rainfall of 1580 mm (approximately 1% greater than average annual rainfall), and therefore is representative of typical conditions. The simulation period experiences one 'extreme' event in August 2009, but given that this represents a small fraction of the total period assessed, the influence on the overall results is negligible.

The rainfall over the period modelled is presented in Appendix C.

5.2.5 Boundary Conditions

5.2.5.1 Design Storm Scenarios

The drainage network discharges to the Fraser River / Parsons Channel at several locations across the study area. The water level in the Fraser River surrounding the study area is influenced by tidal cycles year-round, and by freshet in the spring, which restrict the lowland drainage capacity.

To account for the influence of the Fraser River on lowland drainage, our model's outfalls include a fixed boundary condition representing the 2-year return period winter flow rate in the Fraser River at the study area. This level varies between 2.28 m (geodetic) at the Bon Accord Creek outfall, to 2.67 m (geodetic) at the eastern edge (Port Kells).

The water surface elevations were derived based on data output from the Fraser River Hydraulic Model created by Northwest Hydraulic Consultants (NHC). As part of the Port Mann / Highway 1 project, the Fraser River Hydraulic Model was used to establish water levels corresponding to the 2-year return period winter flow rate near the Bon Accord, Big Bend, and Port Kells watersheds. We linearly interpolated this data to derive boundary conditions at each outfall in the current model.

We used winter conditions, rather than spring freshet, to assess the performance of the drainage system. When using freshet boundary conditions, the inundation of the lowlands dominates model results and masks critical pipe capacity issues. While some backwater influence from the Fraser River is necessary to identify flooding concerns in the lowlands (due to limited culvert capacity), a full analysis of extreme flooding by the Fraser River is best addressed outside of the context of an ISMP.

5.2.5.2 Extended Period Simulation

For the simulation period (January 1, 2009 to January 1, 2012), we compiled observed water level data from the New Westminster water level gauge operated by the Department of Fisheries and Oceans Canada (DFO).

This gauge is located approximately 8 km downstream of the outfalls modelled (based on Fraser River Hydraulic Model chainage). We adjusted the observed water levels from the New Westminster gauge to account for the outfall locations in our model as shown in Table 5-4.

Table 5-4
New Westminster Water Level Gauge Adjustments to the Study Area

Model Outfall Location	October to March Adjustment	April to September Adjustment
Bon Accord	+0.03 m	+0.15 m
Surrey Bend	+0.22 m	+0.34 m
Port Kells	+0.42 m	+0.54 m

The adjustments are based on the output of the Fraser River Hydraulic Model, which suggests that the difference in upstream water levels is less pronounced during the winter months (October to March) than the summer months (April to September).

5.3 MODEL RESULTS

The summarized findings of our modelling of Scenarios 1 through 3 are discussed in the following sections. For each scenario, additional model results are presented in Appendix C.

5.3.1 Minor System (Scenario 1)

We assessed the adequacy of the minor system based on the City of Surrey's design criteria, which states that pipe capacity should be such that surcharging does not occur during the 5-year return period event (Scenario 1). For the purpose of our assessment, surcharging is defined as the peak HGL exceeding the pipe obvert at the upstream end (i.e. the upstream end of the pipe is 'full'), but is not necessarily reaching ground elevation. We imposed the additional criteria that a surcharge must be present for 12 minutes or greater, in order to screen out results based on model instabilities and routing anomalies.

The modelled system generally meets the stated criteria for both existing and future development conditions.

One significant deficiency was noted in the trunk system in eastern Port Kells (see Map 5-2). The trunk system (PK1 on Map 5-2) in this area is comprised of pipes ranging from 900 mm to 1050 mm in diameter, with relatively low slopes. North of 96 Avenue along the 194 Street alignment (PK2 on Map 5-2), a series of storm pipes provides some mild relief to the trunk system. The upstream invert of PK2 is over 1 m higher than the trunk system at this location, and many of the pipes are 600 mm or 675 mm diameter; thus, relief capacity is limited.

Under current conditions, both PK1 and PK2 are subject to significant surcharging, with the peak HGL breaching the ground surface as several locations.

Our analysis suggests that the surcharging of both PK1 and PK2 is best addressed by improving the relief capacity of PK2. We recommend the pipes along PK2 be upgraded to 1050 mm diameter from 96 Avenue to the discharge point north of 98A Avenue. The upstream invert at 96 Avenue should also be lowered to match that of the PK1 trunk at this location (9.05 m elevation). This approach poses minimal disturbance, as the majority of the work does not require the disruption of traffic. We note that the upgrade as proposed does not eliminate surcharging pipes upstream of the relief (along PK1), but reduces the surcharge such that it does not breach the surface.

5.3.2 Major System (Scenario 2)

We assessed the capacity of the major drainage system based on the 100-year return period event (Scenario 2). The major drainage system for the purposes of this ISMP does not assess major overland flow routes in urban areas (i.e. along roadways), but assessed culverts along major watercourses.

No deficiencies in the major system were noted. The City's design criteria for culverts suggest that surcharging is acceptable, provided no impacts to upstream property occur. The City's preference for culvert design is to utilize storage in the upstream channel as a way of reducing the required culvert diameter. We assessed surcharged culverts across the study area, and noted no specific flooding concerns.

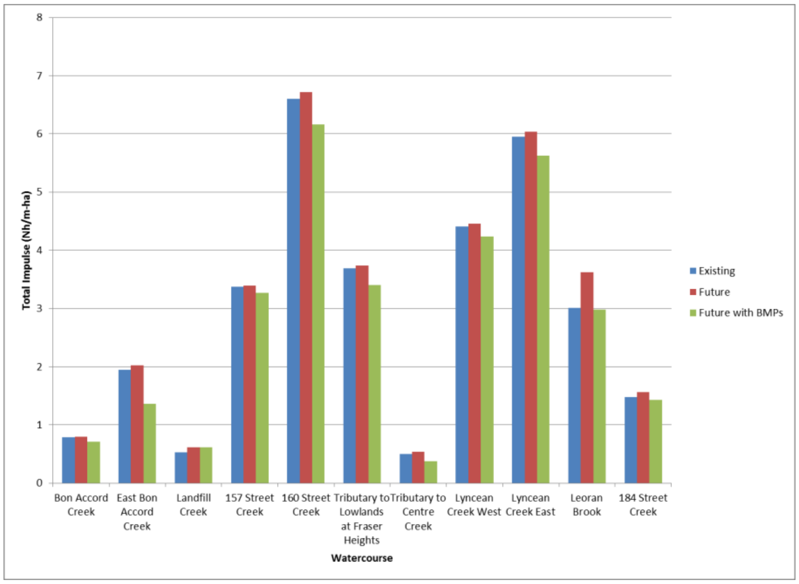
We assessed the peak HGL relative to the rim elevation of the modelled manholes to indicate where the trunk systems surcharge to ground during the 100-year return period event. The results are presented in Appendix C. We note that our model is configured to store surcharged water at the nodes, and that this volume is reintroduced into the system as capacity becomes available. In reality, ponded water will generally not remain at the surcharged node, but rather flow downstream and may re-enter the system at downstream points, or bypass it entirely. Interpretation and use of the presented results should consider this limitation.

5.3.3 Erosion Potential and Typical Hydrology (Scenario 3)

We ran an extended period simulation (EPS) to assess the stream power and erosion potential within natural watercourses (Scenario 3). We compared the results of the scenario over the three-year simulation period under existing conditions, future development conditions if no mitigation measures are undertaken, and future development conditions if widespread source controls are implemented across the study area.

The indicators of erosion potential in a natural watercourse are the tractive force and stream impulse. Tractive force is the shear force acting on the stream bed, caused by flowing water concentrated in the watercourse. When tractive force exceeds the threshold of movement of bed material, erosion occurs. Stream impulse is a parameter that describes the energy of a given watercourse, and is a function of the tractive force and the wetted perimeter over time. To determine the threshold of movement, details of bed composition must be known. The biophysical surveys performed on each watercourse for past studies only qualitatively describe the bed material, and as such, insufficient information is available to arrive at a conclusive critical shear force value. Therefore, we calculated stream impulse for each time step in the EPS, rather than only those time steps in which the critical tractive force was exceeded. Further, our model is uncalibrated, as no relevant hydrometric data is available. Therefore, the values of tractive force and stream impulse are qualitatively indicative of development impacts and provide a relative comparison of the stream impulse and tractive force within each watercourse.

Figure 5-1 shows the maximum tractive force and total stream impulse over the three-year simulation period. The reporting locations for this figure are shown on Map 5-3. The results have been normalized based on upstream tributary area for easier comparison of the impact magnitudes.



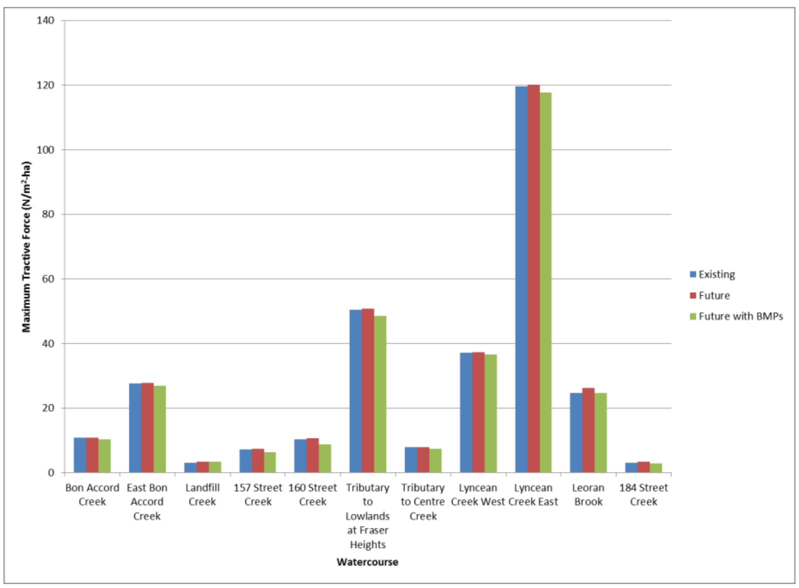


Figure 5-1

Tractive Force and Stream Impulse on the Study Area Watercourses

Table 5-5 highlights the hydrologic conditions of each development condition for each watershed in the study area.

Table 5-5
Subcatchment Hydrology over Three Years

Watershed	Runoff Volume (ML)			Reduction in Future Runoff Volume if Source Controls Widely Applied (%)
	Existing Conditions	Future Conditions	Future Conditions with Mitigative Source Controls	
Bon Accord	14434	15141	10978	27%
157 Street	2230	2272	2064	9%
160 Street	683	699	625	11%
Fraser Heights	7076	7461	5404	28%
Big Bend	5976	6229	5111	18%
Surrey Bend	4171	4171	4171	0%
Port Kells	18359	19875	15428	22%
Total Study Area	**52929**	**55848**	**43798**	**22%**

Analysis of the results leads to the following conclusions:

- Leoran Brook is at the greatest risk for accelerated erosion as a result of the Anniedale-Tynehead development if mitigative measures are not in place.
- Lyncean Creek is subject to high tractive forces relative to its tributary area; attenuation of runoff from upstream developments is therefore critical.
- The widespread implementation of recommended source controls leads to total runoff volume reduction of 22% over a three-year period of ‘typical’ rainfall. This result excludes Surrey Bend.

5.4 CLIMATE CHANGE IMPACTS

In the Lower Mainland, the major impacts resulting from climate change are expected to include an increase in the magnitude of design storms, a reduction in water availability during the summer months, and sea level rise.

The City’s Climate Adaptation Strategy (2008) suggests that by the 2050s, the City will experience an increase in peak rainfall intensity of 21% on ‘very wet days (>95th percentile).’ The result will be a proportional increase in peak flows throughout the drainage system.

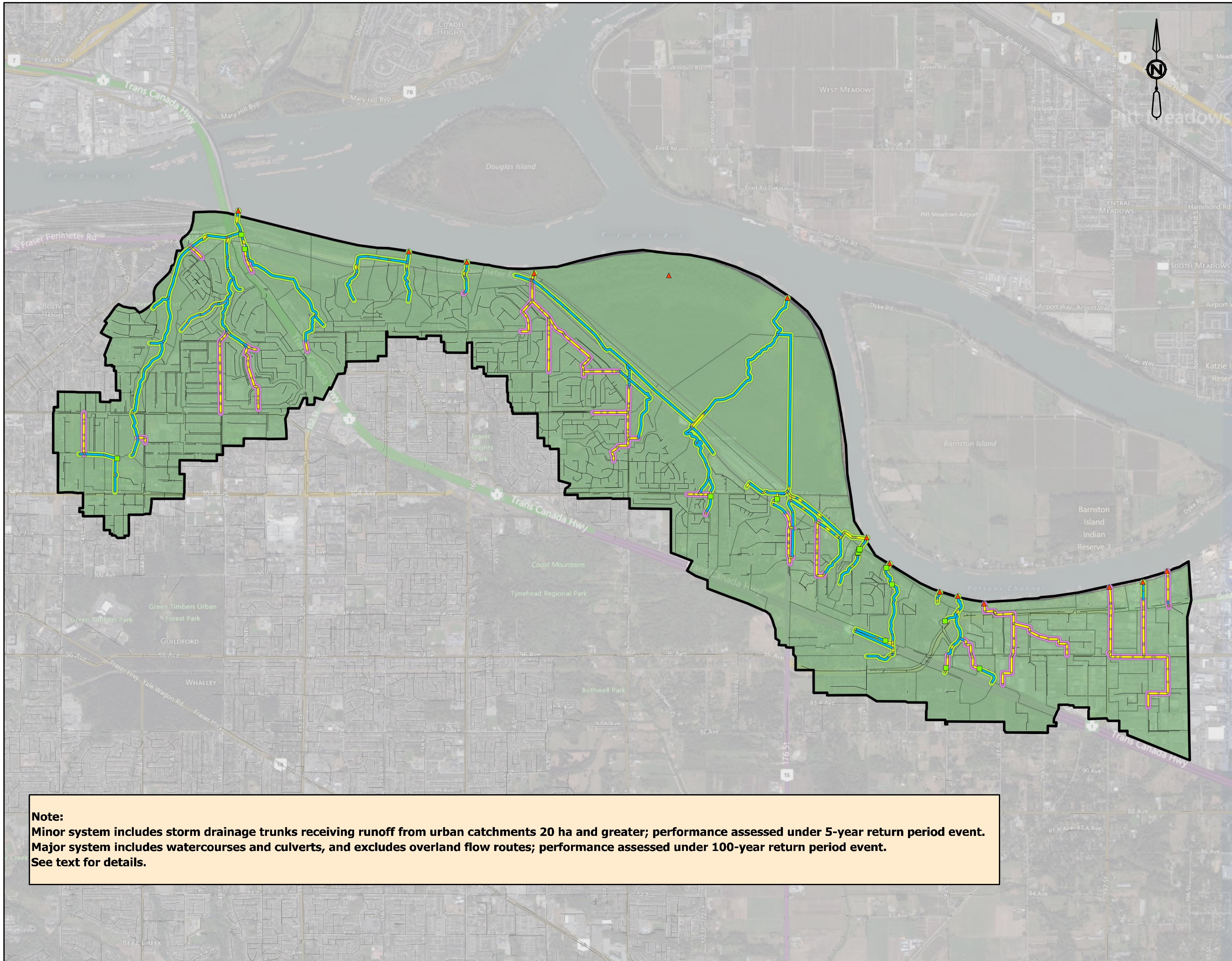
Furthermore, the lowlands of the Bon Accord – North Slope (East) watersheds discharge to the Fraser River, which is tidally influenced. Sea level rise in the vicinity of the lower mainland is anticipated to be 1.0 m by the year 2100, based on 2010 levels. For the purposes of design of lowland flood protection, the Province of BC recommends the use of 0.5 m sea level rise by the year 2050 (BC MoE, 2013). This has the potential to cause significant backwater effects that may restrict the capability of the culverts beneath the SFPR and CN railway to drain.

Many drainage pipes in both the minor and major drainage system presently meeting design criteria may be degraded under this scenario, and eastern Port Kells (where the drainage system is presently stressed) will see more noticeable impacts. Additionally, erosion in watercourses will be more pronounced and will progress at faster rates than are presently experienced. Sea level rise has the potential to cause significant backwater effects that may restrict the capability of the culverts beneath the SFPR and CN railway to drain, and may lead to flooding that is not apparent given the modelling done for this ISMP.

To assess the impact of increased rainfall on the drainage system, we ran a sensitivity test using the 5-year return period ADS, with rainfall increased by 21%.

We determined that in general, the minor system drainage trunks modelled are not significantly impacted, with the exception of the trunk beneath 148 Street north of 108 Avenue in the East Bon Accord subwatershed, which has insufficient capacity for the increased peak flows. Additionally, the trunks in Port Kells that are currently deficient experience a significant increase in peak HGL. Refer to Map 5-4 for the trunk system components potentially most impacted by the anticipated effects of climate change.

We anticipate that the greatest impacts of climate change will take the form of increased flood extents in lowland areas as a result of sea level rise, and more frequent nuisance flooding in neighbourhoods with smaller (<600 mm diameter) storm pipes.



Note:
Minor system includes storm drainage trunks receiving runoff from urban catchments 20 ha and greater; performance assessed under 5-year return period event.
Major system includes watercourses and culverts, and excludes overland flow routes; performance assessed under 100-year return period event.
See text for details.

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Legend

Study Area Boundary
CoS Storm Network (not modelled)

Modelled Network
Storage Node
Outfall
Junction
Conduit: Open Channel
Conduit: Storm Pipe
Subcatchment

System Classification
Major System
Minor System

0 2 km

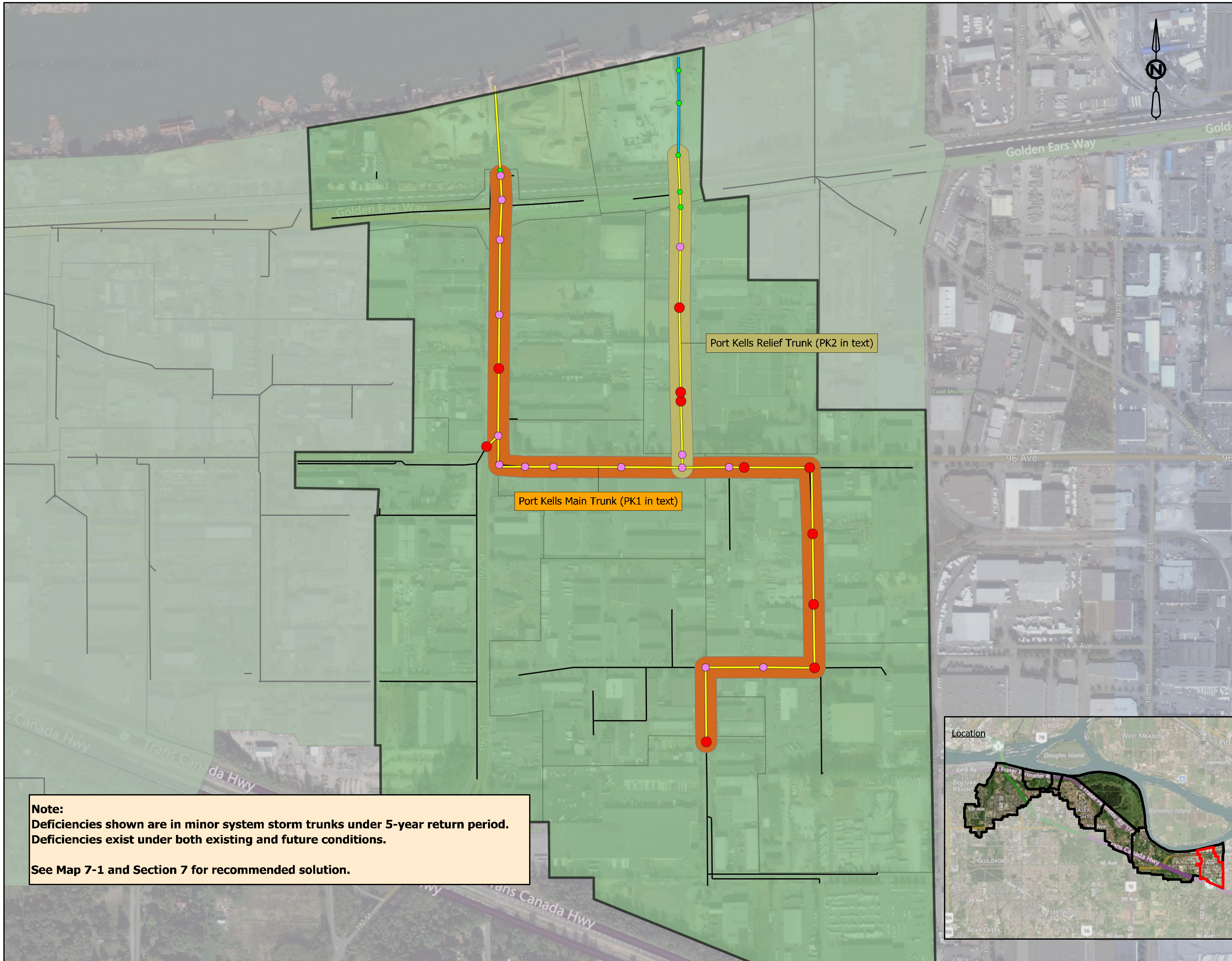
Map 5-1: Modelled Drainage Network

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:55,000

DATE: May 2015



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CoS Storm Pipes (not modelled)

Surcharge Condition
- Surcharged: HGL Above Ground
- Surcharge: HGL Below Ground
- No Surcharge

Model Component
- Conduit: Open Channel
- Conduit: Storm Pipe
- Subcatchment

Trunk Identifier in Text
- Main Trunk - PK1
- Relief Trunk - PK2

0 500 m

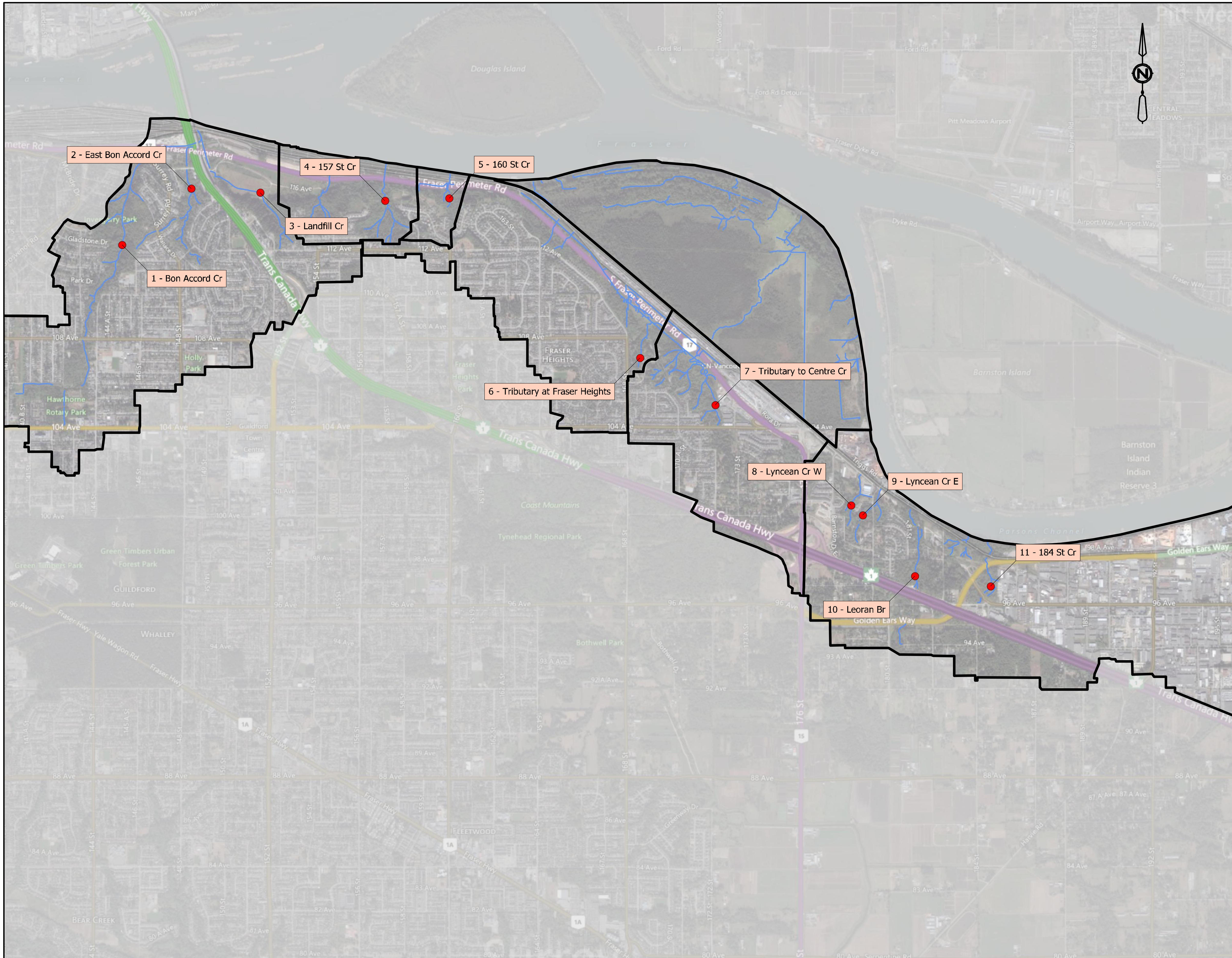
Map 5-2: Port Kells Deficiencies

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:10,000

DATE: May 2015



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Legend

Watershed Boundary
Watercourse
Flow Regime Reporting Locations

0 — 2 km

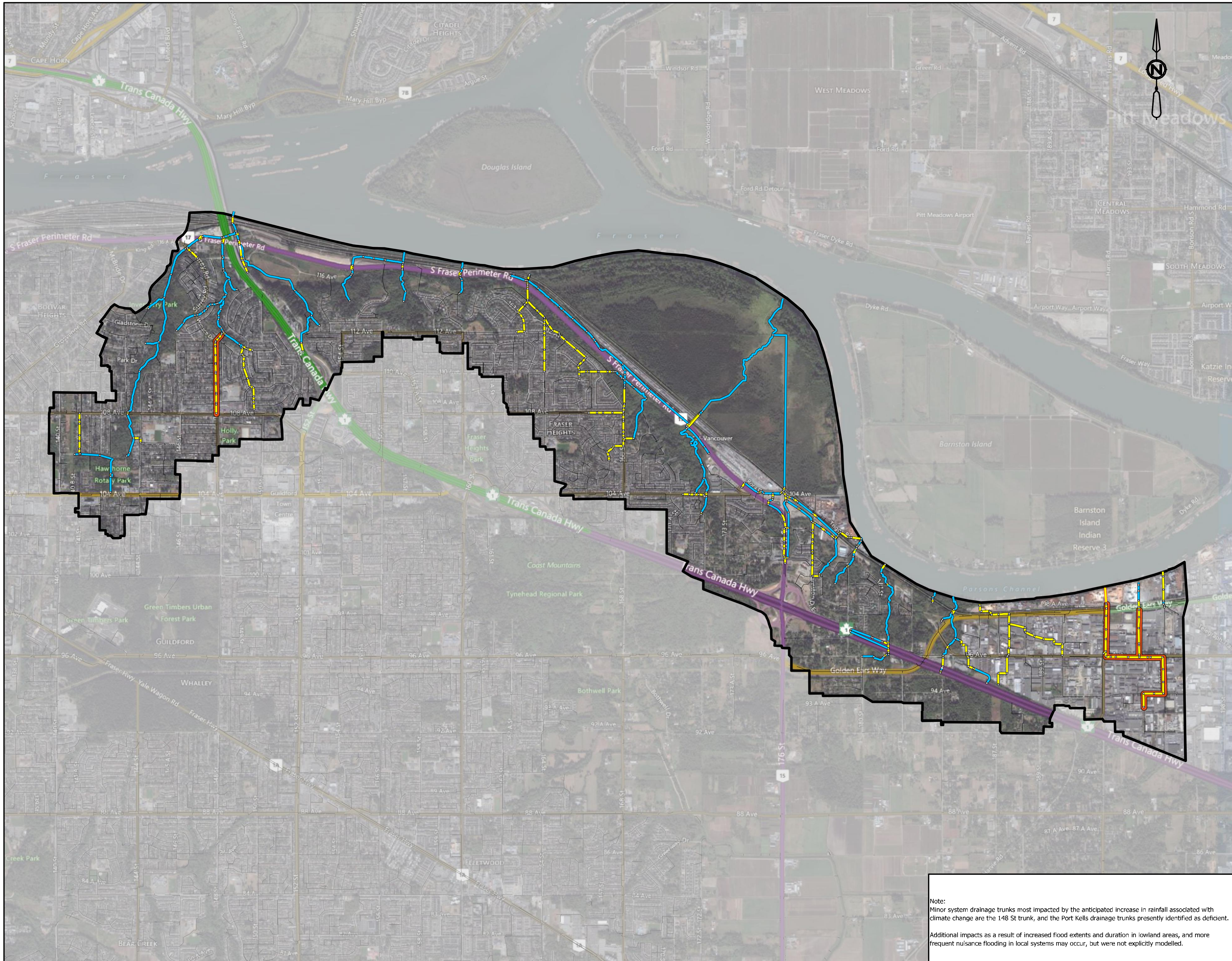
Map 5-3: Flow Regime Reporting Locations

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:50,000

DATE: May 2015



Legend

- Study Area Boundary
- CoS Storm Network (not modelled)

Modelled Network

- Junction
- Conduit: Open Channel
- Conduit: Storm Pipe
- Climate Change-Sensitive Storm Trunks

Note:
Minor system drainage trunks most impacted by the anticipated increase in rainfall associated with climate change are the 148 St trunk, and the Port Kells drainage trunks presently identified as deficient.

Additional impacts as a result of increased flood extents and duration in lowland areas, and more frequent nuisance flooding in local systems may occur, but were not explicitly modelled.

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Map 5-4: Storm Trunk Locations with Greatest Sensitivity to Impacts of Climate Change

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:55,000

DATE: May 2015

6 Goals and Objectives

The overarching objective of the Bon Accord – North Slope (East) ISMP is to stress the integration of stormwater / rainwater management into sustainable planning, development, redevelopment and environmental enhancement projects to improve the health of the watersheds.

Integrated stormwater management is directly linked to the stated goals and objectives of other City sustainability initiatives, including the Biodiversity Conservation Strategy, the Sustainability Charter, and the Climate Adaptation Strategy. As such, the recommendations in this ISMP should be seen as having enhanced value and worth actively working towards.

The following is the vision statement for the Bon Accord – North Slope (East) ISMP:

> **By 2020, the Bon Accord – North Slope (East) watersheds will be a model for the integration of natural areas within an urban context, resulting in improved watershed health when compared to current conditions.**

The goals and objectives of the ISMP are presented in Table 6-1.

Table 6-1
Goals and Objectives for the Bon Accord – North Slope (East) ISMP

Goals and Objectives	
1.	Proactively address the implications of climate change on the drainage system to prevent flooding and promote the protection of public property and health.
2.	Direct long-term redevelopment and economic activity towards sustainable practices and support community initiatives set to accomplish this.
3.	Preserve existing green space and undeveloped lands.
4.	Protect Surrey Bend Regional Park by restricting further encroachment of development into the area and tempering development in the Big Bend watershed.
5.	Improve biodiversity by supporting the maintenance and enhancement of the Green Infrastructure Network described in the City's Biodiversity Conservation Strategy.
6.	Enhance watershed health through specific environmental enhancement projects, ravine restoration projects, enforcement of riparian setbacks and by including responsible stormwater management in all infrastructure projects, including road rehabilitation projects.
7.	Enhance aquatic habitat through the removal of historic constraints, and the restoration of degraded habitat, considering fish presence, fish potential, and inputs to downstream habitat.

7 Recommended Improvement Projects

The present land use characteristics of the Bon Accord – North Slope (East) watersheds, combined with the few formal development plans for the area require a twofold implementation plan to achieve the objectives of enhancing watershed health:

1) Identified deficiencies and environmental constraints must be addressed through the implementation of specific projects.
2) Viable source controls and performance targets must be available to guide development, redevelopment and densification.

While the first can be accomplished with relative ease by the City, the second requires a cooperative effort with affected stakeholders. Source controls can be made a requirement for the Anniedale-Tynehead development, but that only covers a fraction of the total study area. Source controls are more effective at improving watershed health if widespread. This requires the desire (or at minimum, the willingness) of private land owners, community and environmental groups, and developers to incorporate these measures into small projects that may not be overseen in such great detail by the City. This also requires the City to promote the inclusion of ISMP objectives into projects that may otherwise not be seen as having a significant stormwater management component, such as road projects, biodiversity enhancements, and so on.

7.1 DRAINAGE AND ENVIRONMENTAL ENHANCEMENT PROJECTS

Drainage Projects

We recommend that the following drainage improvement projects are undertaken / proceed as planned:

- Provide increased relief capacity along the 194 Street alignment north of 96 Avenue in Port Kells (see Map 7-1 for details).
- Proceed with the East Bon Accord peak flow diversion project.

The proposed Port Kells relief project involves the upgrade of approximately 570 m of pipe to 1050 mm diameter.

The East Bon Accord peak flow diversion project is the result of a detailed study of the East Bon Accord subwatershed. The City of Surrey has developed project definition reports and cost estimates for this project, and detailed design of the first phase of six is presently underway. Project cost estimates presented in this ISMP are reproduced from these reports.

Environmental Enhancement Projects

Our recommended environmental enhancement projects are based on our identification of existing constraints throughout the ISMP process, and extend across the entire study area. We have not included any recommendations for Surrey Bend Regional Park, as protection and management of the watershed has been identified by the City and Metro Vancouver as being of critical importance, and specific studies have been undertaken to support the protection of this valuable and ecologically significant area.

Map 7-2(a, b) and Table 7-1(a, b) at the end of this section outline our recommended environmental enhancement projects.

Table 7-2 provides the total estimated cost for the recommended drainage and environmental enhancement projects.

Table 7-2
Cost for Recommended Drainage and Environmental Enhancement Projects

Project Location	Drainage Project Cost	Environmental Project Cost(2)	Total Cost
Bon Accord Watershed	$22,790,000(1)	$755,000	$23,545,000
157 Street Watershed	$ -	$35,000	$35,000
160 Street Watershed	$ -	$35,000	$35,000
Fraser Heights Watershed	$ -	$105,000	$105,000
Big Bend Watershed	$ -	$25,000	$25,000
Port Kells Watershed	$444,600(3)	$380,000	$824,600
Surrey Bend Regional Park(4)	$ -	$ -	$ -
Total Study Area	$23,234,600	$1,335,000	$24,569,600
		Total + Contingency(5)	**$25,103,480**

Notes: 1) City-estimated cost for East Bon Accord peak flow diversion project, presently underway – refer to Appendix A for project definition reports.
2) Refer to Table 7-1 at the end of this section for a breakdown of environmental projects and their associated cost estimates by watershed.
3) Proposed Port Kells Trunk Relief – refer to Map 7-1 at the end of this section for project details.
4) Surrey Bend Regional Park conservation efforts are assumed to be paid jointly between the City of Surrey and Metro Vancouver and in line with the park's management plan; costs have therefore been excluded in this ISMP.
5) Contingency is applied as [(Total Drainage Cost + Total Environmental Cost – East Bon Accord Diversion Cost) x 1.3]. The diversion project is assumed to include its own contingency.

7.2 SOURCE CONTROLS AND PERFORMANCE TARGETS

The following sections outline practical source controls and performance targets for residential lots, industrial/commercial lots, and roadways. We note that the findings of our public consultation strategy suggest that familiarity with the terminology associated with stormwater source controls is not widely known; therefore, an effort should be made on the City's part to undertake public engagement efforts and enhance the public's understanding of the purpose and types of source controls available.

7.2.1 Residential Lots

Residential land uses make up 37% and 39% of the total study area under existing and projected future conditions, respectively.
Older residential lots tend to have a relatively small building footprint, and a substantial proportion of pervious surface. In contrast, newly developed lots typically maximize building coverage, and include additional impervious features such as garages, sheds, concrete slab patios and larger driveways. Figure 7-1 illustrates the general difference in lot configuration between old (7-1a) and new (7-1b) residential developments.

Newer lots typically have a total building coverage of 40%, with paved surfaces comprising an additional 30%, and pervious surfaces such as lawns and gardens only occupying 30% of the total lot area. Through the use of permeable pavement and absorbent soil / growing media, we estimate that up to 60% of these lots can be dedicated to source controls (absorbent soil and permeable pavement, Figure 7-1c).

7.2.1.1 Residential Performance Targets

All residential lots (urban, suburban and rural) undergoing development or redevelopment should target a minimum of 60% pervious coverage through the use of source controls. Further, vegetation should be planted and / or preserved.

Peak allowable runoff rates under the 24-hour duration, 2-year return period design storm shall be no greater than 3 L/s/ha. This represents an Effective Impervious Area (EIA) of 40% for residential lots. We note that our analysis suggests limited volume reduction over an extended period (approximately 7% over a 25-year period); therefore, we do not propose specific volume reduction targets for residential lots. The primary benefit of residential source control will be attenuation, with limited volume reduction a secondary benefit.

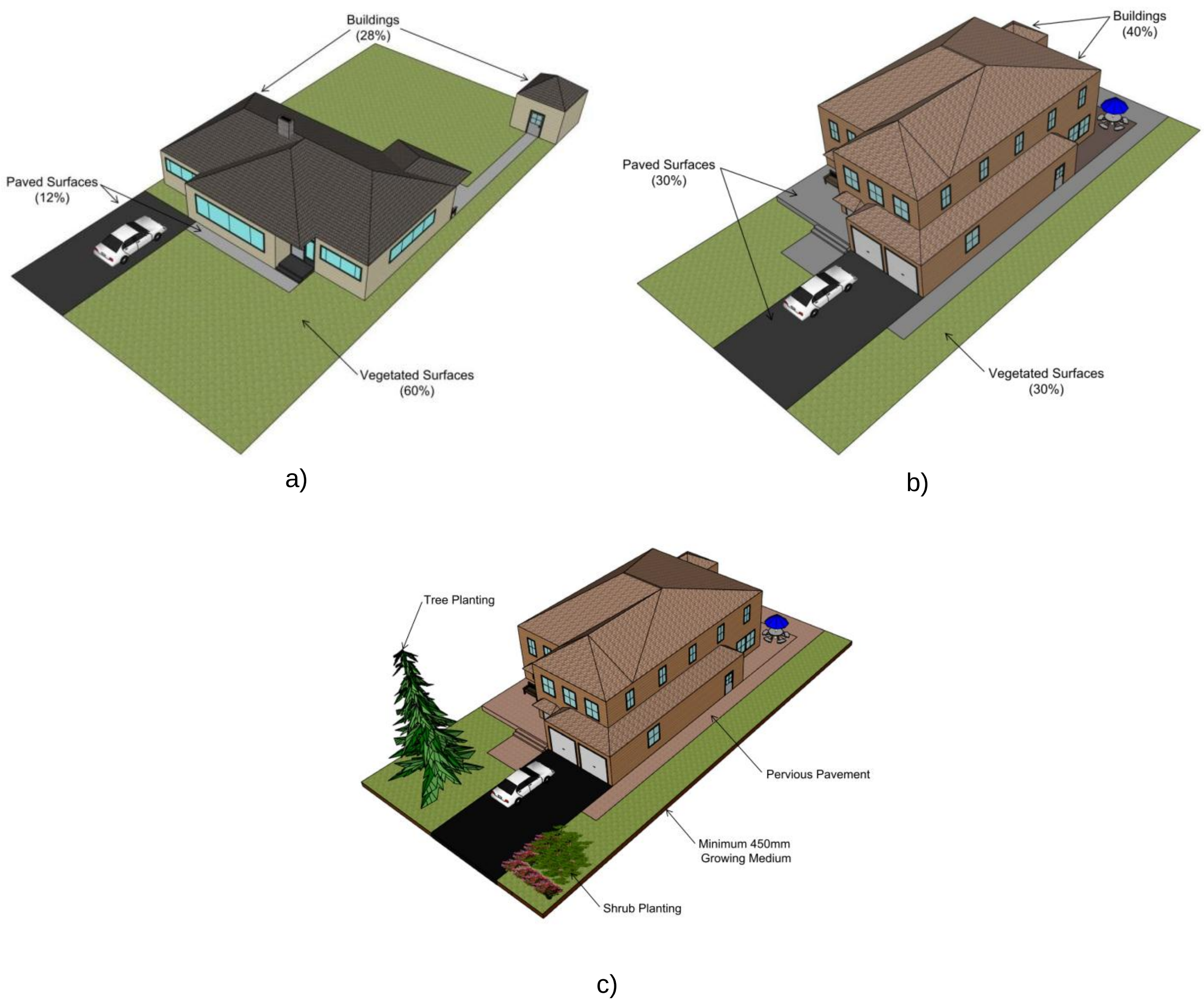


Figure 7-1
Residential Lot Layouts

a) Older residential lot; b) Newly constructed / redeveloped residential lot;

c) Newly constructed / redeveloped residential lot with mitigative source controls / BMPs

7.2.1.2 Residential Source Controls

The source controls that are most applicable to residential developments are described below.

Roof Drain Disconnection

Houses constructed prior to 1984 typically have roof drains that are directly connected to the storm system. Runoff originating from the roofs of these buildings is therefore unattenuated. During redevelopment of these lots, roof drains should be disconnected from the storm system, and instead discharge to pervious surfaces, such as lawns or gardens.

Absorbent Landscaping and Growing Media

Absorbent landscaping acts like a sponge that retains rainfall, stores it temporarily, and then slowly releases it. Its primary purpose is to mimic the hydrologic function of undeveloped land on a developed site. It tends to have only a limited capacity, and will saturate and lose functionality during large rainfall events. Regardless, it is an appropriate measure to manage stormwater at the source, and is particularly effective for small, frequent rainfall events. Additionally, the filtration mechanism of the soil layer provides water quality benefits.

Absorbent landscapes typically consist of a layer of absorbent soil with vegetation such as shrubs and trees. The vegetation provides an additional function of supporting interception and evapotranspiration. Absorbent landscapes receive direct rainfall and runoff from small impervious surfaces (such as driveways, paths and patios). Additionally, roof downspouts can be directed such that they discharge to the absorbent landscape, rather than directly to other impervious surfaces or the storm drainage network.

Absorbent landscapes are easily applied (relative to other source controls) to existing residential lots, and provide aesthetic benefits for the community and individual homeowners. Vegetation can be selected such that it also supports backyard biodiversity and the increased presence of native plants. Required maintenance includes typical gardening activities such as weeding and replacing dead plants, as well as watering during extended dry periods. As well, an overflow should be considered, and should be inspected monthly and debris removed.

For the purpose of effective stormwater management, the depth of absorbent soils should be a minimum of 450 mm, and be comprised of soils with high organic content, such as sandy loam.

Pervious Pavement

Pervious pavement provides an alternative to otherwise impermeable surfaces, such as driveways, walkways and patios. It consists of a paving system that allows rainfall to percolate into an underlying subgrade reservoir. If sufficient infiltration capacity exists in the subgrade or underlying soils, the water will be infiltrated. Otherwise, it can be discharged to the storm network through an underdrain.

Metro Vancouver’s Stormwater Source Control Guidelines (2012) suggests that pervious pavement can receive runoff from other impermeable areas, provided sediment loads are not excessively high. Pervious pavement can provide a reduction in peak flows and runoff volume, as well as some contaminant removal, and in certain areas assists in rehabilitating baseflows to natural watercourses via groundwater recharge.

Pervious pavement typically consists of five layers including the surface (porous asphalt / concrete, concrete / plastic grid pavers, concrete pavers installed with gapped joints), an aggregate bedding, open graded base, open graded sub base, and subsoil. Additionally, the use of a geotextile to prevent migration of fines into the base drainage courses is recommended. With relatively impermeable soils, as may be encountered in the study area, a partial-infiltration configuration that includes an underdrain may be required.

On residential lots, pervious pavement provides excellent mitigation to the effects of driveway expansions, new walkways, porches and patios. Due to the relatively complicated nature of construction, however, home owners may be hesitant to install pervious pavement for these types of projects. Supplemental support and encouragement from the City may be necessary to maximize the implementation of pervious pavements over the Bon Accord – North Slope (East) watersheds.

7.2.2 Industrial / Commercial Lots

Industrial / commercial lots occupy 15% and 18% of the study area under existing and projected future conditions, respectively, and are primarily concentrated in Port Kells.

As with residential lots, recently constructed industrial lots tend to have greater impervious coverage than older ones, as illustrated in Figure 7-2. Bioswales, rain gardens and green roofs could feasibly be applied to 35% of total lot coverage if planned appropriately.

7.2.2.1 Industrial / Commercial Performance Targets

All industrial lots undergoing development or redevelopment should target 35% pervious coverage through the use of bioswales, rain gardens and green roofs. Further, vegetation should be planted and / or preserved.

Peak allowable runoff rates under the 24-hour duration, 2-year return period design storm shall be no greater than 5 L/s/ha. This represents an EIA of 65% for industrial lots.

All industrial lots undergoing development or redevelopment must include provisions for the treatment of runoff resulting from the majority (90%) of rainfall events, prior to discharge off-site. This is typically estimated as 72% of the 24-hour duration, 2-year return period design storm.

At a minimum, measures must be in place to achieve an 80% reduction in Total Suspended Solids (TSS) concentration. We note that appropriately designed source controls, such as rain gardens and bioswales are generally acknowledged to achieve these targets. Where insufficient lot area is available to meet these targets, manufactured treatment units with sufficient capacity must be selected and installed. All water quality devices (manufactured units and source controls) must be capable of bypassing the City's design peak flow rates (presently the 5-year return period event) with no resuspension of settled material.

We recommend that the City require proponents of industrial lot development or redevelopment determine potential contaminants of concern, and provide measures to address contaminants of concern. These include, but are not limited to heavy metals, oils, and grease.

Where feasible, storage provisions are to be provided to limit the peak flows released from the site for a 24-hour duration, 5-year return period storm event under postdevelopment (or redevelopment) conditions such that peak flows do not exceed 50% of the peak flow rate generated by the site for a 24-hour duration, 2-year return period storm event under current development conditions. This criterion provides improved management of peak flows, even if the site's impervious coverage is not significantly altered during redevelopment. This can be achieved through above-ground storage. In Port Kells, the potential for high groundwater can result in ineffective subsurface storage due to inflows vastly reducing the available active storage. Subsurface storage should only be permitted where investigation has confirmed that such facilities are not adversely impacted by groundwater conditions.

We recommend the following targets for on-site retention / detention storage:

Minimum required storage volume: 350 m^3/ha
Maximum allowable release rate: 9.0 L/s/ha
Volume release pattern: 50% in first 24 hours, 50% in next 48 hours.

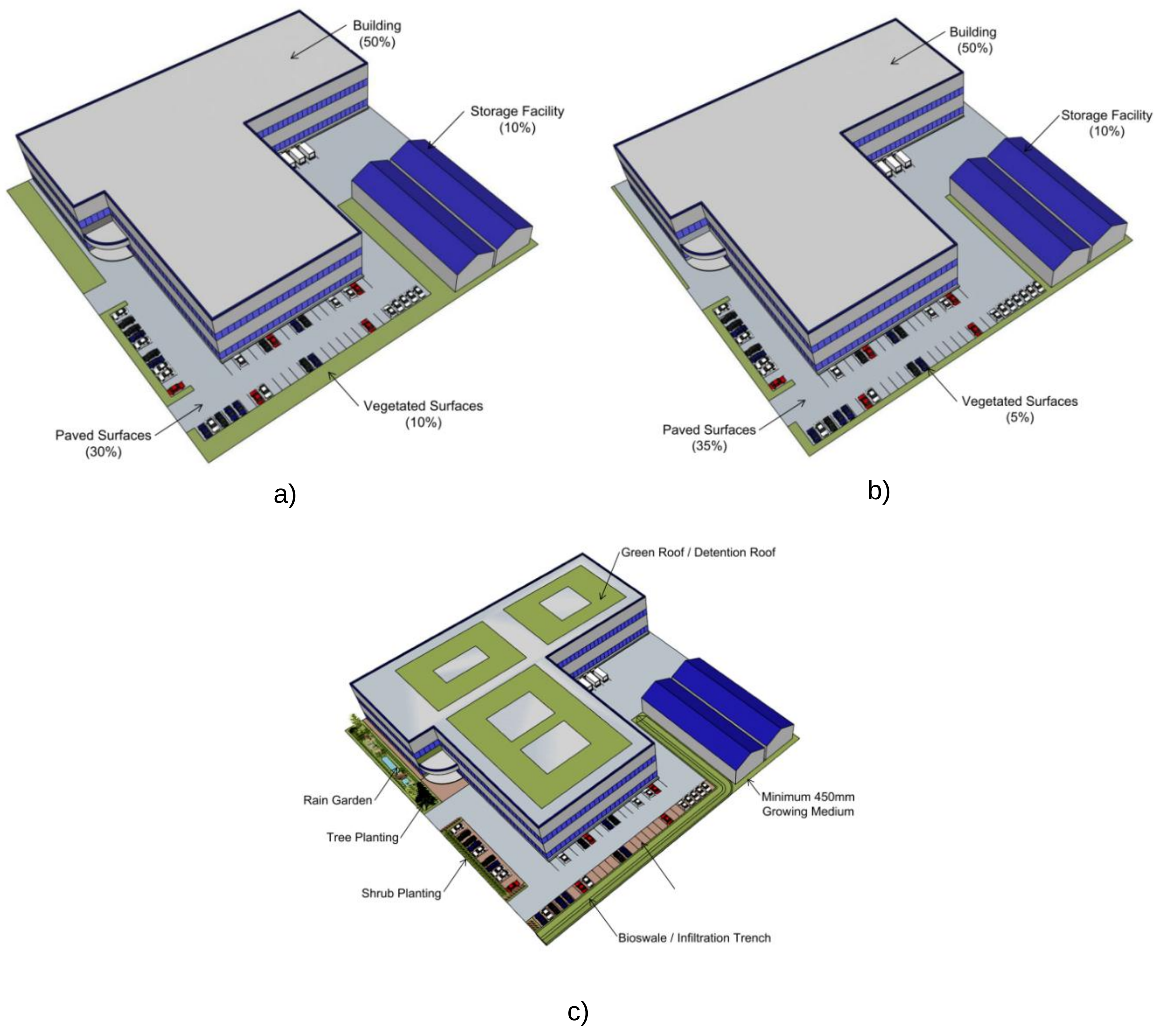


Figure 7-2
Industrial Lot Layouts

a) Older industrial lot; b) Recently constructed / redeveloped industrial lot

c) Recently constructed / redeveloped industrial lot with mitigative source controls / BMPs

7.2.2.2 Industrial / Commercial Source Controls

The most applicable source controls for industrial / commercial lots are described below.

Absorbent Soils
Absorbent soils are described in Section 7.2.1.2, and may be applied to landscape areas on industrial / commercial lots to achieve attenuation of runoff.

Bioswales
Bioswales are shallow open channels that capture and convey stormwater runoff. They are typically comprised of a vegetated topsoil layer, a drain rock layer and a subgrade drain. In locations where stormwater treatment is a concern, as with industrial developments, bioswales provide stormwater treatment by assisting in the removal of Total Suspended Solids (TSS), heavy metals and some hydrocarbons.

Compared to a traditional piped drainage network, bioswales can significantly attenuate runoff received from impervious surfaces due to the relatively high roughness of the surface layer, the effect of temporary subsurface storage in the drain rock layer, and the promotion of shallow infiltration.

Bioswales can be implemented along the edges of parking lots and provide benefits to stormwater quality while lessening the strain on the City's piped drainage network.

Green Roof
A green roof is a modified conventional roof that incorporates features such as planter boxes that support living vegetation. For the purposes of stormwater management, soil depth is typically 300 mm or less. Green roofs operate similar to absorbent landscaping by soaking up and temporarily retaining direct rainfall.

Buildings located on industrial lots tend to occupy a significant fraction of the total lot area and typically have flat roofs. This makes the implementation of green roofs practical and very effective for these areas.

Various studies have highlighted that green roofs provide extra insulation reducing heat transfer as well as improve the longevity of the roof structure by helping to protect the membrane from extreme temperature fluctuations (Metro Vancouver, 2012). With proper communication of these benefits, industrial property managers may be more inclined to support the inclusion of green roofs on their lots.

Rain Gardens
Rain gardens are aesthetically pleasing landscape features designed to capture, detain, treat and infiltrate stormwater runoff. Rain gardens typically consist of 450 mm of absorbent topsoil supporting trees, shrubs and groundcover, overlying a drain rock reservoir. The soil and vegetative layers provide attenuation and treatment of water as it percolates and collects in the drain rock reservoir. If infiltration capacity in the drain rock reservoir is sufficient, the water will infiltrate. Otherwise, the water is directed into the storm drainage network either through an overflow catch basin at the surface or through a subdrain located in the drain rock layer.

Within industrial areas, rain gardens can provide a pleasant aesthetic feature while collecting and treating the majority of runoff generated from impervious surfaces such as parking lots or rooftops.

7.2.3 Roadways

In line with the stated objectives of this ISMP, the City should maximize the opportunity for implementing source controls by promoting incorporation of sustainable stormwater management principles into all types of projects, including road construction / rehabilitation projects.

7.2.3.1 Roadway Performance Targets

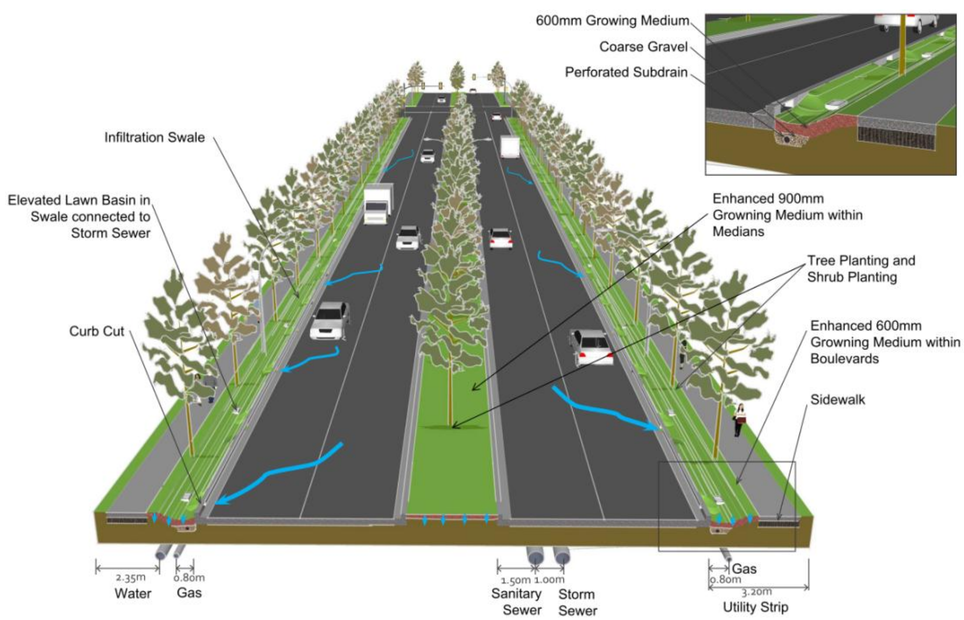
Projects on roads classified as either collector, arterial, or highway should include provisions for the treatment of heavy metals, oil and grease.

Where possible, and where safety concerns can be adequately addressed, road drainage should be directed to pervious areas such as bioswales, rain gardens, pervious shoulders / parking areas prior to discharge to the piped storm system.

Peak flow targets are not prescribed, given the variability in scope of road improvement projects.

Figure 7-3 illustrates the potential configuration of roadway source controls to maximize hydrologic benefits across the study area. These measures should be implemented where possible.

a)



b)

Figure 7-3
Road Right-of-Way Source Control Configurations

a) Local and collector roads; b) Arterial roads

7.2.3.2 Roadway Source Controls

The most applicable source controls for roadway projects are described below.

Bioswales / Enhanced Ditches

The hydrologic benefits and typical structure of bioswales was discussed in Section 7.2.2.2.

Runoff from travelled lanes and parking areas can be directed to bioswales, rather than being immediately discharged into the storm drainage network. This provides for treatment of TSS, heavy metals and hydrocarbons, reducing the direct loading on the storm drainage network.

Pervious Pavement

The hydrologic benefits and typical structure of pervious pavements were discussed in Section 7.2.1.2.

While pervious pavement should not be implemented in high-traffic areas due to potential structural concerns and ponding, sidewalks and parking lanes can utilize pervious pavement to attenuate runoff and promote shallow infiltration to the underlying soil.

Rain Gardens

The hydrologic benefits and typical structure of rain gardens were discussed in Section 7.2.2.2.

Runoff from travelled lanes and parking lanes can be directed to rain gardens to provide treatment and runoff attenuation. Rain gardens can be placed at the downstream ends of bioswales to provide maximum treatment efficiency and runoff reduction. Rain gardens may be linear features or incorporated into curb bulges.

Absorbent Landscaping and Street Trees

The hydrologic benefits and structure of absorbent landscaping were discussed in Section 7.2.1.2.

Absorbent landscaping can be employed in combination with street trees to support the City's ultimate tree canopy goals as well as the City's goal to provide aesthetically pleasing communities. Absorbent landscaping in a roadway context is best suited to the inclusion of street trees to maximize the hydrologic benefits. Trees can consist of coniferous or deciduous trees, and are most beneficial if they possess high leaf densities. Coniferous trees are preferred over deciduous trees, as leaf litter can restrict the absorption of the underlying soil, and their retention of foliage through the winter rainy season promotes maximum interception.

For maximum effectiveness, the growing medium should have a minimum depth of 450 mm. Analysis of the feasibility of street trees must consider implications to the surrounding pavement structures, as tree roots can damage concrete sidewalks and paved roads, although this effect can be mitigated by the use of structural soils.

Structural soils are soil media that can be compacted to meet pavement design and installation requirements while permitting adequate root growth. It is generally composed of gap-graded crushed stone, clay loam and a hydrogel stabilizing agent to bind the mixture together. It provides a root-penetrable, high strength pavement system that shifts design away from individual tree pits.

Structural soil can be located under the sidewalks adjacent to most arterial and local roads. By allowing roots to cover a greater area without damaging pavement structure, structural soil can reduce some of the drawbacks of street trees.

7.3 ANNIEDALE-TYNEHEAD NEIGHBOURHOOD CONCEPT PLAN

As discussed, the land development associated with South Port Kells Anniedale-Tynehead NCP is the most significant development project planned for the study area. A corporate report presented to the City of Surrey Mayor and Council in April 2012 describes the proposed stormwater servicing strategy for the Anniedale-Tynehead area. The information is derived from the Anniedale-Tynehead NCP (April, 2012).

The proposed stormwater servicing strategy for Anniedale-Tynehead is in general adherence to the objectives of this ISMP, and integrates source controls and water quality enhancements into the design. As the design progresses, Anniedale-Tynehead should review and incorporate the source control measures recommended in this ISMP, where applicable. A copy of the corporate report is included as Appendix D.

Two notable differences between the Anniedale-Tynehead NCP strategy and this ISMP are:

- The Anniedale-Tynehead NCP proposes a minimum 300 mm depth of absorbent topsoil, while this ISMP recommends 450 mm minimum. We recommend 450 mm be used as a minimum.
- The Anniedale-Tynehead NCP proposes to capture 50% of Average Annual Rainfall, where we recommend 72% capture. Our recommendation is based on DFO Criteria; however, we note that 50% of Average Annual Rainfall is a typical and accepted practice in British Columbia.

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Legend

- CoS Existing Storm Pipe
- CoS Existing Storm Manhole
- Recommended Pipe Upgrade

Reference Table 7-2 for Cost Estimate

0 — 200 m

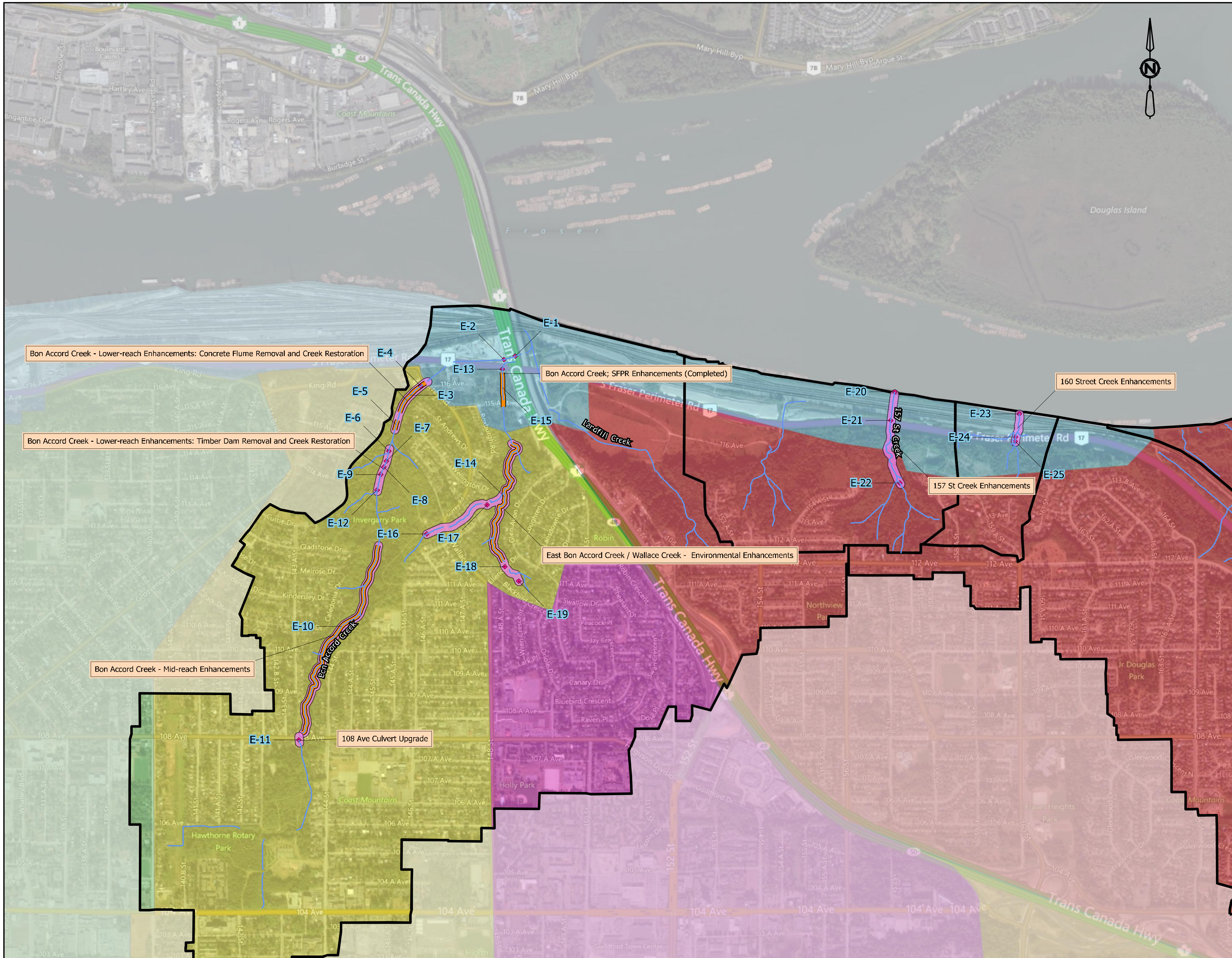
Map 7-1: Recommended Port Kells Trunk Relief

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:5,000

DATE: May 2015



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Legend

Recommended Environmental Projects

Reference Table 7-1a and b

- Project Linkages (Table 7-1a)
- Enhancement Sites (Table 7-1b)
- Enhancement Regions (Table 7-1b)
- Watercourse
- Watershed Boundary

Biodiversity Management Areas

(From Biodiversity Conservation Strategy)

- Fleetwood
- Fraser River Industrial
- Green Timbers
- Surrey Bend
- Tynehead
- Newton (not in study area)
- Serpentine Nicomekl (not in study area)

0 1 km

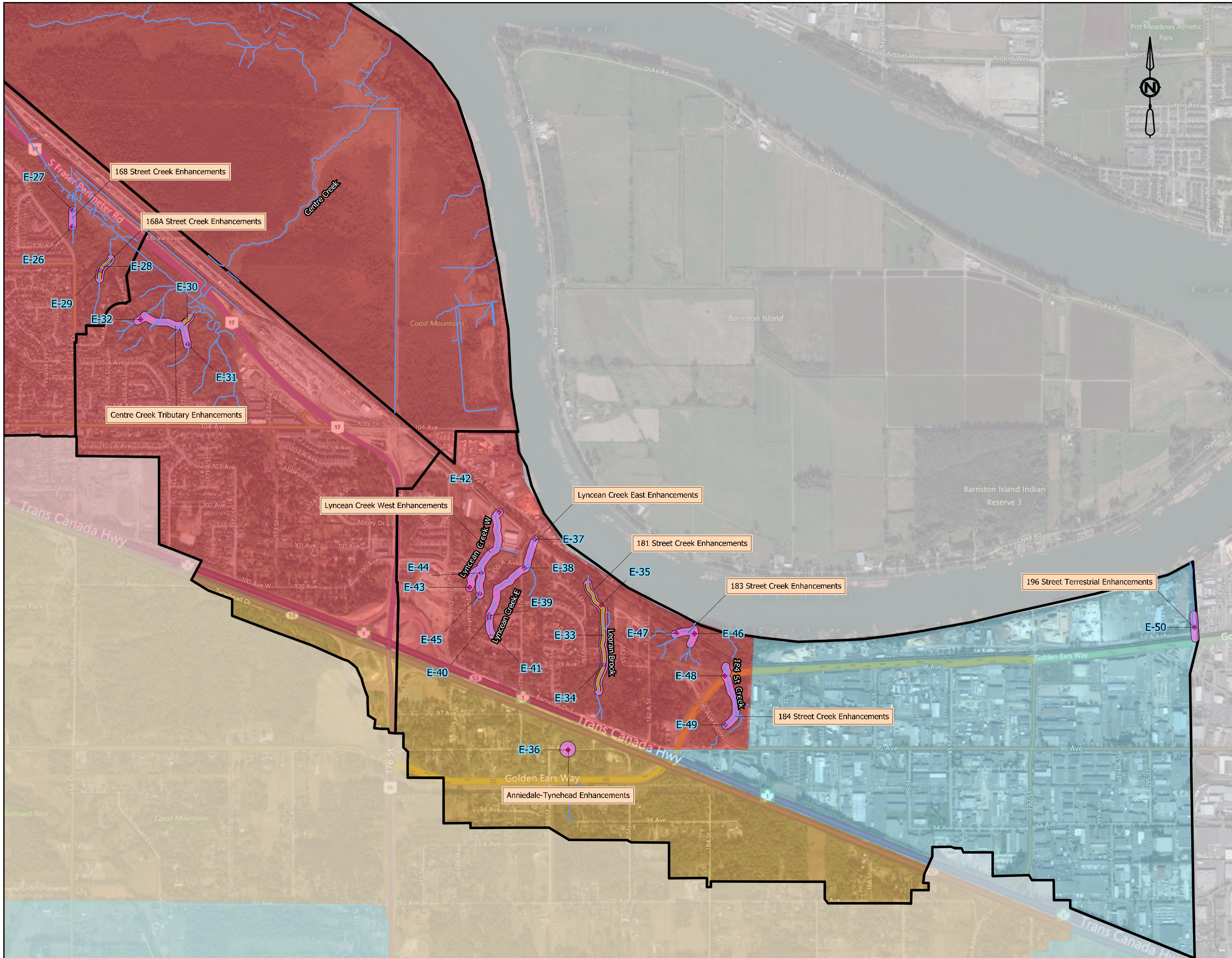
Map 7-2a: Recommended Environmental Enhancement Projects

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:25,000

DATE: May 2015



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Legend

Recommended Environmental Projects
Reference Table 7-1a and b
Project Linkages (Table 7-1a)
Enhancement Sites (Table 7-1b)
Enhancement Regions (Table 7-1b)

Watercourse
Watershed Boundary

Biodiversity Management Areas
(From Biodiversity Conservation Strategy)
Fleetwood
Fraser River Industrial
Green Timbers
Surrey Bend
Tynehead
Newton (not in study area)
Serpentine Nicomekl (not in study area)

0 1 km

Map 7-2b: Recommended Environmental Enhancement Projects

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:25,000

DATE: May 2015

Table 7-1a
Recommended Environmental Enhancement Project Linkages
Reference Map 7-2

Watershed	Project Overview	ID[1]	Project Scope Summary (see Table 7-1b for components)	Project Trigger	Estimated Project Cost	Priority
Bon Accord	Bon Accord Creek: Lower-Reach Enhancements: SFPR Upgrades	E-1,2	N/A	*Completed During SFPR Construction*	**N/A**	**N/A**
	Bon Accord Creek: Lower-Reach Enhancements: Concrete Flume Removal and Creek Restoration	E-3,4	Remove concrete flume; restore creek to provide fish passage and habitat provisions.	Ravine Erosion Work (116A Ave: 10-Year Plan)	**$325,000 (2)**	**High**
		E-5	Modify boulder cascade to facilitate fish passage.			
	Bon Accord Creek: Lower-Reach Enhancements: Timber Dam Removal and Creek Restoration	E-6,7	Remove debris jams.	Independent Project	**$375,000**	**High**
		E-8,9	Remove remnant timber dam / hanging culvert and restore stream banks; provide fish habitat and passage provisions.			
		E-12	Replace culvert with small bridge at trail crossing and construct meandering channel to provide fish access to tributary; construct off-channel habitat at confluence with Bon Accord Creek.			
	Bon Accord Creek: Mid-Reach Enhancements: Debris removal	E-10	Remove / modify debris jams to facilitate fish passage.	Independent Project	**$15,000**	**Low**
	Bon Accord Creek: 108 Ave Culvert Upgrade	E-11	Include fish passage provisions in culvert replacement.	Culvert Replacement Work (108 Ave: 10-Year Plan)	**$40,000 (3)**	**Medium**
	East Bon Accord Creek: Lower-Reach Enhancements: SFPR Upgrades	E-13,15	N/A	*Completed During SFPR Construction*	**N/A**	**N/A**
	East Bon Accord Creek / Wallace Creek: Environmental Enhancements	E-14,16,17,18,19	Provide habitat enhancement; remove debris jams; stabilize channel and improve fish access through culverts. To be included in work for East Bon Accord Peak Flow Diversion.	East Bon Accord Peak Flow Diversion	**N/A**	**High**
157 Street	157 Street Creek: Environmental Enhancements	E-20,21,22	Modify culvert outlet to Fraser River; remove debris jams / barriers to fish passage. (4)	Independent / CN Rail construction or maintenance	**$35,000**	**Low**
160 Street	160 Street Creek: Environmental Enhancements	E-23,24,25	Modify culvert outlet to Fraser River; remove debris jams / barriers to fish passage.	Independent / CN Rail construction or maintenance	**$35,000**	**Low**
Fraser Heights	168 Street Creek: Environmental Enhancements	E-26,27	Excavate channel and daylight existing storm pipe to improve fish habitat.	Independent Project	**$50,000**	**Low**
	168A Street Creek: Environmental Enhancements	E-28,29	Remove debris to facilitate fish passage.	Ravine Erosion Work (Salisbury Dr on 108 Ave: 10-Year Plan)	**$55,000 (5)**	**Medium**
Big Bend	Centre Creek Tributary: Environmental Enhancements	E-30,31,32	Modify culvert to facilitate fish passage and remove debris.	Independent Project	**$25,000**	**Low**
Port Kells	181 Street Creek: Environmental Enhancements	E-33,34,35	Remove debris and provide habitat enhancement provisions.	Independent Project	**$15,000**	**Low**

Table 7-1a
Recommended Environmental Enhancement Project Linkages
Reference Map 7-2

Watershed	Project Overview	ID[1]	Project Scope Summary (see Table 7-1b for components)	Project Trigger	Estimated Project Cost	Priority
	Anniedale-Tynehead Development: Environmental Enhancements	E-36	Realign channel, re-vegetate riparian area, construct rearing pool.	Anniedale-Tynehead Neighbourhood	**N/A (6)**	**High**
Port Kells	Lyncean Creek East: Environmental Enhancements	E-37,38,39,40,41	Remove / modify fish passage barriers and existing ponds.	Ravine Erosion Work (179 St: 10-Year Plan)	**$150,000 (7)**	**Medium**
	Lyncean Creek West: Environmental Enhancements	E-42,43,44,45	Restore failing banks; remove debris to facilitate fish passage; undertake riparian planting.	Independent / Lyncean Creek East Restoration	**$35,000**	**Low**
	183 Street Creek: Environmental Enhancements	E-46,47	Improve culvert crossing and habitat conditions around CN rail line.	Independent / CN Rail construction or maintenance	**$150,000**	**Medium**
	184 Street Creek: Environmental Enhancements	E-48,49	Remove debris and construct spawning channel / rearing pool.	Independent / CN Rail construction or maintenance	**$25,000**	**Medium**
	196 Street Creek: Environmental Enhancements	E-50	Manage invasive species and accumulation of trash in riparian area.	Independent Project	**$5,000**	**Medium**

Notes:
1) Refer to Map 7-2 for locations, Table 7-1b for enhancement descriptions.
2) Includes $200,000 ravine erosion cost (City estimate) + $100,000 for flume / stream restoration.
3) Includes $29,000 culvert replacement cost (City estimate) + $11,000 for fish provisions.
4) Orange-coded stream – passage enhancements only effective if culvert modifications below CN rail line can occur first.
5) Includes $50,000 ravine erosion cost (City estimate) + $5,000 for debris removal provisions.
6) Assumed to be included in Anniedale-Tynehead Development.
7) Includes $100,000 for planned erosion work (City estimate) + $50,000 for fish provisions.

Table 7-1b
Site-Specific Environmental Constraints and Enhancement Opportunities
Reference Map 7-2

Location / Zone ID (Map 7-2)	Watershed	Type of Issue	Constraint Summary	Enhancement Opportunity Summary	Source for Constraint Information	Source for Enhancement Information
E-1 (see note)	*Bon Accord*	*Debris Jam*	*Debris is an obstacle at some flows*	*Remove debris to facilitate access upstream*	*Coast River 1997*	*ISMP work, based on prev report*
E-2 (see note)	*Bon Accord*	*Elevated Pipe*	*Potentially catches debris and obstructs flows*	*Remove debris and monitor to prevent accumulation of debris that may limit upstream access*	*Coast River 1997*	*ISMP work, based on prev report*
E-3	Bon Accord	Concrete Flume	593 m long concrete channel with high velocities that likely impede fish passage	Install timber or concrete baffles throughout flume section to improve upstream migration of salmonids	Coast River 1997; ECL 2001; ISMP fieldwork	ECL 2001; ISMP fieldwork
E-4	Bon Accord	Enhancement Opportunity	N/A	Reconstruct flume sections, incorporating off-channel rearing pools, spawning channels, and native riparian planting	Coast River 1997; ECL 2001; ISMP fieldwork	ISMP work, based on prev report
E-5	Bon Accord	Boulder Cascade	High gradient (33%) likely impedes some fish species	Modify boulder cascade to facilitate fish passage	Coast River 1997; ECL 2001	ECL 2001; ISMP fieldwork
E-6	Bon Accord	Debris Jam	Debris is an obstacle at some flows	Remove debris to facilitate access upstream	Coast River 1997	ISMP work, based on prev report
E-7	Bon Accord	Debris Jam	Debris is an obstacle at some flows	Remove debris to facilitate access upstream	Coast River 1997	ISMP work, based on prev report
E-8	Bon Accord	Timber Dam	Timber dam acts obstructs flow and impedes fish passage	Remove remnant timber dam or construct fish ladder around timber dam to improve upstream fish access for salmonids. Restore upstream channel area including hanging culvert (Point 9)	Coast River 1997; ECL 2001; ISMP fieldwork	ECL 2001; ISMP fieldwork
E-9	Bon Accord	Hanging Culvert	Hanging culvert does not allow upstream fish passage	Replace hanging culvert with fish passable culvert or bridge	Coast River 1997; ECL 2001; ISMP fieldwork	ECL 2001; ISMP fieldwork
E-10	Bon Accord	Debris Jam	Several debris jams act as obstacles at some flows	Remove or modify debris jams to facilitate upstream access for salmonids	Coast River 1997; ECL 2001	ECL 2001
E-11	Bon Accord	Culvert	Steeply-sloped culvert acts as a barrier to fish passage	Modify culvert to provide fish passage	Coast River 1997; ECL 2001	ECL 2001
E-12 (see note)	*Bon Accord*	*Enhancement Opportunity*	*N/A*	*Replace culvert with small bridge at trail crossing and construct meandering channel to provide potential fish access to tributary. Construct off-channel habitat at confluence with Bon Accord Creek.*	*N/A*	*ISMP fieldwork*
E-13 (see note)	*Bon Accord*	*Pipe crossing*	*Pipe creates a weir causing an obstruction at low flows*	*Modify pipe to facilitate upstream access*	*Coast River 1997*	*ISMP work, based on prev report*
E-14	Bon Accord	Enhancement Opportunity	N/A	Construct pool and off-channel habitat to increase availability of rearing habitat	N/A	Coast River 1997
E-15	Bon Accord	Debris Jam	Two debris jams present potential barriers	Remove debris jams to facilitate access upstream	Coast River 1997	ISMP work, based on prev report
E-16	Bon Accord	Debris Jam	Accumulated debris on trash rack may obstruct fish	Remove debris to facilitate access upstream	Coast River 1997	ISMP work, based on

Table 7-1b
Site-Specific Environmental Constraints and Enhancement Opportunities
Reference Map 7-2

Location / Zone ID (Map 7-2)	Watershed	Type of Issue	Constraint Summary	Enhancement Opportunity Summary	Source for Constraint Information	Source for Enhancement Information
			passage			prev report
E-17	Bon Accord	Enhancement Opportunity	N/A	Channel stabilization just northeast of the east end of Roxburgh Road	N/A	Coast River 1999
E-18	Bon Accord	Enhancement Opportunity	N/A	Improve culvert access at Ellendale Dr.	N/A	Coast River 1999
E-19	Bon Accord	Enhancement Opportunity	N/A	Re-introduce resident cutthroat trout in the upper reach between Ellendale Dr and Partridge Cr	N/A	Coast River 1999
E-20	157 Street	Culvert	Culvert outlet to Fraser River is 1.0 m above high-tide level, and therefore a barrier to fish passage	Modify culvert to facilitate upstream access	ECL 2000	ECL 2000
E-21	157 Street	Log Barrier	1 m drop created by a log is a barrier to fish passage	Remove log barrier to allow fish access upstream	ECL 2000	ECL 2000
E-22	157 Street	Debris Jam	0.5 m high debris jam is a barrier to fish passage	Remove debris to create fish access upstream	ECL 2000	ECL 2000
E-23	160 Street	Culvert	Culvert outlet to Fraser River is 0.35 m above high-tide level, and therefore a barrier to fish passage	Modify culvert to improve access	ECL 2000	ECL 2000
E-24	160 Street	Rockfall	0.45 m high rockfall is an obstacle to fish passage, only passable during high flow	Remove rockfall barrier to improve access upstream	ECL 2000	ECL 2000
E-25	160 Street	Debris Jam	Log and railway tie obstruct to fish passage, only passable during high flow	Remove debris jam to create access to pond, and/or construction of fishway where mainstem discharges into pool	ECL 2000	ECL 2000
E-26	Fraser Heights	Enhancement Opportunity	N/A	Excavate channel between the small higher-gradient tributary and the lowland channel to improve fish access to spawning habitat	N/A	ISMP fieldwork
E-27	Fraser Heights	Enhancement Opportunity	N/A	Excavate pool and add woody debris to improve cover. Daylight a portion of the existing stormwater pipe to promote fish habitat.	N/A	ISMP fieldwork
E-28	Fraser Heights	Debris Jam	Debris jams at six locations (236, 246, 248, 336, 341, and 368 m upstream of the wetland) ranging between 0.5 and 0.8 m high are only passable during high flows	Remove debris jams to facilitate access upstream	ECL 2000	ISMP work, based on prev report
E-29	Fraser Heights	Old Shed	An old shed constructed directly on top of the creek acts as a barrier	Remove shed	ECL 2000	ISMP work, based on prev report
E-30	Big Bend	Debris Jam	Debris jams act as barriers in three locations (97, 158, and 175 m upstream of the wetland), ranging from 0.4 to 0.6 m high	Remove debris jams to facilitate access upstream	ECL 2000	ISMP work, based on prev report
E-31	Big Bend	Culvert	Impassable 20 m culvert (600mm dia) - Culvert inlet is 450 mm	Enlarge culvert opening	ECL 2000	ISMP work, based on prev report
E-32	Big Bend	Culvert	Culvert almost entirely infilled with sediment, obstructing fish passage	Remove fines and gravel from culvert to create access to upper reaches of creek	ECL 2000	ECL 2000

Table 7-1b
Site-Specific Environmental Constraints and Enhancement Opportunities
Reference Map 7-2

Location / Zone ID (Map 7-2)	Watershed	Type of Issue	Constraint Summary	Enhancement Opportunity Summary	Source for Constraint Information	Source for Enhancement Information
E-33	Port Kells	Debris Jam	Four debris jams cause obstructions that restrict but do not prevent passage	Remove debris jams to facilitate access upstream	ECL 2000	ECL 2000
E-34	Port Kells	Enhancement Opportunity	N/A	Install splash pool on downstream side of concrete pad protecting gas line to mitigate erosion and facilitate upstream access	N/A	ECL 2000
E-35	Port Kells	Enhancement Opportunity	N/A	Remove ivy and ornamental plants and replant with native species on either bank of pond	N/A	ISMP fieldwork
E-36	Port Kells	Enhancement Opportunity	N/A	Realign west section through forested area and complex; re-vegetate riparian area in private property; construct rearing pool upstream of Highway 1	N/A	ISMP fieldwork
E-37	Port Kells	Debris Jam	Debris is an obstruction at some flows	Remove debris jam to facilitate salmonid access upstream	ECL 2000	ECL 2000
E-38	Port Kells	Enhancement Opportunity	N/A	Construct rearing pond near confluence of tributary	N/A	ISMP fieldwork
E-39	Port Kells	Culvert	400 mm culvert with 0.6 m drop is a barrier to fish passage	Construct fish ladders to the first ornamental pond and between the two ponds to improve fish access	ECL 2000	ECL 2000
E-40	Port Kells	Pond access	Pond inlet chute is 1.8 m above water level preventing access to pond from downstream	Construct a fish ladder to facilitate access	ECL 2000	ISMP work, based on prev report
E-41	Port Kells	Root mass	Creates a barrier to fish passage	Further investigation is required to determine appropriate enhancement opportunity	ECL 2000	ISMP work, based on prev report
E-42	Port Kells	Enhancement Opportunity	N/A	Provide native riparian planting on the landscaped portion of the lower section of the watercourse	N/A	ECL 2000
E-43	Port Kells	Enhancement Opportunity	N/A	Remediate bank failure and address slope erosion. Remove Himalayan blackberry and English Ivy at 100 Ave and replace with native plants	N/A	ISMP fieldwork
E-44	Port Kells	Debris Jam	0.6 m high debris jam restricts access upstream	Remove debris jams to facilitate access upstream	ECL 2000	ECL 2000
E-45	Port Kells	Debris Jam	Debris jams act as barriers	Remove debris jams to facilitate access upstream	ECL 2000	ECL 2000
E-46	Port Kells	Enhancement Opportunity	N/A	Construct off-channel rearing pond downstream of railway crossing. Remove wooden pallets piled in creek at mouth and install woody debris as cover.	N/A	ISMP fieldwork
E-47	Port Kells	Culvert	Two 600 mm culverts beneath CNR tracks are impassable to salmonids	Realign stream channels upstream of railway and consolidate flows into one culvert under railway	ECL 2000; ISMP fieldwork	ISMP fieldwork
E-48	Port Kells	Enhancement Opportunity	N/A	Plant native species beneath overpass. Realign tributary channel beneath overpass at Golden Ears Way to construct spawning channel, or construct rearing pool	N/A	ISMP fieldwork
E-49	Port Kells	Debris Jam	Debris is an obstacle at some flows	Remove debris jams to facilitate access upstream	ECL 2000	ECL 2000

Location / Zone ID (Map 7-2)	Watershed	Type of Issue	Constraint Summary	Enhancement Opportunity Summary	Source for Constraint Information	Source for Enhancement Information
E-50	Port Kells	Enhancement Opportunity	N/A	Remove invasive species (Himalayan blackberry and Scotch broom), install water quality treatment measures, or evaluate effluent sources, and remove garbage from watercourses	N/A	ISMP fieldwork

Note: Completed as part of the South Fraser Perimeter Road construction – included for completeness.

8 Funding Strategy

A variety of funding sources are available to support the implementation, operation and maintenance of the stormwater management components recommended for the Bon Accord – North Slope (East) ISMP.

Individual land owners are responsible for funding and implementation of source controls and BMPs specific to their own properties. Further, offsite upgrades to City-controlled infrastructure directly related to development activities will also be chargeable to the subject property owner / developer.

The City is generally responsible for City-owned property and infrastructure upgrades that are either eligible for Development Cost Charges (DCCs), or are not otherwise related to development activities. Major system works identified in the City's 10-Year Servicing Plan are prioritized with other City projects. Developers can pay for these works if they are required sooner than the plan specifies, and recover the DCC-eligible portion of the total cost.

8.1 MUNICIPAL FUNDING

The City of Surrey's 10-Year Servicing Plan compiles and prescribes engineering infrastructure projects across the City required to support existing and required future infrastructure. The plan is developed based on projects proposed in the City's OCP, NCPs, ISMPs, and other specific studies. The required projects identified in the Plan are queued by priority, and annual funds are allocated accordingly. The funding sources most relevant to the Bon Accord – North Slope (East) ISMP study area are Development Cost Charges (DCCs) and utility service charges. We discuss these funding options below. We note that development-driven upgrades servicing catchments greater than 20 hectares are eligible for funding from DCCs, while upgrades related to developments in service areas smaller than 20 hectares must be directly funded by development proponents.

We encourage the City to include the implementation of source controls along local, collector, and arterial projects, and in road renewal projects where applicable. This will provide a substantial benefit to watershed health, and be much more cost-effective than stand-alone stormwater management projects in locations where roads are not otherwise being improved.

8.1.1 Development Cost Charges

Development Cost Charges (DCCs) are governed by the Surrey Development Cost Charge By-law No. 18148 (2014). They provide approximately one third of total funding to the Capital Construction Program to support development associated with works identified in the City's Official Community Plan (OCP) and Neighbourhood Concept Plans (NCPs).

DCCs are paid to the City by proponents who obtain approval for lot subdivision or a building permit to develop or alter buildings. Areas zoned as residential pay a particular price per lot, while all other land uses pay on a per-area basis. The fees are typically City-wide, except where a particular project necessitates an alternate rate. For example, in the Port Kells watershed, the Anniedale-Tynehead development has a project-specific drainage DCC for Industrial land use. Following review of the recommendations in this ISMP, the Anniedale-Tynehead DCC should be reviewed to ensure the City's drainage costs resulting from the development are fully accounted for.

As noted previously, developers fronting the costs for City-planned infrastructure upgrades are eligible for reimbursement of the DCC-eligible portion of the total cost.

8.1.2 Drainage Parcel Tax

The drainage element of utility funding comes from the Drainage Parcel Tax, which is based on a flat rate and is collected by the City along with property taxes.

As of 2014, the rate charge varies on a per-lot basis depending on property class (as determined by BC Assessment). Residential, non-profit recreational, and farm properties pay $201/parcel, and non-residential properties pay $224/parcel. While variation in fees based on Property Class is a positive improvement over the tax structure of previous years, the flat-fee structure (rather than per-area) does not reflect the magnitude of discharge to the drainage system. Since these funds are specifically allocated to drainage system expenditures, it would be in the City's interest to revise the fee structure to more representatively reflect the impact of the property on the drainage system by accounting for parcel area and other factors, such as impervious coverage.

8.2 LAND OWNERS AND PRIVATE DEVELOPERS

Land owners and private developers do not receive City-controlled funding to implement stormwater Best-Management Practices on private property. The cost of constructing, operating and maintaining source controls, riparian area buffers, Green-Infrastructure Network (GIN), stormwater detention or retention facilities, and system upgrades necessitated as part of the development is the responsibility of land owners and developers.

Given that existing residential and industrial developments comprise the majority of the Bon Accord – North Slope (East) ISMP, the greatest opportunity for the City to achieve an improvement in watershed health is by promoting the use of source controls by private property owners. This is best accomplished by offering incentives to private property owners to support faster and more widespread application of source controls.

Three incentive programs are reviewed in the following sections.

8.2.1 One-Time Rebates

While incentive programs are relatively low-cost to the City, they do result in deferred revenue that would be otherwise used on capital projects. As such, we recommend that rebate-centered incentive programs be offered on a one-time basis to promote the initial establishment of source controls and awareness of their benefits.

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 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 developments to construct stormwater source control measures and detention and retention systems on their properties. The program could potentially be administered through the City of Surrey Planning and Development Department.

We recommend that in the initial stages of the project 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 constructed works. For the program to be effective, it will be important for the City to promote the inter-related benefits of stormwater management features, such as reduced municipal water requirements for landscaping (thus reducing their potable water use in association with the Surrey Water Meter Program), and the insulation benefits of a green roof for industrial and commercial property owners.

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

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

Administering a Stormwater Management Rebate Program for works completed on private property will prove to be more challenging than Tree Voucher 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.

8.2.2 Stormwater and Property Tax Rebates

We discussed the existing Drainage Parcel Tax in Section 8.1.2. It provides a significant source of revenue to the City to be used towards capital drainage projects. Presently, the tax is assessed on a per-lot basis, rather than a per-area basis.

Incentives could be provided to private property owners in the form of a reduced drainage parcel tax. Although this would result in reduced revenue to the City, we recommend changes to the assessment of this tax on a per-area basis. Initially, this would provide increased revenue on those lots with the greatest area. The initial tax rate could be assessed based on Total Impervious Area (TIA), which is relatively simple to assess based on aerial imagery. Land owners could implement source controls to reduce the Effective Impervious Area (EIA) by hydraulically disconnecting runoff from the receiving storm drainage infrastructure. Land owners could then apply for a re-evaluation of their rates with supporting evidence, such as photographs or contractors invoices. The simultaneous implementation of tax rebate incentives to implement source controls, and a revised Drainage Parcel Tax fee structure could be implemented such that the City would see no loss in revenue.

These changes would be applied for future development and redevelopment projects and enable substantial watershed health improvements in the Bon Accord – North Slope (East) study area. The proposed utility rate structure and rebate program will require a relatively accurate measurement of the EIA ratios of each lot, which may prove 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.

8.2.3 Salmon Marshall Certification Program

The City’s Salmon Habitat Restoration Program (SHaRP) presently runs a Salmon Marshall (SaM) certification program. The program provides certification to businesses who consciously undertake action items that lead to salmon protection and habitat enhancement. The program offers bronze, silver, gold and platinum certification based on the level of effort put forth by a particular business. For certification to be granted, businesses must commit to action items and meet certain long-term requirements. The more action items taken on by businesses, the more prestigious certification received. The benefit to businesses is that they become more involved in their communities and can be seen as watershed stewards with a commitment to environmental protection. To date, this program has seen great success.

One ‘action item’ listed in the existing program is for the business to collect water samples for a nearby stream a minimum of 3 times, and then annually. Given the cost of City-sponsored water quality programs, businesses undertaking this action item should work with the City to sample watercourses identified in Section 10 of this ISMP as being at risk from development activities and watershed health degradation.

Additionally, the City could produce further action items specifically related to the objectives of this ISMP, including: source control implementation, monitoring and pilot studies; daylighting of storm pipes; and environmental enhancement projects identified in Section 7.

8.3 FEDERAL FUNDING

The federal government provides funding for infrastructure and environmental projects primarily through Infrastructure Canada and Environment Canada.

Although typically not as readily available as municipal funding sources, we highlight below some of the programs most applicable to the type of works recommended in this ISMP.

8.3.1 New Building Canada Plan

The New Building Canada Plan (NBCP) is a federal government program intended to support infrastructure projects across Canada. Much of the funding is intended for projects of national, regional, or local significance, and therefore may not be accessible for the projects associated with this ISMP; however, part of the NBCP is the Federal Gas Tax Fund, intended to provide municipalities with stable and predictable funding over the next 10 years to support infrastructure projects. It is allocated on a per-capita basis to all municipalities across Canada, and can be used for infrastructure upgrade projects in the Bon Accord – North Slope (East) study area.

We anticipate that within municipal governments such as the City of Surrey, competition for these funds may not allow a significant investment in independent drainage projects. We strongly recommend the City push to have stormwater BMPs included in all infrastructure projects, where practical.

8.3.2 EcoAction Community Funding Program

The EcoAction Community Funding Program provides funds to non-profit community-based groups.

The City of Surrey is not eligible to apply for funding. Community or environmental groups may apply for funding for various environmental enhancement projects. Minor terrestrial or riparian enhancement projects, such as the removal of debris jams and management of invasive species are the most likely types of projects to have success under this arrangement, and should be encouraged by the City where possible to improve watershed health.

8.3.3 Green Municipal Fund

The Green Municipal Fund (GMF) is distributed through the Federation of Canadian Municipalities (FCM), but funded by the Government of Canada. The GMF funds municipal environmental initiatives, including plans, studies, and projects. Projects in the energy, transportation, waste and water sectors undergo a competitive process and are ultimately reviewed for approval or denial by the GMF Council. In 2014-2015, the fund aims to provide $40M in loans and $5M in grants for capital projects in energy, transportation, waste and water sectors.

The stormwater management projects supported by the fund must manage the majority of rainfall events for a community, which is the shared objective of source controls and stormwater BMPs. The funding is therefore directly relevant to the goals of this ISMP, and should be applied for as applicable.

8.4 PROVINCIAL FUNDING

The British Columbia provincial government provides funding for community and stormwater management projects through the Ministry of Community, Sport and Cultural Development. Currently, the only applicable funding source is the Infrastructure Planning Grant Program, as the funds from all other relevant programs are fully allocated.

8.4.1 Infrastructure Planning Grant Program

The Infrastructure Planning Grant Program provides grants up to $10,000 to assist in the development or improvement of long-term comprehensive plans. Existing projects (such as this ISMP) are ineligible for the funding. However, this planning-level ISMP recommends further studies in particular locations of concern within the study area, and this funding may be available for those studies.

9 Enforcement Strategy

Critical to the implementation of the ISMP recommendations is the ability of the City to enforce the recommendations.

The Bon Accord – North Slope (East) requires both an enforceable regulatory framework for the City to refer to, and community motivation to actively work towards improved watershed health.

9.1 UPDATES AND ADDITIONS TO CITY POLICIES, BYLAWS AND MANUALS

Several of the recommendations critical for supporting watershed health and responsible stormwater management within the study area are not currently supported by enforcement mechanisms under the City's current bylaws, policies and design guidelines. In the following sections we outline key recommended changes to relevant policies to assist in enforcing the recommendations in this ISMP.

We note that these documents are typically City-wide, and our recommendations must be considered in the context of recommendations arising from other City studies.

9.1.1 City of Surrey Engineering Design Criteria Manual

The City of Surrey provides an Engineering Design Criteria Manual to present the minimum requirements for engineering design of projects located in the City of Surrey. The most recent edition of the manual is from May 2004. The Storm Drainage System section of the manual provides guidelines to assist in planning and designing stormwater drainage facilities and systems.

The Design Criteria Manual is a powerful tool that provides consistency in design across the entire City of Surrey. It provides critical information on minimum design standards.

We recommend the following updates to the manual:

- Provide clear guidance to designers as to how to incorporate climate change impacts into sizing of drainage infrastructure. This may be addressed through a more rigorous 'minor system' return period (10- or 25-year return period), or through more simplified measures, such as adding a 20% allowance to any peak flow derived based on current methodology. The details of how climate change impacts should be accounted for in infrastructure sizing is beyond the scope of this ISMP, yet is critical, and should be addressed immediately.
- Add maximum acceptable runoff rates by land use (performance targets).
- Add source control design criteria, including:
  - Maximum outflow rates per hectare of tributary area,
  - Rainfall capture targets (72% of 2-year return period, 24-hour duration rainfall)
  - Water quality objectives and a list of acceptable mechanisms to achieve these targets (bioswales, manufactured treatment units, constructed ponds/wetlands).
  - Minimum subsoil infiltration rate for infiltration-based BMPs to be permitted.

9.1.2 City of Surrey Zoning Bylaw, 1993, No. 12000

The purpose of the Zoning Bylaw is to regulate lot use permissions and restrictions, the location and height of buildings, required setbacks from various features, floodproofing requirements, minimum and maximum floor areas, and other land-use-specific parameters.

Within the Bon Accord – North Slope (East) ISMP study area, there are 30 distinct zoning classifications. By area, the seven most significant classifications, and their relevant bylaw sections are provided in Table 9-1.

Table 9-1
Prominent Zoning Classifications in the Study Area

Zoning Code	Zoning Classification	Area (ha)	City of Surrey Bylaw Section
RF	Single Family Residential Zone	523	Part 16
IL	Light Impact Industrial Zone	460	Part 48
RA	One-Acre Residential Zone	449	Part 12
I-P(2)	Industrial Park Zone Two	404	*[See Note]*
RH-G	Half-Acre Residential Gross Density Zone	96	Part 15
RC	Cluster Residential Zone	40	Part 15A
CD	Comprehensive Development Zone	37	Part 52

Note: The I-P(2) zoning classification covers the upland/lowland interface and transportation corridor (SFPR and CN rail) between 176 St and 164 St and Surrey Bend Regional Park. According to Part 3B of the City of Surrey Zoning Bylaw, 1993, No. 12000, the I-P(2) Industrial Park Zone (Two) remains from the former Surrey Zoning Bylaw, 1979, No. 5942, and is excluded from Schedule A of Bylaw No. 12000 until amendments to include these lots have been adopted.

The zoning classifications listed above represent 95% of the study area, and are therefore the focus of this section.

We note that the City's zoning classification does not include distinct zoning for green space, and therefore apparent industrial zonings are inflated [e.g. Surrey Bend Regional Park is zoned as I-P(2)]. For the purposes of this section, we have not adjusted zoning based areas to reflect actual land use.

To ensure that the recommendations of this ISMP are properly implemented for each zoning type, we recommend that Surrey Zoning Bylaw No. 12000 be amended as shown in Table 9-2. Many of the changes recommended below can be applied to zoning sub-classifications (e.g. recommendations for RF could be applied to RF-12, RF-9 and so on), but our focus is on the 7 most significant zoning classifications within the Bon Accord – North Slope (East) study area.

Table 9-2
Recommended Zoning Bylaw Amendments

Bylaw Part	Recommendations
General	The Zoning Bylaw No. 12000 should be amended to include the I-P(2) classification.
Part 5: Parking and Loading / Unloading	Part 5, Section 5(a) states "All parking areas, excluding those listed under Sub-section A.5(b) shall be surfaced with an asphalt, concrete or similar pavement, so as to provide a surface that is dust free and shall be so graded and drained as to properly dispose of all surface water." We recommend modification to this section to specifically mention permeable pavement. Additional notation on structural requirements will be needed. Further, the term "properly dispose of all surface water" should be defined to include meeting runoff control targets, and 'dispose' should be reworded to 'manage.'
Part 7: Special Building Setbacks	Part 7 describes specific atypical building setbacks depending on proximity to major road allowances within the City of Surrey. Once the Riparian Areas Bylaw (discussed in the following section) is implemented, this section should be amended to reference specific requirements for lots located adjacent to watercourses, GIN hubs and corridors, wetlands, ponds, and areas of environmental significance.
Part 12: RA: One-Acre Residential Zone	Section F describes Yards and Setback requirements. On private residential lots, it is more practical for the City to monitor and enforce source controls (absorbent soils, rain gardens) when they are located in front yards. To facilitate this, we recommend the minimum front yard setback to the principal building be increased. Section I describes landscaping requirements. We recommend this Section be reworded to require the provision of a minimum 450 mm thick layer of absorbent topsoil on all landscaped areas.
Part 15: RH-G: Half-Acre Residential Gross Density Zone	Section F describes Yards and Setback requirements. We recommend the minimum front yard setback to the principal building be increased to facilitate enforcement of source controls. Section I describes landscaping requirements. We recommend this Section be reworded to require the provision of a minimum 450 mm thick layer of absorbent topsoil on all landscaped areas.
Part 16: RF – Single Family Residential Zone	Section F describes Yards and Setback requirements. We recommend the minimum front yard setback to the principal building be increased to facilitate enforcement of source controls, and that the relaxation of the minimum setback requirement as per Note 1 in the Bylaw not be permitted. Section I describes landscaping requirements. We recommend Subsection I.1. be reworded to include provision of a minimum 450 mm thick layer of absorbent topsoil in all landscaped areas. Further, Subsection I.2 should be revised to require a minimum pervious surface coverage of 35% (increased from the current 30% provision); although we note that as per our recommendations in Section 2, the target pervious surface coverage (including permeable pavement) is 60%.
Part 48: Light-Impact Industrial Zone	Section I describes landscaping requirements, including a special provision of a minimum 1.5 m landscaping strip for all developed sites of the lot which abut a highway. We recommend that these sections be reworded to require a minimum 450 mm thick layer of absorbent topsoil on all landscaped areas, including the landscape strips described.

9.1.3 City of Surrey Drainage Parcel Tax Bylaw, 2001, No. 14593

The Drainage Parcel Tax Bylaw 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 bylaw imposes a 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.

The bylaw and fee assessment should be revised to collect fees on a per-area and TIA coverage basis, rather than a flat rate.

9.1.4 City of Surrey Stormwater Drainage Regulation and Charges Bylaw, 2008, No. 16610

The Stormwater Drainage Regulation and Charges Bylaw is in place to allow the City to operate and maintain a storm drainage system as a municipal service for the benefits of residents and property owners in the City of Surrey. The bylaw 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 bylaw 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.” We recommend this definition be expanded to encompass redeveloped parcels.

Part 8 of the bylaw 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. While Part 10 outlines offences and penalties for non-compliance with any provisions within the bylaw, we recommend that specific consequences for non-compliance with the elements described in Part 8 be developed and enacted.

Further, we recommend that Part 8 be revised to reference stormwater quality and quantity performance targets described within the City’s Integrated Stormwater Management Plans. We note that to be effective, this provision may require a comprehensive review of the recommendations from ISMPs for all watersheds within the City to ensure consistent application.

9.1.5 City of Surrey Erosion and Sediment Control Bylaw, 2006, No. 16138

The Erosion and Sediment Control Bylaw 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 bylaw 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 BMPs 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:

- Stockpiling and placement of growing media, and
- Protection of trees, shrubs and their planting locations.

9.1.6 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 physical design, construction, and operation and maintenance procedures for pervious pavement, green roofs, bioswales, infiltration trenches and rain gardens. Formal specifications and standards will encourage their use while promoting standard and effective design, construction, implementation, operation and maintenance of the facilities.

9.1.7 Riparian Areas Regulation Bylaw

We understand that the City presently follows the Land Development Guidelines for the Protection of Aquatic Habitat (DFO, 1993), and intends to pass a formal bylaw outlining setback requirements in accordance with the Ministry of Environment’s (MoE) Riparian Areas Regulation (RAR).

The development of this bylaw should account for aquatic habitat, overall watershed health, and terrestrial habitat / wildlife movement corridors. The development and implementation of a riparian areas bylaw should reference setback guidance from the City’s Biodiversity Conservation Strategy and MoE’s RAR, and use the most stringent setback criteria.

9.2 DEVELOPMENT APPLICATIONS

Individuals wanting to develop or alter the use of land within 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 OCP, Zoning Bylaw, 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.

As discussed in Section 3.3, special requirements are in place for development applications in areas designated as hazard lands (prone to flooding or adjacent to steep slopes).

Given that the primary development activities anticipated in the Bon Accord – North Slope (East) ISMP study area will be redevelopment of existing lots, it is important that the recommendations of this document be reflected in the appropriate land development and building permit application forms and checklists to ensure they are successfully incorporated into the planning and permitting phases of development.

9.2.1 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 media,
- Site plans showing the locations and extents of pervious pavement, and
- Summary of hydrologic calculations used to prove that selected source control measures meet the performance targets described in this ISMP, or clear reference to the City's standard designs and details for stormwater source control features.

9.2.2 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 prove that selected source control measures meet the performance targets described in this ISMP.
- Summary of calculations and methodology used to design and locate any detention/retention storage facilities, which may consist of calculations and specifications from suppliers in the case of proprietary design products. Detention / retention storage facilities must meet the performance targets described in this ISMP.

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. In these instances, developers or property owners should utilize the City of Surrey's standard details and designs for stormwater source control facilities.

10 Monitoring and Assessment Plan

To adequately manage development in the watersheds, the City must monitor key metrics that indicate the state of the watersheds. These will track the condition of the watershed and identify areas of particular success, or where further mitigative efforts need to be applied.

We assessed the recommended monitoring parameters from Metro Vancouver's Monitoring and Adaptive Management Framework (AMF, 2014) and the ISMP Template (2005) to create a suite of indicators capable of tracking the success of the ISMP and the short-term and long-term health of the watersheds.

Below we briefly describe each of the recommended metrics, divided into three categories:

1) **Land Use Metrics** – intended to identify subtle changes resulting primarily from small-lot redevelopment and minor enhancement projects that may otherwise be overlooked, and to address the terrestrial component of the ISMP.
2) **Flow Regime Metrics** – intended to monitor the condition of the major natural watercourses and ravine areas to identify major changes in flow patterns (positively or negatively).
3) **Environmental Metrics** – intended to track the success of environmental enhancement projects and source controls on supporting habitat.

We note that the hydrometric, water quality, and benthic invertebrate metrics should be integrated with City-wide monitoring efforts in accordance with the AMF. The additional metrics presented should be integrated into other City programs and development activities where appropriate, to improve the efficiency of problem-identification as it pertains to the objectives of this ISMP.

10.1 LAND USE METRICS

Metric 1 – Percent Tree Cover

To track the progress of the objectives in City's Sustainability Charter, the City has developed an online 'sustainability dashboard' that tracks several indicators. As part of the 'ecosystems' theme, vegetative cover is tracked. The City's goal is to maintain vegetation on at least 50% of Surrey's land area (excluding the ALR) over time.

Extensive vegetative cover supports terrestrial habitat and can reduce or attenuate runoff through interception and evapotranspiration.

Since vegetative cover is currently monitored City-wide, an extension of the assessment specific to the Bon Accord – North Slope (East) catchments will be of little additional cost to the City; therefore, we recommend the City establishes a baseline vegetative cover value using the same process as is used for the City-wide tracking, and revisits the value in subsequent assessments.

Measurement: Percent vegetative cover.

Timing / Triggers: Calculated each time vegetative cover is assessed for the City's Sustainability Dashboard. Decreased vegetative cover should trigger restorative work, and should focus specifically on enhancing terrestrial hubs and corridors identified in the City's Biodiversity Conservation Strategy for maximum value.

Cost: $500 per assessment.

Metric 2 – Percent Total Impervious Area (TIA)
Percent Total Impervious Area (TIA) is a measure of the proportion of the total area covered by impervious surfaces (e.g. asphalt, concrete, buildings) to the total watershed area. It is an indicator of the general intensity of development, and whether development is occurring in accordance with applicable zoning bylaws. Our assessment yielded the suggestion that impervious area coverages for almost all zoning classifications are higher than the zoning bylaw's allowable building coverage due to additional hard surfaces, such as patios, driveways, parking lots, and so on; as such, the TIA values are more closely aligned with those values in the City's 2004 Engineering Design Criteria Manual

It is possible to arrive at more detailed TIA values by either using LiDAR, or by tracing hard surfaces in GIS using aerial photos and polygon overlays; both of these options, however, are incredibly data-intensive and require significant quality control for the results to be accurate. The incremental benefit of this methodology is typically not worth the effort, and so was excluded from the scope of this ISMP. Even the use of readily-established building layers is limited, because the layers generally do not include walkways, driveways, and other hard surfaces that contribute to the overall lot- and neighbourhood-scale TIA values.

We therefore recommend the City monitor TIA values based on blanket zoning classifications in line with the Engineering Design Criteria Manual (2004). This will capture major zoning reclassifications. The City should monitor and assess the impacts of any major potential change in TIA as a result of zoning reclassification. For example, rezoning of a one-acre residential lot into light-impact industrial would result in a TIA increase from 50% to 90%.

Table 10-1 describes the baseline TIA for each watershed to be compared against in the future.

Table 10-1
Baseline Total Impervious Area by Watershed

Watershed Name	Baseline Total Impervious Area
Bon Accord	52%
157 Street	53%
160 Street	67%
Fraser Heights	58%
Big Bend	56%
Port Kells	70%

Surrey Bend Regional Park is excluded from TIA assessment due to unique hydrology and a separate park management plan.

The Anniedale-Tynehead development in South Port Kells is anticipated to lead to the greatest increase to TIA; although sporadic rezoning will cause minor impacts elsewhere, including the Bon Accord watershed.

Tracking zoning-based TIA can identify subcatchments where independent rezoning projects may have a cumulative effect on the hydrologic response. The limitations are that zoning-based TIA will not capture redevelopment where zoning classification remains the same; nor does it account for the effect of source controls. Flow monitoring data can be utilized as a check on TIA assessments.

The intent of assessing TIA is to identify areas of potentially increasing development-related impacts so that the City can ensure that stormwater best management practices are being employed in these areas to mitigate increases to TIA.

Measurement: Percentage of total impervious area (based on zoning classifications) to total watershed area.

Timing / Triggers: Reassessed during the next ISMP cycle.

Cost: $2,000 per investigation.

Metric 3 – Percent Effective Impervious Area (EIA)

In principle, effective impervious area (EIA) provides a more precise indicator of runoff generation than percent TIA. EIA accounts for pervious open space that hydrologically functions like impervious surfaces, and vice versa. It also accounts for the effect of impervious surfaces which are hydraulically disconnected from the storm system (e.g. roof downspouts discharging to lawns rather than to storm pipes).

An objective determination of EIA requires an extremely detailed evaluation of the watershed, essentially on a lot-by-lot scale. A detailed evaluation to this degree was not included in the scope of this ISMP, and would be challenging for the City to undertake, even once.

EIA estimates can be made using the data collected from hydrometric monitoring. EIA can be calculated using the runoff response to a known rainfall event. This can provide an indication of the overall EIA of the gauged catchment area, but will not provide a detailed breakdown by land use or by neighbourhood. Once the City determines a baseline EIA value, further hydrometric monitoring data can be analyzed to look for changes in EIA. Due to the variability of runoff characteristics, EIA should be assessed based on a relatively frequently recurring real event. Efforts should be made in subsequent years to select a rainfall / runoff event with similar characteristics to that used in establishing the baseline value. EIA will only be calculable for those watersheds with hydrometric monitoring.

Measurement: Percentage of effective impervious area for watersheds with hydrometric data.

Timing / Triggers: Assessed during the next ISMP cycle for those areas where hydrometric data is available.

Cost: $5,000 for investigations where flow monitoring data is available. Flow monitoring costs are discussed under Metric 6.

Metric 4 – Percent Riparian Forest Integrity (RFI)

Percent Riparian Forest Integrity (RFI) is a key factor used in establishing overall watershed health. In the context of watershed health, natural watercourses (excluding lowland watercourses) should maintain an appropriate buffer on either side of the watercourse such that the riparian forest remains intact. This supports riparian functions that contribute to terrestrial and aquatic health, erosion mitigation, and helps to maintain natural flow regimes in the watercourses.

The desired riparian corridor for the watercourses in the Bon Accord – North Slope (East) study area is based on a total width of 64 m. This represents a 4 m stream width plus 30 m corridor buffer on either side of the watercourse.

Table 10-2 presents the baseline RFI values for the watercourses in the study area. The assessment is based on the March 2014 orthophoto and includes the significant non-lowland natural watercourses in the study area and their tributaries, as illustrated on Map 10-1.

Table 10-2
Baseline Riparian Forest Integrity by Watercourse

Watercourse	Intact Riparian Area (ha)	Target Riparian Area (ha)	% RFI
Bon Accord Creek	19.6	29.8	66%
East Bon Accord Creek	8.6	13.1	66%
Landfill Creek	3.8	9.9	38%
154 Street Creek	4.9	6.2	79%
157 Street Creek	7.2	9.6	75%
160 Street Creek	1.9	3.0	63%
Tributaries to Fraser Heights Lowlands	5.1	8.8	58%
Tributaries to Centre Creek	13.1	20.3	65%
Lyncean Creek West	1.6	4.2	38%
Lyncean Creek East	3.4	5.3	64%
Leoran Brook	3.6	5.8	62%
183 Street Creek	2.4	4.8	50%
184 Street Creek	3.6	5.5	65%

Given the importance of an intact riparian area in all of the fundamental functions of natural watercourses, maintenance or improvement of RFI is a critical contributor to watershed health. The reestablishment of riparian vegetation takes time, and therefore a noted reduction in RFI is difficult to reverse. It is therefore critical that the riparian setbacks in place for development and redevelopment be clearly established, communicated to developers, and enforced. RFI as a key performance indicator will quickly identify where development and/or redevelopment are/is impacting watershed health.

Measurement: Percentage of actual intact riparian forest cover to the desired riparian corridor based on the ideal 64 m total width.

Timing / Triggers: Reassessed during the next ISMP cycle, or if development / redevelopment within the watersheds equal or exceed 5% of the total study area.

Cost: $4,000 per investigation.

10.2 FLOW REGIME METRICS

Metric 5 – Number and Condition of Erosion Sites

The City of Surrey biannually engages consultants to undertake ravine stability assessments of numerous watercourses across the City. At the time of this ISMP, the 2011 Ravine Stability Assessment performed by Web Engineering Ltd., was the latest completed assessment, and identified a total of 2 high risk, 16 medium risk, and 60 low risk (78 total) erosion sites in the Bon Accord – North Slope (East) watersheds. The tributaries assessed, and the risk rankings are summarized in Table 10-3, and shown on Map 10-2.

Table 10-3
2011 Ravine Stability Assessment Erosion Sites

2011 Ravine Assessment Site ID	Watercourse	Number of Identified Erosion Sites			
		High Risk	Medium Risk	Low Risk	Total
11	Bon Accord Creek	1	7	26	***34***
12, 13	East Bon Accord Creek	0	4	11	***15***
15	157 Street Creek	0	0	4	***4***
16, 17	Tributaries to lowlands over North Slope at Fraser Heights	0	2	9	***11***
18	Lyncean Creek West	0	0	3	***3***
19	Lyncean Creek East	1	2	1	***4***
20	Leoran Brook	0	1	6	***7***
	Total	***2***	***16***	***60***	***78***

The regular ravine stability assessments are extremely beneficial, not only for identifying high and medium risk erosion sites, but also for monitoring the progression of erosion. The progression of even low-risk erosion areas over time can be indicative of broader watershed problems, including insufficient RFI, lack of upstream source controls, or redevelopment impacts; similarly, decelerated erosion may indicate that upstream source controls / mitigation measures (such as the East Bon Accord peak flow diversion) are functioning as intended, with positive impact on watershed health.

Although valuable, monitoring and assessment of low risk sites would greatly expand the cost of the existing ravine assessment program. Instead, a desktop assessment of potential causes could be undertaken when a significant change in erosion processes is noted as a result of the Ravine Stability Assessment program.

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

- Date of and conditions during survey,
- Photographs of the following:
  - Erosion site,
  - Channel and bank substrate,
  - Upstream and downstream channel conditions.
- Bank location,
- Channel dimensions,
- Risk probability and consequence,
- Description of stability issue(s),
- Notation on progression since previous assessment, including for low-risk sites,
- Approximate dimensions / scale of erosion, and
- Cost to mitigate.

Timing / Triggers: Nominally, every two years. A desktop assessment of potentially contributing factors and mitigation projects should be undertaken for watersheds where a widespread increase in erosion risk is identified during the Ravine Stability Assessment program.

Cost: Included as part of the City's overall Ravine Stability Assessment budget. The Bon Accord – North Slope (East) study area accounts for approximately 9% of the total watercourses assessed across the city.

Metric 6 – Hydrometric Monitoring

The Bon Accord – North Slope (East) ISMP area presently has no hydrometric data for discharge or water level. Hydrometric data provides insight into the actual response of the watersheds to rainfall events. Sufficient monitoring periods are required to establish a reliable record for making representative assessments. The data is also necessary to estimate effective impervious area, as discussed in Metric 3.

Metro Vancouver's AMF recommends a minimum of one-year of continuous hydrometric monitoring, and provides guidance on collection methodology and analysis of hydrologic indicators. The AMF recommends that where resources allow, longer duration flow monitoring be done to provide additional benefits. Some of these benefits include:

- Improved dataset representativeness;
- Increased value because the majority of costs are incurred in the first year or two of data collection;
- More reliable identification of temporal trends;
- More reliable data for statistical analysis to determine the magnitude of extreme events;
- Potential application of the data to similar catchments with limited / no hydrometric data.

For the Bon Accord – North Slope (East) study area, monitoring for one year at multiple locations is significantly less beneficial than ongoing monitoring at key strategic locations.

Recommended hydrometric monitoring sites are shown on Map 10-3 at the end of this section.

We recommend the City prioritize continuous, ongoing monitoring in Bon Accord Creek and Leoran Brook.

Bon Accord Creek represents one of the most significant watercourse in the study area, and Leoran Brook will provide insight into flow regime alterations as a result of the Anniedale-Tynehead development.

If resources allow, East Bon Accord Creek should be monitored as well. This site will assess whether the East Bon Accord peak flow diversion is effectively diverting peak flows while maintaining adequate baseflows to support aquatic health.

Measurement: Continuous water level and flow data.

Timing / Triggers: Data to be collected continuously on a permanent basis. Hydrometric data may be processed continuously by the FlowWorks software the City uses for other monitoring stations around the City. Once every five years, data should be analyzed for the parameters recommended in the AMF (i.e. T_{Qmean}, low pulse count and duration, summer baseflow, winter baseflow, high pulse count and duration).

Cost: $30,000 for initial setup and $5,000 annually for data collection, per monitoring location.

10.3 ENVIRONMENTAL METRICS

Metric 7 – Water Quality Monitoring

Monitoring the water quality at key locations within the watersheds can provide insight into the success of the ISMP and identify areas of concern where mitigative measures may be required.

Metro Vancouver's AMF suggests water quality monitoring be done in low gradient, high gradient, and piped systems, with samples taken two periods per year – once in the dry season (July to August) and once in the wet season (November to December). The recommended sampling procedure is to collect 5 samples over a 30-day period on a weekly basis. The AMF recommends testing dissolved oxygen, temperature, turbidity, pH, conductivity, nitrate, E. coli, fecal coliforms, total iron, total copper, total lead, total zinc, and total cadmium.

In addition to the primary constituents outlined above, Total Suspended Solids (TSS) should be monitored. Most water quality source controls are designed based on TSS removal efficiency and therefore TSS data can enhance the City's understanding of the effectiveness of various source controls such that effective decisions can be made when additional source controls are employed. We note that TSS is less indicative of issues in natural watercourses than in piped systems, and this should be considered in the analysis of results.

Testing for polycyclic aromatic hydrocarbons (PAH) is beneficial to monitor the performance of water quality devices, such as oil-water separators, but is relatively costly to implement. Without mandating stormwater source controls as a way of addressing historic contamination, the presence of PAHs may not be actionable by the City. We recommend that PAH testing is done for locations where distinct concerns are noted in the field (e.g. oily sheen on the surface of natural streams, evidence of spills).

Potential sites for water quality monitoring are shown on Map 10-3 at the end of this section.

We recommend the City prioritize water quality monitoring on both Bon Accord Creek and Leoran Brook.

The following secondary sites should be monitored if resources allow (listed from highest priority to lowest priority):

- At least one site receiving drainage from Port Kells:
  - 86 Street storm outfall, or
  - 192 Street storm pipe.
- East Bon Accord Creek.
- Centre Creek.
- At least one site receiving drainage from Anniedale-Tynehead:
  - Lyncean Creek East, or
  - 184 Street Creek.
- Fraser Heights storm outlet.

Measurement: Water quality monitoring of the following parameters:

- Dissolved oxygen;
- Temperature;
- Turbidity;
- Total Suspended Solids;
- pH;
- Conductivity;
- Nitrate;
- E. coli;

- Fecal coliforms;
- Total iron, total copper, total lead, total zinc and total cadmium.

Timing / Triggers: Two sampling periods per year (wet season and dry season) as per the AMF on a maximum repeated cycle of five years.

Cost: $8,000 per site per sampling period (including analysis and reporting).

Metric 8 – Benthic Invertebrates (B-IBI)

The relevance and current state of benthic invertebrate sampling in the watersheds is discussed in Section 4.3. To date, samples on Bon Accord Creek and Leoran Brook have been taken.

Leoran Brook is at a high risk of degradation, given the change of upstream land use from residential to light industrial as part of the Anniedale-Tynehead development; therefore continued monitoring is critical to identify and address issues as they arise.

The goal for each of the assessed watercourses should be to maintain or improve B-IBI scores over time. Adequate source controls integrated into the design of the Anniedale-Tynehead development are the primary means of achieving this goal for Leoran Brook.

Potential sites for benthic invertebrate sampling are shown on Map 10-3 at the end of this section.

We recommend that the City of Surrey continue benthic invertebrate sampling at the two locations sampled in 2012, 2013 and 2014 (Bon Accord Creek, Leoran Brook) as part of the ongoing City-wide B-IBI sampling program. Further, monitoring of species composition should be emphasized in the B-IBI sampling and analysis program, as a change in composition is a more significant indicator of an improvement or degradation of stream health than the raw numerical scores. The City has observed that the overall B-IBI scores can vary widely from year to year, and does not directly correlate with the health of the City's watercourses. These results should be compared against observations and long term norms for watercourses throughout the City of Surrey.

Given the enhancement work undertaken in the subcatchments to East Bon Accord Creek, we recommend the City add a sampling site along East Bon Accord Creek in the next sampling period. The future construction work as part of the peak flow diversion project upstream has the potential to vastly improve the conditions of East Bon Accord Creek, but may also lead to degradation if proper erosion and sediment control measures are not adhered to during construction. Therefore, testing prior to construction is important to establish a baseline condition for future results to be compared.

Measurement: Mean B-IBI score and benthic invertebrate composition.

Timing / Triggers: Once per year (spring) in concert with the City's Benthic Sampling Program. Additional watercourses should be sampled if development and/or redevelopment in their upstream subcatchments exceeds 5% of the total tributary area.

Cost: $3,500 per site. Part of the City of Surrey Benthic Invertebrate Sampling Program.

Metric 9 – Fisheries Habitat Assessment

The British Columbia Ministry of Environment (MoE) created and regularly updates 'Habitat Wizard,' an online program that documents information on fish observations, fish ranges, and fish stocking records. Although the Habitat Wizard provides some indication of fisheries habitat, it cannot be considered a comprehensive database. Some observations listed in the Habitat Wizards are from old reports, prior to major construction / development projects that altered the condition of fisheries habitat. Additionally, the database is not exhaustive. We have compared the information on Habitat Wizard with the City of Surrey's own Watercourse Classification Maps, and note the following:

- Tributaries to Centre Creek are listed as Class B on the City's Watercourse Classification Map, but have documented fish observations according to the Habitat Wizard.
- A watercourse along the 177 Street alignment near Daly Road is listed as Class C on Surrey's Watercourse Classification Maps, but has documented fish observations according to the Habitat Wizard.
- Lyncean Creek East, Leoran Brook, 184 Street Creek, and several lowland channels are listed as Class A / A(O) on the City's Watercourse Classification Maps, but have no documented occurrences on Habitat Wizard.

The City of Surrey's Watercourse Classification Map classifies streams based on fish presence and duration and source of water and surrounding vegetation potential, adjusted to reflect known barriers to fish passage. It represents a more robust and complete assessment than the Habitat Wizard, and should generally be considered to be of greater accuracy; however, City-classified Class B and C watercourses with documented fish observations on Habitat Wizard should be confirmed in the next revision of the City's mapping.

To better monitor the effect of enhancement projects, we recommend habitat assessments be undertaken when required to address specific enhancement initiatives or for development projects that have the potential to impact or alter aquatic or riparian habitat. Stream reaches should be surveyed in accordance with the Resource Inventory Standards Committee procedures outlined 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 (QEP) to collect information including:

- Channel morphology,
- Wetted width and depth,
- Bankfull 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 habitat degradation is found to be occurring, sufficient information should be collected to identify the source of the degradation (e.g. development in the upstream subcatchment, local loss of bank vegetation, insufficient intact riparian forest), and improvement projects suggested.

Measurement: Stream classification, habitat value.

Timing / Triggers: Prior to instream restoration works and when proposed development may impact watercourse, aquatic and riparian habitat directly or through stormwater discharge. Following completion of the Anniedale-Tynehead development, watercourses downstream of the development should be assessed annually for four years, following which assessments should be triggered by development activity and enhancement initiatives..

Cost: $8,000 per watercourse.

Metric 10 – Spill Reporting

The Bon Accord – North Slope (East) watersheds are at high risk for contaminant release that would detrimentally affect the health of the watersheds. This is due in part to the high level of industrial activity and the major transportation corridors that traverse the base of the escarpment. The consequence of a spill upstream of Surrey Bend Regional Park is high, due to the difficulty of remediation. We recommend that a spill reporting mechanism be in place to protect the health of the watersheds from the release of contaminants. This is equally important in the upland and lowland areas. The program will help to prevent, prepare for, mitigate, and respond to spills that may affect the health of the watersheds. The program will rely on reporting by residents and business owners in the area. With well-documented spill reporting, the City can identify regions that are particularly high-risk for spills. Even if the magnitude of most spills is minor, it can identify problem areas that may one day lead to a greater magnitude spill if pre-emptive mitigative measures are not undertaken. Well-documented spill reporting may also identify the types of development that are most prone to harmful spills. If a correlation between certain types of development and problematic spills is identified, the City may wish to improve spill containment measures for these types of developments.

Individuals can report spills using any of the following numbers:

- City of Surrey Engineering Department (business hours) 604.590.4152
- City of Surrey Engineering Department (24-hour) 604.591.4431
- 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

For the reporting program to be most effective, the City should create and maintain a GIS database that includes the following information for each reported spill:

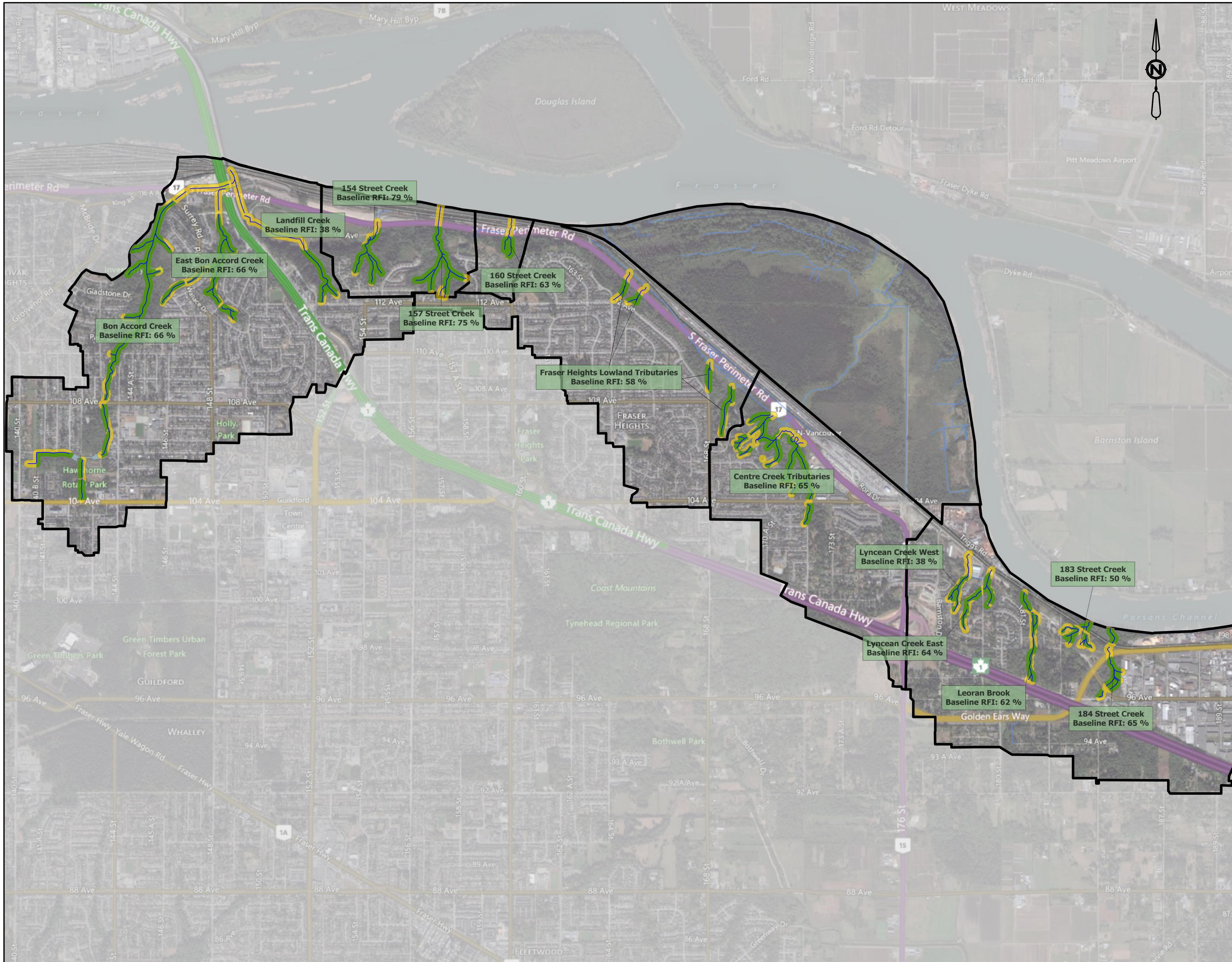
- Reporting person's name and telephone number (unless the reporter wishes to remain anonymous),
- Name and telephone number of person who caused the spill (if available),
- Location and time of the spill,
- Type and quantity of substance spilled,
- Cause and effect of the spill,
- Details of actions taken or proposed to stop, contain and minimize the effects of the spill,
- A description of the spill location and area surrounding the spill,
- Natural watercourses potentially impacted by the spill,
- Details of further action contemplated, required, or undertaken,
- Names of agencies on the scene, and
- Names of other persons or agencies advised concerning the spill.

Three or more occurrences of minor spills, and one occurrence of medium to major spills should trigger a comprehensive review of the cause, and should trigger mitigation work. For example, three releases of hydrocarbons due to accidents at a high-collision intersection should trigger the City to immediately correct the issue to reduce the likelihood of a crash, or apply mitigating technology (e.g. oil-water separators) immediately upstream of the receiving waters.

Measurement: Number and details of reported spills.

Timing / Triggers: When a spill has been reported. Detailed analysis and mitigative measures to be undertaken when three or more minor spills within a 1 km radius, or one medium to major spill is reported.

Cost: $500 per incident. Additional costs to analyse problem areas as they are identified.



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Legend

Intact Riparian Forest
Recommended Riparian Forest
Watershed Boundary

Reference Table 10-2

0 2 km

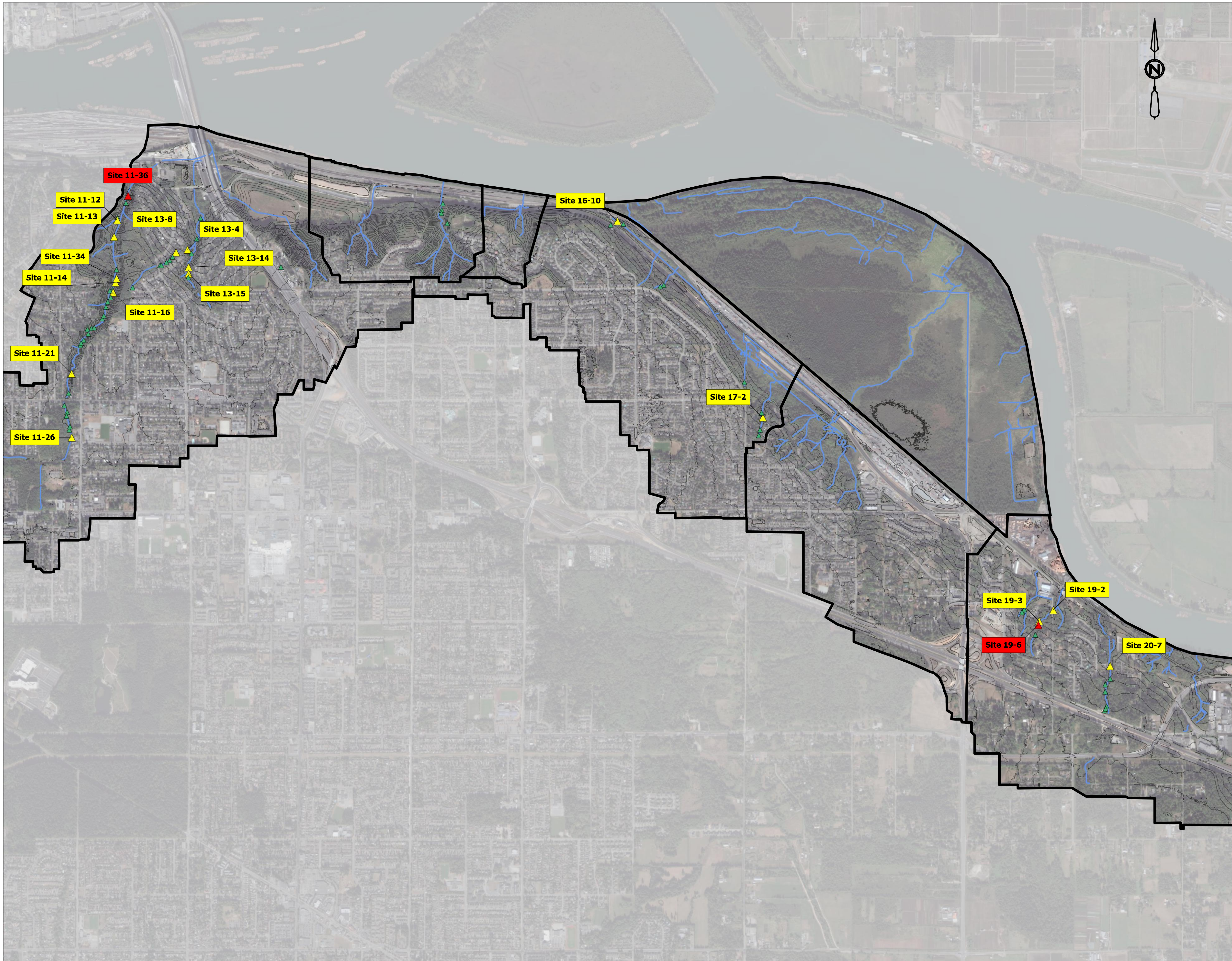
Map 10-1: Baseline Riparian Forest Integrity by Watercourse

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:45,000

DATE: May 2015



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Legend

Watercourse

Surface Contours (5 m)

Watershed Boundary

Ravine Erosion Sites*

High Risk

Medium Risk

Low Risk

11-36 2011 High Risk Site ID*

11-12 2011 Medium Risk Site ID*

*From the City of Surrey 2011 Ravine Stability Assessments

Reference Table 10-3

0 2 km

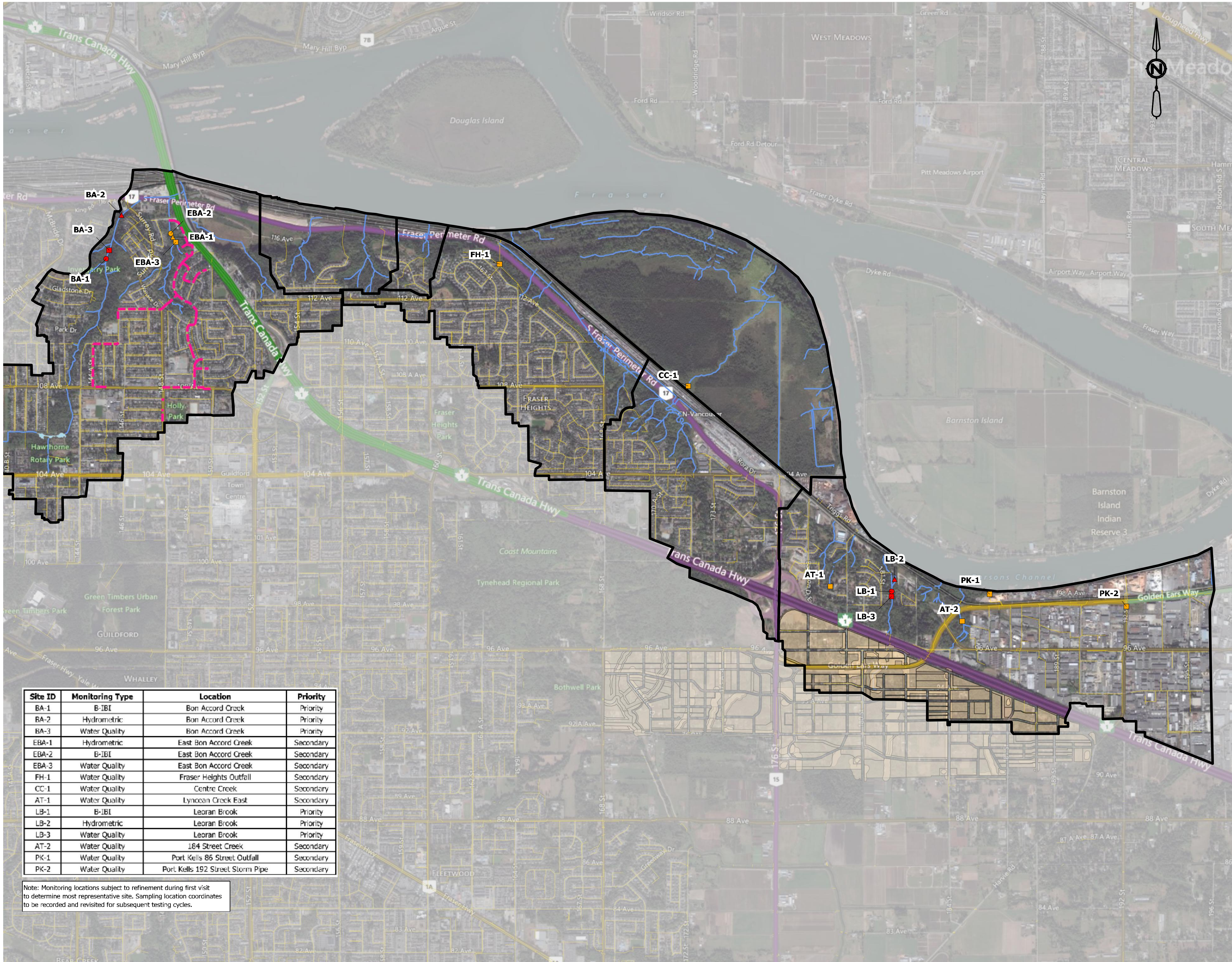
Map 10-2: Ravine Erosion Sites (2011)

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:40,000

DATE: May 2015



Site ID	Monitoring Type	Location	Priority
BA-1	B-IBI	Bon Accord Creek	Priority
BA-2	Hydrometric	Bon Accord Creek	Priority
BA-3	Water Quality	Bon Accord Creek	Priority
EBA-1	Hydrometric	East Bon Accord Creek	Secondary
EBA-2	B-IBI	East Bon Accord Creek	Secondary
EBA-3	Water Quality	East Bon Accord Creek	Secondary
FH-1	Water Quality	Fraser Heights Outfall	Secondary
CC-1	Water Quality	Centre Creek	Secondary
AT-1	Water Quality	Lyncean Creek East	Secondary
LB-1	B-IBI	Leoran Brook	Priority
LB-2	Hydrometric	Leoran Brook	Priority
LB-3	Water Quality	Leoran Brook	Priority
AT-2	Water Quality	184 Street Creek	Secondary
PK-1	Water Quality	Port Kells 86 Street Outfall	Secondary
PK-2	Water Quality	Port Kells 192 Street Storm Pipe	Secondary

Note: Monitoring locations subject to refinement during first visit to determine most representative site. Sampling location coordinates to be recorded and revisited for subsequent testing cycles.

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY — the future lives here.

Legend

Recommended Monitoring Sites

- Priority Site
- Secondary Site (Resource-dependent)
- Benthic Invertebrates
- Hydrometric
- Water Quality

Major Projects

- Anniedale-Tynehead Development
- East Bon Accord Peak Flow Diversion

Existing Drainage Network

- Storm Pipes
- Watercourses

0 2 km

Map 10-3: Recommended Hydrometric, Water Quality and Benthic Invertebrate Monitoring Locations

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

SCALE: 1:50,000

DATE: May 2015

Closure

The management strategies developed and recommended in this Integrated Stormwater Management Plan for the Bon Accord – North Slope (East) watersheds provide a framework for the City to enhance and maintain the health of the study area watersheds, given the anticipated level of development and redevelopment for the area.

Yours truly,

Prepared by:

Jason Kindrachuk, EIT
Lead Project Engineer

Reviewed by:

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
M.R. MacLATCHY
24939

May 11/2015

Michael MacLatchy, Ph.D., P.Eng.
Technical Leader

JK/MM/fd

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REPORT

Appendix A - East Bon Accord Peak Flow Diversion Project Definition Reports

City of Surrey
Project Definition Report

RESOURCE: Drainage
PROGRAM: East Bon Accord Sub Watershed Drainage Improvements
PROJECT NAME: PHASE 1 UPGRADES: Peak Flow Diversion System

LOCATION: Creek and North Birdland Peak Flow Diversion connecting to existing 148 Street Storm Sewer and existing South Birdland Trunk Sewer.

PROJECT MANAGER: Carrie Baron
PROJECT STATUS: Pending
PLANNED START: Pending
PHASE: Construction

PROJECT ESTIMATE: $6,450,000
ESTIMATION VERSION: Class C

SCOPE:

The proposed improvements shall consist of, but are not limited to the following:

Peak Flow Diversion Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	Outfall Leg				
CR-Q100-1	South of 115 Ave ROW	North of 115 Ave ROW	1650	0.7%	19
CR-Q100-2	Crest of Johnston Hill	South of 115 Ave ROW	1500	12.8%	186
CR-Q100-3	Glen Avon Dr, East of Existing Drainage ROW	Crest of Johnston Hill	1800	0.3%	64
CR-Q100-4	Glen Avon Dr & Existing Drainage ROW	Glen Avon Dr, East of Existing Drainage ROW	1800	0.9%	49
CR-Q100-5	Glen Avon Dr & Perth Dr	Glen Avon Dr & Existing Drainage ROW	1800	1.3%	73
	North Birdland Eastern Leg				
NB-E-Q100-1	Loughren Dr & Perth Dr	Glen Avon Dr & Perth Dr	450	9.0%	86
NB-E-Q100-2	Loughren Dr & Ayr Dr	Loughren Dr & Perth Dr	450	3.8%	120
NB-E-Q100-3	Lansdowne Dr & Ayr Dr	Loughren Dr & Ayr Dr	450	6.0%	96
NB-E-Q100-4	Lansdowne Dr & Kew Dr	Lansdowne Dr & Ayr Dr	450	0.9%	52
NB-E-Q100-5	Lansdowne Dr & 150 St	Lansdowne Dr & Kew Dr	300	0.5%	134

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	North Birdland Western Leg				
NB-W-Q100-1	Glen Avon Dr & Ellendale Dr	Glen Avon Dr & Perth Dr	1200	6.8%	323
NB-W-Q100-2	Ellendale Dr, North of Backbird Cresc	Glen Avon Dr & Ellendale Dr	900	6.0%	127
NB-W-Q100-3	Ellendale Dr & 148 St	Ellendale Dr, North of Backbird Cresc	900	11.0%	70
	North Birdland Southern Leg				
NB-S-Q100-1	Glen Avon Dr & Partridge Cresc	Glen Avon Dr & Ellendale Dr	1200	3.6%	234
NB-S-Q100-2	Partridge Cresc & Swallow Dr	Glen Avon Dr & Partridge Cresc	1200	2.6%	67
NB-S-Q100-3	Partridge Cresc & Blakbird Cresc	Partridge Cresc & Swallow Dr	1200	1.7%	59
NB-S-Q100-4	Blackbird Cresc & Oriole Dr	Partridge Cresc & Blakbird Cresc	1200	1.7%	57

Low Flow Discharge Construction:

Identifier	Location	Creek	Diameter (mm)
NB-LFD	Crest of Johnston Hill	Tributary to East Bon Accord	375
RV-LFD	Ellendale Dr, North of Blackbird Cresc	East Bon Accord	525
SB-LFD	Partridge Cresc & Swallow Dr	East Bon Accord	600

Major Inlet Construction:

Identifier	Location
NBI-1	Glen Avon Dr & Perth Dr
NBI-2	Lansdowne Dr, North of Kew Dr
NBI-3	Glen Avon Dr & Ellendale Dr
SBI-8 & RIV-4	Ellendale Dr & Blackbird Cresc
RIV-3	Ellendale Dr & 148 St
SBI-7	Partride Cresc & 111A Ave
SBI-6	Partridge Cresc & Swallow Dr
SBI-5	Blackbird Cresc & Oriole Dr

PURPOSE:

- Establish a major flow path with the Peak Flow Diversion system within the North Birdland and Creek sub-catchments.
- Tie in to existing trunk sewers in the South Birdland and Riverside sub-catchments.
- Regulate flows to East Bon Accord Creek and prevent further erosion.
- Provide major inlet structures to transfer overland flows to the piped system.

COMMENTS:

Engineering services shall consist of, but are not limited to, the following;

- Verification of the flow capacity and HGL elevations of the existing and proposed storm sewer systems during the preliminary design phase.
- Verification of flow requirements to East Bon Accord Creek and functional arrangement for low flow discharges.
- Verification of sizing and locations of major inlet structures.
- Environmental and Geotechnical requirements must be defined and addressed.
- Major inlets and outfall structure shall be designed to provide adequate access for maintenance work.
- ROW requirement plan is necessary for the alignment from Lower Ellendale Park to Glen Avon Dive.
- The drainage system shall adequately convey both the 1 in 5 year (minor) and the 1 in 100 year (major) storm event flows safely downstream.
- Verify basement elevations in North Birdland along proposed layout.
- Identify and resolve any utilities conflicts.
- Storm water control plan.

Permits: MoE, DFO.

Timing: Some works may need to be completed during the fisheries window.

Property: Construction access will require property owners' consent. If required ROWs (either temporary or permanently) shall be established.

Maintenance: Development of a recommended Maintenance Program for the proposed drainage system. The program shall include but is not limited to the types of maintenance required, a schedule of inspections and maintenance activities and an operation manual.

Design Criteria: The design shall meet the latest City of Surrey, Engineering Department, Engineering Design Criteria.

Performance Observations:

- Flow monitoring program at the diversion structure.
- Design consultant will monitor the performance of the constructed improvements during significant rain events to ensure that the improvements are functioning as intended.
- The environmental consultant shall observe the performance of the constructed improvements to ensure that the habitat mitigation strategy and environmental enhancements have addressed the conditions of approval.

City of Surrey
Project Definition Report

RESOURCE: Drainage
PROGRAM: East Bon Accord Sub Watershed Drainage Improvements
PROJECT NAME: PHASE 2 UPGRADES: Peak Flow Diversion System

LOCATION: Riverside and South Birdland Peak Flow Diversion.

PROJECT MANAGER: Carrie Baron
PROJECT STATUS: Pending
PLANNED START: Pending
PHASE: Construction

PROJECT ESTIMATE: $5,970,000
ESTIMATION VERSION: Class C

SCOPE:

The proposed improvements shall consist of, but are not limited to the following:

Peak Flow Diversion Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	South Birdland Northern Leg				
SB-N-Q100-1	Oriole Dr & Lark Pl	Blackbird Cresc & Oriole Dr	1200	3.4%	213
SB-N-Q100-2	Oriole Dr, South of Lark Pl	Oriole Dr & Lark Pl	1200	2.8%	41
SB-N-Q100-3	Oriole Dr & Canary Dr	Oriole Dr, South of Lark Pl	1200	1.4%	110
SB-N-Q100-4	Oriole Dr & Bluebird Cresc	Oriole Dr & Canary Dr	1050	4.1%	67
SB-N-Q100-5	Oriole Dr & 108A Ave	Oriole Dr & Bluebird Cresc	1050	3.8%	35
SB-N-Q100-6	Oriole Dr & 108 Ave	Oriole Dr & 108A Ave	1050	1.9%	137
	South Birdland Spurs				
SB-S-Q100-1	Canary Dr, East of Oriole Dr	Oriole Dr & Canary Dr	750	0.4%	60
SB-S-Q100-2	Bluebird Cresc, East of Raven Pl	Oriole Dr & Bluebird Cresc	750	1.4%	129
	South Birdland Eastern Leg				
SB-E-Q100-1	108 Ave & Raven Pl	Oriole Dr & 108 Ave	1050	0.5%	94
SB-E-Q100-2	108 Ave & 150 St	108 Ave & Raven Pl	900	0.4%	171
SB-E-Q100-3	108 Ave, East of 150 St	108 Ave & 150 St	675	0.8%	28

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	South Birdland Western Leg				
SB-W-Q100-1	108 Ave & 148 St	Oriole Dr & 108 Ave	750	1.4%	298
	Riverside Southern Leg				
RV-S-Q100-1	148 St, South of 107A Ave	148 St & 107A Ave	750	1.3%	114
RV-S-Q100-2	148 St & 107 Ave	148 St & 107 Ave	675	1.0%	102
RV-S-Q100-3	148 St & 108A Ave	148 St & 107 Ave	600	1.0%	190

Minor Storm Sewer Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (m)	Slope (m/m)	Length (m)
	South Birdland				
SB-Q5-1	Partridge Cresc, at Existing Lateral Sewer	Partridge Cres & Blackbird Cresc	300	4.0%	243
SB-Q5-2	150 St & 107A Ave	150 St & 108 Ave	525	1.5%	103
SB-Q5-3	150 St, South of 150 St	150 St & 107A Ave	450	0.5%	144

Major Inlet Construction:

Identifier	Location
SBI-4	Canary Dr, East of Oriole Dr
SBI-3	Blackbird Cresc, East of Lark Pl
SBI-2	108 Ave, East of Oriole Dr
SBI-1	108 Ave, West of Oriole Dr
RIV-1	108 Ave & 148 St
RIV-2	109 Ave & 148 St
RIV-3	110 Ave & 148 St
RIV-4	110 Ave & 148 St

PURPOSE:

- Establish a major flow path with the Peak Flow Diversion system within the South Birdland sub-catchment.
- Provide solution for recurring flooding problems on 108 Ave, 148 St and 150 St

- Replace existing South Birdland Trunk Sewer located on private property and prepare for eventual decommissioning of pipes
- Provide major inlet structures to transfer overland flows concentrating at low points to the piped system.

COMMENTS:

Engineering services shall consist of, but are not limited to, the following;

- Verification of the flow capacity and HGL elevations of the existing and proposed storm sewer systems during the preliminary design phase.
- Verification of sizing and locations of major inlet structures
- Geotechnical requirements must be defined and addressed.
- Major inlets and outfall structure shall be designed to provide adequate access for maintenance work.
- The drainage system shall adequately convey both the 1 in 5 year (minor) and the 1 in 100 year (major) storm event flows safely downstream.
- Verify basement elevations in North Birdland along the proposed layout.
- Identify and resolve any utilities conflicts.
- Storm water control plan.

Permits: N/A

Timing: N/A

Property: N/A

Maintenance: Development of a recommended Maintenance Program for the proposed drainage system. The program shall include but is not limited to the types of maintenance required, a schedule of inspections and maintenance activities and an operation manual.

Design Criteria: The design shall meet the latest City of Surrey, Engineering Department, Engineering Design Criteria.

Performance Observations:

- Design consultant will monitor the performance of the constructed improvements during significant rain events to ensure that the improvements are functioning as intended.

City of Surrey

Project Definition Report

RESOURCE: Drainage
PROGRAM: East Bon Accord Sub Watershed Drainage Improvements
PROJECT NAME: PHASE 3 UPGRADES: Peak Flow Diversion System

LOCATION: Riverside and Wallace Peak Flow Diversion.

PROJECT MANAGER: Carrie Baron
PROJECT STATUS: Pending
PLANNED START: Pending
PHASE: Construction

PROJECT ESTIMATE: $3,740,000
ESTIMATION VERSION: Class C

SCOPE:

The proposed improvements shall consist of, but are not limited to the following:

Peak Flow Diversion Sewer Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	Riverside Western Leg				
RV-W-Q100-1	111A Ave & 147A St	Ellendale Dr & 148 St	750	5.5%	122
RV-W-Q100-2	111A Ave & 146 St	111A Ave & 147A St	750	3.2%	280
	Riverside Northern Leg				
RV-N-Q100-1	148 St, South of 111A Ave	Ellendale Dr & 148 St	750	5.5%	50
	North Wallace Leg				
WL-Q100-1	111 Ave & 146 St	111A Ave & 146 St	900	1.1%	91
WL-Q100-2	110 Ave & 146 St	111 Ave & 146 St	900	1.1%	219
WL-Q100-2	110 Ave & 145A St	110 Ave & 146 St	900	1.5%	51
WL-Q100-3	110 Ave & 145 St	110 Ave & 145A St	750	1.0%	88
WL-Q100-4	110 Ave & 144A St	110 Ave & 145 St	675	2.0%	100
WL-Q100-5	144A St & 109 Ave	144A St & 110 Ave	600	0.8%	203
WL-Q100-6	144A St & 108 Ave	144A St & 109 Ave	525	1.2%	199
WL-Q100-7	108 Ave & 145 St	144A St & 108 Ave	450	0.5%	97
WL-Q100-8	108 Ave, East of 145 St	108 Ave & 145 St	450	0.5%	29

Minor Storm Sewer Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	Wallace				
WL-Q5-1	145A St & 109 Ave	145A St & 110 Ave	375	1.2%	204
WL-Q5-2	145A St & 109 Ave (East Side)	145A St & 109 Ave (West Side)	250	1.5%	13

Low Flow Discharge Construction:

Identifier	Location	Creek	Diameter (mm)
WL-LFD	146 St & 111A Ave	Wallace	375

Major Inlet Construction:

Identifier	Location
WAL-1	146 St & 111A Ave
WAL-2	146 St & 110 Ave
WAL-3	144A St & 110 Ave
WAL-4	108 Ave & 145 St

PURPOSE:

- Establish a major flow path with the Peak Flow Diversion system within the Wallace and North Riverside sub-catchments.
- Provide solution for recurring flooding problems on 110 Ave and 145A St.
- Regulate flows to Wallace Creek and prevent further erosion.
- Replace existing section of Wallace Trunk Sewer located on private property and prepare for eventual decommissioning of pipes
- Provide major inlet structures to transfer overland flows to the piped system.

COMMENTS:

Engineering services shall consist of, but are not limited to, the following:

- Verification of the flow capacity and HGL elevations of the existing and proposed storm sewer systems during the preliminary design phase.
- Verification of flow requirements to Wallace and functional arrangement for low flow discharges

- Verification of sizing and locations of major inlet structures
- Environmental and Geotechnical requirements must be defined and addressed.
- Major inlets and outfall structure shall be designed to provide adequate access for maintenance work.
- The drainage system shall adequately convey both the 1 in 5 year (minor) and the 1 in 100 year (major) storm event flows safely downstream.
- Verify basement elevations in Riverside and Wallace along proposed layout.
- Identify and resolve any utilities conflicts.
- Storm water control plan.

Permits: MoE, DFO.

Timing: N/A

Property: N/A

Maintenance: Development of a recommended Maintenance Program for the proposed drainage system. The program shall include but is not limited to the types of maintenance required, a schedule of inspections and maintenance activities and an operation manual.

Design Criteria: The design shall meet the latest City of Surrey, Engineering Department, Engineering Design Criteria.

Performance Observations:

- Flow monitoring program at the diversion structure.
- Design consultant will monitor the performance of the constructed improvements during significant rain events to ensure that the improvements are functioning as intended.

City of Surrey
Project Definition Report

RESOURCE: Drainage
PROGRAM: East Bon Accord Sub Watershed Drainage Improvements
PROJECT NAME: PHASE 4 UPGRADES: Minor System Improvements

LOCATION: North & South Birdland Minor System Improvements

PROJECT MANAGER: Carrie Baron
PROJECT STATUS: Pending
PLANNED START: Pending
PHASE: Construction

PROJECT ESTIMATE: $2,710,000
ESTIMATION VERSION: Class C

SCOPE:

The proposed improvements shall consist of, but are not limited to the following:

Minor Storm Sewer Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	South Birdland				
SB-Q5-4	Pheasant Dr & Swallow Dr	111A Ave & Partridge Cresc	300	3.2%	295
SB-Q5-5	Pheasant Dr & 152 St	Pheasant Dr & Swan Cresc	300	1.0%	194
SB-Q5-6	Lark Pl	Lark Pl & Oriole Dr	300	2.3%	141
SB-Q5-7	Canary Dr & Raven Pl	Canary Dr, East of Oriole Dr	375	1.1%	447
SB-Q5-8	Bluebird Cresc & Canary Dr	Bluebird Cresc, East of Raven Pl	375	1.5%	273
SB-Q5-9	107A Ave, Western end of 107A Ave	150 St & 107A Ave	450	1.5%	389
	North Birdland				
NB-Q5-1	Kew Dr & 150 St	Kew Dr & Lansdowne Dr	250	4.4%	294
NB-Q5-2	Lansdowne Dr & 150 St	Lansdowne Dr & Kew Dr	250	3.0%	133
NB-Q5-3	Lougren Dr & Glen Avon Dr	Loughren Dr & Ayr Dr	250	3.0%	94
NB-Q5-4	Loughren Dr, East of Perth Dr	Loughren Dr & Perth Dr	250	0.6%	98

PURPOSE:

- Upgrade deficient portions of minor storm system with North and South Birdland sub-catchments

COMMENTS:

Engineering services shall consist of, but are not limited to, the following;

- Verification of the flow capacity and HGL elevations of the existing and proposed storm sewer systems during the preliminary design phase.
- Geotechnical requirements must be defined and addressed.
- The drainage system shall adequately convey 1 in 5 year (minor) storm event flows safely downstream.
- Verify basement elevations in North and South Birdland along proposed layout.
- Identify and resolve any utilities conflicts.
- Storm water control plan.

Permits: N/A

Timing: N/A

Property: N/A

Maintenance: Development of a recommended Maintenance Program for the proposed drainage system. The program shall include but is not limited to the types of maintenance required, a schedule of inspections and maintenance activities and an operation manual.

Design Criteria: The design shall meet the latest City of Surrey, Engineering Department, Engineering Design Criteria.

Performance Observations:

- Design consultant will monitor the performance of the constructed improvements during significant rain events to ensure that the improvements are functioning as intended.

City of Surrey
Project Definition Report

RESOURCE: Drainage
PROGRAM: East Bon Accord Sub Watershed Drainage Improvements
PROJECT NAME: PHASE 5 UPGRADES: Minor System Improvements

LOCATION: North Riverside Minor System Improvements

PROJECT MANAGER: Carrie Baron
PROJECT STATUS: Pending
PLANNED START: Pending
PHASE: Construction

PROJECT ESTIMATE: $1,100,000
ESTIMATION VERSION: Class C

SCOPE:

The proposed improvements shall consist of, but are not limited to the following:

Minor Storm Sewer Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (mm)	Slope (%)	Length (m)
	Riverside				
RV-Q5-1	146 St, North of 108A Ave	146 St & 110A Ave	300	2.6%	153
RV-Q5-2	146 St & 110A Ave	110 Ave & 146A St	375	1.3%	146
RV-Q5-3	110 Ave & 146A St	111 Ave & 146A St	450	1.0%	207
RV-Q5-4	111 Ave & 146A St	111 Ave & 147A St	450	2.5%	171
RV-Q5-5	South Side 111 Ave & 147A St	North Side 111 Ave & 147A St	450	4.8%	13
RV-Q5-6	110A Ave & 146A St	110A Ave & 147A St	300	1.0%	101
RV-Q5-7	110A Ave, East of 146A St	110A Ave & 147A St	250	0.5%	55
RV-Q5-8	Wallace Dr, North of Ellendale Dr	Wallace Dr & Ellendale Dr	300	0.5%	104

PURPOSE:

- Upgrade deficient portions of minor storm system within the Riverside sub-catchment

COMMENTS:

Engineering services shall consist of, but are not limited to, the following;

- Verification of the flow capacity and HGL elevations of the existing and proposed storm sewer systems during the preliminary design phase.
- Geotechnical requirements must be defined and addressed.
- The drainage system shall adequately convey 1 in 5 year (minor) storm event flows safely downstream.
- Verify basement elevations in Riverside along proposed layout.
- Identify and resolve any utilities conflicts.
- Storm water control plan.

Permits: N/A

Timing: N/A

Property: N/A

Maintenance: Development of a recommended Maintenance Program for the proposed drainage system. The program shall include but is not limited to the types of maintenance required, a schedule of inspections and maintenance activities and an operation manual.

Design Criteria: the design shall meet the latest City of Surrey, Engineering Department, Engineering Design Criteria.

Performance Observations:

- Design consultant will monitor the performance of the constructed improvements during significant rain events to ensure that the improvements are functioning as intended.

City of Surrey

Project Definition Report

RESOURCE: Drainage
PROGRAM: East Bon Accord Sub Watershed Drainage Improvements
PROJECT NAME: PHASE 6 UPGRADES: Minor System Improvements

LOCATION: South Riverside Minor System Improvements

PROJECT MANAGER: Carrie Baron
PROJECT STATUS: Pending
PLANNED START: Pending
PHASE: Construction

PROJECT ESTIMATE: $2,820,000
ESTIMATION VERSION: Class C

SCOPE:

The proposed improvements shall consist of, but are not limited to the following:

Minor Storm Sewer Construction:

Identifier	U/S Intersection	D/S Intersection	Diameter (m)	Slope (%)	Length (m)
	Riverside				
RV-Q5-9	106 Ave & 146 St	106 Ave, West of 148 St	300	1.0%	311
RV-Q5-10	106A Ave, East of 146 St	106A Ave, West of 146 St	375	1.2%	210
RV-Q5-11	107 Ave & 146 St	107 Ave & 148 St	375	1.8%	355
RV-Q5-12	107A Ave & 146 St	107A Ave, West of 148 St	375	1.2%	244
RV-Q5-13	108 Ave, East of 146 St	108 Ave, West of 146 St	375	1.6%	270
RV-Q5-14	108A Ave & 146 St	108A Ave & 148 St	375	1.9%	338
RV-Q5-15	109 Ave, East of 146 St	109 Ave & 148 St	300	2.4%	255
RV-Q5-16	110A Ave, East of 146 St	110A Ave & 148 St	300	3.0%	221
	Wallace				
WL-Q5-3	East of Wellington Dr	Southeast of Wellington Dr	300	0.4%	25
WL-Q5-4	Southeast of Wellington Dr	Outlet to Wallace Creek	375	1.3%	11
WL-Q5-5	Wallace Dr, North of 111A Ave	Wallace Dr, North of 111A Ave	300	1.0%	68
WL-Q5-6	Wallace Dr, South of Roxburgh Rd	Wallace Dr, North of Roxburgh Rd	300	4.0%	122

Identifier	U/S Intersection	D/S Intersection	Diameter (m)	Slope (%)	Length (m)
	Creek				
CR-Q5-1	Roxburgh Rd, South of 115A Ave	Roxburgh Rd & 115A Ave	300	0.6%	25

PURPOSE:

- Upgrade deficient portions of minor storm system within the Riverside and Creek sub-catchments

COMMENTS:

Engineering services shall consist of, but are not limited to, the following;

- Verification of the flow capacity and HGL elevations of the existing and proposed storm sewer systems during the preliminary design phase.
- Geotechnical requirements must be defined and addressed.
- The drainage system shall adequately convey 1 in 5 year (minor) storm event flows safely downstream.
- Verify basement elevations in Riverside along proposed layout.
- Identify and resolve any utilities conflicts.
- Storm water control plan.

Permits: N/A

Timing: N/A

Property: N/A

Maintenance: Development of a recommended Maintenance Program for the proposed drainage system. The program shall include but is not limited to the types of maintenance required, a schedule of inspections and maintenance activities and an operation manual.

Design Criteria: the design shall meet the latest City of Surrey, Engineering Department, Engineering Design Criteria.

Performance Observations:

- Design consultant will monitor the performance of the constructed improvements during significant rain events to ensure that the improvements are functioning as intended.

Appendix B - Environmental Assessment

REPORT

City of Surrey

Bon Accord - North Slope (East)
Integrated Rainwater Management Plan
Appendix B - Environmental Assessment

May 2015

Table of Contents

1 Terrestrial Assessment

1.1 ASSESSMENT METHODS

We conducted a terrestrial assessment of the study area on December 16 and 17, 2013 to gain information on habitat types, quality of habitat, and their potential to support various wildlife species, including species at risk. Our assessment included a desktop review of relevant information from the following key resources:

1. Instances of rare or at-risk wildlife and plant occurrences in the study area, and a background search for rare or at-risk species that may be present in the study area through the BC Conservation Data Centre (CDC, 2013),
2. Ortho-imagery and aerial photos of the study area,
3. The City of Surrey's Official Community Plan (1996),
4. Stormwater Planning Guidebook: Developing and Implementing an Integrated Stormwater Management Plan (ISMP; MoE, 2002).

Our field assessment focussed on riparian, forest, and wildlife corridors noting habitat features (ponds, wildlife, trees, evidence of wildlife), ecology and plant communities. We then used this information to identify existing limitations to productivity as well as opportunities to enhance the natural environment that can be integrated into engineering designs, city planning, and economic policies.

1.2 HABITAT CHARACTERISTICS BY LAND USE

The Official Community Plan for the City of Surrey identifies six (6) broad land use designations including commercial (business, city centre, town centre and commercial), residential (multiple residential, urban, suburban and rural), industrial, agriculture, conservation, and First Nations, all of which have designated zoning and land use planning criteria. Land uses present within the study area include:

- Conservation,
- Urban, Suburban, and
- Industrial.

Within these land designations, the OCP identifies Terrestrial Hubs and Eco Sites. Terrestrial Hubs are large areas with complex ecological processes, while Eco Sites are small sites with less habitat complexity. These Sites and Hubs are connected by zoned wildlife corridors that make up a matrix in support of the City's environmental goals to preserve, protect and enhance natural ecological processes, as outlined in the City of Surrey Ecosystem Management Strategy (2011) and Biodiversity Conservation Strategy (2014).

1.2.1 Conservation

The Surrey Bend Regional Park area is a particularly important conservation area, as it borders the Fraser River, incorporating open water areas, wetlands, and areas with both terrestrial and wetland characteristics. In 2009, a management plan for the area was jointly developed by the City and Metro Vancouver. This plan preserves 75% of the area as environmentally sensitive, while maintaining the hydrologic processes that support riparian characteristics of the park (City of Surrey & Metro Vancouver, 2010).

The Terrestrial Hubs and Eco Sites are areas that are structurally diverse and include locations with evergreen, deciduous and mixed-wood forest types of young (5-80 years), mature (80-240 years), and old growth (>240 years), Fraser River shoreline, a marsh, and wetland habitat. Vegetation within the forests consists of western hemlock (*Tsuga deterophyilla*), western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis),* red alder (*Alnus rubra*), paper birch (Betula papyrifer) and black cottonwood (*Populus trichoarpa*). Understory vegetation may be comprised of salmonberry red elder (*Sambucus racemosa*), sitka mountain-ash (*Sorbus sitchensis*), beaked hazel (*Corylus cornuta*), tall Oregon grape (*Mahonia aquifolium),* red-osier dogwood (*Cornus stolonifera*), sword fern, licorice fern (*Polypodium glycyrrhiza*), and step moss (*Hylocomium splendens*).

The variety of habitat types provides a diverse landscape for resident and transient wildlife to forage and shelter. Forested areas can provide food resources that include fruits and seeds for birds and small mammals, which provide prey for larger species like coyotes or black bears (*Ursus americanus*), although these are generally undesirable in such an urban setting. Wildlife trees, coarse woody debris, and leaf litter will provide shelter and cover for mammals, reptiles and amphibians such as the western garter snake (*Thamnophis elegans*), Pacific chorus frog (*Pseudacris regilla*) or long-toed salamanders (*Ambystoma macrodactylum*) particularly when the habitat is close to a permanent water source (BC CDC 2014). Wildlife trees were found throughout the watersheds, in young to mature forests. These trees provide high wildlife habitat value as they provide forage for insectivorous bird species such as the brown creepers (*Certhia americana*) and woodpeckers as well as nesting cavities for primary and secondary cavity nesters.

Wetland habitat and riparian habitat in the study area is concentrated along the Fraser River and Surrey Bend Regional Park; however, some detention ponds used for stormwater management provide wetland habitat in other areas, such as residential neighbourhoods. Wetland habitat and areas with wetland characteristics are dominated by reed canary grass, cattails (*Typha latifolia*), hardhack (*Spiraea douglasii*), skunk cabbage (*Lysichton americanus*), horsetail (*Equisetum* spp.), alder (*Alnus* spp.) and Himalayan blackberry. Wildlife found in these areas may include muskrats (*Ondatra zibethicus*), beavers (*Castor canadensis*), Pacific water shrews (*Sorex bendirii),* northern red-legged frogs (*Rana aurora*) Pacific chorus frogs, long-toed salamanders, and red-winged blackbirds (*Agelaius phoeniceus*).

1.2.2 Urban and Suburban Residential

Based on population, the City of Surrey is the second largest city in BC, and contains high-density City and Town Centres, urban and suburban areas. Natural vegetation within these areas is limited to parks, small Terrestrial Hubs, and Eco Sites with limited wildlife movement between these sites. These areas tend to have young to old growth forest of cedar and alder accompanied by salmonberry, sword fern, manicured grass lawn and playgrounds. Land is a limiting resource for the City of Surrey, and the creation of new parks or natural areas in lieu of new infrastructure or economic opportunities would require a significant amount of financial and public support. Privately owned properties may be potential areas where environmental enhancement opportunities could occur, but would require landowner permission, cooperation, and commitment.

1.2.3 Industrial

Industrial land in the study area is highly developed with some semi-modified natural areas along the Fraser River and bordering industrial lands. These areas generally have little to no natural vegetation due to being highly developed. Resident wildlife species may include, but are not limited to the black-capped chickadees (*Poecile atricapillus*), the American crow (*Corvus brachyrhynchos*), and the house sparrow (*Passer domesticus).* In these areas, we conducted only a limited terrestrial habitat survey.

1.3 SPECIES AT RISK

1.3.1 Rare and Endangered Wildlife

The watersheds within the study area provide habitat for a variety of species at risk, including insects, mammals, birds, and amphibians with a high potential for at least 11 species at risk to occur, with eight of those species federally listed under Schedule 1 of the Species at Risk Act. A desktop examination of wildlife occurrences within 20 km of the study area was conducted, and is summarized in Table 1.

Table 1
Listed Species within a 20 km Radius of the Centre of the Study Area

Common Names	Scientific Name	*BC Listing	**COSEWIC	***SARA	Preferred Habitat	Potential to Occur in the Project Area
Emma's Dancer	*Argia emma*	Blue			Lakes, rivers, streams, ponds, open water, and riparian areas.	High
Trowbridge's Shrew	*Sorex trowbridgii*	Blue			Mixed wood forests and riparian areas with abundant ground cover	High
Northern Red-legged Frog	*Rana aurora*	Blue	SC	1	Temporary and permanent pools, wetlands, fens, bogs, streams in close proximity to forest or woodland habitat types.	High – This species has been detected directly adjacent to the Project Area
Green Heron	*Butorides virescens*	Blue			Lakes, rivers, ponds, open water, wetlands, marshes, and riparian areas.	High
American Bittern	*Botaurus lentiginosus*	Blue			Lakes, rivers, ponds, open water, wetlands, marshes, estuaries, and occasionally riparian areas.	Moderate
Peregrine Falcon *anatum* subspecies	*Falco peregrinus anatum*	Red	SC	1	Agricultural lands, grasslands and shrubby areas, riparian areas, lakes, rivers, wetlands, bogs, fens, swaps, cliffs, rocky and sparely vegetation areas, and occasional use of rural, suburban, and urban areas.	High
Peregrine Falcon *pealei* subspecies	*Falco peregrinus pealei*	Blue	SC (2007)	1	Agricultural lands, grasslands and shrubby areas, riparian areas, lakes, rivers, wetlands, bogs, fens, swaps, cliffs, rocky and sparely vegetation areas, and occasional use of rural, suburban, and urban areas.	High - This species has been detected directly adjacent to the Project Area
Great Blue Heron	*Ardea herodias fannini*	Blue	SC	1	Lakes, ponds, open water, wetlands, marsh, swaps, mudflats, mixed wood, deciduous and conifer forests, agricultural lands, rural, suburban, and urban areas.	High – This species has been detected in the Project Area
Autumn Meadowhawk	*Sympetrum vicinum*	Blue			Lakes, ponds, open water, streams, rivers, riparian areas, and mixed wood forests.	High
Beaverpond Baskettail	*Epitheca canis*	Blue			Lakes, ponds, open water, streams, rivers, riparian areas, fens and bogs.	High - This species has been detected in the Project Area
Beaverpond Baskettail	*Epitheca canis*	Blue			Lakes, ponds, open water, streams, rivers, riparian areas, fens and bogs.	High - This species has been

1 - Terrestrial Assessment

Common Names	Scientific Name	*BC Listing	**COSEWIC	***SARA	Preferred Habitat	Potential to Occur in the Project Area
						detected in the Project Area
Townsend`s Big-eared Bats	*Corynorhinus townsendii*	Blue			Subterranean, caves, riparian forests, conifer, deciduous and mixed wood forests, grasslands, industrial areas, rural, suburban, and urban areas.	High
Blue Dasher	*Pachydiplax longipennis*	Blue			Wetland, marsh, riparian forests, lakes, ponds, open water, sparsely vegetated rocks, cliffs, streams and rivers.	Moderate
Olympic Shrew	*Sorex rohweri*	Red			Mix wood forests, riparian areas, and gravel bars,	Moderate
Grappletail	*Octogomphus specularis*	Red			Riparian areas, streams and rivers.	Moderate
Pacific Water Shrew	*Sorex bendirii*	Red	E	1	Wetlands, swamp, marsh, fens, bogs, riparian areas, gravel bars, and moist conifer forests.	High – This species has been detected in the Project Area
Painted Turtle - Pacific Coast Population	*Chrysemys picta pop. 1*	Red	E	1	Lakes, ponds, open water, wetlands, swamp, marsh, fens, bogs, riparian areas, gravel bars, industrial, urban areas.	Moderate
Dun Skipper	*Euphyes vestris*	Red	T	1	Grasslands, meadow, seasonal seeps.	Moderate
Oregon Forest snail	*Allogona townsendiana*	Red	T	1	Mixed wood forests	Moderate
Southern Red-backed Vole	*Myodes gapperi occidentalis*	Red			Moist conifer forests and riparian forests.	Moderate
Audouin's Night-stalking Tiger Beetle	*Omus audouini*	Red	T		Moist forest, grasslands, mudflats, sand spits, close to saltwater.	Low
American Avocet	*Recurvirostra americana*	Blue			Lakes, ponds, open water, alkali ponds, salt flats, wetlands, bogs, fens, and swamps.	Moderate

Common Names	Scientific Name	*BC Listing	**COSEWIC	***SARA	Preferred Habitat	Potential to Occur in the Project Area
Blue Dasher	*Pachydiplax longipennis*	Blue			Wetland, marsh, riparian forests, lakes, ponds, open water, sparsely vegetated rocks, cliffs, streams and rivers.	Moderate
Olympic Shrew	*Sorex rohweri*	Red			Mix wood forests, riparian areas, and gravel bars,	Moderate
Grappletail	*Octogomphus specularis*	Red			Riparian areas, streams and rivers.	Moderate
Pacific Water Shrew	*Sorex bendirii*	Red	E	1	Wetlands, swamp, marsh, fens, bogs, riparian areas, gravel bars, and moist conifer forests.	High – This species has been detected in the Project Area
Painted Turtle - Pacific Coast Population	*Chrysemys picta pop. 1*	Red	E	1	Lakes, ponds, open water, wetlands, swamp, marsh, fens, bogs, riparian areas, gravel bars, industrial, urban areas.	Moderate
Dun Skipper	*Euphyes vestris*	Red	T	1	Grasslands, meadow, seasonal seeps.	Moderate
Oregon Forest snail	*Allogona townsendiana*	Red	T	1	Mixed wood forests	Moderate
Southern Red-backed Vole	*Myodes gapperi occidentalis*	Red			Moist conifer forests and riparian forests.	Moderate
Audouin's Night-stalking Tiger Beetle	*Omus audouini*	Red	T		Moist forest, grasslands, mudflats, sand spits, close to saltwater.	Low
American Avocet	*Recurvirostra americana*	Blue			Lakes, ponds, open water, alkali ponds, salt flats, wetlands, bogs, fens, and swamps.	Moderate

Source: BC CDC, 2014.

***Red-listed** species are those indigenous species, subspecies or ecological communities that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia. **Blue-listed** species are those indigenous species, subspecies, or ecological communities considered to be of Special Concern in British Columbia because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.

** COSEWIC status is defined as **SC** = Special Concern; **T** = Threatened; **EN** = Endangered; **DD** = Data Deficient; and **NAR** = Not at Risk

*** *Species at Risk Act* – **Schedule 1:** is the official list of species that are classified as extirpated, endangered, threatened and of special concern.

1.3.2 Rare and Endangered Plants

Although we did not complete a detailed vegetation survey as part of the terrestrial assessment, the watersheds within the study area provide a diversity of habitat, ranging from wetland and tidal areas to old growth forest, that can support an assortment of plant species. A desktop examination of plant occurrences within a 10 km radius of the study area was conducted and is summarized in Table 2. Four blue-listed species have a high potential to occur in the study area, while four red-listed species, one of which is listed as Endangered under Schedule 1 of the Species at Risk Act, have a moderate potential to occur in the study area.

Table 2
Listed Plant Species within A 10 km Radius of the Centre of the Study Area

Common Name	Scientific Name	BC Listing	COSEWIC	SARA	Habitat Type	Potential to Occur in the Project Area
Nuttall's waterweed	*Elodea nuttallii*	Blue			Lakes, ponds, open water, streams and rivers.	High
Vancouver Island beggarticks	*Bidens amplissima*	Blue	SC		Tidal shores of Fraser River, mudflats, estuary, beaches, wetlands, and marshes.	High
Small-flowered bittercress	*Cardamine parviflora*	Blue			Habitat Unknown	Moderate due to occurrences in Mary Hill Port Coquitlam B.C.
Three-flowered waterwort	*Elatine rubella*	Blue			Wetlands, bogs, fens, lakes, ponds, open water, mudflats, and estuaries.	High
Pointed rush	*Juncus oxymeris*	Blue			Open wet ground.	Moderate
Pointed broom sedge	*Carex scoparia*	Blue			Riparian, shrubs, and meadows.	Moderate
Streambank lupine	*Lupinus rivularis*	Red	E	1	Streams, rivers, urban, suburban, mudflats, and meadows.	Moderate
Mountain sneezeweed	*Helenium autumnale* var. *grandiflorum*	Blue			Grassland, shrub, and meadows.	Moderate
Northern water-meal	*Wolffia borealis*	Red			Lakes, ponds, and open water	Moderate
False-pimpernel	*Lindernia dubia* var. *anagallidea*	Blue			Riparian, wetlands, bogs, fens, and areas of seasonal seeps.	High
Pink water speedwell	*Veronica catenata*	Red			Wetlands, marsh, riparian, lakes, ponds, open water, grasslands, shrubs, and meadows	Moderate
Green-fruited sedge	*Carex interrupta*	Red			Habitat Unknown	Moderate due to an occurrence along Nelson Creek, B.C.

Common Name	Scientific Name	BC Listing	COSEWIC	SARA	Habitat Type	Potential to Occur in the Project Area
Blue vervain	*Verbena hastata* var. *scabra*	Blue			Wetland, marsh, grassland, shrub, and meadow	Moderate
Ussurian water-milfoil	*Myriophyllum ussuriense*	Blue			Lakes, and riparian.	High – This species occurs directly adjacent to the Project Area
Small spike-rush	*Eleocharis parvula*	Blue			Intertidal marine, mudflats, wetlands, lakes, ponds, and open water	Moderate
Slender-spiked mannagrass	*Glyceria leptostachya*	Blue			Wetlands, swamp, marsh, bog, fen, mudflats, lakes, ponds, and open water	High

Source: BC CDC, 2014.

***Red-listed** species are those indigenous species, subspecies or ecological communities that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia. **Blue-listed** species are those indigenous species, subspecies, or ecological communities considered to be of Special Concern in British Columbia because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.

** COSEWIC status is defined as **SC** = Special Concern; **TH** = Threatened; **EN** = Endangered; **DD** = Data Deficient; and **NAR** = Not at Risk

*** *Species at Risk Act* – **Schedule 1:** is the official list of species that are classified as extirpated, endangered, threatened and of special concern.

1.4 WILDLIFE CORRIDORS

Wildlife corridors are an important habitat feature for maintaining healthy wildlife and plant populations by facilitating movement between fragmented habitat and public safety (e.g. human-wildlife conflicts, such as vehicle collisions and animal habituation).

Our assessment of a subset of wildlife movement corridors within the study area provided evidence that racoon and coyotes are using these areas based on scat, as well as a variety of birds. Wildlife corridors in the study areas vary in quality. Some areas provide good quality cover and connect smaller terrestrial and aquatic hubs, while other sites comprised of thinning cover, increased development, and fencing that would limit wildlife movement for larger mammals.

The continued increase in urban development and infrastructure is infringing on wildlife habitat, resulting in a cumulative loss of habitat, increased disturbance within wildlife areas, and the potential to decrease the quality of available habitat.

1.5 TERRESTRIAL ENVIRONMENT CONSIDERATIONS

Our overview field assessment revealed a high level of weed infestation across the study area by such species as Himalayan blackberry, English ivy (*Hedera helix*), Scotch broom (*Cytisus scoparius*), false lamium (*Lamium galeobdolon),* and creeping buttercup *(Ranunculus repens*), which can limit the productivity, biodiversity and available habitat in the area. Additionally, we identified garbage and debris disposed in forested areas, ravines, and streams which can affect the productivity and quality of habitat in the study area.

Based on the terrestrial assessment and identification of the watershed limitations within the study area, the following opportunities may exist for the City of Surrey to contribute to the protection and enhancement of the watersheds within the Bon Accord – North Slope (east) region:

- Prepare a weed management plan that provides conditions for the removal and continued control of invasive and noxious weed species, followed by immediate revegetation of these areas with native species, such as willow, red alder, salmonberry, red-osier dogwood, thimbleberry, and Oregon grape. Replanting these areas will not only prevent the reestablishment and spread of the non-native species, but will also increase habitat quality and diversity for mammals such as mice, voles, ungulates, coyotes, as well as forest and riparian songbirds and bats.
- Remove garbage regularly and monitor forested areas, gullies and streams to prevent unauthorized waste disposal.
- Ensure land use planning and developments adhere to the environmental and agricultural policies, regulations, and BMPs that apply to the area, as outlined in Develop With Care (MoE, 2012), the City of Surrey Ecosystem Management Plan (HB Lanarc, Raincoast, 2011), the City of Surrey Biodiversity Conservation Strategy (Diamond Head Consulting, 2014), and the City of Surrey Official Community Plan.
- Establish no-disturb buffers around terrestrial and aquatic habitats to protect these areas and wildlife from increased disturbance.

- Increase connectivity between wildlife corridors and habitat.
- Increase and maintain habitat quality in forest, agricultural lands, and wildlife corridors by retaining wildlife trees, undisturbed grasslands, pastures, forests, and natural forest openings (Government of British Columbia, 2013b).
- Locate new trails, buildings and roads away from key habitat areas for such species as birds, ungulates, amphibians and reptiles (Government of British Columbia, 2013b; MoE, 2012; Ovaska et al., 2004).

Educate and support the public in efforts to protect and maintain terrestrial and aquatic habitat through joint projects. This collaboration could allow for the shared responsibilities of financial, economic and environmental responsibilities as well as the creation of new ideas and urban planning designs.

2 Aquatic Assessment

The Bon Accord – North Slope (East) study area has several major streams which drain via the escarpment to the Fraser River. Major streams relevant to the aquatic assessment of the project area include the following:

- Bon Accord Creek and East Bon Accord Creek,
- 157 Street Creek,
- 160 Street Creek,
- Unnamed Creeks at Fraser Heights,
- Centre Creek,
- Lyncean Creek East, Lyncean Creek West
- Leoran Brook, and
- Unnamed Creek at 184 Street.

These major streams and their tributaries generally flow through highly-developed residential uplands towards commercial and industrial areas and transportation corridors in the lowlands before discharging to the Fraser River.

The aquatic habitat of these streams range from highly modified, disturbed and degraded channels and riparian areas to undeveloped, high-value, natural corridors and stream habitats. Historical land development in the study area has resulted in the loss of open channels and headwater tributaries through piping or infilling, and habitat degradation through channel re-alignment, flow alteration and water quality degradation. Remnant natural sections of some streams are preserved as part of city parks or stream setback areas. Other natural stream sections are present in undeveloped areas along the steep north-facing slopes.

2.1 FISH SPECIES

Many streams within the study area have been classified as fish-bearing. Several fish species have been documented in streams within the study area either seasonally or year-round. Documented fish species are listed in Table 3.

Table 3
Fish Species Present in Major Streams of the Study Area

Common Name	Scientific Name
Black Crappie*	*Pomoxis nigromaculatus*
Brassy Minnow*	*Hybognathus hankinsoni*

Common Name	Scientific Name
Brown Bullhead*	*Ameiurus nebulosus*
Bull trout / Dolly Varden	*Salvelinus malma*
Carp*	*Cyprinidae*
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*O. keta*
Coastal cutthroat trout	*O. clarki clarki*
Coho salmon	*O. kisutch*
Largescale sucker*	*Catostomus macrocheilus*
Leopard dace*	*Rhinichthys falcatus*
Longnose dace*	*R. cataractae*
Mountain whitefish	*Prosopium williamsoni*
Northern pikeminnow*	*Ptychocheilus oregonensis*
Peamouth chub*	*Mylocheilus caurinus*
Pink salmon	*O. gorbuscha*
Prickly sculpin	*Cottus cognatus*
Rainbow trout	*O. mykiss*
Redside shiner*	*Richardsonius balteatus*
Sockeye Salmon	*O. nerka*
Starry flounder*	*Platichthys stellatus*
Steelhead salmon	*O. mykiss*
Threespine stickleback	*Gasterosteus aculeatus*

Sources: BC MoE, 2014a, b, c; DFO, 1999; City of Surrey and Metro Vancouver, 2010.

* Only noted in Centre Creek.

2.2 STREAM HABITAT

2.2.1 Assessment Methods

We assessed stream habitat conditions by conducting a desktop review of background information and reports, available mapping, and ortho-imagery. We assembled and reviewed available information to characterize fish habitat, including features and potential habitat limitations, and to identify potential enhancement opportunities within the study area.

We completed a limited field assessment on December 16 and 17, 2013 to assess the current fish habitat conditions, to identify specific issues related to erosion, bank instability, barriers to fish passage, and to verify and supplement the compiled background information. We also noted potential opportunities for habitat enhancement and restoration during the field assessments.

We selected the sites for focussed field assessment from a sub-sample of streams in the study area. Sites were located in all major stream watersheds, and included a sub-sample of stream classifications in the study area.

Our field assessments were conducted at each site following Resource Inventory Standards Committee protocols (RISC, 2001). We assessed the streams on foot, and collected detailed information, including:

- Channel morphology,
- Channel width and depth, and wetted width and depth,
- Substrate composition,
- Barriers to fish movement,
- Fish observations,
- Riparian vegetation,
- Habitat values, and
- Potential constraints and habitat enhancement opportunities.

We georeferenced each site and feature in the field with GPS, and photographed the locations.

2.2.2 Habitat Features

We have summarized the fish habitat characteristics and features at each site during field investigations in Table 4. The site assessment locations are shown on the map at the end of this document, with photographs appended.

Fish habitat information has been compiled based on background information, and supplementary field investigations. Key habitat values and notable features for major streams in the project area are summarized in subsequent sections.

Table 4
Summary of Fish Habitat Characteristics for Watercourse Sites Visited During Aquatic Assessments

Site #	Stream name	Location	CW (m)	WW (m)	Wb (m)	Subst. (D/Sd)	Grad. (%)	Morph.	Habitat features	Fish use	Photos
1	Bon Accord Creek	Outlet of pond in Hawthorne Rotary Park	5.3	5.0	0.8	F	0.5	LC	Slow moving, deep water glides. Overhanging vegetation and woody debris cover.	Good rearing and overwintering habitat. Poor spawning habitat.	1
2	Hawthorne Creek	Headwaters of Bon Accord at hydro ROW, near 141 St. and 105 Ave.	2.4	1.8	0.3	F	0.5	LC	Straight, slow moving, low gradient ditch. Intact riparian area in park. Garbage in areas along street.	Poor rearing, overwintering and spawning habitat	2
3	Hawthorne Creek	In hydro ROW south of 106 Ave.	2.2	1.4	0.3	F	n/a	LC	Limited water and channel depth, narrow riparian corridor	Limited water precludes fish presence	3
4	Unnamed	Tributary to Bon Accord near Surrey Rd.	n/a	n/a	n/a	n/a	n/a	n/a	Mapped location in narrow steep ravine area on east bank of Bon Accord Creek. No visible channel.	n/a	4
5	Unnamed	Tributary to Bon Accord Creek in middle reaches near 114 Ave	3.0	2.2	0.4	F/G	3	RP	Straight to sinuous riffle-pool channel. Gravel and fine substrates. Intact forest riparian area.	Culvert under trail to Bon Accord impassable. Fish presence may be limited by water flows.	5-7
6	Bon Accord Creek	At trail crossing in middle reaches	4.9	3.6	0.5	G/F,C	7	CP	Good cover with wood, pools, and overhanging vegetation. Mix of gravel, cobbles and fine substrates. Slow areas with good cover. Steep bank slopes.	Good salmonid rearing and spawning habitat.	8-11
7	East Bon Accord Creek	Upstream of 115A Ave and wetland	3.6	2.7	0.4	G/F	1	RP	Straight to sinuous riffle-pool channel. Compact gravels and fines. Limited	Poor to moderate rearing in extensive riffle areas	12

Site #	Stream name	Location	CW (m)	WW (m)	Wb (m)	Subst. (D/Sd)	Grad. (%)	Morph.	Habitat features	Fish use	Photos
		area							cover and water depth. Intact forest riparian area	and limited water depth.	
8	Unnamed	Tributary to East Bon Accord at headwaters and stormwater outlet	2.6	1.9	0.4	C/G	15	CP	Steep, straight to sinuous cascade and step-pool channel starting at stormwater outlet. Moderate cover. Limited water depth. Intact forest riparian area	Limited water precludes fish presence.	13
9	Unnamed	157th St. stream on north slope, near 114 Ave. and 158A St.	1.4	0.9	0.4	F/G	10	RP/CP	Small, sinuous stream. Intact forest riparian area.	Limited water precludes fish presence	14
10	Unnamed	Stream on north slope, near 168 St. and 108 Ave.	2.1	1.2	0.4	C/G	10	CP	Straight, riffle channel starting at stormwater outlet. Log weir enhancements. Gravel and cobble substrates. Limited water flow.	Spawning habitat with suitable flows. Limited rearing areas.	15, 16
11	Unnamed	Stream at bottom of north slope, near 168 St. and 108 Ave.	6.0	6.0	0.4	F	0	LC	Poor cover and compact fines/sands near stormwater outlet. Channel becomes braided and indistinct in channel wetland section downstream.	Good rearing habitat in well-defined channel areas.	17
12	Unnamed	Tributary to Centre Creek upstream of SFPR near 104A Ave.	2.6	1.6	0.3	F/G	6	RP	Straight to sinuous riffle-pool channel. Compact gravels and fines. Limited cover and water depth. Intact forest riparian area	Limited water precludes fish presence.	18
13	Centre Creek	Channelized wetland upstream of SFPR	n/a	n/a	n/a	n/a	n/a	n/a	Slow-moving, low gradient, multi-channelled wetland section. Fines and organic substrates. Multiple culverts at SFPR.	Good rearing habitat in well-defined channel areas. No spawning substrates in lowland	19, 20

Site #	Stream name	Location	CW (m)	WW (m)	Wb (m)	Subst. (D/Sd)	Grad. (%)	Morph.	Habitat features	Fish use	Photos
										sections.	
14	Unnamed	Headwaters of small stream at 100 Ave. and Lyncean Dr.	1.4	0.9	0.4	G/F	17	CP	Steep, sinuous stream starting at stormwater outfall. Compact fine substrates. Limited water flow. Steep, eroding banks.	Limited water and gradient precludes fish presence.	21, 22
15	Unnamed	Downstream of 179 St. near 100A Ave.	2.0	1.0	0.5	G/F	5	RP	Slow moving, meandering channel. Trace woody debris and pools. Limited water flow. Road culvert at 179th St.	Spawning and rearing habitats with adequate flows.	23
16	Unnamed	Headwaters of small stream on 181 St., habitat enhancement site	1.2	0.7	0.3	F	n/a	n/a	Constructed headwater/stormwater pond at stormwater outlet. Two outlet streams are small, sinuous channels. Intact forest riparian area.	Limited water precludes fish presence	24, 25
17	Leoran Brook	Mainstem near 181 St.	4.6	2.0	0.5	G/C	6	RP	Sinous, riffle to cascade-pool channel. Good cover with pools, boulder, woody debris. Constructed pond and notched weir structure in lower reach.	Good spawning and rearing areas for salmonids.	26-28
18	Unnamed	Headwater stream at 100 Ave. and 176 St.	1.6	0.8	0.3	F	n/a	n/a	Small, sinous, riffle-pool headwater stream. Channel indistinct, flows through forested area to roadside ditches. Limited water flow.	Limited water precludes fish presence.	29
19	Unnamed	Small streams east of 182A St. near railway adjacent to Fraser River.	2.5	2.2	0.3	F	3	RP	Small, sinuous, riffle-pool channels upstream (S) of railway with large, shallow pool areas. Water flow and culverts under railway limit fish distribution.	Moderate value rearing habitats. Some spawning substrates downstream of railway culverts.	30-34
20	Unnamed	184 St. stream,	2.2	1.6	0.5	F	3	RP	Riffle-pool to slow moving meandering	Low to high value rearing	35-38

Site #	Stream name	Location	CW (m)	WW (m)	Wb (m)	Subst. (D/Sd)	Grad. (%)	Morph.	Habitat features	Fish use	Photos
		near golden ears way and 96 Ave.							wetland channel. Overhanging and instream cover. Fine/sand substrate. Intact forest riparian area	areas are present for salmonids. Some spawning substrates present. Spent male coho under Golden Ears bridge.	
21	Unnamed	Drainage channel in Port Kells near 197 St. and 88B Ave.	4.0	2.6	0.8	G/C	n/a	n/a	Straight, uniform drainage channel. Some overhanging cover. Compact sands and gravel substrate. Poor water quality (turbid). Previous slope stability work.	Poor water quality and lack of cover limits fish presence. Poor rearing, overwintering and spawning habitat.	39
22	Leoran Brook	Headwaters on 96 Ave.	2.0	1.2	0.6	n/a	n/a	n/a	Roadside drainage ditch along 96th Ave. at 180th St. Remnant sinuous channel through section of properties south of 96th Ave. Constructed channel and new culverts at highway crossing.	Low to moderate value rearing areas are present for salmonids. Some spawning substrates. Limited water flow.	40
23	Unnamed	160th St. stream on north slope, near 113 Ave and 159B St.	1.8	1.1	0.3	C/B	6	n/a	Small, straight headwater channel starting at stormwater outfall. Intact forest riparian area. Iron staining on substrate.	Limited water precludes fish presence	41
24	Unnamed	156 St. ditch at Northview park	3.4	0.8	0.8	n/a	n/a	n/a	Roadside drainage ditch. Uniform channel dimension. Limited flow. Piped downstream. Mowed grasses	Limited water and piped sections downstream. No fish presence.	42

Notes:

CW: Channel Width; WW: Wetted Width; Wb: Bankfull Depth; Subst. (D/Sd): Substrate (Dominant/Subdominant), C – Cobble, B – Boulder, G – Gravel, F – Fines; Grad: Gradient;

Morph: Channel morphology, RP – Riffle-Pool, CP – Cascade-Pool, LC – Large Channel; N/A – Not available/Not Applicable

2.2.3 Bon Accord Creek

Bon Accord Creek and its tributaries (including East Bon Accord Creek) have been significantly impacted by urban residential development in the middle and upper reaches, and historic industrial developments in the lower reaches. However, many sections of the creek are located in forested ravine areas and protected parks. Most of the Bon Accord Creek mainstem reaches flow through property owned by the City of Surrey, with the exception of a portion of land north of 108 Avenue and south of 110 Avenue, which is privately owned land (ECL, 2001).

Many reaches in the watershed provide valuable fish-bearing habitats and important food and nutrient sources. Potential spawning and rearing habitat for salmonids was identified in previous reports (Coast River, 1997; Coast River, 1999; DFO, 1999; ECL, 2001) and during our field assessments. Spawning habitat value in Bon Accord Creek ranges from low to high in the lower reaches, high in the middle reaches, and low in the upper reaches. Rearing habitat is rated as high value in the lower and middle reaches, and moderate to high value in the upper reaches; however, a number of barriers to fish passage have been identified which limit access to high-value rearing and spawning habitat (ECL, 2001).

2.2.4 157 Street Creek

157 Street Creek and its tributaries drain a relatively small area on the steep slopes north of 112 Avenue to the Fraser River. The stream generally flows as natural channels through steep-sloped forested ravines. Stormwater from a residential area in the upper portion of the catchment is piped to the bottom of the Surrey escarpment, prior to discharging to the Fraser River.

To date, no fish presence has been documented in this stream (ECL, 1999; MoE 2014). The stream provides important food and nutrient value to downstream fish populations in the Fraser River.

2.2.5 160 Street Creek

160 Street Creek and its tributaries drain the north slope and flow through a steep-sloped forested area. The stream receives stormwater from a residential area in the upper portions of the catchment conveyed to a stormwater outfall at the north end of 159B Street.

The stream channel is small, and to date fish presence has not been documented in this stream (ECL, 2000). The stream provides important food and nutrient value to downstream fish populations in the Fraser River.

2.2.6 Unnamed Tributaries at Fraser Heights

Several unnamed streams and channels drain the steep north slopes of the Fraser Heights area. The headwater streams are small and steep with step-pool and cascade pool morphologies. Streams originate on the slope as indistinct seepages and at stormwater outfalls (ECL, 2000). Water collects in wetland areas at the bottom of the slope and in drainage channels along the SFPR and CN Railway rights-of-way. Based on our field observations, channel sections in the wetland area are occasionally poorly defined and discontinuous. Flows are conveyed to the northwest, and discharge to the Fraser River under the SFPR and CN Railway.

Headwater tributaries are generally inaccessible to fish, but provide important food and nutrient value to downstream fish populations (ECL, 2000). Slow-moving, low-gradient, lowland reaches of these unnamed creeks provide potential rearing and overwintering habitats for salmonids in well-defined channels and open-water areas (DFO, 1999). Areas of suitable spawning substrate are limited.

2.2.7 Centre Creek

The headwaters of Centre Creek include several small tributaries flowing off Surrey's north slope between 168 Street and 176 Street. The headwater channels are steep, small channels which originate as seepages or at stormwater outfalls from the surrounding residential area. The headwaters are highly developed residential areas encompassing a large portion of the catchment area. Tributaries combine into a channelized wetland area at the bottom of the slope on the south side of the SFPR at Centre Creek. The stream flows under multiple culverts at the SFPR and CN railway before flowing through Surrey Bend Regional Park and ultimately to the Fraser River.

Surrey Bend Regional Park is undyked and is part of the Fraser River floodplain. Centre Creek habitat in the park includes channels, ponds, and forested swamp areas (City of Surrey & Metro Vancouver, 2010; DFO, 1999). These areas provide high value rearing and overwintering habitats to salmonids and other species in Centre Creek. Spawning habitat is limited to areas upstream of the railway and upper portions of tributaries that are fish accessible (DFO, 1999). Headwater tributaries provide important food and nutrient sources to fish-accessible spawning and rearing habitat downstream.

2.2.8 Lyncean Creek West and Lyncean Creek East

The headwaters of Lyncean Creek West and Lyncean Creek East near 179 Street start on the north side of Lyncean Drive and flow down the north slope through a remnant forested area and narrow riparian corridor toward Daly Road (ECL, 1994b). Several stormwater outfalls drain the surrounding residential and industrial areas and empty into these two streams (ECL, 1994b). These streams have been degraded by previous land developed, with impacts including culverts, land clearing, and channel narrowing due to infilling (ECL, 1994b). A constructed pond is also present along Lyncean Creek West, which was previously stocked with cutthroat trout. At Daly Road, both streams enter culverts under the road and adjacent railway which conveys flow to the Fraser River (ECL, 1994b).

Lyncean Creek East is fish-bearing and provides moderate value rearing habitat and low-value spawning habitat. Several fish have previously been captured in the stream to the west and it has been stocked with cutthroat trout, as previously mentioned (ECL, 1994b). However, currently watercourse classification mapping designates the creek as non-fish bearing (Class B).

A watercourse Habitat Compensation Area has been recently constructed at 99A Avenue as part of advanced works for the Golden Ears Connector, and drains to Lyncean Creek East.

2.2.9 Leoran Brook

The headwaters of Leoran Brook include roadside drainage ditches and small stream channels near 96 Avenue and 180 Street. Flows are conveyed through constructed channel sections on the south side of Highway 1 and then through a highway culvert to the north side. On the north side, the stream flows through a remnant forested ravine for its entire length to its confluence to the Fraser River. Two fish ladders, a pond, and a driveway culvert are present in this section of the creek (ECL, 2000).

Riffles, cascades and pools in the forested ravine section downstream of Highway 1 provide high-value fish habitat, including areas for rearing, overwintering and spawning (ECL, 2000). Additional moderate-value fish habitat is provided in a short section upstream of the highway before low flows preclude fish presence further upstream. Non-fish-bearing ditches and remnant tributaries in the headwaters provide important food and nutrient sources to downstream fish populations.

2.2.10 Unnamed Creek at 184 Street (184 Street Creek)

The headwaters of this unnamed stream include roadside ditches on the south side of Highway 1 near 94 Avenue in a low-density urban and rural area. The stream flows through a forested area north of Highway 1 near 96 Avenue and Golden Ears Way and receives stormwater drainage from the adjacent industrial areas and railway corridor before emptying into the Fraser River.

Slow-water areas, off-channels, and riffle-pool habitats present in the stream reaches from the mouth to the north side of 96 Avenue provide low- to high-value rearing and overwintering habitats for salmonids (ECL, 2000). A culvert is present at the railway crossing, but it is passible and does not prevent fish access to these habitats. Suitable spawning substrates for salmonids are limited. However, we observed a carcass of a spent coho salmon at the Golden Ears Way crossing. Headwater drainage ditches and channels south of the highway provide food and nutrient values, but are inaccessible to fish due to extensive piping south of 96 Avenue.

3 Hydrogeological Assessment

3.1 ASSESSMENT OBJECTIVES

We undertook an overview hydrogeologic investigation of the watersheds within the study area. The hydrogeologic conditions in the uppermost sediments determine the feasibility of subsurface infiltration of stormwater. Therefore, our investigation concentrated on establishing the characteristics of these surficial deposits via literature review and field assessment. The results will allow for the planning of future assessment phases, and the suitability and effectiveness of infiltration-based stormwater management techniques, including Best Management Practices (BMPs) and Low-Impact Development (LID) /Source Controls.

We note that infiltration is not the only approach for reducing runoff volumes, but is often relied upon if large scale development has drastically reduced vegetative cover / forest canopy and created a high proportion of impervious surface. This is particularly the case in the east of our study area (Port Kells).

3.2 SCOPE OF WORK

The overview hydrogeological assessment used existing information to characterize groundwater and surficial soil stratigraphy to identify areas where stormwater infiltration may be feasible. The conditions within the study area build on previous work completed for other studies.

The hydrogeological investigation was made up of the following three tasks:

1. *Desktop Study:* review of available maps, studies and reports as they pertain to the study area;
2. *Field Investigations:* “Ground-truthing” surficial soil sediments, indicating areas of groundwater upwelling and areas where BMPs and LIDs may be appropriately used; and
3. *Reporting:* including the findings with relation to the Stage 1 ISMP.

This section documents the methods of investigation, physiographic setting of the study area, field investigation results, implications for stormwater drainage, conclusions, and recommendations. The results of the desktop study and field investigation are presented in Sections 3.3.4 and 3.3.5, respectively.

3.3 METHODS OF INVESTIGATION

3.3.1 Desktop Study

The desktop study included review of pertinent documents as they relate to the hydrogeology of the study area. Reports supplied by the City of Surrey were reviewed for hydrogeology-related content. The BC EcoCAT database was queried for relevant hydrogeologic studies and reports, and two main documents were reviewed in greater detail: the Groundwater Supply Study (Halstead, 1986) and the South Fraser Perimeter Road Hydrogeology Impact Assessment (Golder, 2006).

Soils and surficial geology mapping was included in our investigation, as the shallow groundwater regime is strongly dependent on the material type present at surface. Additionally, the BC Ministry of Environment (MoE) Water Resources Atlas was queried for more general information, such as mapped aquifers present and available water well information.

3.3.2 Field Investigations

The field review was conducted during the winter within a few days following rainfall, providing optimal conditions for locating groundwater discharge areas.

As much of the study area is developed for residential housing and industrial buildings, ravines and stream paths provide the best locations for assessment, as the natural geologic and soil units are exposed or accessible. We targeted erosional features, as the underlying soils are most visible at these locations.

We undertook our field investigation on January 23, 2014. This included groundwater and watercourse investigations.

We conducted the groundwater investigation by:

- Investigating soil conditions at exposures in the ravines and on the steep slopes, and
- Observing groundwater conditions, including seepages and the presence of flowing water from natural soil exposures, erosional features and vegetation patterns along the natural drainages.

We conducted watercourse investigation by traversing stream courses and:

- Inspecting channel conditions, such as shape and morphology,
- Identifying surficial geological and soil units exposed, and
- Determining areas of groundwater seepage along the watercourse.

3.4 DESKTOP STUDY RESULTS

3.4.1 Surficial Geology

The surficial geology and stratigraphy in the Lower Mainland area has been compiled through exposures along eroding coastlines and river banks, in gravel pits and other excavations, and through borehole logs (Armstrong and Hicock, 1980; Armstrong, 1984; Clague, 1994). Six (6) main surficial geologic units are exposed or are present at depth in the study watershed (soils are mapped in the main body of this ISMP).

Table 5
Summary of Surficial Geology Units

Unit	Identifier	Age	Description
Modern Sediments		10,000 – present	Present day fluvial and colluvium deposits present in the draws along the streams
Salish Sediments	SAb	10,000 – present	Bog, swamp, and shallow lake deposits. Lowland peat up to 14 m thick, overlying Fraser River sediments. Salish Sediments include all post glacial terrestrial or marine sediments deposited when the sea was within 15 m of present sea level.
Fraser River Sediments	Fc	10,000 – present	Deltaic and distributary channel fill sediments overlying and cutting estuarine sediments and overlain in part by overbank sediments. Overbank sandy to silt loam up to 2 m thick overlying Fraser River channel fill.
Capilano Sediments (post-glacial)	Cd, Ce	11,000 – 13,000	Marine to glaciomarine stony to stone-less silt loam to clay loam with minor sand and silt, between 3 – 60+ m thick often containing marine shells.
Vashon Drift (Fraser Glaciation)	Va	13,000 – 18,000	Lodgement till (with sandy loam matrix) and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt
Quadra Sand (Fraser Glaciation)	PVa,c,f	18,000 – 26,000	Fluvial channel fill and floodplain deposits, cross-bedded sand containing minor silt and gravel lenses and interbeds. Some marine interbedded fine sand to clayey silt are offshore deposits.

Reference: Armstrong and Hicock, 1980; Armstrong, 1984; Clague, 1994.

The Fraser Upland is comprised of three surficial deposit layers present as horizontal tabular bodies. Capilano Sediments are widespread at surface and consist of thick marine and glaciomarine till and related deposits. Underlying this are Vashon Drift till and waterlain units from the last main glacial advance. These are exposed at surface at certain higher elevations in the study area. Underlying these are the Quadra Sand sediments which are exposed along the north slope and in the ravines where they are cut through by stream and slope erosion.

The bedrock underlying the study area starts more than 100 m below surface and so has negligible effect on the surface hydrogeologic conditions.

3.4.2 Agricultural Soils

The agricultural soils for the study area were mapped at a general scale when the land was still mostly undeveloped (Kelley and Spilsbury, 1939). The Fraser Heights Upland area is primarily composed of Alderwood Series silt loam. Soils are mapped as Mixed Area 3 (a light sandy loam) in the Port Kells area.

The low-lying areas of Surrey Bend Regional Park and the lower reaches proximal to the base of the Port Mann Bridge are mapped as peat, consistent with other areas within the Fraser River floodplain:

- The 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 No. 3 soil series comprised of a surface soil of light sandy loam, light brown in colour, between 30 and 46 cm deep. In places the soil is underlain by fine sands, or by a variable mixture of coarse sand, gravel and small stones.

The Alderwood silt loam and Mixed Area 3 soil areas 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 (Kelly & Spilsbury, 1939).

In summary, early agricultural soils mapping indicated fine-grained soils were present near surface developed in silt loams with strongly restricted vertical infiltration, and lateral drainage occurs preferentially along restrictive layers in the surface units.

During more recent soil surveys, the western portion of the study area was not mapped, due to the degree of urban development, and the low opportunity for agriculture (Luttmerding, 1980, 1984). The easternmost portions were mapped in greater detail as part of the soil surveys conducted for the northwestern Langley area. Three main soil groupings as broken down by area can be gleaned from the surficial soils data present in recent soils maps (Map 3-6, with detailed soil descriptions in Luttmerding 1980, 1984):

- The Fraser Heights Upland (where mapped) is predominantly comprised of Bose Soils. These well to moderately well drained soils are characterized by 30-160 cm of gravelly lag or glacial outwash deposits over moderately coarse textured glacial till, and some moderately fine textured glaciomarine deposits. Areas of littoral deposits (Heron and Boosey soils) overlaying the glacial till and glaciomarine deposits display poor drainage, or a perched water table.
- To the east of the study area, soils in the Port Kells area are predominantly well to rapid draining glacial outwash deposits (Columbia and Sunshine soils) with some localized moderately poor draining fine to moderately fine textured marine deposits (Milner and Cloverdale soils). These free-draining materials at surface would be most conducive to enhanced stormwater-to-ground drainage projects.

- On the Fraser Lowlands, adjacent to the Fraser River, soils change to very poorly drained peat-dominated soils (Lumbum, Gibson, Triggs and Glen Valley soils) or fluvial channel deposits (Fairfield and Hjorth soils). The areas are characterized by very poor draining soils when associated with peat, and high groundwater tables often associated with seasonal flooding.

3.4.3 Hydrogeology Overview

The hydrogeology of the study area has been investigated in one general overview study (Halstead, 1986), and one recent detailed groundwater assessment related to stream base flow for the SFPR Hydrogeology Impact Assessment (Golder, 2006), both of which are summarized below.

Halstead Overview Study

A hydrogeologic overview of the Fraser Lowland was provided in MoE (2013b), which summarized work by Halstead (1986). Halstead defines various “hydrostratigraphic units,” which are major glacial and post-glacial depositional units with consistent hydrogeological properties.

Hydrostratigraphic Unit A is correlated with the Capilano Sediments, and includes marine and glaciomarine clay, stoney clay and silty clays, with varying stone content. This unit has a blocky structure and a buff colour (from weathering) when dry and exposed at surface. 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 or solid waste disposal sites are associated with it. No groundwater studies related to deep building foundations are available based on a search of the BC EcoCAT database.

Hydrostratigraphic Unit B (glaciomarine stony clay) is found as the surface layer through much of the upland areas and can be correlated with Vashon Drift till and its waterlain subunits. Groundwater flow rates are slow due to the fine grain size and compaction.

Hydrostratigraphic Units C, D, and F (glaciofluvial deposits, glacial till, and bedrock, respectively) are generally not found at or near surface in the study area.

Hydrostratigraphic Unit E was deposited during the early part of the Fraser Glaciation, and consists mainly of marine, estuarine and fluvial deposits of fine sand, silt and clayey silts. This unit can be correlated with the Quadra Sand sediments. These deposits are generally present several metres or more below the upland and at surface in the ravines and at the base of the steep north-facing slope. Groundwater flow rates are generally slow and the water has dissolved solids from the long residence time.

SFPR Perimeter Road Hydrogeology Impact Assessment

In 2006, Golder Associates conducted a hydrogeology impact assessment as Technical Volume 10 of the Environmental Assessment Application for the SFPR. The assessment was conducted to evaluate the potential impacts of the construction of the SFPR on the groundwater quantity and quality within the area and to identify mitigation measures, where required, to avoid or mitigate potential impacts.

The SFPR is over 40 km long, and only a portion of the Golder study is relevant to our study area. The results relevant to our study area are summarized as follows:

- The stratigraphy of the Fraser Heights upland area of Surrey is characterized by a thick deposit of silt and sand with gravel and/or glacial till. This is consistent with the regional geological maps, which indicate surficial till or “steepland sediments” of ice age origin in the area.
- In the lowland areas north of Fraser Heights, peat was encountered below 3.5 – 6.1 m of sand that was interpreted to be pre-load material. Underlying the peat are deposits of clay and silt.
- Groundwater discharge from the Fraser Heights embankment is known to sustain water courses that either directly or indirectly support fish habitat through the supply of nutrients, and contribution to base flow.
- Seepage mapping along the Fraser Heights embankment suggested a prominent seepage zone in that area at a ground surface elevation between 18 and 30 m above sea level. This is consistent with the surficial mapping outcrop of Quadra sands. Seepage control measures, consisting of a network of culverts, cisterns and regularly spaced topographic benches are located through most of the embankment area. Flow rates of surface seepages within this zone ranging from 0.1 to 5.35 L/min were observed by Golder.
- Groundwater discharges toward the north of the study area, where outcrops of fine sand and silty material daylight in the slopes below the Fraser Heights Upland.
- Surface water features within the study area were interpreted to flow northward, with the headwaters situated in the Fraser Heights Upland, and the watercourses draining to the Fraser River.
- East of Highway 91, groundwater sampled displayed chemistry typical of surficial sand and gravel aquifers, with calcium-magnesium-sodium bicarbonate water types, near neutral pH and slightly reducing conditions.

Additional Hydrogeology Investigations

The BC MoE’s Water Resources Atlas was queried as to the presence and nature of aquifers in the study area (MoE, 2011a). The compiled information indicates three aquifers at depth beneath the study area:

- The *Newton Upland Aquifer* (B.C. MoE aquifer # 61) is a class IIIC aquifer, with a low demand, high productivity and low vulnerability. The aquifer is approximately 137.4 km^2, and underlies most of the Surrey highlands. The sand and gravel aquifer materials correlate to the Quadra sands seen in exposures along the north slope of the study area.

- The *South Fraser River Junction Aquifer* (B.C. MoE aquifer # 48) is a class IIIB aquifer, with low demand, and moderate productivity and vulnerability. The small aquifer is approximately 9 km^2, is comprised of Fraser River sand and gravel sediments, and water from this aquifer is typically used for irrigation purposes (non-drinking water usage).
- The *Nicomekl-Serpentine Aquifer* (B.C. MoE aquifer # 58) is a class IIC aquifer, with moderate demand and productivity, and a low vulnerability. The aquifer is approximately 194.1 km^2, and underlies most of the Port Kells portion of the study area. The confined sand and gravel aquifer is associated with materials deposited in a glaciomarine environment.

Inspection of a selection of the water well records in the study area indicates several widely dispersed wells which encountered 20 to 40 m of dense gravelly silts (till), overlying a deeper aquifer of sands and gravels which correlate with the Quadra sands. There are many older well records within the study area which show a combination of deeper drilled wells and shallow dug wells completed in the upper dense till or clay, with only marginal flow rates indicated. It is inferred that in the study area, there were many shallow dug wells before the municipal water system was constructed.

No specific infiltration rate or hydraulic conductivity values for the upper sediments in the study area were obtained from the literature review; although other studies in nearby and similar surface sediments provide values (Table 3-8). Based on these published values, the maximum infiltration rate in the weathered surface soil subsoil likely ranges from approximately 0.2 to 6 mm/hour.

Table 6
Summary of Local Soil Infiltration Rates

Location	Soil Type	Initial Infiltration Rate (mm/hr)	Final Infiltration Rate (mm/hr)
Kerr Wood Leidel (2006)			
East Clayton, east central Surrey	Till, Observed Values	0.9 (with interflow) 1.6 (without interflow)	
	Clay, Observed Values	0.7	
Literature Values Cited	Till	0.5 – 2.5	
	Clay	0.2 – 2.5	

Areas with a high seasonal water table are present throughout the study watershed, such as topographic depressions, the areas within the Fraser River floodplain (i.e. Surrey Bend Park), along the northern CN Railway right-of-way, and where extensive sloped areas lead downslope to flatter areas.
In summary, three (3) main hydrogeologic units are present:

1. Unit A: Comprised of Capilano sediments, including glaciomarine silts and clays, with some gravel, and a weathered surface (the active soil horizon);
2. Unit B: Comprised of Vashon Drift sediments, including glaciomarine stony clays; and
3. Unit C: Comprised of Pre-Vashon sediments, correlative with the Quadra Sands, and comprised of fine silty sands.

3.4.4 Field Investigation Results

3.4.4.1 Surficial Deposits

The locations of surficial geological observation sites are presented on the map at the end of this section. Further site information and photographs are provided in Appendix G.

Three of the main surficial units that underlie the study area were observed in the field:

- Capilano Sediments – Marine and glaciomarine stony (including till-like deposits) to stone-less silt loam to clay loam with minor sand and silt, normally less than 3 m thick, but up to 30 m thick, containing marine shells.
- Vashon Drift – Lodgement till (with sandy-loam matrix) and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony-silt.
- Quadra Sands – Quadra fluvial channel fill and floodplain deposits, cross-bedded sand containing minor silt and gravel lenses and interbeds. In places, interbedded with fine sand to clayey silt.

Modern alluvial gravels, cobbles and sands were present along many of the creeks. Some minor areas of colluvium on creek ravine slopes were noted. On top of the surficial deposits is the weathered soil horizon, which ranges from about 0.2 to 0.7 m thick. In many of the creeks, the underlying till-like deposits were exposed as the creek channels were clay bottomed with occasional mobile gravels.

3.4.4.2 Hydrogeology Observations

The hydrogeologic conditions encountered in the field reflected the following attributes:

- The local climate,
- The surficial sediment composition,
- The layering and superposition of the various sediment horizons,
- Post-glacial weathering of the parent materials present, and
- A low surface gradient, therefore low hydraulic potential gradients.

Most of the local groundwater infiltration and lateral movement occurs in the top 3 to 5 m of surficial sediment. This interpretation is in agreement with earlier hydrogeological studies (Halstead, 1986; Golder, 2006; Associated Engineering, 2004; 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 about 3 to 5 m below ground surface. 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.

We also noted minor groundwater seepages into streams and ravines where modern alluvial sands and gravels overlie dense silty fine sand of glaciomarine origins. We have listed these locations on the map at the end of this section. Table 7 summarizes the observed field parameters at these locations.

Table 7
Field Water Quality Parameters

Location	pH	EC (µS)	Temp. (°C)	Flow (L/s)	Comment
#1	7.9	127	3.7	0.13	Seepage from water course west of constructed wetland
#2	7.7	173	5.9	0.32	Main drainage, brown to clear flow
#3	7.5	260	10.0	0.06-0.13	Tributary to #2 (spring), rusty red precipitate.
#4	8.0	142	6.3	0.63	Drainage from headbox from Tilbury Pl.
#5	8.1	164	7.2	0.32	Main drainage, clear
#6	8.4	184	5.6	0.06-0.13	Tributary to #5 (spring), clear.
#7	8.2	183	7.6	0.32	Creek off Salisbury Dr.
#8	7.9	87	4.4	<0.06	Tributary to #7, GW seep from side of bank, overland flow.
#9	8.0	229	7.6	0.32	Lyncean Creek, west limb.
#10	8.0	188	5.6	<0.06	Bon Accord headwaters, Hawthorne Park.

In larger stream ravines with colluvial deposits developed from weathered and sloughed sediments on steeper slopes, we infer that soil water movement to the stream may occur quite quickly through this unconsolidated material with higher pore space. These colluvial deposits are found over such a restricted area, and on such steep slopes that they would not be useful for stormwater infiltration from adjacent road or residential areas. In the northern portions of the study area, these materials already exhibit groundwater upwelling in the form of springs and seepages.

We found perched water tables just below the surface at many locations, likely due to then-recent heavy winter rains, located on top of the low permeability glaciomarine unit. Some natural forested areas had fine, humic material on the surface and water ponding marks, suggesting surface inundation by standing water for some period during the year. In many locations, the soil parent material had oxidized iron and reduced manganese deposited in the natural fractures (soil gleying), suggesting seasonal saturation and changing oxidizing/reducing conditions.

Based on these observations, we interpret that a high proportion of rainfall produces surface runoff, and little groundwater infiltrates into the surficial deposits below about 1 or 2 m (at the bottom of hydrogeological Unit A), and little infiltrates through the thick (3 – 30 m) layer of glaciomarine deposits to the deep aquifer (Unit B) in the underlying sands and gravels (Unit C).

We present the areas of inferred groundwater discharge in Map 3-7, as determined through site observations, interpretation of topography, and indicator plants and trees. Along Bon Accord Creek in Invergarry Park (north of 110 Avenue), a large ravine area with areas of deciduous vegetation appears to discharge groundwater. Areas along the SFPR at the base of the Fraser Heights Upland also present wet surface soils, standing water, and hydrophytic vegetation (plants that are adapted to thriving in aquatic environments), suggesting a groundwater discharge area. These groundwater discharge areas connect with the surface creeks and conveyances leading to the Fraser River.

3.4.5 Implications for Stormwater Drainage

The presence of springs and seepages along the north-facing slopes towards the Fraser River, the naturally low infiltration capacity of the silty sand glaciomarine deposits at the surface in the upland areas, and the characteristics of existing residential and industrial areas, all have implications for stormwater drainage and management through BMPs and LIDs.

We outline some of these key considerations as follows:

1. In the upland areas, the addition of surface drainage to the low infiltration subsoil from roadside swales or rain gardens may contribute to the development of localized perched water tables. This water will slowly drain downslope until it meets an obstruction, such as a house foundation or road curb, where it will either form another perched water table or break out to the surface and flow downslope. This re-located surface water may lead to flooding or infrastructure deterioration. To effectively achieve infiltration or attenuation benefits, there would need to be a connected series of swales or rain gardens leading to a developed watercourse or stormwater inlet.

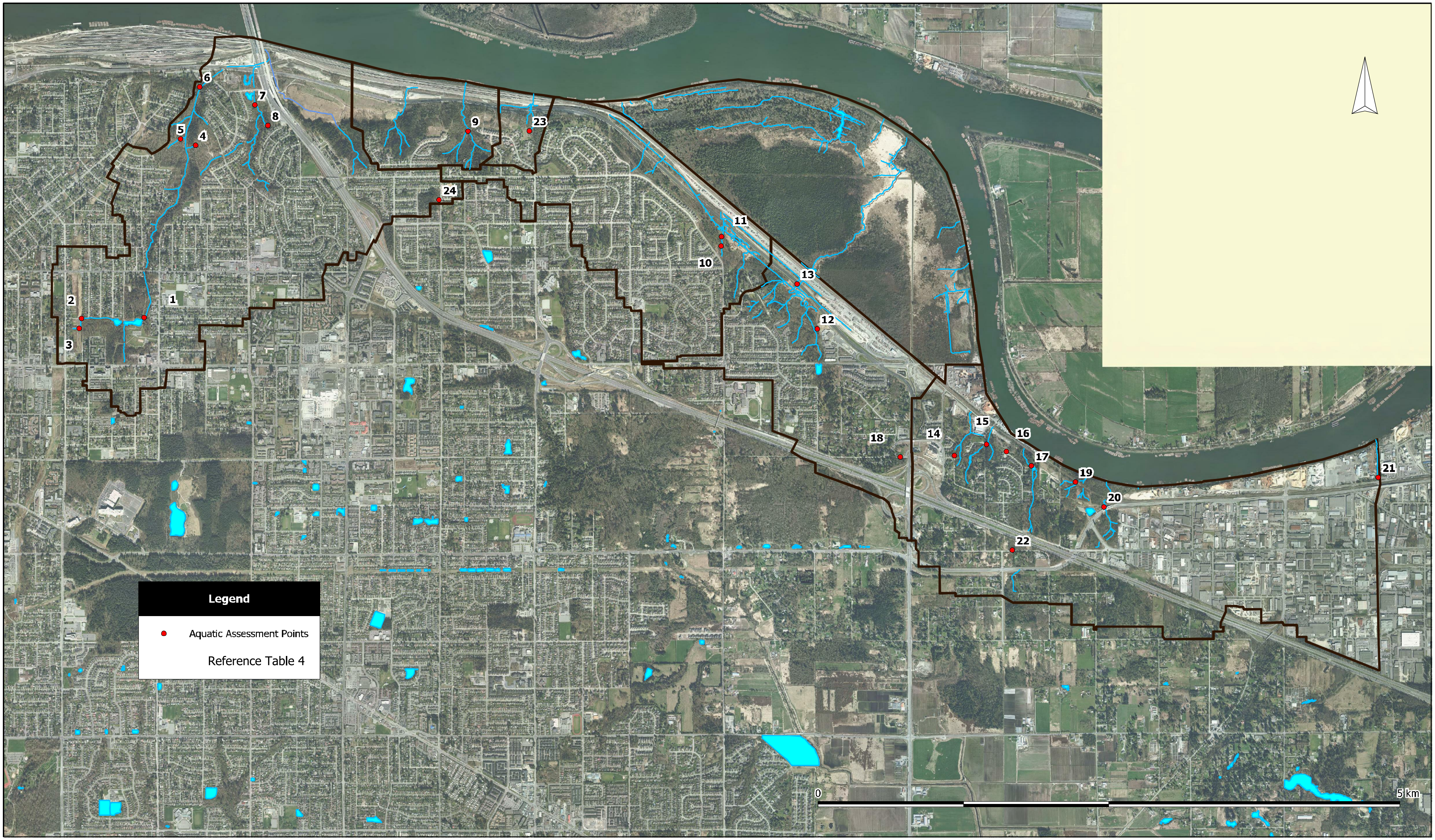
2. Other parts of the city, such as the East Clayton area, have used infiltration swales and rain gardens for stormwater control. It would be beneficial to investigate the performance of these measures in areas with poor infiltration to determine the most successful methods and locations for infiltration. Indicators of poor performance include daylighting or ponding stagnant water, bio-fouling or the growth of hydrophytic vegetation, and a decline in groundwater quality. Indicators of good performance are drained soils after recent light rainfall events, healthy vegetation, and an improvement in groundwater quality.

3. The areas of natural seasonal ponding indicate regions where the volume of precipitation received exceeds the soil’s capacity to infiltrate the water into available pore space and disperse the water through downslope soil water flow. During major winter storms, significant area will have temporary surface water pooling and perched water tables. These areas of existing inundation would be unsuitable for locating infiltration facilities unless the overall near-surface groundwater table could be lowered through improved lateral drainage.

4. In areas where thin permeable sand and gravel layers overlie dense subsurface silty sand units, any addition of stormwater to infiltration structures would have a short residence time before lateral flow brought it to the surface again at the base of a slope as heavy seepage.

5. Much of the upland area has already been developed, and residential areas comprise much of the headwater areas for the creeks within the study area, especially for the areas east of 168 Street, and north of Highway 1. Most of the development along the northern edge of this area consists of single-family dwellings. Though this land-use typically has fewer impermeable surfaces than commercial or industrial areas, the proximity of these developments to steep slopes precludes the use of distributed water retention features.

6. Port Kells is primarily an industrial area. Industrial areas are generally densely developed with high proportions of impermeable surfaces, including roads, parking lots, and large roofs. There is little available space for infiltration structures. Opportunities for rooftop water retention appear limited, given that the existing structures were not designed for this. These areas will present challenges for the development of on-site infiltration facilities, and so off-site locations in parks or similar areas would need to be considered in the Port Kells area.



No.	REVISION	DATE

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Aquatic Assessment Locations

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

DATE: March 24, 2014

SCALE: 1:30,000

Time: 1:17:00 PM | Date: 3/24/2014
Scale: 1:30,000

Photo 1: Bon Accord Creek at Hawthorne Rotary Park

Photo 3: Headwater tributary to Bon Accord Creek at hydro ROW

Photo 5: Bon Accord tributary U/S of trail crossing

Photo 2: Hawthorne Creek (tributary to Bon Accord Creek)

Photo 4: No visible channel at mapped location of tributary to Bon Accord

Photo 6: Culvert under trail to Bon Accord Creek

Note: ROW – Right of Way, U/S – Upstream, CV – Culvert	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

Photo 7: Culvert outlet for Bon Accord tributary

Photo 9: Hanging CV (fish barrier) on Bon Accord Creek at trail crossing

Photo 11: Bon Accord Creek concrete flume at downstream trail crossing

Photo 8: Bon Accord Creek representative habitat

Photo 10: Old wooden water supply dam and slope failure on left bank

Photo 12: Representative habitat, East Bon Accord Creek

Note: CV – Culvert	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: City of Surrey, the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	Summit Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies

Photo 13: Tributary to East Bon Accord Creek

Photo 15: Unnamed stream in Fraser Heights, headwater habitat and log weirs

Photo 17: Lowland channel becomes braided and indistinct, in marshy lowlands

Photo 14: 157 St. stream, representative habitat

Photo16: Garbage left on trail adjacent to headwater streams in Fraser Heights

Photo 18: Tributary to Centre Creek near 104A Ave.

Note: WPT – Waypoint, D/S – Downstream	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: City of Surrey the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies

Photo 19: Channelized wetland section of Centre Creek near SFPR

Photo 21: Unstable banks of headwater stream near 179 St.

Photo 23: 179 St. stream, lower reaches.

Photo 20: Wetland section of Centre Creek near SFPR

Photo 22: English ivy in riparian area near 100 Ave

Photo 24: Headwater stormwater pond. 99A Habitat enhancement site

Note: SFPR – South Fraser Perimeter Road	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

Photo 25: Outlet channel from stormwater pond

Photo 27: Pond and fish ladder in Leoran Brook

Photo 29: Remnant stream in forested area near 176th St.

Photo 26: Leoran Brook, representative habitat and steep eroded banks

Photo 28: Fish ladder downstream of driveway CV in Leoran Brook

Photo 30: Representative habitat of unnamed stream downstream of railway

Note: CV – Culvert	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

Photo 31: Representative habitat of unnamed stream downstream of railway

Photo 33: CV inlet for unnamed stream at railway

Photo 35: Representative habitat of 184th St. Creek at Golden Ears Way

Photo 32: CV / pipe under railway

Photo 34: Representative habitat in unnamed streams upstream of railway

Photo 36: Small stormwater run-off tributary under Golden Ears Way.

Note: CV – Culvert	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	SUMMIT ENVIRONMENTAL CONSULTANTS INC. A Member of the Associated Engineering Group of Companies

Photo 37: Potential planting areas on 184th St. Creek next to Golden Ears Way

Photo 39: Representative habitat at Port Kells drainage channel

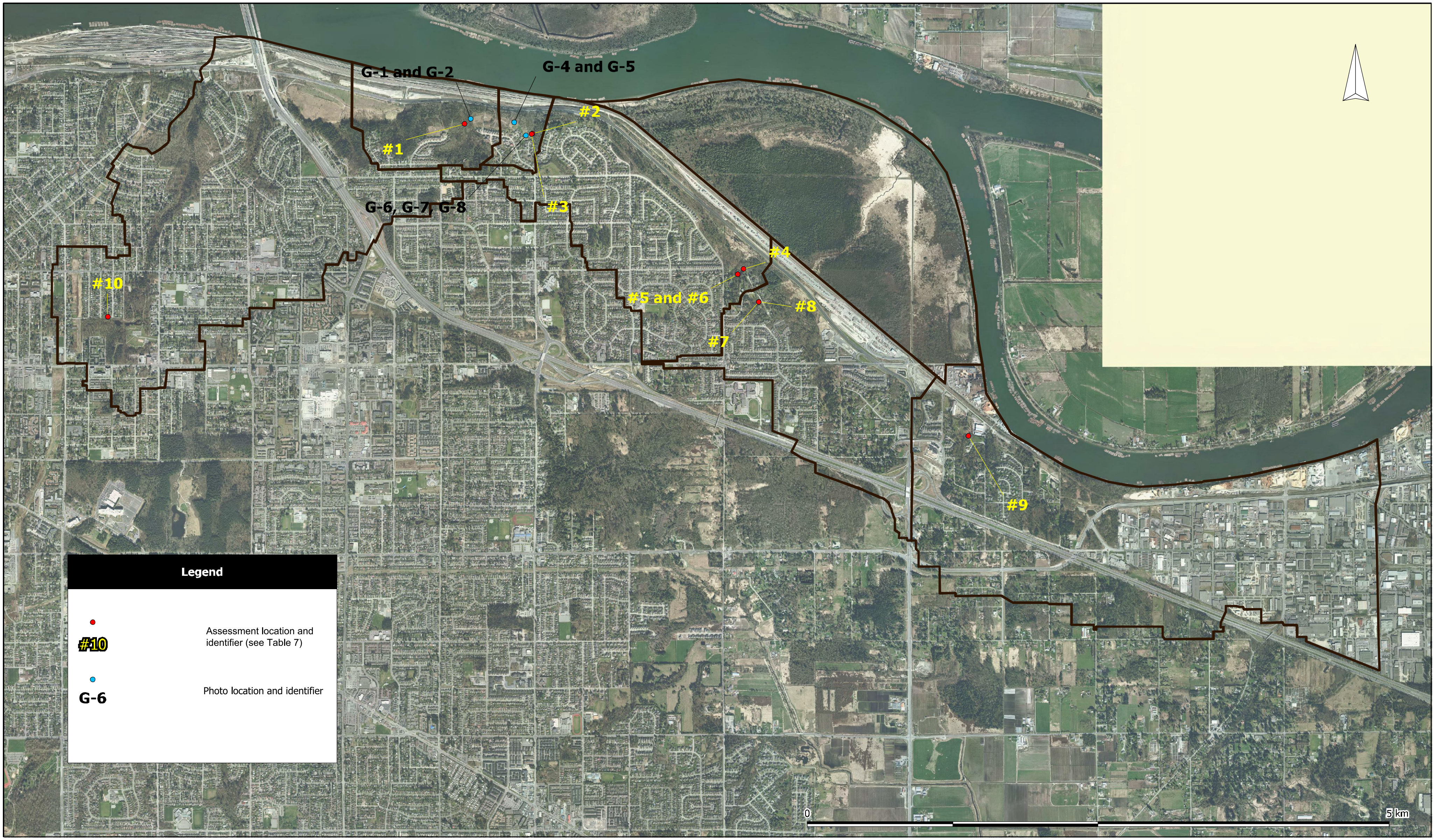
Photo 41: 160th St. creek headwaters, representative habitat

Photo 38: 184th St Creek near 96th Ave.

Photo 40: Representative habitat of remnant section of Leoran Brook headwaters

Photo 42: Drainage ditch along 156th St. at Northview Park

Note:	Project Number: 2013-2512.010.014	Date: January 2014	Bon Accord North Slope East ISMP – Aquatic Assessment
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos December 2013	SUMMIT Environmental Consultants Inc. A Member of the Associated Engineering Group of Companies



No.	REVISION	DATE

Hydrogeological Assessment Locations

Bon Accord - North Slope (East) ISMP

PROJECT No: 20132512

DATE: March 24, 2014

SCALE: 1:30,000

Time: 1:21:38 PM | Date: 3/24/2014

Scale: 1:30,000

Photograph 1
Exposure of Quadra Sands, 157th St.

Photograph 2
Quadra Sands detail, x-stratified bedding

Photograph 3
Ponded wetland area, 157A St.

Photograph 4
Controlled Dispersal Area, 158th street

Photograph 5
Rock drain at bottom of dispersal pit, 158 St.

Photograph 6
Greenbelt at crest of slope, behind lowermost row of houses, 160 St.

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Photograph 7
Contoured draw, stormwater relief, 160 St.

Photograph 8
Perennially wet area, part of greenbelt, 160 St.

Photograph 9
Weathered soils atop competent till, Centre Ck. off Salisbury Dr.

Photograph 10
Sandy silts atop clayey till substrate, West Lyncean Ck.

Appendix C - Hydrologic and Hydraulic Modelling Inputs and Results

APPENDIX C CONTENTS:

- PCSWMM – MODEL PARAMETERS / RAINFALL DATA
- PCSWMM RESULTS SUMMARY
  - SUBCATCHMENT RESULTS
  - PIPE / CULVERT RESULTS
  - OPEN CHANNEL RESULTS
- MAJOR WATERCOURSES - FLOW DURATION EXCEEDANCE CURVES

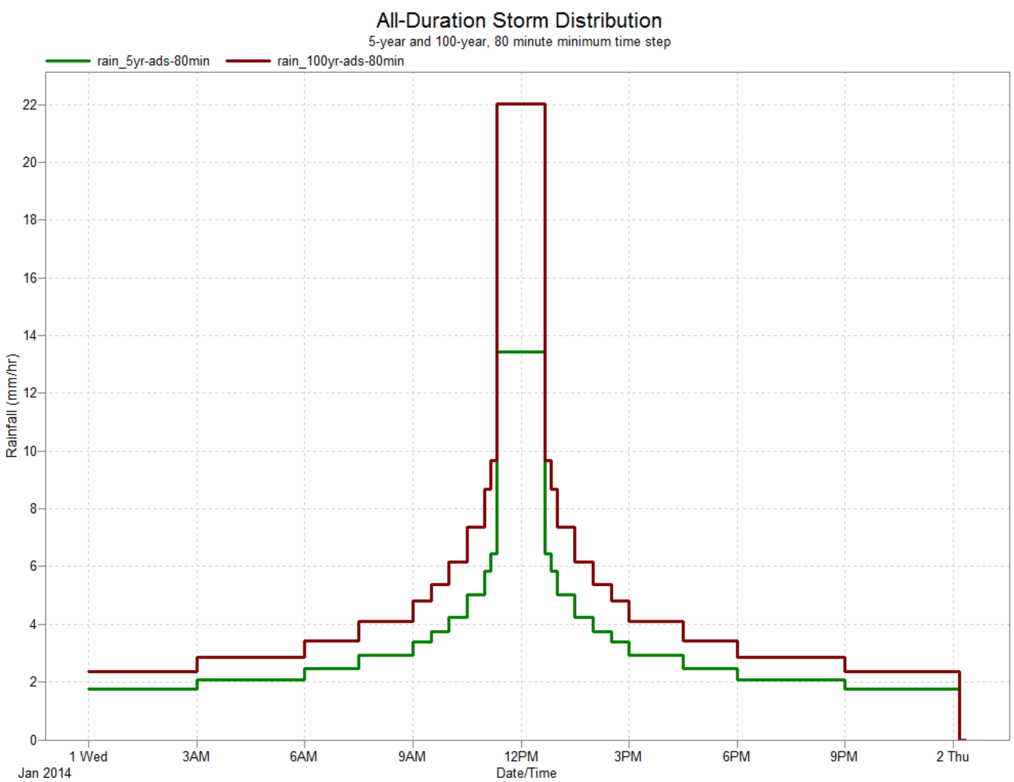
PCSWMM – MODEL PARAMETERS / RAINFALL DATA

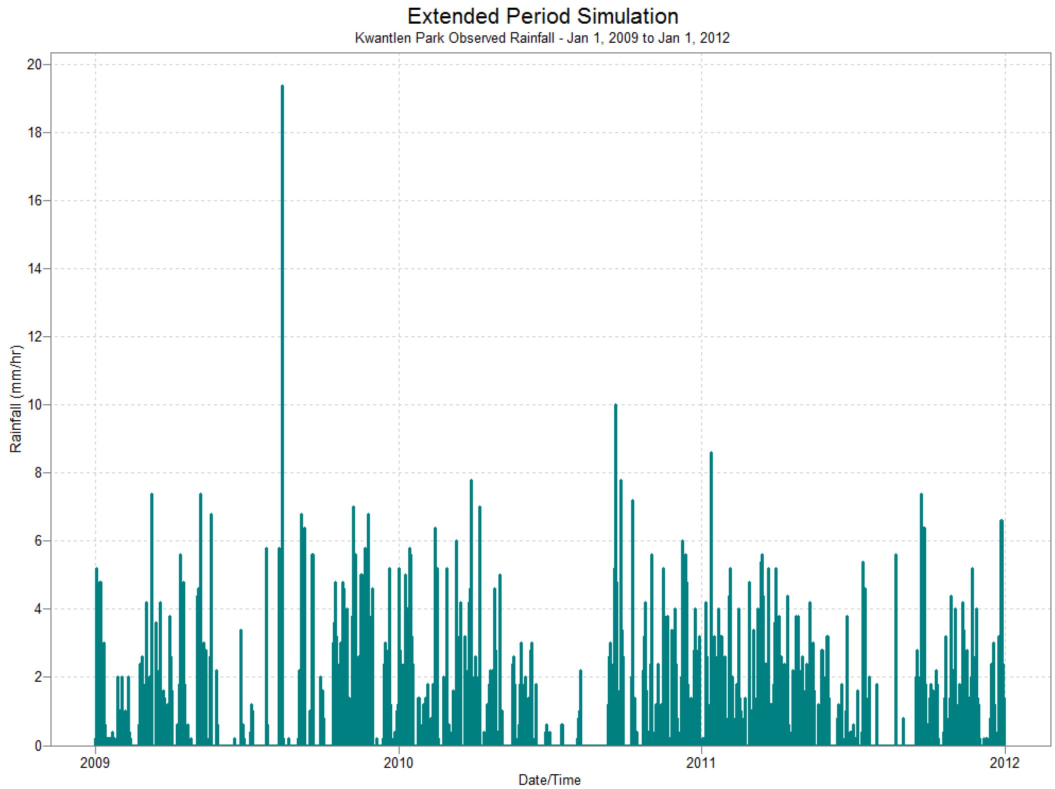
Physical Characteristics
Subcatchment / Conduit Model Parameters

Horton Infiltration Parameters	
Maximum Infiltration Rate (mm/hr)	5
Minimum Infiltration Rate (mm/hr)	1.5
Decay Constant (hr $^{-1}$)	5.4
Drying Time (days)	7
Depression Storage	
Impervious Surface (mm)	1.3
Pervious Surface (mm)	3.8
Conduit Minor Losses	
Entrance Loss Coefficient	0.2 to 0.9
Exit Loss Coefficient	0.5 to 1.0

Manning's Roughness Coefficient, n, for Overland Flow	
Impervious Surface (overland flow)	0.012
Pervious Surface (overland flow)	0.240
PVC	0.010
HDPE	0.012
Steel	0.012
Concrete	0.013
Corrugated Steel Pipe (CSP)	0.024
Structural-Plate Corrugated Steel Pipe (SPCSP)	0.032
Ditches / Watercourses	0.035

Rainfall Data

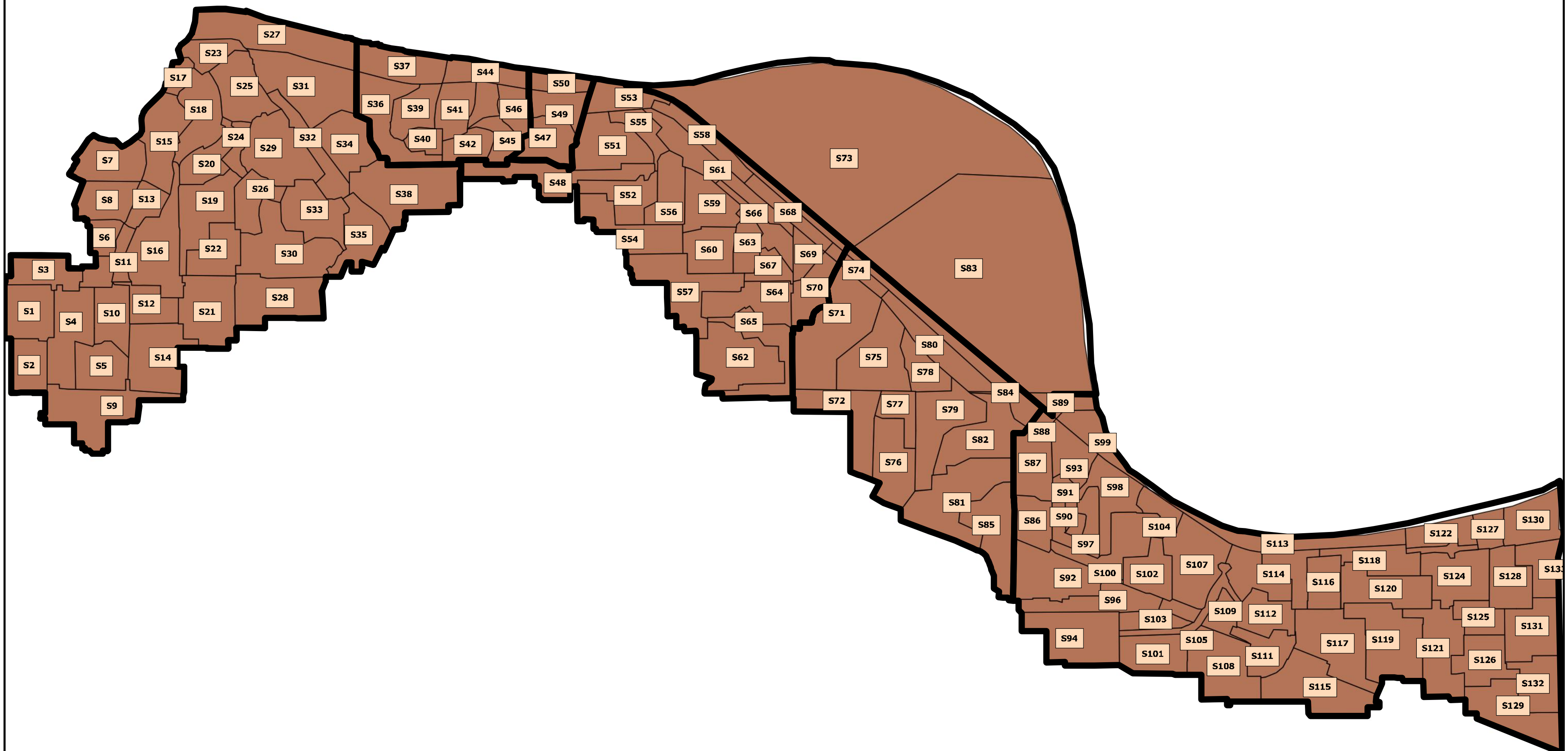




Extended Period Simulation
Kwantlen Park Observed Rainfall - Jan 1, 2009 to Jan 1, 2012
Rainfall (mm/hr)
20
18
16
14
12
10
8
6
4
2
0
2009
2010
2011
2012
Date/Time

PCSWMM MODEL RESULTS SUMMARY

SUBCATCHMENT RESULTS



0 2 km

SEE RESULTS TABLE C-1

PREPARED BY:

Associated Engineering

PREPARED FOR:

City of SURREY

SUBCATCHMENT ID

BON ACCORD - NORTH SLOPE (EAST) ISMP
APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015

TABLE C-1
PCSWMM - SUBCATCHMENT RESULTS; PEAK RUNOFF, RUNOFF COEFFICIENT; RUNOFF VOLUME

Catchment ID	Watershed	Area (ha)	Peak Runoff (m^3/s)				Runoff Coefficient				Runoff Volume (ML)		
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 3 Extended Period Simulation (3-year)		
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	C Future Source Controls
S1	Bon Accord	14.3	0.40	0.41	0.72	0.74	0.706	0.728	0.786	0.802	339	361	237
S2	Bon Accord	10.3	0.30	0.31	0.54	0.54	0.704	0.721	0.786	0.798	238	250	188
S3	Bon Accord	11.1	0.36	0.37	0.62	0.63	0.751	0.773	0.822	0.837	291	309	199
S4	Bon Accord	18.6	0.52	0.54	0.94	0.96	0.697	0.716	0.780	0.794	427	452	301
S5	Bon Accord	12.5	0.28	0.28	0.54	0.55	0.569	0.572	0.687	0.689	171	174	155
S6	Bon Accord	5.4	0.19	0.19	0.32	0.32	0.800	0.825	0.859	0.876	161	171	109
S7	Bon Accord	14.6	0.46	0.47	0.81	0.82	0.705	0.722	0.788	0.801	332	350	245
S8	Bon Accord	11.6	0.39	0.40	0.66	0.67	0.786	0.812	0.847	0.865	334	357	222
S9	Bon Accord	24.4	0.80	0.82	1.38	1.40	0.804	0.824	0.858	0.872	752	788	542
S10	Bon Accord	11.3	0.29	0.30	0.55	0.55	0.624	0.634	0.728	0.735	194	201	155
S11	Bon Accord	4.2	0.33	0.33	0.56	0.56	0.869	0.883	0.909	0.918	240	259	150
S12	Bon Accord	13.6	0.44	0.46	0.76	0.78	0.787	0.812	0.846	0.865	397	423	262
S13	Bon Accord	6.2	0.19	0.19	0.34	0.34	0.604	0.609	0.718	0.722	91	93	85
S14	Bon Accord	20.4	0.60	0.63	1.06	1.09	0.765	0.788	0.827	0.845	582	615	398
S15	Bon Accord	17	0.42	0.42	0.80	0.80	0.554	0.554	0.678	0.678	199	199	196
S16	Bon Accord	22.3	0.64	0.67	1.13	1.17	0.748	0.775	0.815	0.835	610	653	409
S17	Bon Accord	2.9	0.09	0.09	0.16	0.16	0.592	0.594	0.711	0.712	40	41	39
S18	Bon Accord	16	0.49	0.50	0.86	0.88	0.707	0.726	0.790	0.803	369	391	275
S19	Bon Accord	18.6	0.58	0.60	1.01	1.04	0.775	0.803	0.837	0.857	535	572	353
S20	Bon Accord	9.8	0.34	0.34	0.57	0.58	0.755	0.777	0.826	0.841	259	275	181
S21	Bon Accord	20.1	0.67	0.69	1.15	1.17	0.806	0.829	0.860	0.876	618	653	421
S22	Bon Accord	11.5	0.40	0.41	0.67	0.68	0.804	0.828	0.860	0.877	349	371	234
S23	Bon Accord	7.5	0.26	0.26	0.44	0.44	0.796	0.807	0.855	0.862	220	226	200
S24	Bon Accord	4.3	0.14	0.14	0.24	0.24	0.620	0.635	0.730	0.740	68	73	62
S25	Bon Accord	15.6	0.46	0.48	0.83	0.84	0.644	0.664	0.745	0.760	282	306	244
S26	Bon Accord	10.1	0.34	0.35	0.58	0.59	0.759	0.780	0.828	0.843	268	285	184
S27	Bon Accord	27.8	0.98	0.98	1.65	1.65	0.900	0.900	0.926	0.926	1078	1078	1078
S28	Bon Accord	21.6	0.70	0.72	1.21	1.23	0.793	0.812	0.850	0.864	645	676	492
S29	Bon Accord	21.1	0.68	0.70	1.18	1.20	0.754	0.777	0.823	0.840	561	598	384
S30	Bon Accord	25.4	0.85	0.87	1.45	1.48	0.806	0.830	0.860	0.877	782	828	526
S31	Bon Accord	27.2	0.79	0.79	1.42	1.43	0.658	0.661	0.754	0.756	523	529	514
S32	Bon Accord	10.5	0.38	0.38	0.63	0.63	0.882	0.889	0.915	0.920	384	390	366
S33	Bon Accord	16.4	0.53	0.55	0.92	0.94	0.780	0.805	0.841	0.860	469	500	310
S34	Bon Accord	14.9	0.51	0.51	0.86	0.87	0.731	0.737	0.809	0.813	365	371	298
S35	Bon Accord	14.8	0.51	0.52	0.87	0.88	0.848	0.862	0.890	0.900	506	522	436
S36	157 Street	18.3	0.48	0.50	0.89	0.90	0.654	0.667	0.749	0.758	359	376	297
S37	157 Street	14.6	0.53	0.53	0.88	0.88	0.907	0.907	0.931	0.931	568	568	568
S38	Bon Accord	28.4	0.87	0.90	1.53	1.56	0.750	0.772	0.819	0.835	755	801	528
S39	157 Street	10.1	0.31	0.31	0.55	0.55	0.590	0.590	0.708	0.709	137	138	136
S40	157 Street	4.7	0.16	0.16	0.27	0.27	0.673	0.685	0.770	0.778	93	97	74
S41	157 Street	10.1	0.32	0.33	0.57	0.57	0.679	0.684	0.771	0.774	189	193	169
S42	157 Street	7.6	0.26	0.26	0.44	0.44	0.710	0.722	0.794	0.802	161	168	129
S43	157 Street	4.9	0.16	0.16	0.28	0.28	0.667	0.668	0.764	0.765	86	86	85
S44	157 Street	9.2	0.34	0.34	0.56	0.56	0.921	0.921	0.943	0.943	360	360	360
S45	157 Street	6.8	0.22	0.22	0.39	0.39	0.662	0.668	0.760	0.764	116	120	107
S46	157 Street	7.4	0.25	0.25	0.43	0.43	0.716	0.723	0.798	0.803	161	166	139
S47	160 Street	12	0.39	0.40	0.68	0.69	0.740	0.757	0.814	0.826	287	302	228
S48	Fraser Heights	19.3	0.53	0.56	0.95	0.99	0.727	0.756	0.799	0.821	503	541	354
S49	160 Street	8.8	0.30	0.30	0.51	0.51	0.695	0.696	0.784	0.785	173	174	174

TABLE C-1
PCSWMM - SUBCATCHMENT RESULTS; PEAK RUNOFF, RUNOFF COEFFICIENT; RUNOFF VOLUME

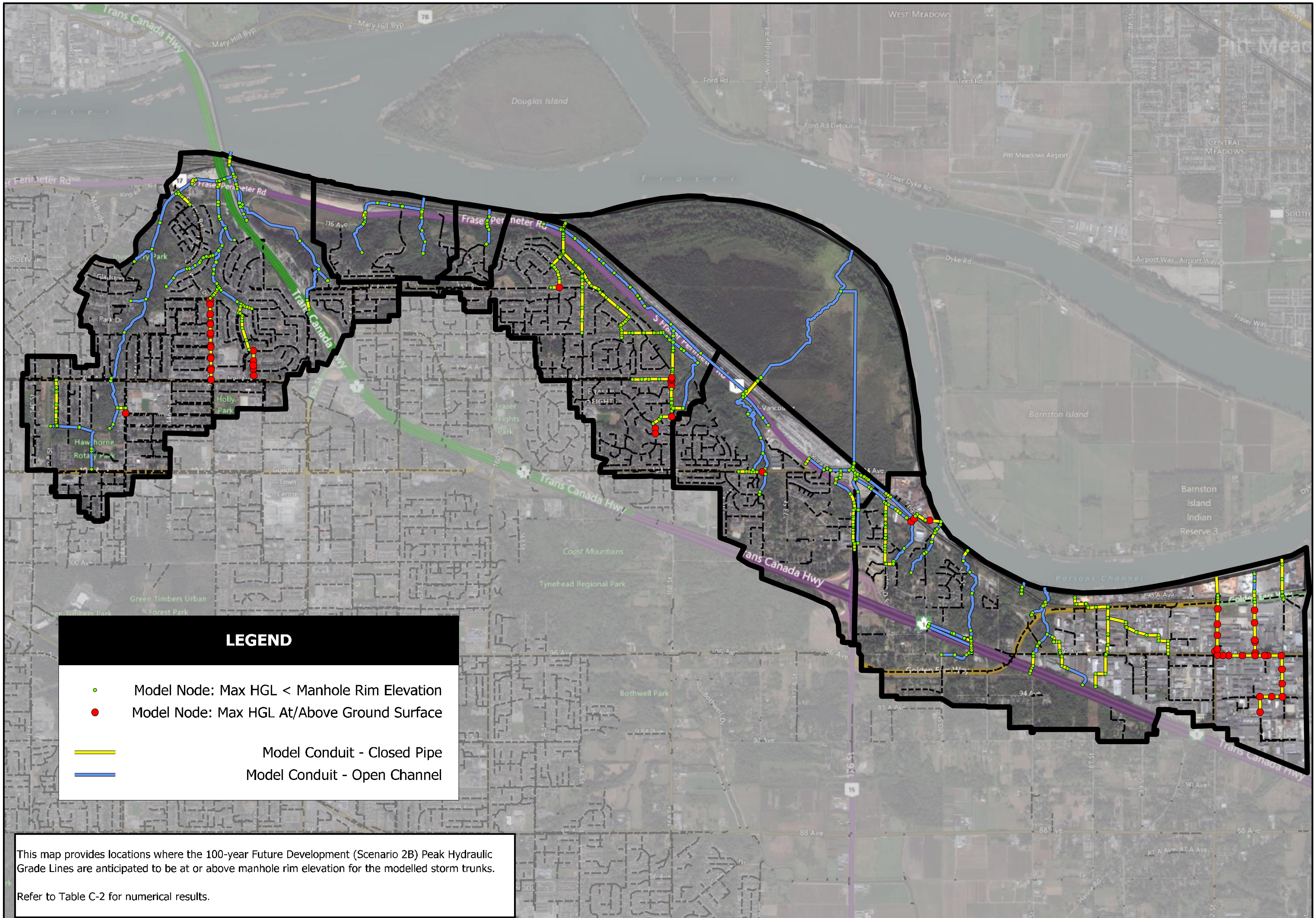
Catchment ID	Watershed	Area (ha)	Peak Runoff (m^3/s)				Runoff Coefficient				Runoff Volume (ML)		
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 3 Extended Period Simulation (3-year)		
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	C Future Source Controls
S50	160 Street	5.7	0.21	0.21	0.35	0.35	0.919	0.920	0.941	0.942	223	223	223
S51	Fraser Heights	17.9	0.53	0.55	0.95	0.96	0.700	0.718	0.784	0.797	406	429	317
S52	Fraser Heights	12.2	0.41	0.42	0.70	0.71	0.788	0.816	0.848	0.868	356	382	235
S53	Fraser Heights	9.4	0.32	0.32	0.54	0.55	0.757	0.762	0.827	0.830	250	253	269
S54	Fraser Heights	15.7	0.45	0.46	0.79	0.82	0.721	0.744	0.796	0.813	393	418	270
S55	Fraser Heights	6.7	0.22	0.22	0.38	0.38	0.739	0.759	0.814	0.828	168	178	129
S56	Fraser Heights	11.6	0.40	0.40	0.68	0.68	0.783	0.806	0.845	0.862	332	353	228
S57	Fraser Heights	22.6	0.68	0.71	1.19	1.23	0.762	0.790	0.826	0.847	635	680	420
S58	Fraser Heights	9	0.32	0.32	0.54	0.54	0.902	0.902	0.928	0.928	350	350	350
S59	Fraser Heights	13.3	0.46	0.46	0.78	0.78	0.754	0.773	0.825	0.839	350	369	269
S60	Fraser Heights	11.9	0.40	0.41	0.68	0.69	0.779	0.804	0.841	0.859	338	361	230
S61	Fraser Heights	16.8	0.41	0.41	0.75	0.76	0.651	0.658	0.743	0.749	344	352	350
S62	Fraser Heights	23.1	0.73	0.75	1.27	1.30	0.750	0.772	0.820	0.836	610	649	414
S63	Fraser Heights	7.7	0.27	0.27	0.46	0.46	0.799	0.820	0.857	0.873	228	241	163
S64	Fraser Heights	15.5	0.52	0.54	0.89	0.91	0.791	0.816	0.850	0.868	453	484	299
S65	Fraser Heights	15.4	0.49	0.50	0.84	0.86	0.772	0.797	0.835	0.853	437	466	295
S66	Fraser Heights	7.5	0.21	0.21	0.38	0.38	0.668	0.682	0.760	0.770	153	160	124
S67	Fraser Heights	5.5	0.19	0.20	0.33	0.33	0.787	0.811	0.850	0.866	158	168	107
S68	Fraser Heights	7.3	0.26	0.26	0.44	0.44	0.905	0.905	0.930	0.930	285	285	285
S69	Fraser Heights	5.3	0.17	0.17	0.29	0.29	0.643	0.647	0.745	0.748	95	97	96
S70	Fraser Heights	10.8	0.35	0.35	0.60	0.61	0.690	0.706	0.779	0.790	232	245	200
S71	Big Bend	32.6	0.91	0.94	1.64	1.68	0.695	0.714	0.779	0.792	741	783	571
S72	Big Bend	18.1	0.56	0.58	0.98	1.00	0.754	0.778	0.822	0.840	489	521	341
S73	Surrey Bend	205.8	2.08	2.08	3.99	3.99	0.342	0.342	0.448	0.448	2076	2076	2093
S74	Big Bend	4.7	0.17	0.17	0.28	0.28	0.911	0.911	0.935	0.935	182	182	182
S75	Big Bend	22.3	0.66	0.67	1.18	1.19	0.679	0.691	0.769	0.778	465	486	367
S76	Big Bend	17	0.56	0.58	0.96	0.98	0.781	0.807	0.843	0.861	489	522	371
S77	Big Bend	7.3	0.24	0.24	0.42	0.42	0.690	0.705	0.779	0.790	156	165	129
S78	Big Bend	9	0.33	0.33	0.54	0.54	0.892	0.898	0.922	0.926	338	342	316
S79	Big Bend	20.8	0.65	0.67	1.14	1.16	0.741	0.765	0.814	0.831	534	571	417
S80	Big Bend	14.6	0.51	0.51	0.86	0.86	0.899	0.899	0.925	0.925	567	567	567
S81	Big Bend	27.6	0.81	0.83	1.43	1.46	0.726	0.741	0.801	0.812	690	720	625
S82	Big Bend	19.6	0.63	0.65	1.10	1.11	0.755	0.771	0.824	0.836	521	546	453
S83	Surrey Bend	187.1	2.03	2.03	3.83	3.83	0.358	0.358	0.458	0.458	2095	2095	2095
S84	Big Bend	4.6	0.17	0.17	0.28	0.28	0.908	0.922	0.934	0.944	175	181	162
S85	Big Bend	20	0.66	0.67	1.13	1.14	0.814	0.823	0.865	0.872	629	643	610
S86	Port Kells	9.6	0.36	0.36	0.59	0.59	0.917	0.924	0.941	0.945	374	379	317
S87	Port Kells	13.2	0.46	0.46	0.77	0.78	0.795	0.813	0.854	0.867	388	406	290
S88	Port Kells	2.3	0.08	0.08	0.14	0.14	0.910	0.895	0.936	0.925	87	85	72
S89	Port Kells	5.9	0.21	0.21	0.36	0.36	0.911	0.911	0.935	0.935	229	229	171
S90	Port Kells	3.6	0.12	0.12	0.21	0.21	0.730	0.751	0.809	0.823	87	93	71
S91	Port Kells	4.6	0.16	0.16	0.27	0.27	0.716	0.734	0.799	0.811	107	113	83
S92	Port Kells	20.9	0.68	0.77	1.17	1.26	0.781	0.914	0.842	0.938	600	815	673
S93	Port Kells	10.3	0.37	0.37	0.62	0.62	0.842	0.852	0.889	0.896	338	346	284
S94	Port Kells	23.3	0.70	0.82	1.24	1.37	0.718	0.843	0.796	0.887	561	780	572
S95	Port Kells	1.7	0.06	0.06	0.10	0.10	0.750	0.773	0.824	0.840	44	46	34
S96	Port Kells	14.1	0.43	0.51	0.75	0.85	0.753	0.917	0.821	0.939	380	556	444
S97	Port Kells	6.7	0.22	0.22	0.38	0.38	0.707	0.725	0.791	0.804	153	162	123
S98	Port Kells	14.1	0.47	0.48	0.81	0.82	0.772	0.786	0.837	0.847	390	405	330

TABLE C-1
PCSWMM - SUBCATCHMENT RESULTS; PEAK RUNOFF, RUNOFF COEFFICIENT; RUNOFF VOLUME

Catchment ID	Watershed	Area (ha)	Peak Runoff (m^3/s)				Runoff Coefficient				Runoff Volume (ML)		
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 3 Extended Period Simulation (3-year)		
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	C Future Source Controls
S99	Port Kells	9.1	0.33	0.33	0.55	0.55	0.912	0.912	0.936	0.936	353	353	265
S100	Port Kells	15.2	0.47	0.49	0.83	0.85	0.727	0.748	0.803	0.819	373	397	292
S101	Port Kells	14	0.45	0.47	0.78	0.81	0.724	0.772	0.802	0.837	339	390	255
S102	Port Kells	11	0.33	0.33	0.59	0.59	0.603	0.606	0.716	0.718	163	166	154
S103	Port Kells	6.1	0.19	0.21	0.33	0.36	0.682	0.831	0.772	0.880	127	196	150
S104	Port Kells	6.6	0.23	0.23	0.39	0.39	0.816	0.822	0.869	0.874	204	207	184
S105	Port Kells	6.6	0.19	0.22	0.34	0.38	0.734	0.839	0.807	0.883	170	221	216
S106	Port Kells	2.8	0.10	0.10	0.17	0.17	0.886	0.888	0.919	0.920	103	104	103
S107	Port Kells	21.3	0.62	0.63	1.11	1.12	0.689	0.699	0.776	0.783	465	479	423
S108	Port Kells	21.9	0.62	0.73	1.12	1.25	0.681	0.801	0.770	0.857	469	663	430
S109	Port Kells	5.6	0.20	0.20	0.33	0.33	0.796	0.799	0.856	0.858	164	165	149
S110	Port Kells	11.7	0.38	0.38	0.66	0.66	0.763	0.767	0.830	0.833	319	323	272
S111	Port Kells	10.3	0.36	0.36	0.61	0.61	0.833	0.818	0.881	0.870	332	321	299
S112	Port Kells	10.7	0.39	0.39	0.64	0.64	0.875	0.883	0.910	0.916	381	389	290
S113	Port Kells	15.1	0.47	0.47	0.82	0.82	0.769	0.771	0.832	0.834	428	430	335
S114	Port Kells	9.2	0.33	0.33	0.55	0.55	0.880	0.887	0.914	0.919	330	335	275
S115	Port Kells	24.2	0.74	0.87	1.30	1.45	0.720	0.867	0.799	0.904	583	852	653
S116	Port Kells	9.5	0.35	0.35	0.58	0.58	0.918	0.928	0.941	0.948	371	379	279
S117	Port Kells	22.7	0.78	0.79	1.33	1.33	0.862	0.869	0.899	0.904	808	818	673
S118	Port Kells	11.1	0.40	0.40	0.67	0.67	0.907	0.914	0.932	0.937	430	436	356
S119	Port Kells	23.6	0.84	0.85	1.41	1.41	0.871	0.879	0.907	0.913	838	854	658
S120	Port Kells	16.5	0.60	0.60	1.00	1.00	0.910	0.919	0.934	0.941	643	656	479
S121	Port Kells	19.4	0.71	0.71	1.18	1.18	0.911	0.920	0.935	0.941	757	772	579
S122	Port Kells	8.8	0.33	0.33	0.54	0.54	0.917	0.917	0.940	0.940	346	346	273
S123	Port Kells	2.7	0.10	0.10	0.17	0.17	0.914	0.916	0.938	0.939	107	107	101
S124	Port Kells	16.9	0.62	0.62	1.03	1.03	0.914	0.924	0.937	0.944	662	675	495
S125	Port Kells	7.9	0.29	0.29	0.48	0.48	0.917	0.926	0.940	0.947	308	314	231
S126	Port Kells	12.8	0.47	0.47	0.78	0.78	0.918	0.927	0.941	0.947	501	510	389
S127	Port Kells	5.6	0.21	0.21	0.34	0.34	0.916	0.916	0.939	0.939	219	219	177
S128	Port Kells	12.6	0.46	0.47	0.77	0.77	0.913	0.923	0.937	0.944	493	503	369
S129	Port Kells	19.6	0.70	0.71	1.17	1.18	0.904	0.913	0.929	0.936	762	777	566
S130	Port Kells	13.4	0.49	0.49	0.81	0.81	0.913	0.913	0.937	0.937	523	523	418
S131	Port Kells	16.4	0.60	0.60	1.00	1.00	0.913	0.922	0.937	0.943	641	653	497
S132	Port Kells	13	0.48	0.48	0.79	0.79	0.912	0.922	0.936	0.943	508	518	379
S133	Port Kells	10.3	0.38	0.38	0.62	0.62	0.913	0.923	0.937	0.944	401	409	300

PCSWMM MODEL RESULTS SUMMARY

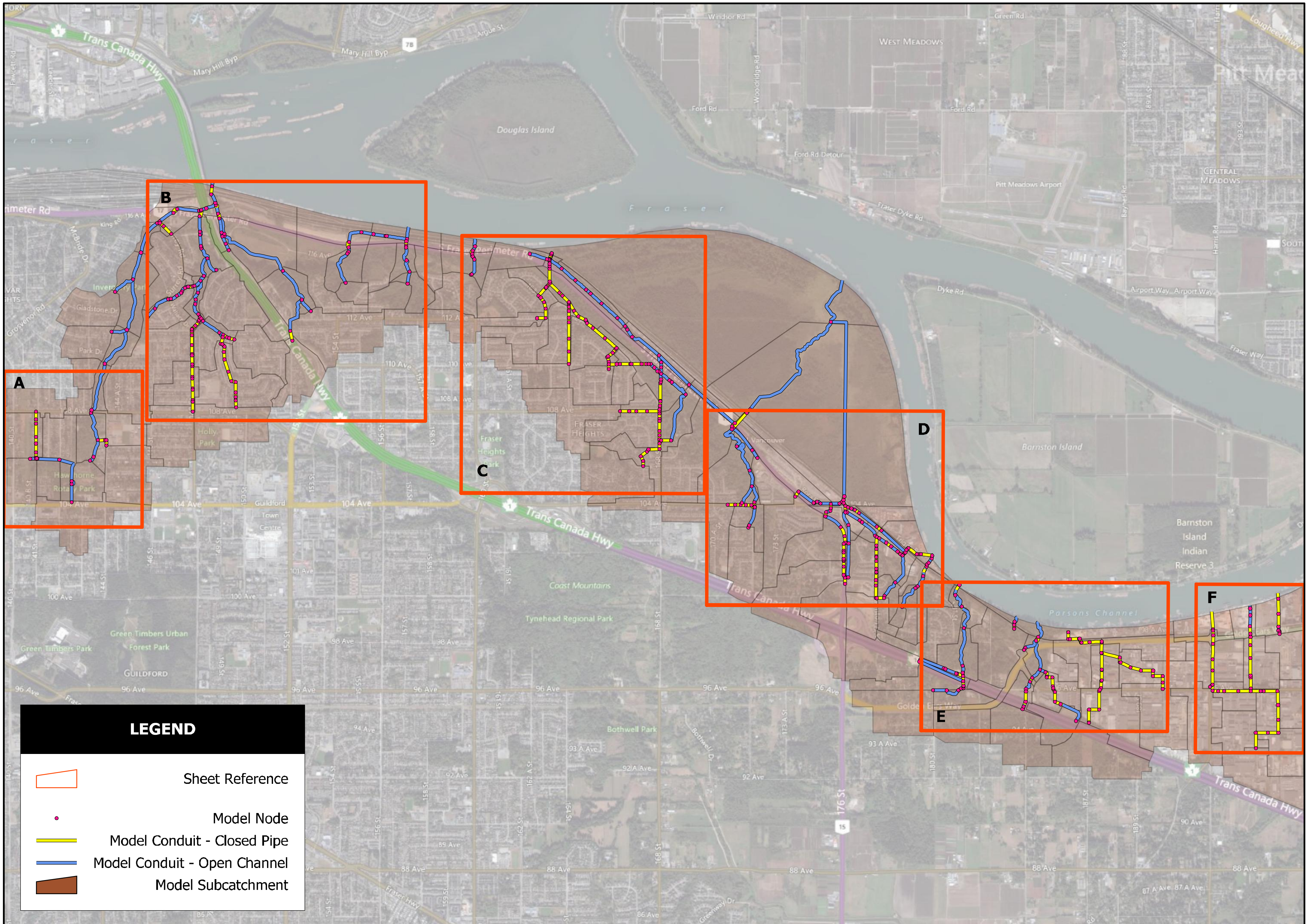
PIPES / CULVERTS



This map provides locations where the 100-year Future Development (Scenario 2B) Peak Hydraulic Grade Lines are anticipated to be at or above manhole rim elevation for the modelled storm trunks.

Refer to Table C-2 for numerical results.

0 — 2 km	SEE RESULTS TABLE C-2	PREPARED BY: Associated Engineering	PREPARED FOR: City of Surrey	**SCENARIO 2B: MAX HGL RELATIVE TO GROUND** BON ACCORD - NORTH SLOPE (EAST) ISMP APPENDIX C	PROJECT No.: 20132512 DATE: MAY 2015



0 2 km

SEE RESULTS TABLE C-2

PREPARED BY: Associated Engineering

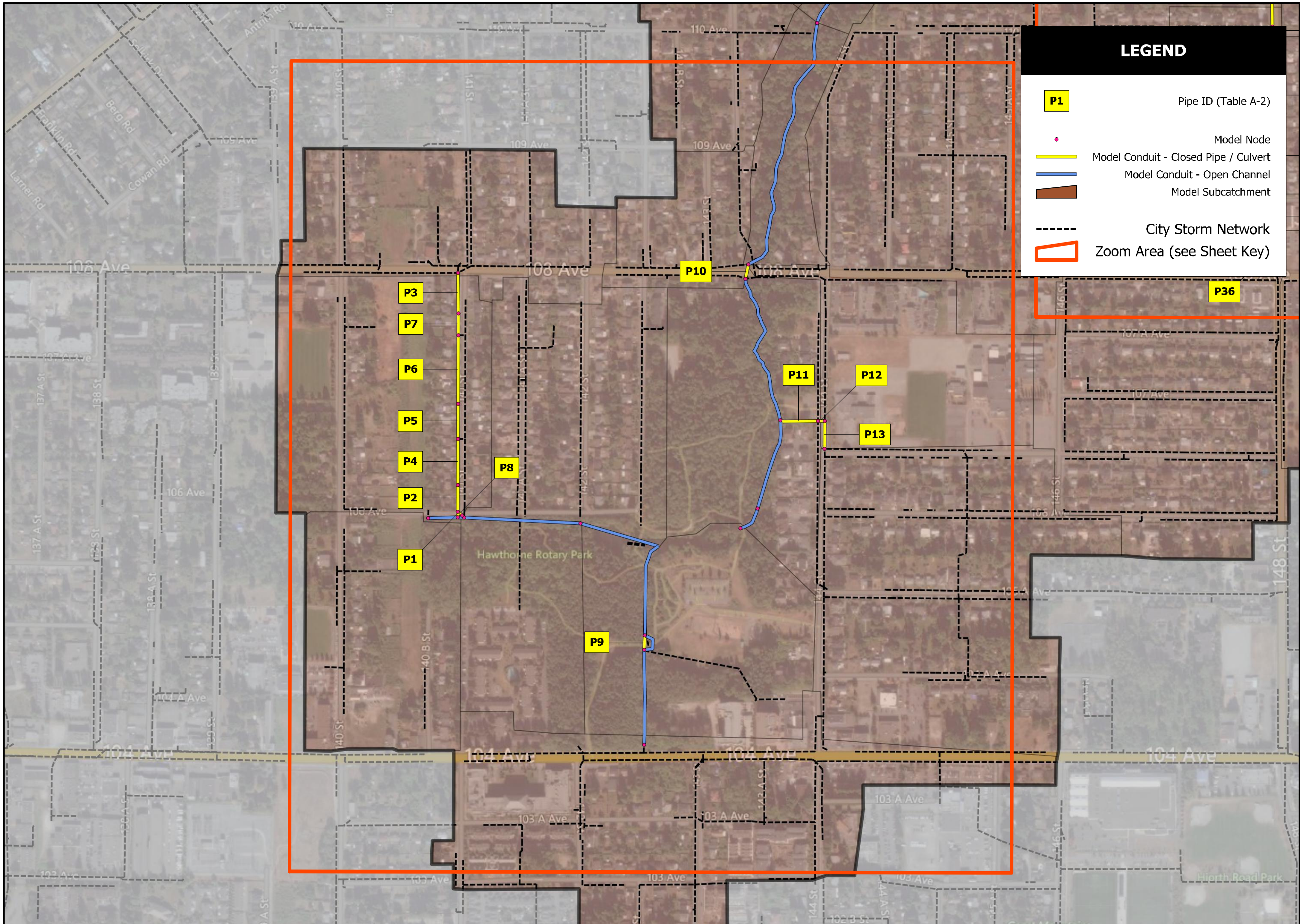
PREPARED FOR: City of Surrey

LINK REPORTING - SHEET KEY

BON ACCORD - NORTH SLOPE (EAST) ISMP
APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



SEE RESULTS TABLE C-2

PREPARED BY: Associated Engineering

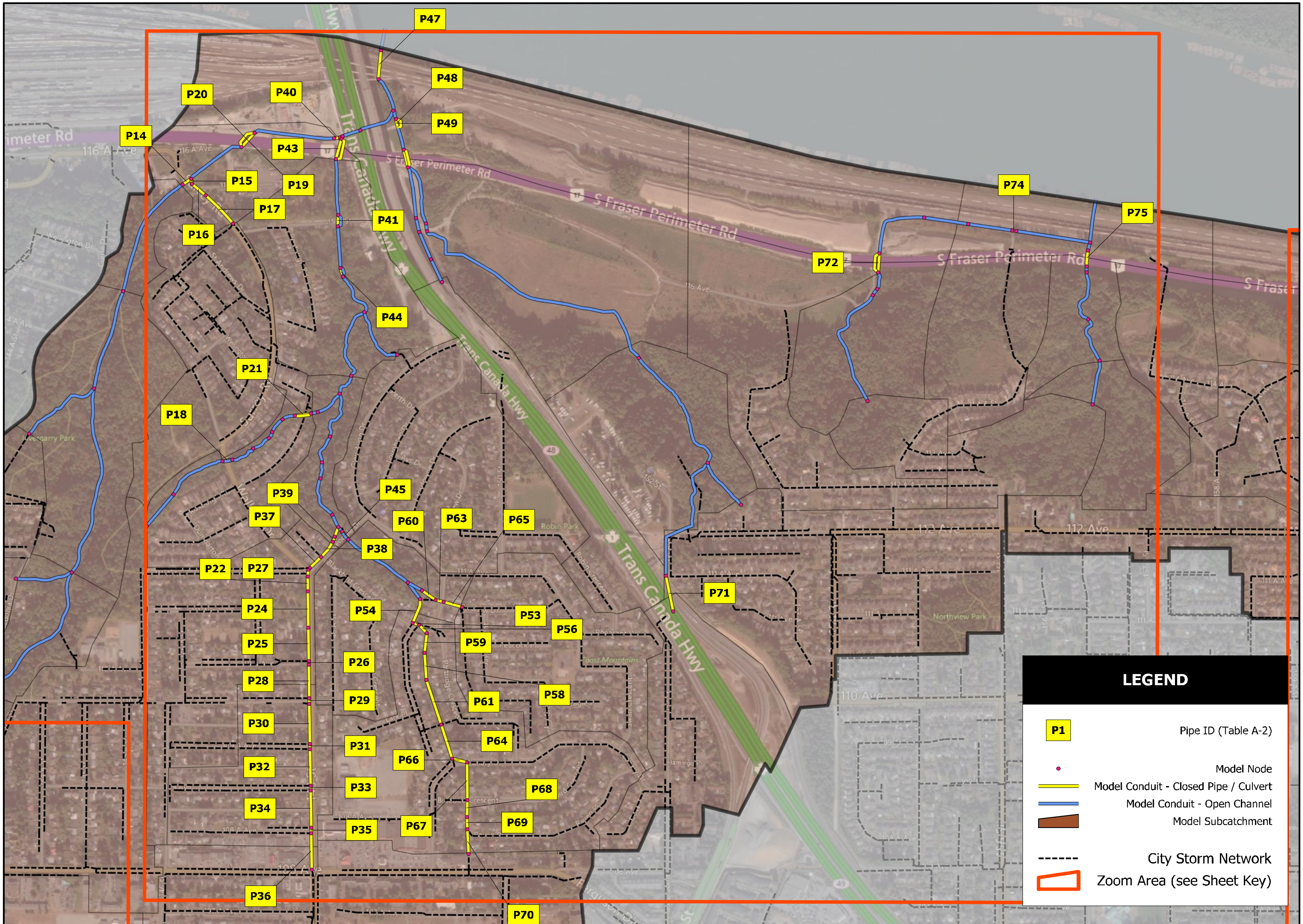
PREPARED FOR: City of Surrey

LINK REPORTING - SHEET A

BON ACCORD - NORTH SLOPE (EAST) ISMP
APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



0 500 m

SEE RESULTS TABLE C-2

PREPARED BY: Associated Engineering

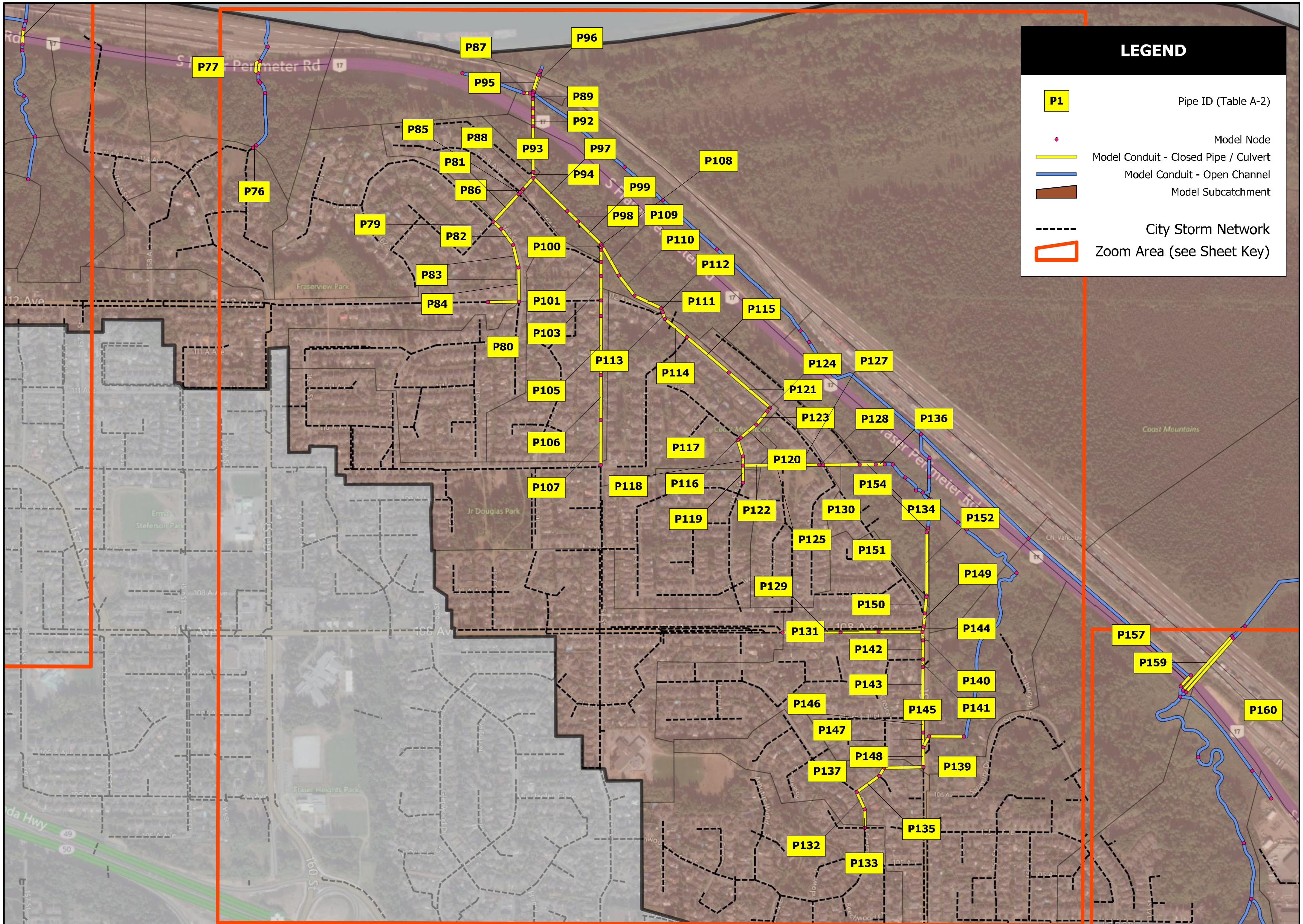
PREPARED FOR: City of Surrey

LINK REPORTING - SHEET B

BON ACCORD - NORTH SLOPE (EAST) ISMP
APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



0 500 m

SEE RESULTS TABLE C-2

PREPARED BY:

Associated Engineering

PREPARED FOR:

SURREY

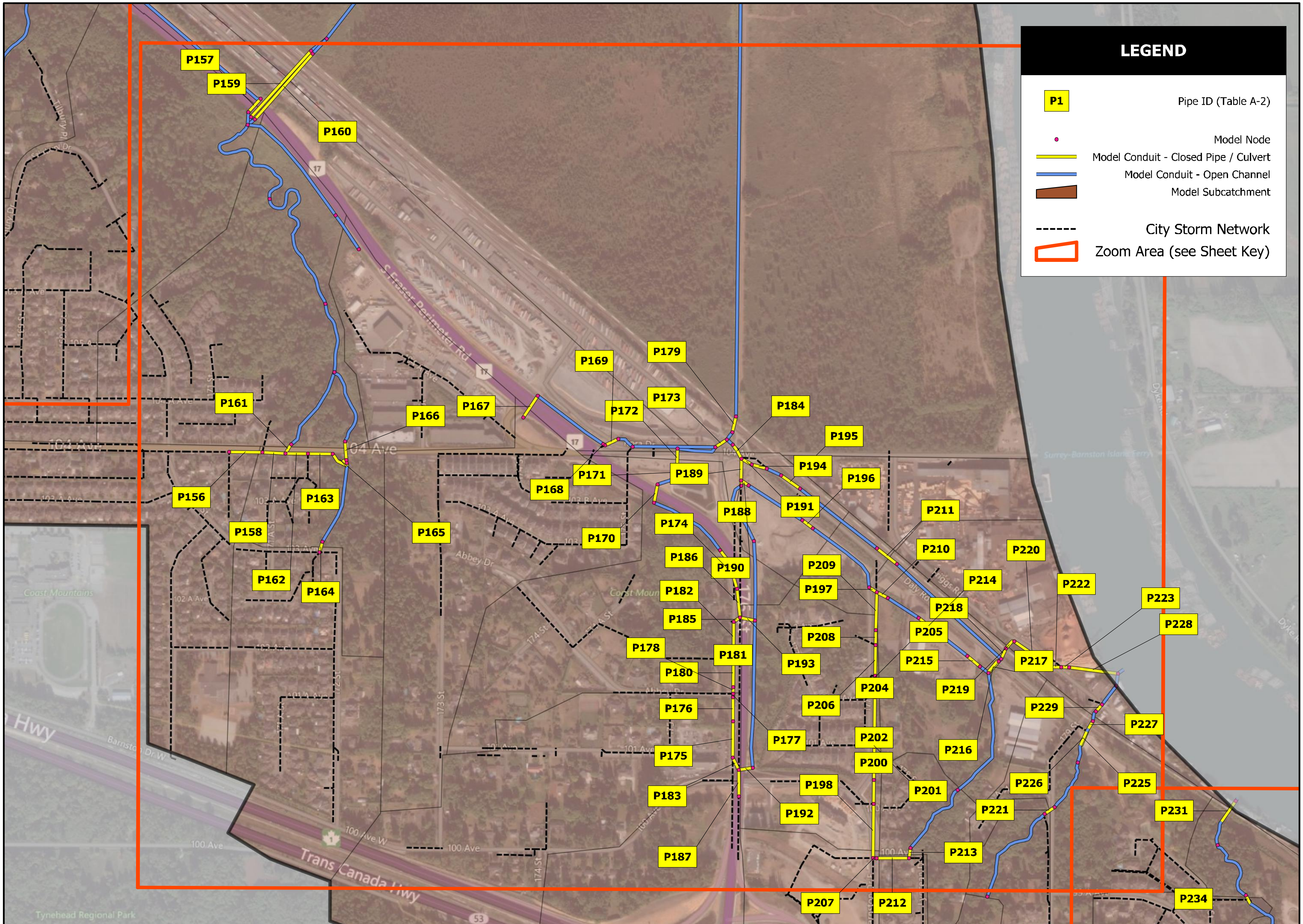
LINK REPORTING - SHEET C

BON ACCORD - NORTH SLOPE (EAST) ISMP

APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



SEE RESULTS TABLE C-2

PREPARED BY: Associated Engineering

PREPARED FOR: City of Surrey

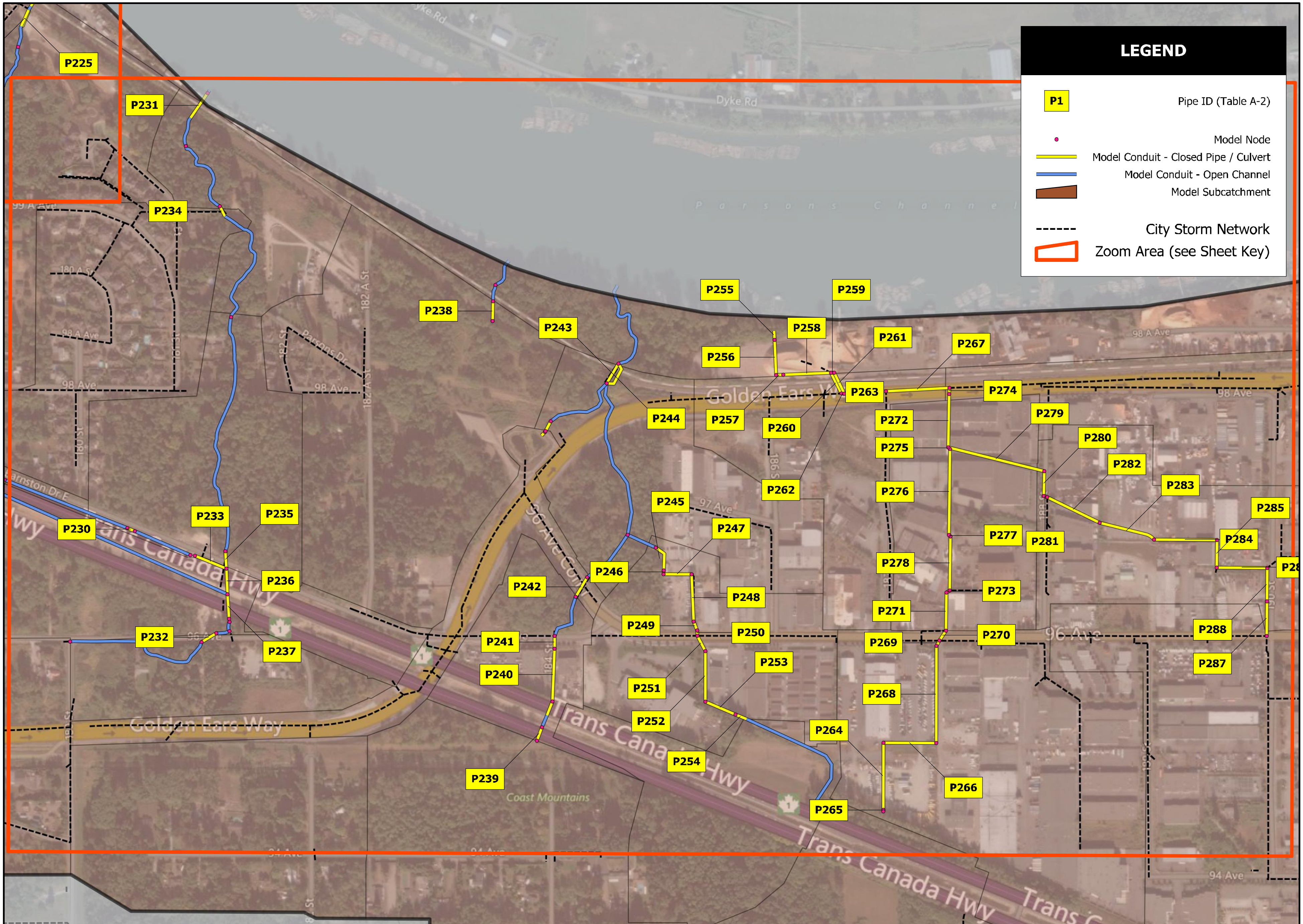
LINK REPORTING - SHEET D

BON ACCORD - NORTH SLOPE (EAST) ISMP

APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



0 500 m

SEE RESULTS TABLE C-2

PREPARED BY:

Associated Engineering

PREPARED FOR:

City of Surrey

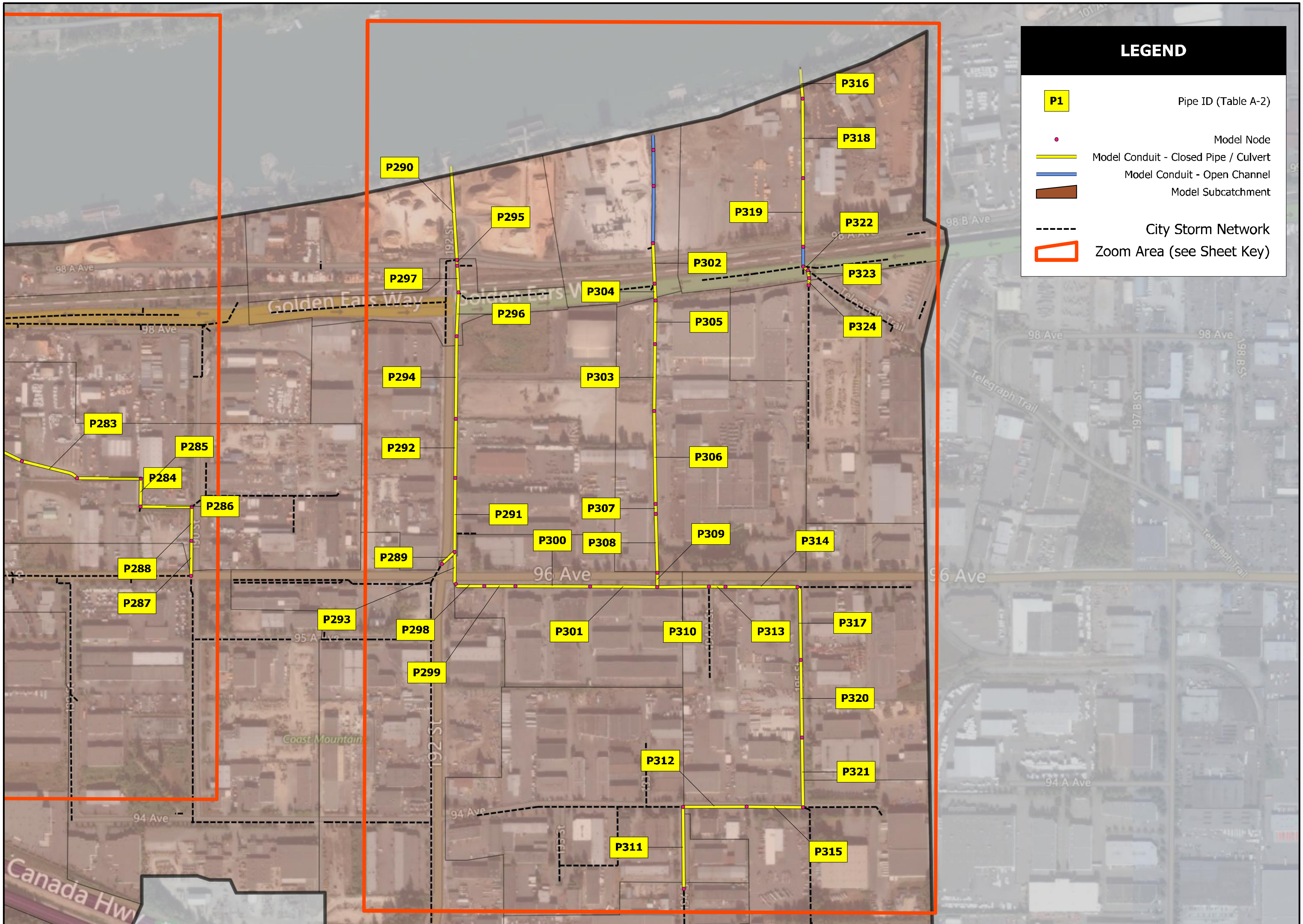
LINK REPORTING - SHEET E

BON ACCORD - NORTH SLOPE (EAST) ISMP

APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



SEE RESULTS TABLE C-2

PREPARED BY: Associated Engineering

PREPARED FOR: City of Surrey

LINK REPORTING - SHEET F

BON ACCORD - NORTH SLOPE (EAST) ISMP
APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

Pipe ID	Pipe Length (m)	U/S Rim Elevation (m)	D/S Rim Elevation (m)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
(SEE FIGURES)		(APPROX.)	(APPROX.)				Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing	A Existing	B Future	B Future	A Existing	A Existing	B Future	B Future
											Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
P1	9.2	102.12	104.89	CIRCULAR	750	Minor	0.17	0.18	0.31	0.31	100.62	100.61	100.63	100.63	100.88	100.86	100.89	100.87
P2	44.8	101.81	102.12	CIRCULAR	750	Minor	0.36	0.37	0.62	0.63	100.68	100.62	100.69	100.63	101.02	100.88	101.04	100.89
P3	68	104.32	102.34	CIRCULAR	600	Minor	0.36	0.37	0.62	0.63	102.56	101.55	102.57	101.55	102.77	101.90	102.93	101.96
P4	77.1	102.38	101.81	CIRCULAR	750	Minor	0.36	0.37	0.62	0.63	100.81	100.68	100.82	100.69	101.26	101.02	101.28	101.04
P5	58.7	102.16	102.38	CIRCULAR	750	Minor	0.36	0.37	0.62	0.63	100.92	100.81	100.93	100.82	101.51	101.26	101.47	101.28
P6	114.7	102.21	102.16	CIRCULAR	750	Minor	0.36	0.37	0.62	0.63	101.29	100.92	101.30	100.93	101.79	101.51	101.84	101.47
P7	36.6	102.34	102.21	CIRCULAR	750	Minor	0.36	0.37	0.62	0.63	101.55	101.29	101.55	101.30	101.90	101.79	101.96	101.84
P8	9.5	102.12	101.43	CIRCULAR	750	Minor	0.19	0.20	0.31	0.32	100.62	100.61	100.63	100.62	100.88	100.86	100.89	100.87
P9	24.3	100.39	100.46	CIRCULAR	450	Major	0.26	0.26	0.26	0.26	101.07	100.76	101.08	100.77	101.12	100.93	101.12	100.94
P10	24.7	102.77	102.64	CIRCULAR	900	Major	2.91	2.99	4.34	4.38	98.35	96.04	98.46	96.05	100.50	96.14	100.56	96.14
P11	63.7	101.64	99.41	CIRCULAR	750	Minor	0.60	0.63	1.06	1.09	100.68	99.72	100.69	99.73	100.85	100.50	100.88	100.56
P12	11.3	101.67	101.64	CIRCULAR	600	Minor	0.60	0.63	1.06	1.09	100.93	100.68	100.95	100.69	101.27	100.85	101.24	100.88
P13	46.6	101.87	101.67	CIRCULAR	600	Minor	0.60	0.63	1.06	1.09	101.43	100.93	101.45	100.95	102.58	101.27	102.72	101.24
P14	25.1	14.51	10.90	RECT_CLOSED	1250 x 2200	Major	5.03	5.15	8.23	8.33	11.69	10.16	11.69	10.16	11.75	10.31	11.76	10.32
P15	12.4	11.89	10.90	CIRCULAR	600	Minor	0.49	0.50	0.87	0.88	10.61	10.16	10.62	10.16	11.23	10.31	11.23	10.32
P16	43	12.88	11.89	CIRCULAR	600	Minor	0.49	0.50	0.86	0.88	11.31	10.61	11.32	10.62	12.62	11.23	12.61	11.23
P17	94.5	18.20	12.88	CIRCULAR	600	Minor	0.49	0.50	0.86	0.88	16.26	11.31	16.27	11.32	16.36	12.62	16.36	12.61
P18	23.9	69.65	63.92	CIRCULAR	600	Major	0.06	0.07	0.12	0.13	66.71	61.82	66.71	61.83	66.73	61.86	66.74	61.87
P19	46.2	9.00	7.61	RECT_CLOSED	1800 x 1800	Major	5.55	5.68	9.12	9.24	6.30	5.68	6.30	5.69	6.49	5.87	6.49	5.87
P20	55.7	9.00	7.61	FILLED_CIRCULAR	1000	Major	0.00	0.00	0.00	0.00	6.30	5.68	6.30	5.69	6.49	5.87	6.49	5.87
P21	39.5	39.82	39.49	CIRCULAR	900	Major	0.80	0.83	1.29	1.33	35.80	26.88	35.81	26.89	35.87	26.93	35.88	26.93
P22	35.4	77.01	75.46	CIRCULAR	600	Minor	1.07	1.10	1.55	1.58	76.15	74.87	76.17	74.88	77.73	75.47	77.84	75.52
P23	16.8	75.46	75.07	CIRCULAR	600	Minor	1.07	1.10	1.55	1.58	74.87	74.13	74.88	74.14	75.47	74.40	75.52	74.41
P24	87.2	80.47	77.01	CIRCULAR	600	Minor	1.07	1.10	1.55	1.58	79.45	76.15	79.46	76.17	83.31	77.73	83.58	77.84
P25	80.2	82.84	80.47	CIRCULAR	600	Minor	1.07	1.11	1.56	1.58	82.13	79.45	82.14	79.46	88.44	83.31	88.87	83.58
P26	8.6	83.12	82.85	CIRCULAR	600	Minor	1.07	1.09	1.57	1.59	82.40	82.13	82.42	82.14	89.00	88.44	89.44	88.87
P27	5.5	75.07	74.38	CIRCULAR	600	Minor	1.07	1.10	1.55	1.58	74.13	73.32	74.14	73.33	74.40	73.39	74.41	73.39
P28	80.2	86.28	83.12	CIRCULAR	600	Minor	1.07	1.09	1.58	1.61	85.06	82.40	85.07	82.42	94.21	89.00	94.82	89.44
P29	13.9	86.65	86.28	CIRCULAR	600	Minor	0.67	0.69	1.06	1.08	85.41	85.06	85.42	85.07	94.57	94.21	95.18	94.82
P30	96.3	89.37	86.65	CIRCULAR	600	Minor	0.67	0.69	1.04	1.05	88.62	85.41	88.62	85.42	97.14	94.57	97.84	95.18
P31	12.2	89.57	89.37	CIRCULAR	600	Minor	0.67	0.69	1.02	1.04	89.02	88.62	89.03	88.62	97.47	97.14	98.19	97.84
P32	87.8	91.51	89.57	CIRCULAR	600	Minor	0.67	0.69	1.02	1.03	90.71	89.02	90.72	89.03	99.86	97.47	100.67	98.19
P33	11	91.74	91.51	CIRCULAR	600	Minor	0.67	0.69	1.03	1.05	90.98	90.71	90.99	90.72	100.16	99.86	100.98	100.67
P34	89.6	94.01	91.74	CIRCULAR	600	Minor	0.67	0.69	1.06	1.08	92.69	90.98	92.70	90.99	102.67	100.16	103.57	100.98
P35	13.2	94.37	94.01	CIRCULAR	600	Minor	0.67	0.69	1.09	1.11	93.05	92.69	93.06	92.70	103.05	102.67	103.97	103.57
P36	87.5	96.75	94.37	CIRCULAR	600	Minor	0.67	0.69	1.12	1.14	95.32	93.05	95.33	93.06	105.77	103.05	106.79	103.97
P37	37.6	74.38	69.96	CIRCULAR	675	Minor	1.07	1.10	1.55	1.58	73.32	68.85	73.33	68.86	73.39	68.98	73.39	68.99
P38	46.2	69.96	65.05	CIRCULAR	675	Minor	1.64	1.71	2.54	2.59	68.85	63.25	68.86	63.25	68.98	63.42	68.99	63.44
P39	13.1	65.05	59.83	CIRCULAR	600	Minor	1.64	1.71	2.54	2.59	63.25	56.27	63.25	56.28	63.42	56.42	63.44	56.43
P40	14.3	3.93	3.86	RECT_CLOSED	1250 x 3050	Major	5.79	5.93	9.50	9.62	3.36	3.22	3.38	3.23	3.86	3.49	3.88	3.50
P41	27.1	3.99	4.18	ARCH	1120 x 1830	Major	5.46	5.49	5.88	5.89	5.64	5.09	5.68	5.17	6.69	6.67	6.79	6.76
P42	50.7	3.00	4.61	FILLED_CIRCULAR	1800	Major	5.42	5.57	8.05	8.17	5.08	3.19	5.16	3.20	6.67	3.46	6.76	3.47
P43	62.1	3.00	4.61	FILLED_CIRCULAR	1000	Major	0.94	0.98	1.50	1.53	5.08	3.19	5.16	3.20	6.67	3.46	6.76	3.47
P44	22.1	7.26	8.41	ARCH	1120 x 1830	Major	6.17	6.33	9.85	9.95	5.73	5.65	5.79	5.69	7.08	6.70	7.11	6.79

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

Pipe ID (SEE FIGURES)	Pipe Length (m)	U/S Rim Elevation (m) (APPROX.)	D/S Rim Elevation (m) (APPROX.)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
							Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing Upstream	A Existing Downstream	B Future Upstream	B Future Downstream	A Existing Upstream	A Existing Downstream	B Future Upstream	B Future Downstream
P45	24.8	58.99	56.92	CIRCULAR	600	Major	0.31	0.32	0.53	0.54	55.22	53.17	55.22	53.17	55.28	53.27	55.28	53.27
P47	69.6	1.34	1.03	RECT_CLOSED	1500 x 4800	Major	13.06	13.38	20.23	20.59	2.58	2.30	2.60	2.30	3.01	2.33	3.03	2.33
P48	22.9	0.00	1.99	CIRCULAR	900	Major	1.22	1.23	1.44	1.44	0.00	2.60	0.00	2.62	0.00	3.02	0.00	3.05
P49	33.3	0.00	1.99	RECT_CLOSED	1000 x 5000	Major	0.00	0.00	1.31	1.39	0.00	2.60	0.00	2.62	0.00	3.02	0.00	3.05
P50	43.4	3.06	3.84	RECT_CLOSED	1800 x 1800	Major	2.55	2.57	4.71	4.76	3.06	3.06	3.07	3.08	3.49	3.47	3.49	3.48
P51	47.5	3.06	3.84	FILLED_CIRCULAR	1000	Major	0.14	0.14	0.32	0.33	3.06	3.06	3.07	3.08	3.49	3.47	3.49	3.48
P53	16.1	72.98	72.93	CIRCULAR	900	Minor	0.70	0.72	1.20	1.23	72.21	71.88	72.22	71.89	72.51	72.52	72.59	72.59
P54	60.8	72.93	70.91	CIRCULAR	900	Minor	1.55	1.59	2.64	2.69	71.88	70.31	71.89	70.32	72.52	70.44	72.59	70.44
P56	27.1	73.51	72.98	CIRCULAR	900	Minor	0.70	0.72	1.20	1.22	72.63	72.21	72.63	72.22	72.82	72.51	72.82	72.59
P58	65	77.13	74.94	CIRCULAR	900	Minor	0.70	0.72	1.20	1.22	75.82	73.93	75.83	73.93	75.92	74.03	75.93	74.03
P59	47.5	74.94	73.51	CIRCULAR	900	Minor	0.70	0.72	1.20	1.22	73.93	72.63	73.93	72.63	74.03	72.82	74.03	72.82
P60	40.1	73.19	70.89	CIRCULAR	600	Minor	0.54	0.55	0.92	0.94	71.14	70.41	71.15	70.42	71.90	70.51	71.94	70.52
P61	112.9	80.25	77.13	CIRCULAR	900	Minor	0.70	0.72	1.20	1.22	79.13	75.82	79.14	75.83	79.23	75.92	79.23	75.93
P63	19.8	73.57	73.19	CIRCULAR	600	Minor	0.54	0.55	0.92	0.94	71.40	71.14	71.41	71.15	72.34	71.90	72.40	71.94
P64	86	82.32	80.25	CIRCULAR	900	Minor	0.70	0.72	1.20	1.22	81.31	79.13	81.32	79.14	81.41	79.23	81.42	79.23
P65	46	74.20	73.57	CIRCULAR	600	Minor	0.54	0.55	0.92	0.94	72.04	71.40	72.05	71.41	73.37	72.34	73.48	72.40
P66	36.8	82.79	82.32	CIRCULAR	600	Minor	0.70	0.72	1.20	1.22	82.30	81.31	82.33	81.32	83.28	81.41	83.34	81.42
P67	90.5	84.81	82.79	CIRCULAR	600	Minor	0.70	0.72	1.20	1.22	84.09	82.30	84.09	82.33	86.71	83.28	86.89	83.34
P68	40.7	85.91	84.81	CIRCULAR	600	Minor	0.70	0.72	1.20	1.22	84.78	84.09	84.81	84.09	88.26	86.71	88.50	86.89
P69	29.3	86.43	85.91	CIRCULAR	600	Minor	0.70	0.72	1.20	1.22	85.62	84.78	85.63	84.81	89.37	88.26	89.65	88.50
P70	59.5	87.63	86.43	CIRCULAR	600	Minor	0.70	0.72	1.21	1.23	86.80	85.62	86.81	85.63	91.66	89.37	92.03	89.65
P71	87.4	86.10	82.38	CIRCULAR	675	Minor	0.51	0.52	0.87	0.88	83.69	81.37	83.69	81.37	83.87	81.41	83.88	81.41
P72	45.8	7.27	6.00	CIRCULAR	1000	Major	0.22	0.22	0.49	0.49	6.00	5.22	6.00	5.22	6.22	5.54	6.23	5.55
P73	55.1	7.27	6.00	FILLED_CIRCULAR	1400	Major	0.74	0.74	1.22	1.23	6.00	5.22	6.00	5.22	6.22	5.54	6.23	5.55
P74	9.5	4.97	4.48	CIRCULAR	900	Major	1.21	1.22	1.74	1.75	4.92	4.11	4.93	4.12	5.53	4.19	5.54	4.19
P75	38.4	5.16	6.02	FILLED_CIRCULAR	1400	Major	0.64	0.64	1.10	1.11	4.61	3.56	4.62	3.56	4.80	3.65	4.80	3.65
P76	9.8	27.31	25.65	CIRCULAR	750	Minor	0.40	0.40	0.68	0.69	24.92	24.41	24.93	24.41	25.26	24.45	25.28	24.45
P77	30.1	10.77	6.45	FILLED_CIRCULAR	1050	Major	0.00	0.00	0.00	0.00	9.23	6.26	9.23	6.26	9.33	6.32	9.33	6.32
P78	39.6	10.77	6.45	FILLED_CIRCULAR	1400	Major	0.70	0.70	1.19	1.20	9.23	6.26	9.23	6.26	9.33	6.32	9.33	6.32
P79	25.8	49.84	50.00	CIRCULAR	900	Minor	0.94	0.98	1.65	1.69	48.29	47.21	48.31	47.22	48.81	47.32	48.83	47.33
P80	76.7	63.33	59.55	CIRCULAR	600	Minor	0.53	0.56	0.96	0.99	60.16	56.40	60.17	56.41	62.00	59.55	62.55	59.94
P81	91.7	49.99	40.88	CIRCULAR	900	Minor	1.47	1.53	2.60	2.65	47.21	35.66	47.22	35.67	47.32	35.76	47.33	35.77
P82	49	50.66	49.84	CIRCULAR	900	Minor	0.94	0.98	1.65	1.69	48.68	48.29	48.69	48.31	49.25	48.81	49.31	48.83
P83	57.1	54.18	50.66	CIRCULAR	600	Minor	0.94	0.98	1.65	1.69	52.17	48.68	52.18	48.69	54.18	49.25	54.18	49.31
P84	83.9	59.55	54.18	CIRCULAR	600	Minor	0.94	0.98	1.65	1.69	56.40	52.17	56.41	52.18	59.55	54.18	59.94	54.18
P85	6.5	40.88	40.28	CIRCULAR	900	Minor	1.47	1.53	2.60	2.65	35.66	34.76	35.67	34.77	35.76	34.87	35.77	34.88
P86	10.5	40.28	38.37	CIRCULAR	900	Minor	1.47	1.53	2.60	2.65	34.76	33.49	34.77	33.50	34.87	33.59	34.88	33.60
P87	15	3.43	2.63	CIRCULAR	600	Major	0.31	0.31	0.56	0.58	3.08	2.81	3.08	2.82	3.70	3.51	3.73	3.55
P88	37	38.37	32.96	CIRCULAR	900	Minor	1.47	1.53	2.60	2.65	33.49	27.50	33.50	27.51	33.59	27.66	33.60	27.67
P89	10	3.94	1.19	CIRCULAR	1800	Minor	4.04	4.01	6.87	6.91	2.91	2.80	2.91	2.82	3.77	3.51	3.82	3.55
P90	23.2	10.51	3.94	CIRCULAR	900	Minor	3.71	3.81	6.45	6.56	9.09	2.91	9.10	2.91	9.32	3.77	9.34	3.82
P91	20.6	16.38	10.51	CIRCULAR	900	Minor	3.71	3.81	6.44	6.56	14.39	9.09	14.39	9.10	14.51	9.32	14.52	9.34
P92	23.6	19.65	16.38	CIRCULAR	900	Minor	3.71	3.81	6.44	6.56	17.09	14.39	17.10	14.39	17.28	14.51	17.29	14.52

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

Pipe ID (SEE FIGURES)	Pipe Length (m)	U/S Rim Elevation (m) (APPROX.)	D/S Rim Elevation (m) (APPROX.)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
							Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing Upstream	A Existing Downstream	B Future Upstream	B Future Downstream	A Existing Upstream	A Existing Downstream	B Future Upstream	B Future Downstream
P93	111.8	31.49	19.65	CIRCULAR	900	Minor	3.30	3.40	5.70	5.80	26.07	17.09	26.08	17.10	26.26	17.28	26.27	17.29
P94	14.6	32.96	31.49	CIRCULAR	900	Minor	3.08	3.18	5.32	5.42	27.50	26.07	27.51	26.08	27.66	26.26	27.67	26.27
P95	42.3	2.85	4.55	CIRCULAR	1800	Major	3.99	4.10	6.71	6.83	2.80	2.42	2.82	2.42	3.53	2.43	3.57	2.43
P96	42.4	1.99	4.63	CIRCULAR	1800	Major	3.98	4.09	6.71	6.83	2.80	2.42	2.82	2.42	3.53	2.43	3.57	2.43
P97	116.7	31.74	32.96	CIRCULAR	1350	Minor	1.61	1.65	2.72	2.77	29.16	27.50	29.17	27.51	29.43	27.66	29.44	27.67
P98	37.2	31.95	31.74	CIRCULAR	1350	Minor	1.61	1.65	2.73	2.77	29.28	29.16	29.30	29.17	29.58	29.43	29.59	29.44
P99	79.6	32.46	31.95	CIRCULAR	1350	Minor	1.61	1.65	2.73	2.77	29.44	29.28	29.45	29.30	29.78	29.58	29.80	29.59
P100	13.5	33.22	32.46	CIRCULAR	675	Minor	0.84	0.87	1.47	1.50	30.96	29.44	30.97	29.45	31.05	29.78	31.06	29.80
P101	29.6	35.67	33.22	CIRCULAR	675	Minor	0.84	0.87	1.47	1.50	32.86	30.96	32.86	30.97	32.98	31.05	32.99	31.06
P102	34.5	39.81	35.67	CIRCULAR	675	Minor	0.44	0.46	0.79	0.82	35.03	32.86	35.03	32.86	35.10	32.98	35.11	32.99
P103	60	43.24	39.81	CIRCULAR	675	Minor	0.44	0.46	0.79	0.82	40.15	35.03	40.15	35.03	40.22	35.10	40.23	35.11
P104	38.3	44.15	43.24	CIRCULAR	675	Minor	0.44	0.46	0.79	0.82	41.03	40.15	41.04	40.15	41.17	40.22	41.18	40.23
P105	144.9	57.80	44.15	CIRCULAR	675	Minor	0.44	0.46	0.79	0.82	54.86	41.03	54.86	41.04	54.93	41.17	54.93	41.18
P106	110.5	63.63	57.80	CIRCULAR	675	Minor	0.45	0.46	0.79	0.82	60.64	54.86	60.65	54.86	60.72	54.93	60.73	54.93
P107	110.4	67.34	63.63	CIRCULAR	675	Minor	0.45	0.46	0.79	0.82	65.04	60.64	65.04	60.65	65.13	60.72	65.13	60.73
P108	4.8	32.55	32.46	CIRCULAR	1050	Minor	0.78	0.79	1.27	1.28	29.44	29.44	29.45	29.45	29.80	29.78	29.81	29.80
P109	83	33.81	32.55	CIRCULAR	1050	Minor	0.78	0.79	1.26	1.28	29.63	29.44	29.64	29.45	29.94	29.80	29.96	29.81
P110	62.8	32.87	33.81	CIRCULAR	1050	Minor	0.78	0.79	1.26	1.27	29.82	29.63	29.82	29.64	30.07	29.94	30.09	29.96
P111	72.4	31.92	32.87	CIRCULAR	1050	Minor	0.78	0.79	1.26	1.28	30.02	29.82	30.02	29.82	30.27	30.07	30.28	30.09
P112	10.4	32.30	31.92	CIRCULAR	1050	Minor	0.78	0.79	1.26	1.28	30.03	30.02	30.04	30.02	30.27	30.27	30.28	30.28
P113	17.6	31.90	32.30	CIRCULAR	1050	Minor	0.78	0.79	1.26	1.28	30.12	30.03	30.12	30.04	30.31	30.27	30.32	30.28
P114	70	31.76	31.90	CIRCULAR	1050	Minor	0.32	0.33	0.51	0.51	30.18	30.12	30.19	30.12	30.35	30.31	30.36	30.32
P115	134.9	32.41	31.76	CIRCULAR	900	Minor	0.32	0.33	0.49	0.50	30.46	30.18	30.46	30.19	30.57	30.35	30.57	30.36
P116	9.5	48.70	48.73	CIRCULAR	450	Minor	0.32	0.33	0.49	0.50	46.04	44.91	46.04	44.91	46.08	44.95	46.08	44.95
P117	42.3	51.47	48.70	CIRCULAR	450	Minor	0.32	0.33	0.49	0.50	49.33	46.04	49.33	46.04	49.38	46.08	49.38	46.08
P118	22.4	52.79	51.47	CIRCULAR	450	Minor	0.32	0.33	0.49	0.50	50.67	49.33	50.67	49.33	50.72	49.38	50.72	49.38
P119	42	55.38	52.79	CIRCULAR	450	Minor	0.40	0.41	0.69	0.69	53.11	50.67	53.11	50.67	53.23	50.72	53.23	50.72
P120	49.6	48.73	42.13	CIRCULAR	450	Minor	0.32	0.33	0.49	0.50	44.91	40.40	44.91	40.41	44.95	40.44	44.95	40.44
P121	133.1	33.09	32.41	CIRCULAR	900	Minor	0.32	0.33	0.49	0.50	30.81	30.46	30.81	30.46	30.91	30.57	30.91	30.57
P122	69.6	52.79	48.76	CIRCULAR	450	Minor	0.08	0.08	0.19	0.20	50.67	46.20	50.67	46.20	50.72	46.25	50.72	46.25
P123	42.4	42.13	33.70	CIRCULAR	450	Minor	0.32	0.33	0.49	0.50	40.40	31.77	40.41	31.77	40.44	31.82	40.44	31.82
P124	11.4	33.70	33.09	CIRCULAR	450	Minor	0.32	0.33	0.49	0.50	31.77	30.81	31.77	30.81	31.82	30.91	31.82	30.91
P125	27.8	48.76	45.21	CIRCULAR	450	Minor	0.08	0.08	0.19	0.20	46.20	42.24	46.20	42.24	46.25	42.29	46.25	42.29
P126	81.1	61.42	53.38	CIRCULAR	600	Minor	0.68	0.71	1.19	1.23	60.41	52.38	60.41	52.39	60.50	52.50	60.51	52.51
P127	90.6	45.21	30.01	CIRCULAR	450	Minor	0.08	0.08	0.19	0.20	42.24	28.55	42.24	28.55	42.29	28.61	42.29	28.62
P128	9.7	30.01	30.13	CIRCULAR	450	Minor	0.08	0.08	0.19	0.20	28.55	27.99	28.55	27.99	28.61	28.06	28.62	28.06
P129	61.6	53.38	49.65	CIRCULAR	600	Minor	0.68	0.71	1.19	1.23	52.38	48.76	52.39	48.76	52.50	48.85	52.51	48.86
P130	89.7	30.13	15.95	CIRCULAR	450	Minor	0.35	0.35	0.65	0.66	27.99	14.98	27.99	14.98	28.06	15.05	28.06	15.05
P131	93.6	49.65	41.07	CIRCULAR	600	Minor	0.68	0.71	1.19	1.23	48.76	39.61	48.76	39.61	48.85	39.70	48.86	39.72
P132	46.4	55.93	56.10	CIRCULAR	600	Minor	0.73	0.75	1.26	1.29	53.66	52.77	53.70	52.78	56.63	55.16	57.32	55.30
P133	45.4	56.21	55.93	CIRCULAR	600	Minor	0.73	0.75	1.27	1.29	54.30	53.66	54.38	53.70	58.55	56.63	59.32	57.32
P134	39.5	15.95	10.39	CIRCULAR	450	Minor	0.35	0.35	0.65	0.66	14.98	8.47	14.98	8.47	15.05	8.59	15.05	8.59
P135	68.2	56.10	52.36	CIRCULAR	600	Minor	0.73	0.75	1.26	1.29	52.77	50.65	52.78	50.66	55.16	52.36	55.30	52.33

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

Pipe ID	Pipe Length (m)	U/S Rim Elevation (m)	D/S Rim Elevation (m)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
(SEE FIGURES)		(APPROX.)	(APPROX.)				Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing	A Existing	B Future	B Future	A Existing	A Existing	B Future	B Future
											Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
P136	22	10.39	6.53	CIRCULAR	450	Minor	0.35	0.35	0.65	0.66	8.47	5.49	8.47	5.50	8.59	5.71	8.59	5.71
P137	23.6	52.36	51.74	CIRCULAR	600	Minor	0.73	0.75	1.26	1.29	50.65	49.85	50.66	49.86	52.36	51.34	52.33	51.61
P138	108	41.07	30.34	CIRCULAR	600	Minor	0.68	0.71	1.19	1.23	39.61	28.94	39.61	28.95	39.70	32.35	39.72	32.74
P139	96.7	51.74	49.03	CIRCULAR	675	Minor	0.73	0.75	1.26	1.29	49.85	46.99	49.86	47.00	51.34	49.03	51.61	49.05
P140	20.9	30.85	30.34	CIRCULAR	750	Minor	0.86	0.89	1.87	1.88	29.48	28.94	29.49	28.95	32.93	32.35	33.32	32.74
P141	18.7	35.34	34.09	CIRCULAR	600	Minor	0.34	0.36	1.02	1.03	34.08	32.68	34.09	32.69	34.63	34.12	35.03	34.54
P142	46.8	34.09	30.85	CIRCULAR	600	Minor	0.34	0.36	1.02	1.03	32.68	29.48	32.69	29.49	34.12	32.93	34.54	33.32
P143	88.2	40.58	35.34	CIRCULAR	525	Minor	0.34	0.36	0.99	0.99	39.93	34.08	39.94	34.09	40.12	34.63	40.12	35.03
P144	13.7	30.34	30.24	CIRCULAR	750	Minor	1.53	1.60	3.04	3.10	28.94	28.27	28.95	28.28	32.35	31.32	32.74	31.67
P145	36	42.56	40.58	CIRCULAR	525	Minor	0.34	0.36	0.99	0.99	40.93	39.93	40.94	39.94	42.48	40.12	42.48	40.12
P146	36.4	45.02	42.56	CIRCULAR	525	Minor	0.34	0.36	0.99	0.99	43.55	40.93	43.56	40.94	44.61	42.48	44.61	42.48
P147	36.2	47.18	45.02	CIRCULAR	525	Minor	0.34	0.36	1.00	1.00	45.38	43.55	45.38	43.56	45.66	44.61	46.35	44.61
P148	48.6	49.03	47.18	CIRCULAR	675	Minor	1.21	1.25	2.10	2.14	46.99	45.38	47.00	45.38	49.03	45.66	49.05	46.35
P149	32.1	30.24	29.45	CIRCULAR	675	Minor	1.53	1.60	3.05	3.10	28.27	24.90	28.28	24.91	31.32	27.14	31.67	27.35
P150	40.8	29.45	21.46	CIRCULAR	675	Minor	1.73	1.79	3.36	3.41	24.90	20.17	24.91	20.18	27.14	20.62	27.35	20.64
P151	3.3	21.46	20.98	CIRCULAR	675	Minor	1.73	1.79	3.36	3.41	20.17	19.66	20.18	19.67	20.62	19.90	20.64	19.92
P152	155	20.98	7.78	CIRCULAR	750	Minor	1.73	1.79	3.36	3.41	19.66	6.39	19.67	6.41	19.90	7.00	19.92	7.01
P153	30.3	47.18	45.57	CIRCULAR	600	Minor	0.88	0.90	1.12	1.18	45.38	44.32	45.38	44.32	45.66	44.42	46.35	45.57
P154	10.5	7.78	6.69	CIRCULAR	1200	Minor	1.73	1.79	3.36	3.41	6.39	5.48	6.41	5.49	7.00	5.68	7.01	5.69
P155	86	45.57	38.93	CIRCULAR	525	Minor	0.88	0.90	1.12	1.16	44.32	36.25	44.32	36.25	44.42	36.27	45.57	36.27
P156	67	41.82	38.39	CIRCULAR	525	Minor	0.56	0.58	0.99	1.00	39.75	36.20	39.75	36.20	39.89	36.36	39.89	36.37
P157	36.5	5.08	4.68	CIRCULAR	800	Major	0.18	0.18	0.41	0.42	3.80	3.78	3.82	3.81	4.45	4.43	4.49	4.46
P158	46.5	38.39	35.66	CIRCULAR	525	Minor	0.56	0.58	0.99	1.00	36.20	33.69	36.20	33.70	36.36	33.77	36.37	33.78
P159	179.6	4.02	3.82	CIRCULAR	1800	Major	1.37	1.42	2.80	2.84	3.78	2.97	3.81	2.99	4.43	3.28	4.46	3.29
P160	175.6	3.70	3.93	CIRCULAR	1800	Major	2.16	2.21	3.28	3.32	3.78	2.98	3.81	3.00	4.43	3.29	4.46	3.29
P161	21.8	35.66	31.40	CIRCULAR	900	Minor	0.09	0.10	0.25	0.26	33.69	30.64	33.70	30.64	33.77	30.68	33.78	30.68
P162	45.3	35.66	32.81	CIRCULAR	525	Minor	0.47	0.48	0.73	0.74	33.69	31.22	33.70	31.23	33.77	31.33	33.78	31.34
P163	50	32.81	29.38	CIRCULAR	525	Minor	0.47	0.48	0.73	0.74	31.22	29.08	31.23	29.10	31.33	29.49	31.34	29.51
P164	21.9	47.23	43.21	CIRCULAR	600	Minor	0.56	0.58	0.96	0.98	43.18	42.30	43.18	42.30	43.31	42.34	43.32	42.34
P165	17.6	29.38	0.00	CIRCULAR	600	Major	0.47	0.48	0.73	0.74	29.08	0.00	29.10	0.00	29.49	0.00	29.51	0.00
P166	37.6	29.47	20.31	CIRCULAR	1050	Major	1.16	1.20	2.05	2.09	18.03	15.13	18.05	15.13	18.27	15.21	18.28	15.21
P167	52.3	8.14	5.94	CIRCULAR	1000	Major	0.65	0.67	1.14	1.16	5.90	5.23	5.92	5.24	6.43	5.33	6.46	5.33
P168	4.5	5.35	5.30	CIRCULAR	600	Major	0.65	0.67	1.01	1.04	3.20	2.95	3.21	2.96	3.96	3.64	4.01	3.67
P169	29.5	5.30	3.03	CIRCULAR	1200	Major	0.65	0.67	1.01	1.04	2.95	2.97	2.96	2.98	3.64	3.62	3.67	3.65
P170	37.4	5.34	5.07	CIRCULAR	1200	Major	1.02	1.04	1.88	1.91	4.82	4.08	4.83	4.11	5.39	4.96	5.43	4.97
P171	20	4.99	6.41	CIRCULAR	1000	Major	1.34	1.36	1.74	1.74	3.73	3.23	3.74	3.24	4.60	4.22	4.63	4.27
P172	38.5	6.41	3.15	CIRCULAR	1000	Major	1.34	1.36	2.56	2.62	3.23	2.99	3.24	3.00	4.22	3.62	4.27	3.65
P173	27.8	3.94	2.76	FILLED_CIRCULAR	1400	Major	1.87	1.91	3.12	3.18	2.96	2.86	2.98	2.87	3.62	3.28	3.65	3.30
P174	85.8	13.35	7.45	CIRCULAR	900	Minor	1.04	1.06	2.13	2.17	12.39	5.47	12.39	5.48	12.54	5.59	12.54	5.59
P175	73	41.69	37.29	CIRCULAR	600	Minor	0.54	0.55	1.01	1.02	40.75	35.93	40.75	35.93	40.85	36.03	40.86	36.03
P176	48.4	37.29	33.37	CIRCULAR	600	Minor	0.54	0.55	1.01	1.02	35.93	32.09	35.93	32.09	36.03	32.25	36.03	32.26
P177	7	33.37	32.69	CIRCULAR	750	Minor	1.35	1.38	2.45	2.48	32.09	31.56	32.09	31.56	32.25	31.73	32.26	31.74
P178	13.2	32.69	31.49	CIRCULAR	750	Minor	1.35	1.38	2.45	2.48	31.56	30.61	31.56	30.62	31.73	30.74	31.74	30.74

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

Pipe ID	Pipe Length (m)	U/S Rim Elevation (m)	D/S Rim Elevation (m)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m³/s)				Peak Hydraulic Grade Line (HGL, m)							
(SEE FIGURES)		(APPROX.)	(APPROX.)				Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing Upstream	A Existing Downstream	B Future Upstream	B Future Downstream	A Existing Upstream	A Existing Downstream	B Future Upstream	B Future Downstream
P179	32.4	2.93	1.83	CIRCULAR	1200	Major	2.72	2.76	4.00	4.05	2.86	2.63	2.87	2.64	3.28	2.79	3.30	2.79
P180	55.9	31.49	26.07	CIRCULAR	750	Minor	1.35	1.38	2.45	2.48	30.61	23.60	30.62	23.60	30.74	23.73	30.74	23.73
P181	14.8	26.07	24.78	CIRCULAR	750	Minor	1.35	1.38	2.45	2.48	23.60	21.95	23.60	21.96	23.73	22.08	23.73	22.09
P182	60.6	24.78	19.24	CIRCULAR	750	Minor	1.35	1.38	2.45	2.48	21.95	15.39	21.96	15.40	22.08	15.63	22.09	15.64
P183	27.5	43.30	41.69	CIRCULAR	600	Minor	0.54	0.55	1.01	1.02	42.30	40.75	42.31	40.75	42.42	40.85	42.42	40.86
P184	30.9	3.34	2.61	CIRCULAR	900	Major	0.86	0.86	0.99	0.98	3.20	2.86	3.21	2.87	3.64	3.28	3.65	3.30
P185	15.2	19.24	18.92	CIRCULAR	1200	Minor	1.35	1.38	2.45	2.48	15.39	14.57	15.40	14.57	15.63	14.74	15.64	14.75
P186	57.8	18.91	13.35	CIRCULAR	900	Minor	1.04	1.06	2.13	2.17	14.57	12.39	14.57	12.39	14.74	12.54	14.75	12.54
P187	53.4	46.39	43.30	CIRCULAR	600	Minor	0.66	0.67	1.13	1.14	45.00	42.30	45.00	42.31	45.13	42.42	45.13	42.42
P188	10.5	2.87	3.32	CIRCULAR	900	Major	0.45	0.45	0.52	0.52	3.54	3.50	3.55	3.51	3.95	3.91	3.96	3.92
P189	43.5	3.32	3.34	CIRCULAR	900	Major	0.81	0.81	0.85	0.85	3.50	3.20	3.51	3.21	3.91	3.64	3.92	3.65
P190	18.1	5.75	3.32	CIRCULAR	1000	Major	0.41	0.41	0.42	0.42	3.53	3.50	3.54	3.51	3.94	3.91	3.95	3.92
P191	28.7	3.65	3.34	CIRCULAR	900	Major	0.07	0.08	0.10	0.11	3.19	3.20	3.19	3.21	3.65	3.64	3.66	3.65
P192	28.5	43.30	43.31	CIRCULAR	600	Minor	0.12	0.12	0.12	0.12	42.30	40.71	42.31	40.71	42.42	40.71	42.42	40.71
P193	30.7	18.91	18.15	CIRCULAR	450	Minor	0.32	0.32	0.32	0.32	14.57	12.60	14.57	12.60	14.74	12.60	14.75	12.60
P194	30.7	5.34	3.66	CIRCULAR	900	Major	0.07	0.08	0.10	0.11	3.19	3.19	3.19	3.19	3.64	3.65	3.65	3.66
P195	46.6	3.11	3.33	CIRCULAR	900	Major	0.06	0.07	0.09	0.09	3.18	3.19	3.19	3.19	3.64	3.64	3.65	3.65
P196	26.6	6.22	6.13	CIRCULAR	1000	Major	0.48	0.48	0.63	0.63	3.57	3.53	3.58	3.54	3.98	3.94	3.99	3.95
P197	18.2	4.53	4.36	CIRCULAR	1000	Major	0.62	0.63	0.88	0.91	3.63	3.57	3.64	3.58	4.10	3.98	4.11	3.99
P198	108.7	40.04	34.28	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	37.83	30.42	37.83	30.42	37.89	30.49	37.89	30.49
P199	48	34.28	30.62	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	30.42	27.29	30.42	27.29	30.49	27.36	30.49	27.36
P200	66.7	30.62	26.23	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	27.29	23.83	27.29	23.83	27.36	23.89	27.36	23.89
P201	3.3	26.23	25.85	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	23.83	23.00	23.83	23.00	23.89	23.08	23.89	23.08
P202	28.1	25.84	24.04	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	23.00	21.82	23.00	21.82	23.08	21.89	23.08	21.89
P203	68.4	24.04	18.58	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	21.82	17.48	21.82	17.48	21.89	17.54	21.89	17.54
P204	34.5	18.58	16.22	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	17.48	14.54	17.48	14.54	17.54	14.60	17.54	14.60
P205	8.3	16.22	15.42	CIRCULAR	525	Minor	0.33	0.33	0.55	0.55	14.54	13.67	14.54	13.67	14.60	13.72	14.60	13.72
P206	61.7	15.42	8.51	CIRCULAR	600	Minor	0.33	0.33	0.55	0.55	13.67	7.23	13.67	7.24	13.72	7.28	13.72	7.28
P207	7.2	40.04	38.74	CIRCULAR	200	Minor	0.02	0.02	0.04	0.04	37.83	37.70	37.83	37.70	37.89	37.72	37.89	37.72
P208	30	8.51	6.44	CIRCULAR	600	Minor	0.33	0.33	0.55	0.55	7.23	4.24	7.24	4.24	7.28	6.44	7.28	6.21
P209	76.1	6.44	4.53	CIRCULAR	750	Minor	0.79	0.80	1.32	1.33	4.24	3.63	4.24	3.64	6.44	4.10	6.21	4.11
P210	24.9	4.61	4.53	CIRCULAR	1000	Major	0.22	0.23	0.59	0.59	3.63	3.63	3.63	3.64	4.03	4.10	4.04	4.11
P211	51.1	3.95	3.78	CIRCULAR	900	Major	0.11	0.12	0.21	0.22	3.05	3.18	3.06	3.19	3.64	3.64	3.65	3.65
P212	65.3	38.74	33.79	CIRCULAR	250	Minor	0.02	0.02	0.04	0.04	37.70	32.19	37.70	32.19	37.72	32.24	37.72	32.24
P213	20.6	33.79	31.52	CIRCULAR	150	Minor	0.02	0.02	0.04	0.04	32.19	30.69	32.19	30.69	32.24	30.71	32.24	30.71
P214	53	5.88	4.89	CIRCULAR	1000	Major	0.20	0.21	0.54	0.55	3.60	3.62	3.60	3.63	3.90	4.03	3.91	4.03
P215	32.9	5.58	7.60	CIRCULAR	1000	Major	0.19	0.19	0.53	0.53	3.34	3.59	3.34	3.60	3.72	3.90	3.73	3.90
P216	31	3.34	3.65	RECT_CLOSED	1450 x 971	Major	0.42	0.42	0.79	0.79	3.09	3.05	3.10	3.06	3.71	3.63	3.72	3.65
P217	33	3.34	3.65	RECT_CLOSED	610 x 600	Major	0.05	0.05	0.14	0.14	3.09	3.05	3.10	3.06	3.71	3.63	3.72	3.65
P218	23.2	3.58	4.44	CIRCULAR	1800	Major	0.66	0.68	1.15	1.16	3.05	3.04	3.06	3.05	3.63	3.63	3.65	3.64
P219	23.2	4.44	3.69	CIRCULAR	1050	Major	0.88	0.89	1.38	1.39	3.04	2.96	3.05	2.97	3.63	3.47	3.64	3.47
P220	91.1	3.69	3.60	CIRCULAR	1200	Major	1.15	1.17	1.73	1.74	2.96	2.70	2.97	2.71	3.47	2.86	3.47	2.86
P221	24.2	9.39	9.23	ARCH	1800 x 1200	Major	0.29	0.29	0.49	0.49	8.96	8.26	8.96	8.26	9.07	8.28	9.07	8.29

TABLE C-2
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Pipe ID	Pipe Length (m)	U/S Rim Elevation (m)	D/S Rim Elevation (m)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
(SEE FIGURES)		(APPROX.)	(APPROX.)				Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing	A Existing	B Future	B Future	A Existing	A Existing	B Future	B Future
											Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
P222	20.8	3.60	3.60	CIRCULAR	1200	Major	1.15	1.17	1.73	1.74	2.70	2.64	2.71	2.64	2.86	2.72	2.86	2.72
P223	16	3.60	2.59	CIRCULAR	1400	Major	1.15	1.17	1.73	1.74	2.64	2.63	2.64	2.63	2.72	2.69	2.72	2.70
P224	23.5	53.14	47.37	CIRCULAR	600	Major	0.00	0.00	0.00	0.00	48.39	46.75	48.40	46.75	48.47	46.75	48.48	46.75
P225	31.2	0.00	0.00	FILLED_CIRCULAR	1000	Major	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P226	29.8	0.00	0.00	FILLED_CIRCULAR	1200	Major	0.29	0.29	0.44	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P227	17.3	0.00	4.17	CIRCULAR	525	Major	0.30	0.31	0.42	0.43	0.00	4.03	0.00	4.05	0.00	4.81	0.00	4.84
P228	71.1	2.59	5.00	CIRCULAR	1400	Major	1.15	1.17	1.73	1.74	2.63	2.57	2.63	2.57	2.69	2.57	2.70	2.57
P229	18.6	3.85	3.76	CIRCULAR	600	Major	0.65	0.66	0.92	0.92	4.02	3.14	4.05	3.15	4.81	3.19	4.84	3.19
P230	13.4	42.58	42.39	CIRCULAR	600	Major	0.00	0.00	0.00	0.00	41.92	41.73	41.92	41.73	41.92	41.73	41.92	41.73
P231	50.3	0.00	4.10	CIRCULAR	900	Major	1.99	2.10	2.60	2.70	0.00	2.59	0.00	2.59	0.00	2.59	0.00	2.59
P232	28.8	38.90	41.16	CIRCULAR	600	Major	0.69	0.78	0.91	0.95	40.67	38.35	41.20	38.36	42.11	38.38	42.43	38.38
P233	57.1	40.48	40.12	CIRCULAR	450	Major	0.00	0.00	0.00	0.00	39.79	35.39	39.79	35.43	39.79	35.58	39.79	35.61
P234	18.9	0.00	8.60	CIRCULAR	1200	Major	2.96	3.21	4.70	4.95	0.00	8.37	0.00	8.39	0.00	8.46	0.00	8.47
P235	29.2	40.12	41.23	FILLED_CIRCULAR	3000	Major	2.20	2.49	3.54	3.82	35.39	34.38	35.43	34.41	35.58	34.49	35.61	34.51
P236	43	40.38	40.12	FILLED_CIRCULAR	3000	Major	2.20	2.49	3.54	3.82	36.55	35.39	36.59	35.43	36.74	35.58	36.78	35.61
P237	41.2	37.67	40.38	FILLED_CIRCULAR	3000	Major	1.12	1.23	1.65	1.72	37.69	36.55	37.71	36.59	37.78	36.74	37.79	36.78
P238	33	10.76	4.59	CIRCULAR	750	Major	0.62	0.63	1.11	1.12	4.27	3.44	4.28	3.44	4.96	3.52	4.98	3.52
P239	24.1	34.45	34.80	CIRCULAR	900	Major	0.62	0.73	1.12	1.26	33.49	32.68	33.55	32.70	33.70	32.94	33.85	33.15
P240	88.3	32.18	27.45	CIRCULAR	600	Minor	0.61	0.73	0.99	1.10	31.54	25.97	31.57	26.02	31.63	26.14	31.65	26.23
P241	21.4	27.45	26.57	CIRCULAR	600	Minor	0.61	0.73	0.99	1.09	25.97	24.16	26.02	24.18	26.14	24.21	26.23	24.22
P242	38	22.85	19.90	CIRCULAR	1050	Major	0.90	1.02	1.48	1.59	19.43	15.12	19.45	15.13	19.51	15.17	19.53	15.18
P243	38.5	5.07	2.64	CIRCULAR	1500	Major	1.84	1.95	2.76	2.85	3.00	2.60	3.03	2.60	3.22	2.60	3.24	2.60
P244	50.2	5.07	2.64	CIRCULAR	750	Major	0.24	0.27	0.59	0.62	3.00	2.60	3.03	2.60	3.22	2.60	3.24	2.60
P245	45.8	14.29	11.22	CIRCULAR	600	Minor	0.32	0.32	0.44	0.43	9.75	8.43	9.75	8.43	9.80	8.48	9.80	8.48
P246	6.2	14.32	14.29	CIRCULAR	450	Minor	0.32	0.32	0.44	0.43	9.99	9.75	9.99	9.75	10.13	9.80	10.13	9.80
P247	47.1	15.15	14.32	CIRCULAR	450	Minor	0.32	0.32	0.44	0.43	11.58	9.99	11.58	9.99	11.64	10.13	11.64	10.13
P248	79.2	15.72	15.15	CIRCULAR	450	Minor	0.32	0.32	0.44	0.43	12.94	11.58	12.94	11.58	13.67	11.64	13.65	11.64
P249	15.9	15.72	15.72	CIRCULAR	600	Minor	0.32	0.32	0.44	0.43	13.32	12.94	13.32	12.94	13.75	13.67	13.73	13.65
P250	9	16.74	15.72	CIRCULAR	600	Minor	0.32	0.32	0.44	0.44	13.76	13.32	13.76	13.32	13.84	13.75	13.84	13.73
P251	29	17.27	16.74	CIRCULAR	600	Minor	0.32	0.32	0.44	0.43	14.69	13.76	14.69	13.76	14.72	13.84	14.72	13.84
P252	84.7	20.14	17.27	CIRCULAR	525	Minor	0.32	0.32	0.44	0.43	17.33	14.69	17.33	14.69	17.38	14.72	17.38	14.72
P253	54.9	19.32	20.14	CIRCULAR	450	Minor	0.32	0.32	0.44	0.43	18.19	17.33	18.18	17.33	18.84	17.38	18.83	17.38
P254	20	0.00	19.32	CIRCULAR	450	Major	0.32	0.32	0.44	0.43	0.00	18.19	0.00	18.18	0.00	18.84	0.00	18.83
P255	15	5.40	0.00	CIRCULAR	1500	Minor	4.37	4.28	6.73	6.98	5.41	0.00	5.41	0.00	5.35	0.00	5.34	0.00
P256	58.8	7.80	5.40	CIRCULAR	1500	Minor	4.04	4.19	6.73	6.98	2.78	5.41	2.80	5.41	3.12	5.35	3.16	5.34
P257	12	7.36	7.81	CIRCULAR	1500	Minor	4.04	4.19	6.73	6.98	2.84	2.78	2.86	2.80	3.23	3.12	3.25	3.16
P258	80.3	7.50	7.36	CIRCULAR	1500	Minor	4.04	4.19	6.72	6.98	3.36	2.84	3.39	2.86	3.97	3.23	4.04	3.25
P259	5.3	7.86	7.50	CIRCULAR	900	Major	1.26	1.29	1.63	1.69	3.48	3.36	3.50	3.39	4.12	3.97	4.19	4.04
P260	38.8	6.92	7.50	CIRCULAR	1350	Major	2.78	2.90	5.09	5.28	4.04	3.36	4.07	3.39	5.18	3.97	5.33	4.04
P261	38.9	6.87	7.86	CIRCULAR	900	Major	1.26	1.29	1.63	1.69	4.07	3.48	4.10	3.50	5.20	4.12	5.35	4.19
P262	4.9	6.87	6.92	CIRCULAR	1500	Major	2.45	2.58	4.58	4.73	4.07	4.04	4.10	4.07	5.20	5.18	5.35	5.33
P263	69.9	7.16	6.87	CIRCULAR	1500	Minor	3.74	3.92	6.17	6.42	4.60	4.07	4.62	4.10	5.73	5.20	5.93	5.35
P264	112.3	19.09	17.56	CIRCULAR	900	Minor	0.74	0.87	1.30	1.45	16.66	15.51	16.71	15.56	16.87	15.85	17.46	16.75

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

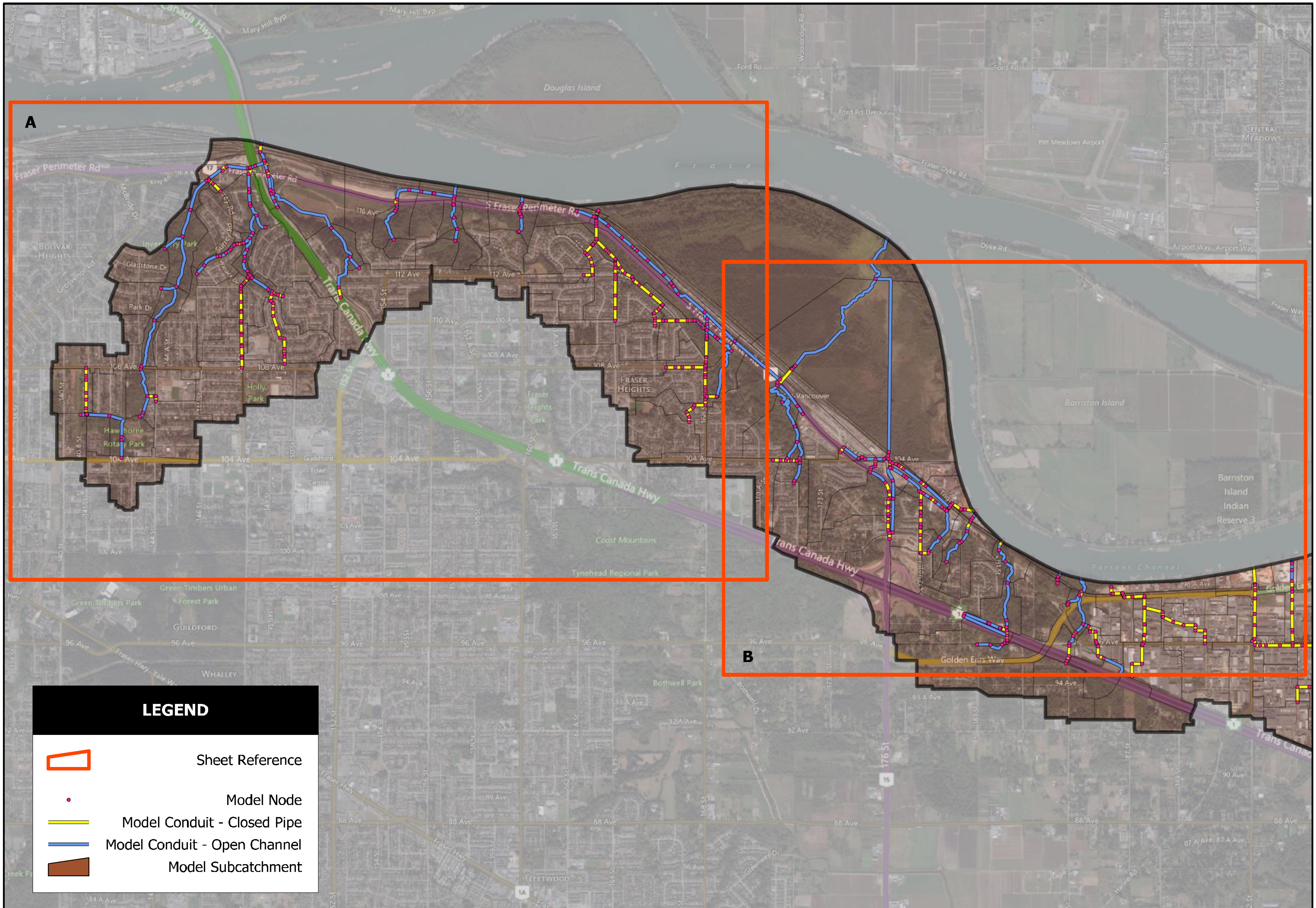
Pipe ID	Pipe Length (m)	U/S Rim Elevation (m)	D/S Rim Elevation (m)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
(SEE FIGURES)		(APPROX.)	(APPROX.)				Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing	A Existing	B Future	B Future	A Existing	A Existing	B Future	B Future
											Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
P265	2.5	18.84	19.09	CIRCULAR	900	Minor	0.74	0.87	1.30	1.45	18.25	16.66	18.26	16.71	18.30	16.87	18.31	17.46
P266	88.6	17.56	17.61	CIRCULAR	900	Minor	0.74	0.87	1.31	1.45	15.51	14.84	15.56	14.89	15.85	15.49	16.75	16.18
P267	106.7	7.80	7.16	CIRCULAR	1500	Minor	3.71	3.86	6.17	6.42	5.06	4.60	5.09	4.62	6.55	5.73	6.81	5.93
P268	162.6	17.61	16.37	CIRCULAR	900	Minor	0.74	0.87	1.33	1.45	14.84	13.72	14.89	13.77	15.49	14.67	16.18	15.15
P269	10.4	16.37	16.70	CIRCULAR	900	Minor	0.74	0.87	1.33	1.45	13.72	13.42	13.77	13.44	14.67	14.62	15.15	15.09
P270	19.6	16.70	16.82	CIRCULAR	900	Minor	0.74	0.87	1.33	1.45	13.42	12.94	13.44	12.98	14.62	14.52	15.09	14.96
P271	63.9	16.82	15.43	CIRCULAR	900	Minor	1.52	1.66	2.61	2.77	12.94	12.12	12.98	12.15	14.52	13.20	14.96	13.46
P272	89.4	8.88	7.77	CIRCULAR	1650	Minor	2.96	3.12	5.07	5.18	5.89	5.22	5.91	5.25	7.07	6.82	7.39	7.11
P273	6.5	15.43	15.33	CIRCULAR	900	Minor	1.52	1.66	2.61	2.77	12.12	12.04	12.15	12.07	13.20	13.07	13.46	13.31
P274	10.2	7.76	7.80	ARCH	1650 x 1000	Major	3.31	3.46	5.54	5.76	5.22	5.06	5.25	5.09	6.82	6.55	7.11	6.81
P275	3.9	8.94	8.88	CIRCULAR	1200	Minor	1.52	1.66	2.63	2.78	6.10	5.89	6.11	5.91	7.09	7.07	7.41	7.39
P276	144.1	15.48	8.94	CIRCULAR	900	Minor	1.52	1.66	2.61	2.78	10.49	6.10	10.51	6.11	10.64	7.09	10.71	7.41
P277	3.5	15.21	15.48	CIRCULAR	900	Minor	1.52	1.66	2.61	2.77	10.66	10.49	10.68	10.51	10.81	10.64	10.86	10.71
P278	90.5	15.33	15.21	CIRCULAR	900	Minor	1.52	1.66	2.61	2.77	12.04	10.66	12.07	10.68	13.07	10.81	13.31	10.86
P279	166	9.56	8.88	CIRCULAR	1200	Minor	1.44	1.47	2.53	2.54	6.79	5.89	6.80	5.91	7.67	7.07	8.03	7.39
P280	41.5	9.27	9.56	CIRCULAR	1050	Minor	0.85	0.92	1.58	1.63	6.95	6.79	6.98	6.80	7.77	7.67	8.14	8.03
P281	6.2	9.33	9.27	CIRCULAR	1050	Minor	1.06	1.05	1.54	1.67	7.05	6.95	7.05	6.98	7.78	7.77	8.15	8.14
P282	97.8	10.18	9.33	CIRCULAR	1050	Minor	0.85	0.86	1.50	1.54	7.34	7.05	7.35	7.05	8.02	7.78	8.41	8.15
P283	96.5	10.20	10.18	CIRCULAR	1050	Minor	0.84	0.85	1.46	1.52	7.71	7.34	7.71	7.35	8.26	8.02	8.67	8.41
P284	105.8	10.03	10.20	CIRCULAR	1050	Minor	0.84	0.85	1.40	1.51	8.16	7.71	8.16	7.71	8.45	8.26	8.95	8.67
P285	46.2	11.42	10.03	CIRCULAR	1050	Minor	0.84	0.85	1.41	1.47	8.41	8.16	8.41	8.16	8.61	8.45	9.07	8.95
P286	84.8	10.83	11.42	CIRCULAR	1050	Minor	0.84	0.85	1.41	1.43	8.76	8.41	8.76	8.41	8.95	8.61	9.28	9.07
P287	58	17.43	13.62	CIRCULAR	750	Minor	0.85	0.85	1.41	1.41	14.41	11.07	14.41	11.07	14.51	11.19	14.51	11.19
P288	55.9	13.62	10.83	CIRCULAR	750	Minor	0.85	0.85	1.41	1.41	11.07	8.76	11.07	8.76	11.19	8.95	11.19	9.28
P289	28.9	13.87	13.38	CIRCULAR	450	Minor	0.71	0.71	1.17	1.17	13.89	12.10	13.94	12.14	23.53	18.79	23.63	18.86
P290	155	9.41	0.00	CIRCULAR	1050	Minor	3.11	3.12	4.28	4.29	5.65	0.00	5.65	0.00	7.37	0.00	7.38	0.00
P291	122.3	13.38	10.99	CIRCULAR	1050	Minor	2.39	2.40	3.22	3.23	12.10	11.16	12.14	11.20	18.79	17.10	18.86	17.16
P292	97.6	10.99	10.55	CIRCULAR	1050	Minor	2.40	2.41	3.25	3.26	11.16	10.42	11.20	10.45	17.10	15.75	17.16	15.80
P293	53.5	14.11	13.38	CIRCULAR	1050	Minor	1.73	1.73	2.39	2.40	12.32	12.10	12.35	12.14	19.13	18.79	19.20	18.86
P294	136.5	10.55	9.97	CIRCULAR	1050	Minor	2.40	2.41	3.31	3.32	10.42	9.49	10.45	9.40	15.75	13.89	15.80	13.93
P295	9.6	9.52	9.41	CIRCULAR	900	Minor	3.01	3.02	4.12	4.13	6.18	5.65	6.19	5.65	7.86	7.37	7.88	7.38
P296	72.5	9.97	10.34	CIRCULAR	900	Minor	3.01	3.02	4.12	4.13	9.49	7.65	9.40	7.39	13.89	10.14	13.93	10.17
P297	44	10.34	9.52	CIRCULAR	900	Minor	3.01	3.02	4.12	4.13	7.65	6.18	7.39	6.19	10.14	7.86	10.17	7.88
P298	49	14.57	14.11	CIRCULAR	1050	Minor	1.49	1.49	2.13	2.13	12.47	12.32	12.50	12.35	19.35	19.13	19.42	19.20
P299	51.6	13.75	14.57	CIRCULAR	1050	Minor	1.49	1.49	2.08	2.09	12.60	12.47	12.63	12.50	19.58	19.35	19.66	19.42
P300	123.7	13.96	13.75	CIRCULAR	1050	Minor	1.49	1.49	2.01	2.01	12.90	12.60	12.94	12.63	20.15	19.58	20.23	19.66
P301	111.1	13.38	13.96	CIRCULAR	1050	Minor	1.49	1.50	1.93	1.93	13.38	12.90	13.23	12.94	20.67	20.15	20.75	20.23
P302	66.9	7.60	6.70	CIRCULAR	900	Minor	1.27	1.28	1.90	1.91	6.47	5.79	6.47	5.79	6.66	5.88	6.66	5.88
P303	110.5	8.07	7.64	CIRCULAR	675	Minor	0.81	0.82	1.18	1.19	8.38	7.64	8.39	7.64	10.46	8.28	10.48	8.29
P304	29.1	7.46	7.60	CIRCULAR	900	Minor	1.27	1.28	1.90	1.91	6.69	6.47	6.69	6.47	6.95	6.66	6.95	6.66
P305	72	7.64	7.46	CIRCULAR	675	Minor	0.81	0.82	1.19	1.19	7.64	6.69	7.64	6.69	8.28	6.95	8.29	6.95
P306	153.5	9.41	8.07	CIRCULAR	600	Minor	0.81	0.82	1.18	1.19	11.06	8.38	11.10	8.39	16.17	10.46	16.23	10.48
P307	16.4	9.42	9.41	CIRCULAR	600	Minor	0.82	0.82	1.19	1.20	11.35	11.06	11.39	11.10	16.78	16.17	16.84	16.23

TABLE C-2
PCSWMM - PIPE RESULTS; PEAK FLOW / HYDRAULIC GRADE LINE

Pipe ID	Pipe Length (m)	U/S Rim Elevation (m)	D/S Rim Elevation (m)	Conduit Shape	Pipe Size (mm)	Major / Minor System	Peak Flow (m^3/s)				Peak Hydraulic Grade Line (HGL, m)							
(SEE FIGURES)		(APPROX.)	(APPROX.)				Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS				Scenario 2 100-Year ADS			
							A Existing	B Future	A Existing	B Future	A Existing	A Existing	B Future	B Future	A Existing	A Existing	B Future	B Future
											Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
P308	97.3	13.63	9.42	CIRCULAR	600	Minor	0.89	0.89	1.20	1.21	13.48	11.35	13.12	11.39	20.44	16.78	20.52	16.84
P309	23.6	13.38	13.63	CIRCULAR	900	Minor	0.89	0.89	1.22	1.23	13.38	13.48	13.23	13.12	20.67	20.44	20.75	20.52
P310	85.6	14.09	13.38	CIRCULAR	1050	Minor	2.27	2.28	3.09	3.10	13.74	13.38	13.79	13.23	21.74	20.67	21.83	20.75
P311	135.3	16.28	17.34	CIRCULAR	900	Minor	0.75	0.83	1.12	1.13	16.57	17.34	16.64	17.34	27.67	27.18	27.80	27.30
P312	105.4	17.34	16.33	CIRCULAR	900	Minor	1.17	1.17	1.82	1.82	17.34	16.27	17.34	16.33	27.18	26.22	27.30	26.33
P313	27.5	13.46	14.09	CIRCULAR	1050	Minor	1.74	1.76	2.35	2.36	13.83	13.74	13.88	13.79	21.94	21.74	22.02	21.83
P314	119.4	15.00	13.46	CIRCULAR	1050	Minor	1.72	1.73	2.32	2.32	14.76	13.83	15.00	13.88	22.78	21.94	22.87	22.02
P315	93.4	16.33	15.39	CIRCULAR	900	Minor	1.17	1.17	1.76	1.76	16.27	15.54	16.33	15.60	26.22	25.39	26.33	25.49
P316	49.3	4.62	0.00	CIRCULAR	900	Minor	0.87	0.87	1.44	1.44	3.33	0.00	3.33	0.00	3.56	0.00	3.56	0.00
P317	121.7	13.99	15.00	CIRCULAR	1050	Minor	1.72	1.90	2.30	2.31	14.68	14.76	14.74	15.00	23.64	22.78	23.74	22.87
P318	131.2	6.07	4.62	CIRCULAR	900	Minor	0.38	0.38	0.62	0.62	4.49	3.33	4.49	3.33	4.57	3.56	4.57	3.56
P319	113.4	9.16	6.07	CIRCULAR	900	Minor	0.38	0.38	0.62	0.62	5.01	4.49	5.01	4.49	5.13	4.57	5.13	4.57
P320	128.2	14.60	13.99	CIRCULAR	1050	Minor	1.62	1.86	2.37	2.37	15.13	14.68	15.20	14.74	24.55	23.64	24.65	23.74
P321	115.2	15.39	14.60	CIRCULAR	1050	Minor	1.64	1.64	2.46	2.47	15.54	15.13	15.60	15.20	25.39	24.55	25.49	24.65
P322	9.9	8.54	8.34	CIRCULAR	600	Minor	0.38	0.38	0.62	0.62	5.52	5.16	5.52	5.16	5.78	5.24	5.78	5.24
P323	13	8.59	8.54	CIRCULAR	600	Minor	0.38	0.38	0.62	0.62	5.62	5.52	5.62	5.52	5.92	5.78	5.92	5.78
P324	12	7.72	8.59	CIRCULAR	600	Minor	0.38	0.38	0.62	0.62	5.69	5.62	5.69	5.62	6.05	5.92	6.05	5.92

PCSWMM MODEL RESULTS SUMMARY

OPEN CHANNELS



0 2 km

SEE RESULTS TABLE C-3

PREPARED BY:

Associated Engineering

PREPARED FOR:

City of Surrey

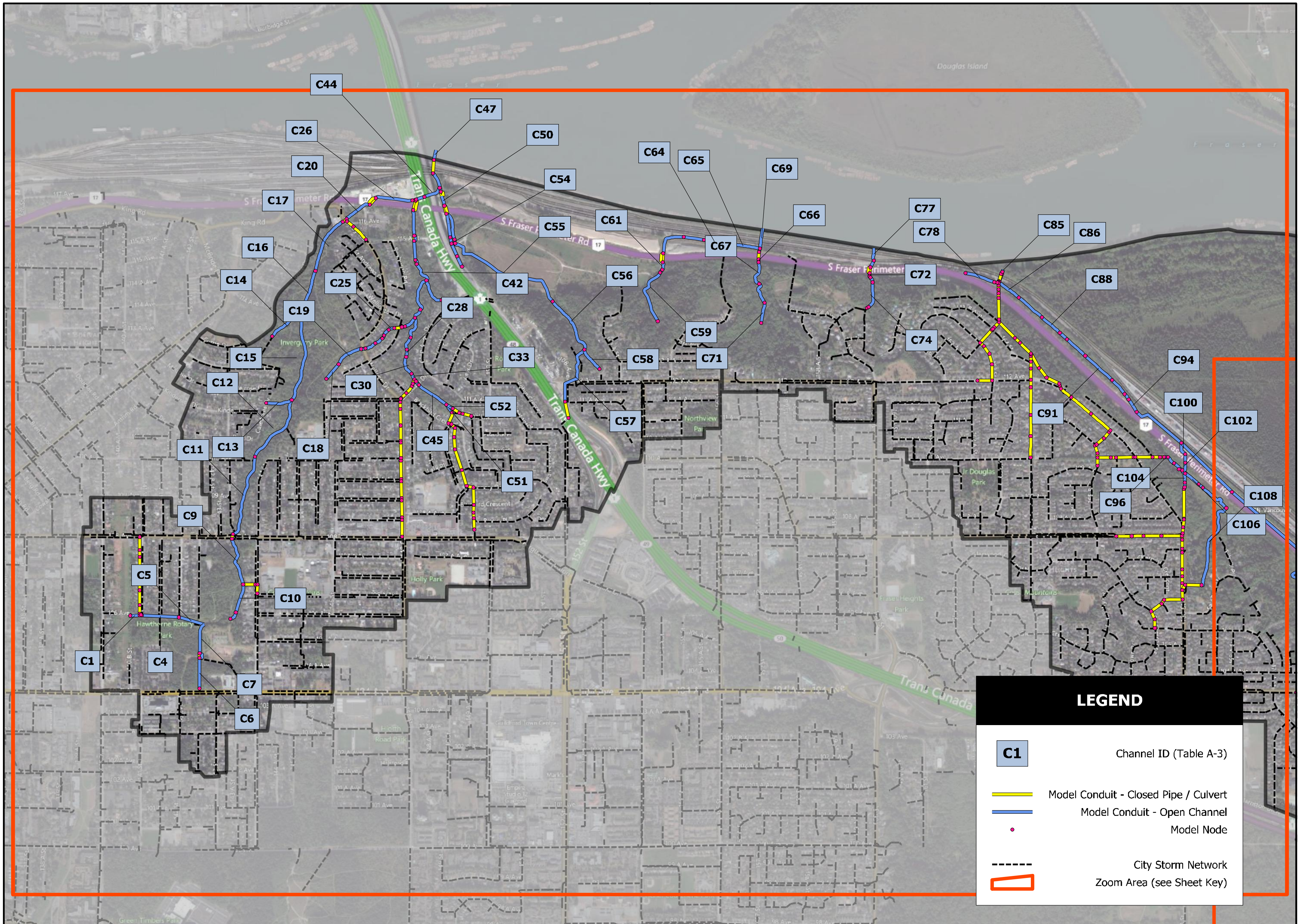
LINK (CHANNEL) REPORTING - SHEET KEY

BON ACCORD - NORTH SLOPE (EAST) ISMP

APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



SEE RESULTS TABLE C-3

PREPARED BY: Associated Engineering

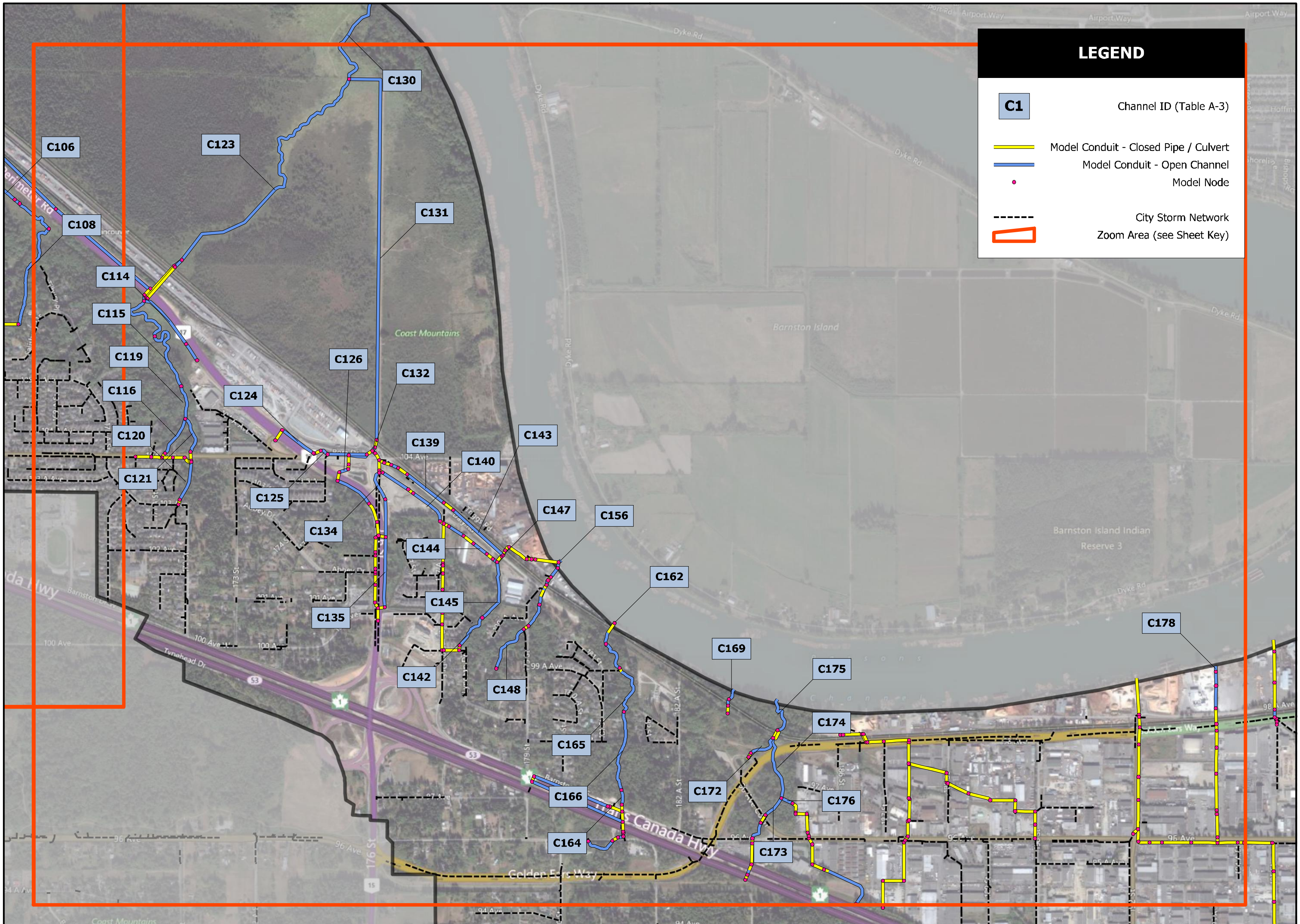
PREPARED FOR: City of Surrey

LINK REPORTING (CHANNEL) - SHEET A

BON ACCORD - NORTH SLOPE (EAST) ISMP
APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015



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SEE RESULTS TABLE C-3

PREPARED BY: Associated Engineering

PREPARED FOR: City of Surrey

LINK REPORTING (CHANNEL) - SHEET B

BON ACCORD - NORTH SLOPE (EAST) ISMP

APPENDIX C

PROJECT No.: 20132512

DATE: MAY 2015

TABLE C-3
PCSWMM - OPEN CHANNEL RESULTS; PEAK FLOW, VELOCITY, DEPTH

Channel ID	Description	Length (m)	Peak Flow (m^3/s)				Maximum Velocity (m/s)				Max Depth (m)			
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS	
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future
C1	Hawthorne Creek	49.6	0.3	0.308	0.531	0.54	0.24	0.24	0.27	0.28	0.45	0.45	0.65	0.65
C2	Hawthorne Creek	10.9	0.861	0.891	1.544	1.578	0.29	0.29	0.35	0.36	0.75	0.8	1	1.05
C3	Hawthorne Connection	5.0	0.193	0.197	0.313	0.317	0.12	0.13	0.14	0.14	0.8	0.8	1.05	1.05
C4	Hawthorne Creek	195.3	1.026	1.059	1.822	1.856	0.26	0.27	0.32	0.33	0.9	0.9	1.15	1.15
C5	Hawthorne Connection	49.8	0.999	1.033	1.782	1.809	0.19	0.19	0.24	0.25	1.05	1.05	1.25	1.3
C6	Bon Accord Creek	158.9	0.803	0.823	1.378	1.402	0.3	0.3	0.44	0.45	0.55	0.55	0.65	0.65
C7	Bon Accord Creek	157.3	0.799	0.819	1.365	1.387	0.52	0.52	0.55	0.55	0.4	0.45	0.65	0.65
C8	Bon Accord Creek	47.2	2.375	2.456	4.265	4.262	0.83	0.84	1.03	1.03	0.7	0.7	0.9	0.9
C9	Bon Accord Creek	245.6	2.939	3.042	5.405	5.476	0.75	0.75	0.73	0.73	1.3	1.35	2.8	2.85
C10	Bon Accord Creek	154.0	2.379	2.459	4.399	4.395	1.05	1.06	1.23	1.23	0.6	0.6	1.05	1.1
C11	Bon Accord Creek	441.9	3.22	3.308	4.939	4.993	2.56	2.58	2.86	2.87	0.4	0.4	0.5	0.5
C12	Bon Accord Creek	378.6	3.522	3.62	5.491	5.557	2.54	2.56	2.84	2.84	0.45	0.45	0.55	0.55
C13	Bon Accord Creek Tributary	138.6	0.389	0.399	0.664	0.675	0.59	0.6	0.73	0.74	0.25	0.25	0.35	0.35
C14	Bon Accord Creek Tributary	204.3	0.458	0.468	0.804	0.815	0.58	0.59	0.72	0.73	0.3	0.3	0.35	0.4
C15	Bon Accord Creek	461.5	4.073	4.183	6.475	6.558	2.66	2.68	3.01	3.02	0.45	0.45	0.6	0.6
C16	Bon Accord Creek	244.7	4.521	4.64	7.27	7.366	2.54	2.56	2.87	2.89	0.5	0.5	0.65	0.65
C17	Bon Accord Creek	303.9	4.928	5.048	8.057	8.156	4.38	4.41	4.99	5.01	0.35	0.35	0.45	0.5
C18	Wallace Creek	99.4	0.64	0.67	1.131	1.173	1.4	1.42	1.74	1.76	0.1	0.1	0.15	0.15
C19	Wallace Creek	150.3	0.659	0.689	1.15	1.192	1.91	1.95	2.38	2.41	0.1	0.1	0.1	0.1
C20	Bon Accord Creek	148.1	5.525	5.658	9.101	9.218	3.32	3.33	3.49	3.5	0.5	0.5	0.65	0.65
C21	Wallace Creek	63.0	0.698	0.729	1.19	1.232	1.65	1.67	2.02	2.05	0.1	0.1	0.15	0.15
C22	Wallace Creek	46.4	0.718	0.749	1.209	1.251	1.91	1.94	2.33	2.36	0.1	0.1	0.15	0.15
C23	Wallace Creek	17.2	0.738	0.769	1.229	1.271	2.06	2.09	2.51	2.54	0.1	0.1	0.1	0.1
C24	Wallace Creek	39.6	0.758	0.789	1.249	1.291	2.07	2.1	2.52	2.55	0.1	0.1	0.1	0.1
C25	Wallace Creek	32.0	0.778	0.809	1.269	1.311	1.22	1.24	1.5	1.52	0.15	0.15	0.2	0.2
C26	Bon Accord Creek	194.3	5.559	5.693	9.13	9.247	1.17	1.18	1.25	1.26	0.95	1	1.3	1.3
C27	Wallace Creek	16.5	1.15	1.186	1.877	1.924	2.06	2.08	2.48	2.5	0.15	0.15	0.2	0.2
C28	East Bon Accord Creek	39.9	4.1	4.22	6.712	6.84	2.94	2.97	3.5	3.52	0.3	0.3	0.3	0.3
C29	East Bon Accord Creek	71.3	4.119	4.239	6.732	6.859	3.06	3.09	3.64	3.66	0.2	0.2	0.3	0.3
C30	East Bon Accord Creek	103.0	4.08	4.203	6.693	6.821	2.69	2.72	3.2	3.22	0.3	0.3	0.4	0.4
C31	Wallace Creek	70.8	1.17	1.206	1.896	1.944	1.1	1.12	1.32	1.33	0.25	0.25	0.35	0.35
C32	East Bon Accord Creek	121.7	4.138	4.257	6.75	6.878	2.42	2.44	2.87	2.88	0.3	0.3	0.4	0.4
C33	East Bon Accord Creek	33.1	4.061	4.186	6.674	6.801	2.34	2.37	2.79	2.8	0.3	0.3	0.4	0.4
C34	East Bon Accord Creek	134.6	6.029	6.203	9.132	9.292	0.56	0.56	0.55	0.55	2.05	2.15	3.65	3.75
C35	Open Flume	24.7	1.643	1.707	2.54	2.592	4.3	4.34	4.75	4.77	0.318	0.33	0.444	0.45
C36	East Bon Accord Creek	99.7	6.122	6.294	9.801	9.992	0.65	0.65	0.62	0.62	2.25	2.3	3.3	3.4
C37	East Bon Accord Creek	13.7	2.418	2.482	4.134	4.21	1.41	1.42	1.72	1.73	0.3	0.3	0.4	0.4
C38	Bon Accord Creek	10.0	5.811	5.947	9.516	9.636	0.79	0.79	0.93	0.93	1.2	1.25	1.5	1.5
C39	East Bon Accord Creek	10.0	6.366	6.551	9.551	9.703	1.05	1.06	1.14	1.15	1.05	1.1	1.35	1.35
C40	East Bon Accord Creek	57.2	5.455	5.613	8.89	9.069	2.64	2.66	3.11	3.13	0.35	0.35	0.5	0.5
C41	Bon Accord Creek	45.4	12.157	12.483	18.98	19.246	1.74	1.76	1.95	1.95	1.15	1.2	1.45	1.45
C42	East Bon Accord Creek	112.0	6.185	6.35	10.095	10.298	3.2	3.21	3.34	3.34	0.75	0.8	1.55	1.55
C43	East Bon Accord Creek	183.3	5.473	5.63	8.907	9.085	1.58	1.6	1.84	1.85	0.55	0.55	0.75	0.75
C44	Bon Accord Creek	98.0	12.175	12.501	18.977	19.223	1.46	1.47	1.59	1.59	1.3	1.3	1.65	1.65
C45	East Bon Accord Creek	177.2	2.082	2.14	3.557	3.626	1.47	1.49	1.81	1.83	0.15	0.15	0.2	0.2
C46	East Bon Accord Creek Tributary	146.8	0.698	0.717	1.196	1.217	0.17	0.17	0.21	0.21	0.4	0.4	0.55	0.55
C47	Bon Accord Creek	53.2	13.928	14.253	21.554	21.913	0.67	0.69	1.03	1.05	2.25	2.25	2.25	2.25
C48	Bon Accord Creek	85.7	13.04	13.362	20.209	20.568	0.76	0.77	0.85	0.85	2	2	2.45	2.45
C49	Landfill Creek	21.9	1.224	1.235	2.499	2.552	0.13	0.13	0.19	0.19	1.65	1.65	2.1	2.1
C50	Landfill Creek	53.1	2.737	2.766	5.16	5.212	0.22	0.22	0.29	0.3	2.05	2.05	2.45	2.5
C51	East Bon Accord Creek	49.6	1.549	1.59	2.638	2.688	2.93	2.96	3.43	3.45	0.3	0.3	0.42	0.42
C52	East Bon Accord Creek	39.0	0.535	0.551	0.921	0.94	2.35	2.37	2.77	2.79	0.2	0.2	0.3	0.3
C53	Landfill Creek	149.0	1.877	1.917	3.239	3.287	0.48	0.48	0.59	0.59	1.15	1.15	1.5	1.5
C54	Landfill Creek	18.8	1.879	1.918	3.241	3.288	1.51	1.52	1.76	1.77	0.4	0.4	0.5	0.5
C55	Landfill Creek	653.6	1.882	1.921	3.245	3.292	1.66	1.67	1.94	1.95	0.35	0.35	0.5	0.5
C56	Landfill Creek	323.4	1.383	1.418	2.391	2.434	1.4	1.41	1.64	1.65	0.35	0.35	0.45	0.45
C57	Landfill Creek	336.7	0.513	0.52	0.866	0.874	1.35	1.35	1.59	1.59	0.15	0.15	0.2	0.2
C58	Landfill Creek Tributary	131.3	0.874	0.902	1.53	1.564	2.23	2.26	2.68	2.7	0.15	0.15	0.2	0.2
C59	157 Street Creek Tributary	312.5	0.161	0.161	0.273	0.274	0.7	0.71	0.86	0.86	0.05	0.05	0.1	0.1

TABLE C-3
PCSWMM - OPEN CHANNEL RESULTS; PEAK FLOW, VELOCITY, DEPTH

Channel ID	Description	Length (m)	Peak Flow (m^3/s)				Maximum Velocity (m/s)				Max Depth (m)			
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS	
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future
C60	157 Street Creek Tributary	18.5	0.16	0.161	0.273	0.274	1.12	1.12	1.35	1.36	0.05	0.05	0.1	0.1
C61	157 Street Creek Tributary	41.8	0.16	0.161	0.273	0.273	0.06	0.06	0.08	0.08	0.4	0.4	0.55	0.55
C62	157 Street Creek Tributary	172.1	0.949	0.962	1.571	1.585	0.4	0.41	0.47	0.47	0.3	0.3	0.8	0.8
C63	157 Street Creek Tributary	106.9	1.37	1.381	2.149	2.161	0.46	0.46	0.44	0.44	0.55	0.55	1.15	1.15
C64	157 Street Creek Tributary	107.1	1.263	1.271	1.882	1.891	0.17	0.17	0.17	0.17	0.9	0.9	1.5	1.5
C65	157 Street Creek Tributary	179.6	1.511	1.521	2.28	2.29	0.62	0.62	0.71	0.71	0.25	0.25	0.35	0.35
C66	157 Street Creek	14.3	0.478	0.481	0.823	0.826	0.25	0.25	0.31	0.31	0.35	0.35	0.45	0.45
C67	157 Street Creek	132.9	0.478	0.481	0.823	0.827	1.38	1.38	1.67	1.67	0.1	0.1	0.1	0.1
C68	157 Street Creek	19.7	0.64	0.643	1.102	1.106	0.4	0.4	0.5	0.5	0.3	0.3	0.4	0.4
C69	157 Street Creek	106.3	2.729	2.743	4.355	4.37	0.2	0.2	0.31	0.31	1.3	1.35	1.35	1.35
C70	157 Street Creek	116.7	0.479	0.482	0.824	0.827	1.18	1.18	1.42	1.42	0.1	0.1	0.15	0.15
C71	157 Street Creek	107.1	0.256	0.258	0.438	0.44	0.72	0.72	0.89	0.89	0.05	0.05	0.1	0.1
C72	160 Street Creek	17.8	0.696	0.702	1.191	1.198	0.77	0.77	0.99	0.99	0.3	0.3	0.35	0.35
C73	160 Street Creek	6.4	0.394	0.4	0.679	0.686	1.12	1.13	1.38	1.39	0.1	0.15	0.15	0.15
C74	160 Street Creek	137.9	0.395	0.401	0.68	0.687	1.55	1.56	1.89	1.89	0.1	0.1	0.15	0.15
C75	160 Street Creek	29.6	0.394	0.4	0.679	0.686	1.14	1.15	1.45	1.46	0.1	0.1	0.15	0.15
C76	160 Street Creek	40.2	0.695	0.702	1.191	1.198	1.82	1.82	2.17	2.17	0.15	0.15	0.2	0.2
C77	160 Street Creek	67.4	0.695	0.701	1.19	1.197	0.11	0.11	0.18	0.18	1.3	1.3	1.3	1.3
C78	Lowland Ditch	158.5	0.318	0.319	0.47	0.469	0.34	0.34	0.37	0.37	0.25	0.25	0.75	0.8
C79	Ditch	6.7	0.779	0.444	1.838	1.853	0.09	0.05	0.14	0.14	1.75	1.8	2.5	2.5
C80	Ditch	4.2	4.619	4.677	7.782	7.747	0.35	0.35	0.43	0.43	2.15	2.2	2.85	2.9
C81	Ditch	4.8	4.065	4.152	8.008	8.301	0.27	0.28	0.31	0.31	2.15	2.2	2.85	2.9
C82	Ditch	4.9	4.03	4.114	8.226	8.582	0.28	0.28	0.32	0.32	2.15	2.2	2.9	2.9
C83	Ditch	7.9	3.986	4.096	6.707	6.825	0.21	0.22	0.36	0.37	2.35	2.35	2.4	2.4
C84	Ditch	8.2	3.983	4.093	6.704	6.825	0.21	0.22	0.36	0.37	2.35	2.35	2.4	2.4
C85	Ditch	10.0	7.965	8.188	13.394	13.636	0.36	0.37	0.6	0.61	2.4	2.4	2.4	2.4
C86	Lowland Ditch	132.4	3.983	4.111	7.284	7.476	0.4	0.4	0.42	0.43	1.7	1.75	2.4	2.45
C87	Lowland Ditch	158.8	3.861	3.979	6.941	7.108	0.8	0.8	0.76	0.76	1.1	1.1	1.75	1.8
C88	Lowland Ditch	124.1	3.821	3.935	6.737	6.882	1	1.01	0.98	0.98	0.9	0.9	1.4	1.45
C89	Lowland Ditch	50.9	3.821	3.934	6.685	6.82	0.81	0.82	0.88	0.88	0.85	0.85	1.25	1.25
C90	Lowland Ditch	128.8	3.823	3.936	6.648	6.776	0.93	0.94	1.02	1.02	0.75	0.75	1.1	1.1
C91	Lowland Ditch	188.3	3.828	3.941	6.65	6.776	0.99	1	1.13	1.13	0.7	0.7	1	1
C92	Lowland Ditch	99.4	3.83	3.942	6.653	6.779	0.98	0.99	1.15	1.16	0.7	0.75	0.95	1
C93	Lowland Ditch	35.5	3.598	3.71	6.27	6.396	0.93	0.94	1.1	1.1	0.7	0.7	0.95	0.95
C94	Lowland Ditch	77.4	3.598	3.71	6.269	6.394	0.92	0.93	1.08	1.09	0.7	0.75	0.95	1
C95	Lowland Ditch	298.1	3.607	3.718	6.277	6.402	0.87	0.88	1.03	1.03	0.75	0.75	1	1
C96	Lowland Ditch	20.1	0.347	0.354	0.648	0.655	0.43	0.43	0.51	0.51	0.5	0.5	0.7	0.7
C97	Lowland Ditch	45.3	0.347	0.353	0.646	0.654	0.39	0.39	0.46	0.47	0.55	0.55	0.75	0.75
C98	Lowland Ditch	43.8	0.346	0.353	0.647	0.654	0.34	0.34	0.42	0.42	0.6	0.6	0.8	0.8
C99	Lowland Ditch	18.9	0.551	0.563	1.018	1.032	0.52	0.53	0.65	0.65	0.6	0.6	0.8	0.85
C100	Lowland Ditch	67.9	3.639	3.748	6.318	6.442	0.38	0.39	0.42	0.42	0.7	0.7	0.95	0.95
C101	Lowland Ditch	23.6	3.126	3.22	5.359	5.47	0.43	0.43	0.48	0.48	0.6	0.6	0.8	0.8
C102	Lowland Ditch	53.1	3.665	3.773	6.357	6.48	0.52	0.53	0.58	0.58	0.55	0.6	0.8	0.8
C103	Lowland Ditch	23.3	1.725	1.791	3.357	3.407	0.58	0.58	0.63	0.64	0.3	0.35	0.55	0.55
C104	Lowland Ditch	48.5	1.72	1.786	3.348	3.398	0.34	0.34	0.39	0.39	0.45	0.45	0.7	0.7
C105	Lowland Ditch	45.5	3.655	3.762	6.34	6.464	0.53	0.53	0.56	0.57	0.6	0.6	0.85	0.85
C106	Lowland Ditch	92.5	1.411	1.439	2.021	2.08	0.78	0.79	0.89	0.89	0.32	0.32	0.4	0.4
C107	Lowland Ditch	27.8	1.255	1.281	1.738	1.796	0.61	0.62	0.7	0.71	0.36	0.36	0.4	0.4
C108	Lowland Ditch	467.8	0.897	0.917	1.144	1.181	1	1.01	1.09	1.09	0.25	0.25	0.3	0.3
C109	Lowland Ditch	181.1	1.256	1.281	1.732	1.791	0.67	0.68	0.75	0.76	0.32	0.32	0.36	0.4
C110	Lowland Ditch	25.6	0.187	0.195	0.436	0.452	0.05	0.04	0.06	0.06	1	1	1.65	1.65
C111	Lowland Ditch	17.1	1.372	1.422	2.806	2.849	0.16	0.16	0.18	0.18	1.25	1.3	1.9	1.95
C112	Lowland Ditch	18.3	1.422	1.45	2.05	2.077	0.32	0.32	0.31	0.31	1.25	1.3	1.9	1.95
C113	Centre Creek Tributary	293.0	1.848	1.92	3.44	3.511	0.34	0.35	0.39	0.39	0.75	0.75	1.1	1.15
C114	Lowland Ditch	261.1	0.326	0.327	0.542	0.543	0.17	0.17	0.18	0.18	0.75	0.75	1.1	1.1
C115	Centre Creek Tributary	358.7	1.255	1.307	2.3	2.355	0.94	0.95	1.15	1.16	0.25	0.25	0.35	0.35
C116	Centre Creek Tributary	173.3	0.093	0.1	0.25	0.26	0.37	0.39	0.61	0.63	0.12	0.12	0.2	0.2
C117	Centre Creek	39.9	1.36	1.41	2.787	2.831	0.36	0.37	0.45	0.45	0.75	0.75	1.05	1.05
C118	Centre Creek	41.4	2.142	2.194	3.263	3.308	0.48	0.48	0.5	0.5	0.9	0.9	1.2	1.2

TABLE C-3
PCSWMM - OPEN CHANNEL RESULTS; PEAK FLOW, VELOCITY, DEPTH

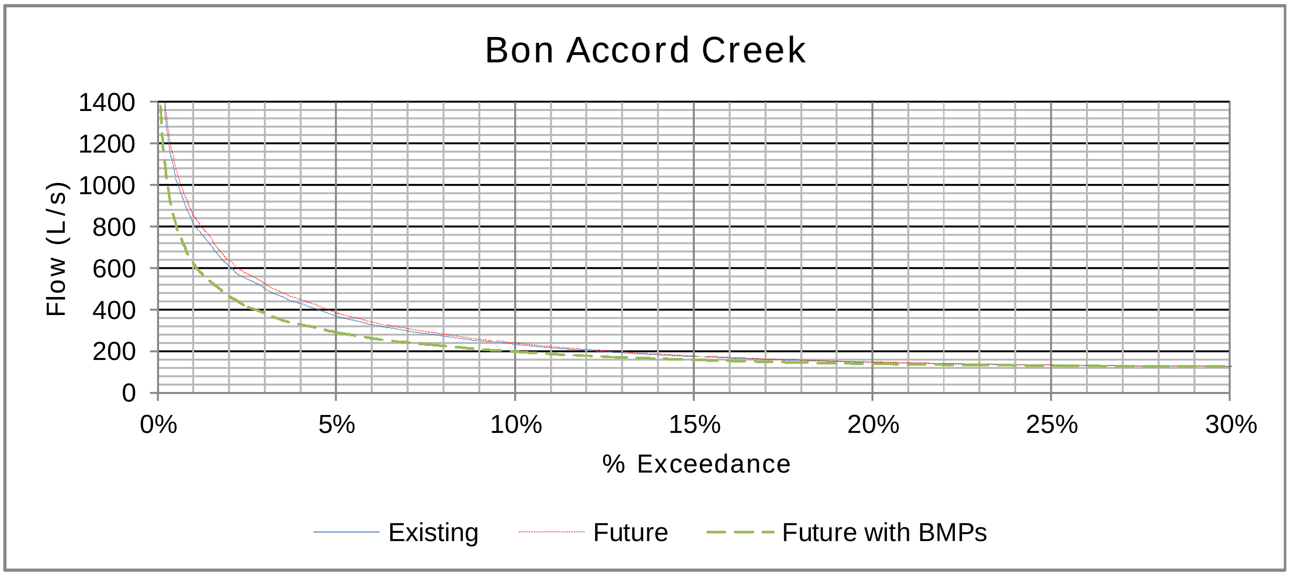
Channel ID	Description	Length (m)	Peak Flow (m^3/s)				Maximum Velocity (m/s)				Max Depth (m)			
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS	
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future
C119	Centre Creek Tributary	143.5	1.251	1.304	2.297	2.352	1.06	1.08	1.31	1.32	0.2	0.2	0.3	0.3
C120	Ditch	163.7	0.559	0.576	0.962	0.981	0.09	0.09	0.13	0.13	1.32	1.32	1.48	1.48
C121	Centre Creek Tributary	158.6	1.159	1.204	2.045	2.089	1.01	1.02	1.21	1.22	0.2	0.2	0.3	0.3
C122	Lowland Ditch	82.6	0.327	0.328	0.543	0.544	0.89	0.89	1.03	1.03	0.2	0.2	0.3	0.3
C123	Centre Creek	1157.3	3.389	3.49	5.95	6.04	0.38	0.39	0.55	0.55	1.5	1.5	1.7	1.7
C124	Ditch	163.6	0.651	0.672	1.138	1.162	0.78	0.78	0.82	0.82	0.4	0.4	0.8	0.85
C125	Lowland Ditch	34.9	0.641	0.662	0.989	1.014	0.26	0.27	0.29	0.29	0.8	0.85	1.45	1.5
C126	Ditch	40.8	1.005	1.031	1.842	1.87	0.51	0.51	0.58	0.58	0.85	0.9	1.75	1.75
C127	Lowland Ditch	166.5	0.6	0.62	0.86	0.882	0.14	0.14	0.16	0.16	1	1	1.65	1.65
C128	Ditch	166.8	1.031	1.06	2.126	2.162	0.37	0.37	0.43	0.44	0.4	0.4	0.75	0.75
C129	Lowland Ditch	81.2	1.341	1.365	2.507	2.559	0.4	0.4	0.4	0.39	0.95	0.95	1.6	1.6
C130	Centre Creek	437.5	7.905	8.047	13.022	13.169	0.46	0.47	0.73	0.74	2.3	2.3	2.35	2.35
C131	Ditch	1652.9	2.886	2.922	4.249	4.302	0.21	0.21	0.28	0.28	2	2	2.15	2.15
C132	Ditch	18.5	2.722	2.76	3.996	4.05	0.14	0.14	0.15	0.15	2.1	2.1	2.5	2.5
C133	Ditch	15.8	0.865	0.863	0.975	0.969	0.09	0.09	0.09	0.09	2.15	2.15	2.55	2.55
C134	Ditch	128.7	0.435	0.435	0.474	0.475	0.15	0.15	0.13	0.12	1	1	1.35	1.35
C135	Ditch	296.1	0.12	0.12	0.12	0.12	0.82	0.82	0.81	0.81	0.1	0.1	0.1	0.1
C136	Ditch	159.7	0.435	0.435	0.438	0.438	1.7	1.71	1.7	1.7	0.15	0.15	0.3	0.3
C137	Ditch	31.9	0.068	0.072	0.085	0.089	0.05	0.05	0.05	0.05	0.8	0.85	1.25	1.3
C138	Ditch	128.7	0.426	0.427	0.521	0.523	0.09	0.09	0.09	0.09	1.55	1.55	1.95	1.95
C139	Ditch	195.7	0.065	0.064	0.128	0.128	0.18	0.17	0.16	0.16	0.5	0.55	1	1
C140	Ditch	172.0	0.561	0.566	0.757	0.762	0.34	0.34	0.32	0.32	1.05	1.05	1.45	1.45
C141	Ditch	73.8	0.211	0.217	0.564	0.569	0.08	0.08	0.12	0.12	0.8	0.8	1.2	1.2
C142	Lyncean Creek West	160.4	0.157	0.159	0.257	0.258	0.84	0.85	0.99	0.99	0.1	0.1	0.1	0.1
C143	Ditch	283.5	0.144	0.152	0.305	0.308	0.09	0.1	0.14	0.14	0.6	0.6	1.15	1.2
C144	Ditch	71.6	0.191	0.197	0.53	0.534	0.11	0.11	0.16	0.16	0.6	0.65	0.9	0.95
C145	Lyncean Creek West	268.9	0.313	0.316	0.523	0.526	0.4	0.4	0.43	0.43	0.4	0.4	0.75	0.75
C146	Ditch	21.5	0.186	0.191	0.695	0.694	0.82	0.82	0.85	0.85	0.25	0.3	0.8	0.8
C147	Ditch	7.0	0.466	0.474	0.921	0.926	0.07	0.07	0.07	0.07	1.2	1.2	1.8	1.8
C148	Lyncean Creek East	221.9	0.07	0.07	0.11	0.11	0.09	0.09	0.1	0.1	0.15	0.15	0.25	0.25
C149	Lyncean Creek East	107.0	0.286	0.29	0.487	0.492	0.38	0.38	0.48	0.48	0.15	0.15	0.2	0.2
C150	Lyncean Creek East	32.9	0.285	0.29	0.486	0.491	0.58	0.58	0.65	0.66	0.45	0.45	0.8	0.8
C151	Lyncean Creek East	2.9	0.285	0.289	0.455	0.459	0.11	0.11	0.13	0.13	0.65	0.65	1.35	1.35
C152	Ditch	7.3	0.278	0.281	0.415	0.419	0.55	0.55	0.54	0.54	0.8	0.85	1.65	1.65
C153	Lyncean Creek East	21.2	0.655	0.663	0.939	0.947	0.18	0.18	0.17	0.17	1.1	1.1	1.85	1.9
C154	Lyncean Creek East	47.2	0.647	0.656	0.916	0.924	0.77	0.77	0.91	0.92	0.25	0.25	0.25	0.25
C155	Lyncean Creek East	36.0	0.647	0.656	0.916	0.924	0.07	0.07	0.1	0.1	1.35	1.35	1.35	1.35
C156	Ditch	10.0	1.801	1.822	2.647	2.663	0.06	0.06	0.09	0.09	2.55	2.55	2.55	2.55
C157	Ditch	119.1	0.699	0.816	1.237	1.372	1.2	1.26	1.38	1.43	0.3	0.35	0.75	0.95
C158	Ditch	414.6	0.677	0.765	1.168	1.264	0.18	0.19	0.25	0.26	0.95	1	1.1	1.1
C159	Ditch	131.8	0.697	0.815	2.033	2.507	0.33	0.3	0.29	0.29	1.2	1.5	2.4	2.7
C160	Leoran Brook	49.6	2.41	2.625	3.627	3.832	0.09	0.09	0.09	0.09	3.85	4.2	5	5
C161	Leoran Brook	121.1	2.964	3.213	4.698	4.944	0.36	0.33	0.3	0.29	1.95	2.1	2.7	2.7
C162	Ditch	5.6	1.989	2.098	2.595	2.699	0.09	0.09	0.11	0.12	2.05	2.05	2.05	2.05
C163	Ditch	22.6	0.693	0.776	0.905	0.948	0.9	0.92	0.94	0.94	0.3	0.35	0.5	0.5
C164	Leoran Brook	63.3	2.198	2.486	3.535	3.818	1.81	1.88	2.09	2.14	0.35	0.35	0.45	0.45
C165	Leoran Brook	217.8	2.522	2.818	4.118	4.413	0.85	0.87	0.87	0.88	0.7	0.8	1.5	1.6
C166	Leoran Brook	344.6	2.217	2.504	3.553	3.837	2.13	2.22	2.46	2.52	0.3	0.35	0.4	0.4
C167	Ditch	16.2	1.124	1.232	1.656	1.731	0.49	0.49	0.49	0.48	0.5	0.55	0.8	0.85
C168	183 Street Creek	28.0	0.62	0.629	1.108	1.119	1.24	1.25	1.51	1.51	0.2	0.2	0.25	0.25
C169	183 Street Creek	50.8	0.619	0.628	1.108	1.118	0.07	0.07	0.13	0.13	1.35	1.4	1.4	1.4
C170	Ditch	21.7	0.619	0.734	1.699	1.675	0.6	0.62	0.68	0.7	0.35	0.4	0.7	0.95
C171	Ditch	84.9	0.765	0.827	1.152	1.26	6.84	6.84	6.84	6.84	0.2	0.2	0.25	0.3
C172	184 Street Creek Tributary	132.1	0.119	0.132	0.181	0.201	0.22	0.23	0.25	0.26	0.4	0.45	0.55	0.55
C173	184 Street Creek	99.7	0.904	1.023	1.48	1.589	1.26	1.34	1.49	1.54	0.25	0.25	0.35	0.35
C174	184 Street Creek	271.1	1.605	1.725	2.541	2.649	0.77	0.79	0.85	0.86	0.55	0.6	0.7	0.75
C175	184 Street Creek	176.7	2.085	2.222	3.346	3.476	0.19	0.21	0.31	0.32	1.6	1.6	1.6	1.6
C176	184 Street Creek Tributary	51.8	0.706	0.705	1.067	1.066	0.91	0.88	1	0.98	0.3	0.3	0.35	0.35
C177	Ditch	234.5	0.363	0.36	0.609	0.605	0.47	0.47	0.53	0.53	0.4	0.4	0.85	0.85

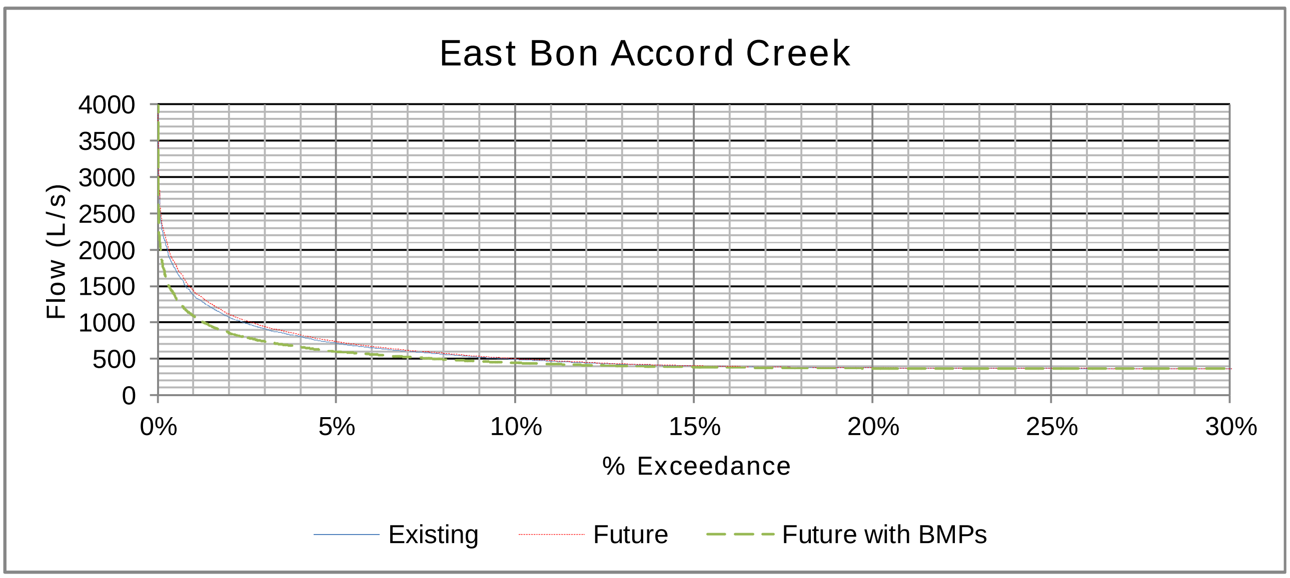
TABLE C-3
PCSWMM - OPEN CHANNEL RESULTS; PEAK FLOW, VELOCITY, DEPTH

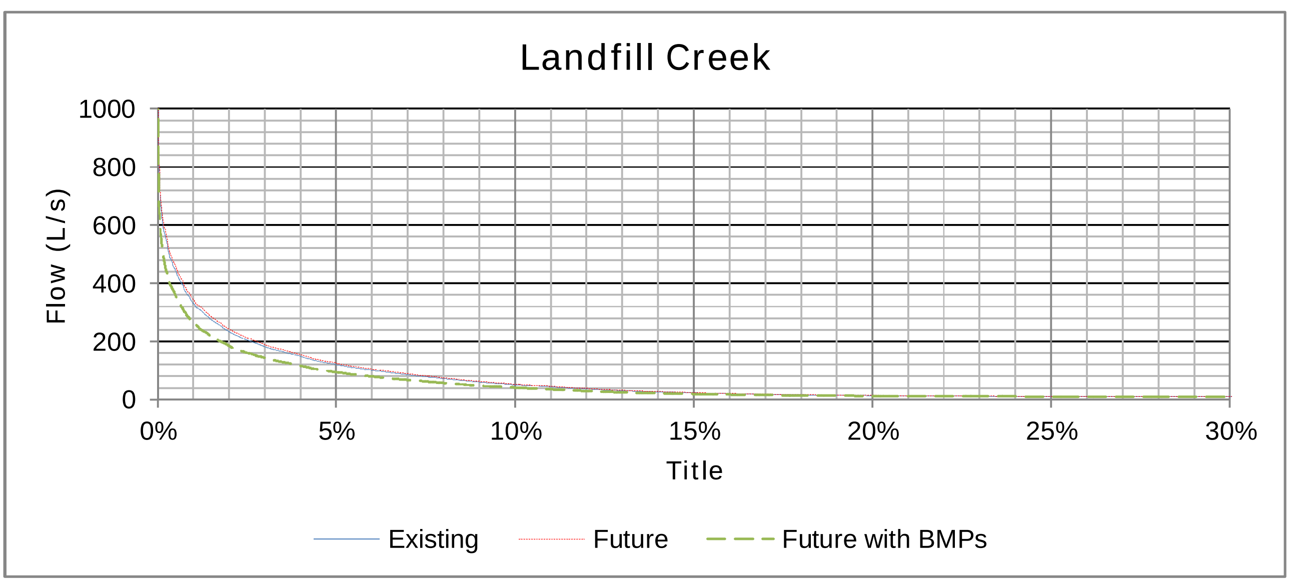
Channel ID	Description	Length (m)	Peak Flow (m^3/s)				Maximum Velocity (m/s)				Max Depth (m)			
			Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS		Scenario 1 5-Year ADS		Scenario 2 100-Year ADS	
			A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future	A Existing	B Future
C178	Ditch	24.0	1.273	1.277	1.899	1.904	1.03	1.03	1.2	1.2	0.23	0.23	0.28	0.28
C179	Ditch	94.5	1.273	1.278	1.901	1.905	0.77	0.77	0.91	0.91	0.3	0.3	0.37	0.37
C180	Ditch	59.5	1.273	1.278	1.9	1.904	1.04	1.04	1.22	1.22	0.22	0.23	0.28	0.28
C181	Ditch	32.7	0.377	0.378	0.623	0.624	0.62	0.62	0.68	0.68	0.3	0.3	0.4	0.4

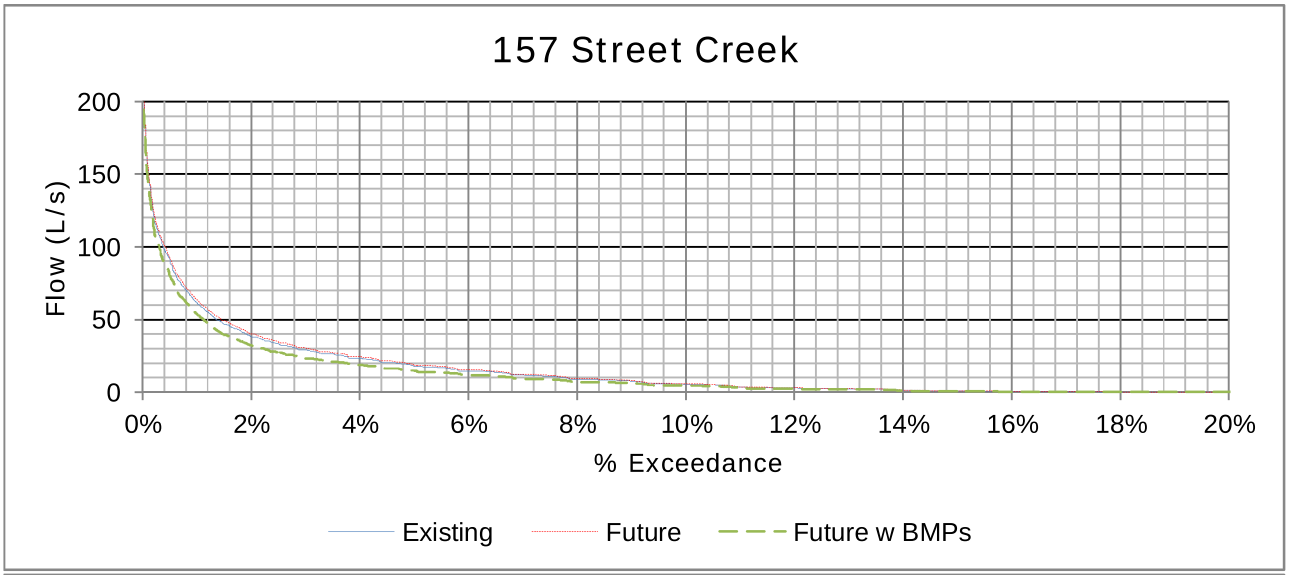
MAJOR WATERCOURSES

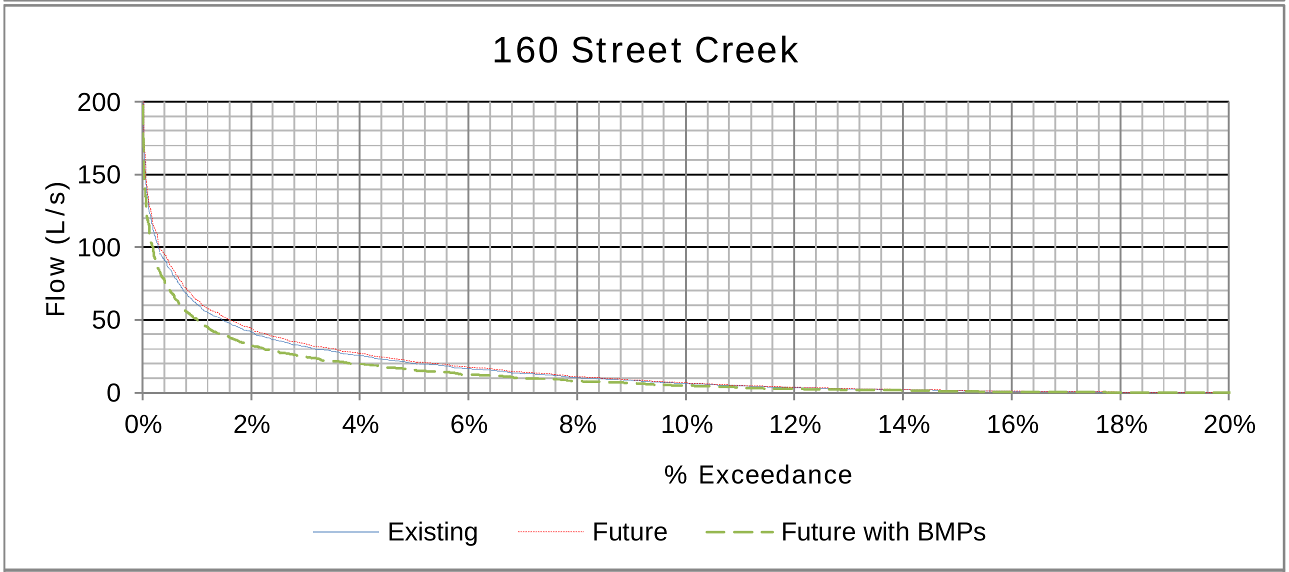
FLOW DURATION-EXCEEDANCE CURVES

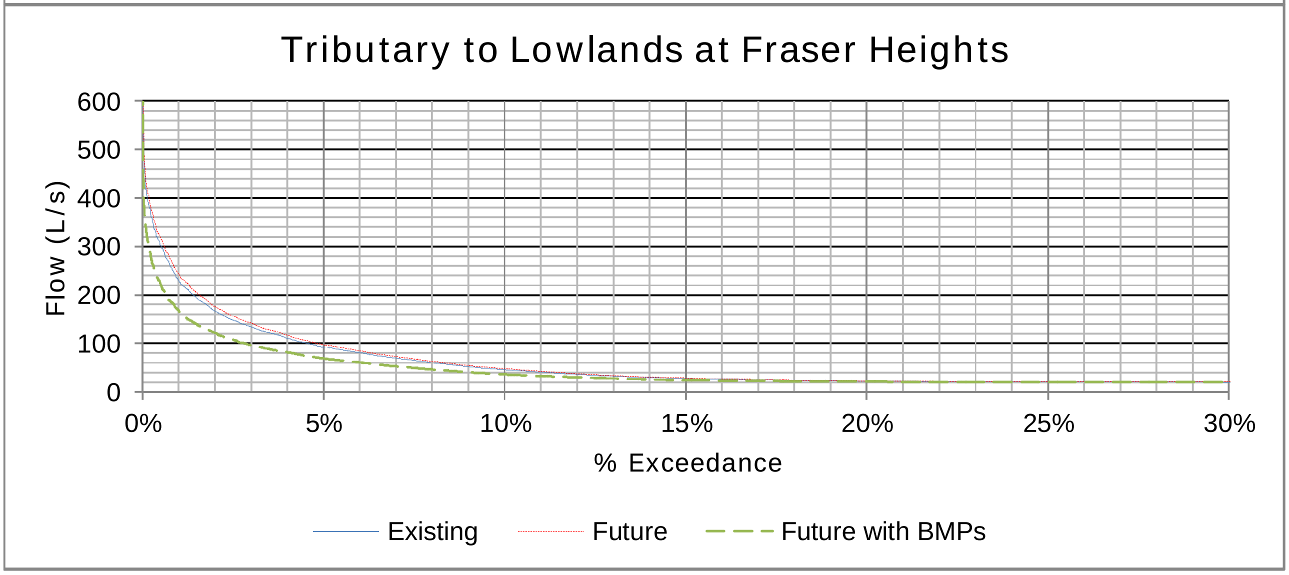

Bon Accord Creek
Flow (L/s)
1400
1200
1000
800
600
400
200
0
0%
5%
10%
15%
20%
25%
30%
% Exceedance
Existing
Future
Future with BMPs

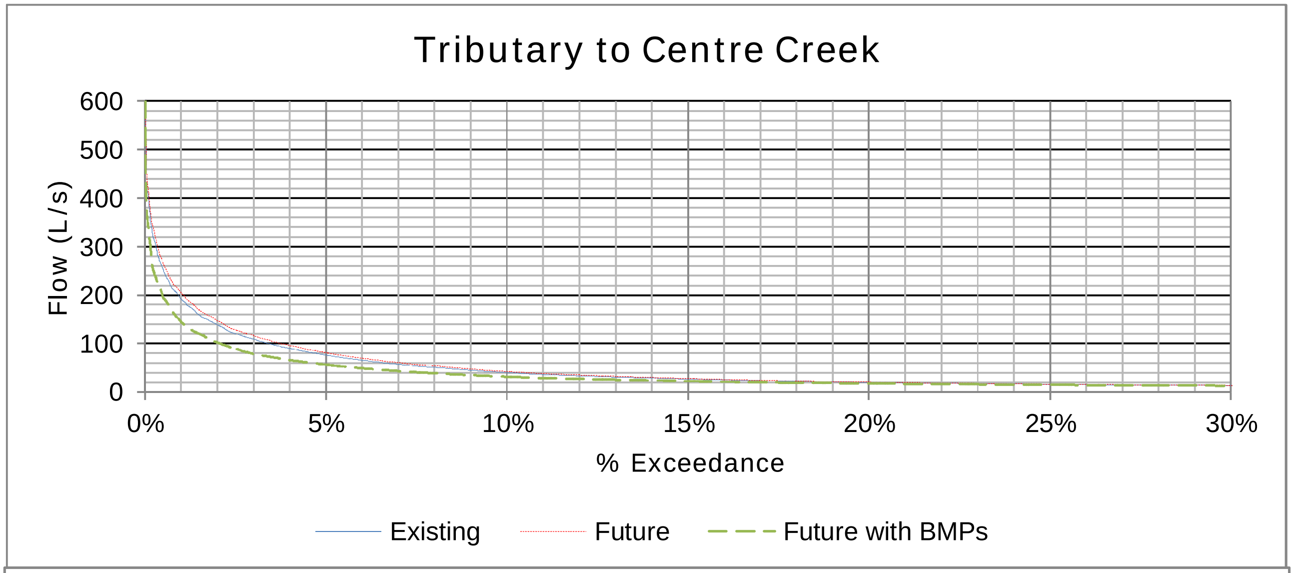

East Bon Accord Creek
Flow (L/s)
4000
3500
3000
2500
2000
1500
1000
500
0
0%
5%
10%
15%
20%
25%
30%
% Exceedance
Existing
Future
Future with BMPs

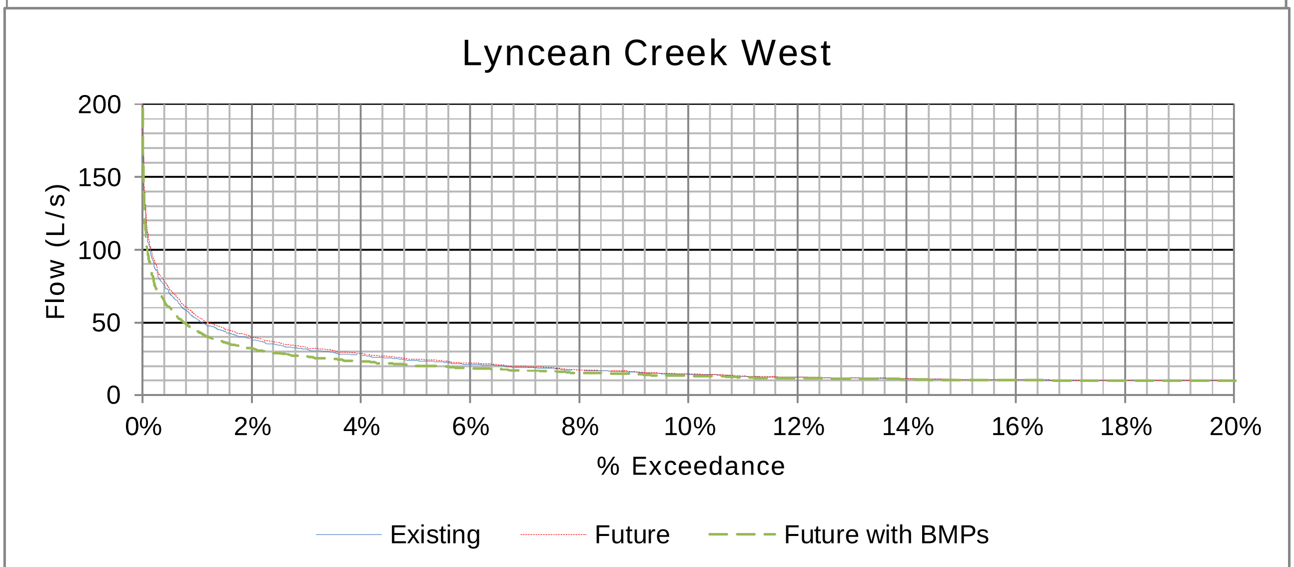

Landfill Creek
Flow (L/s)
1000
800
600
400
200
0
0%
5%
10%
15%
20%
25%
30%
Title
Existing
Future
Future with BMPs

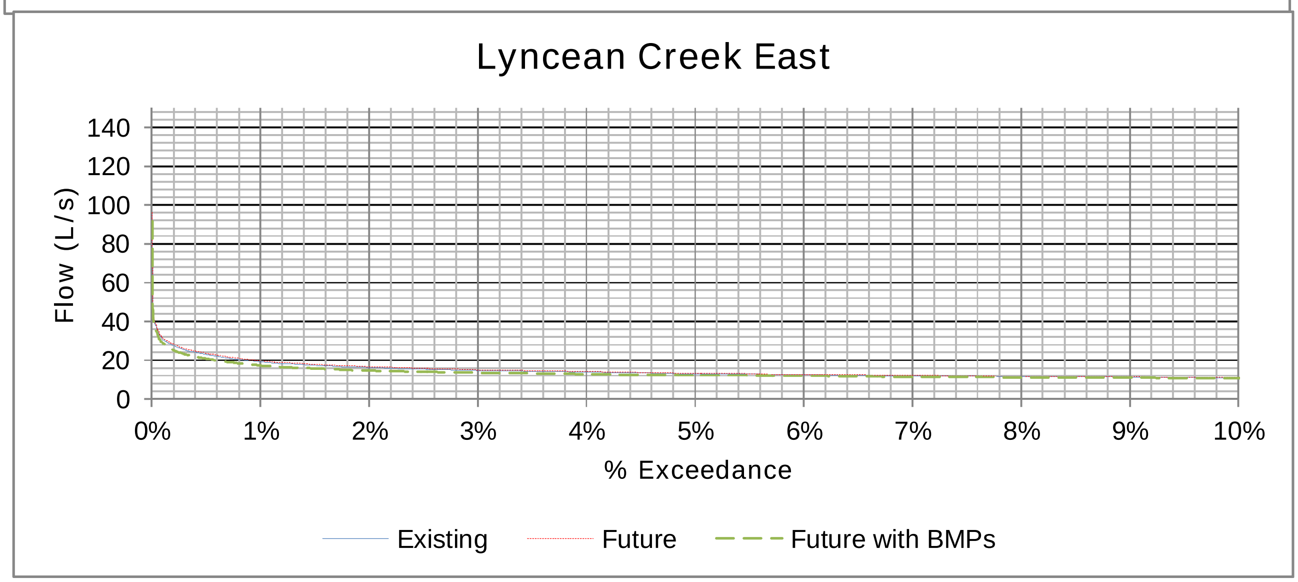

157 Street Creek
Flow (L/s)
200
150
100
50
0
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
% Exceedance
Existing
Future
Future w BMPs

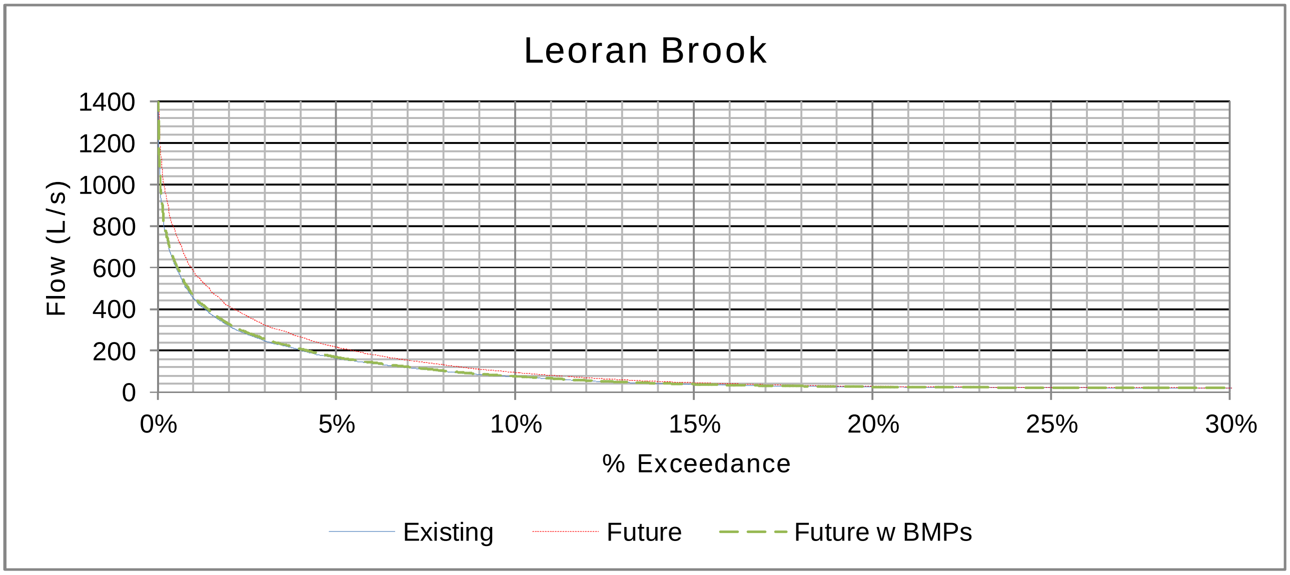

160 Street Creek
Flow (L/s)
200
150
100
50
0
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
% Exceedance
Existing
Future
Future with BMPs

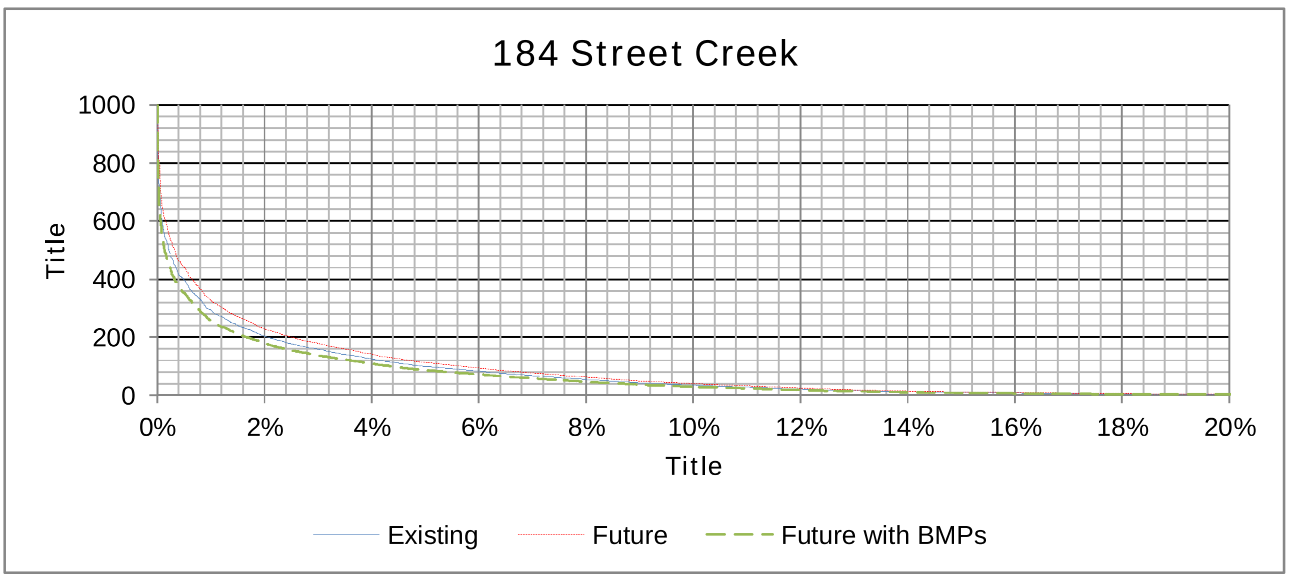

Tributary to Lowlands at Fraser Heights
Flow (L/s)
600
500
400
300
200
100
0
0%
5%
10%
15%
20%
25%
30%
% Exceedance
Existing
Future
Future with BMPs


Tributary to Centre Creek
Flow (L/s)
600
500
400
300
200
100
0
0%
5%
10%
15%
20%
25%
30%
% Exceedance
Existing
Future
Future with BMPs


Lyncean Creek West
Flow (L/s)
200
150
100
50
0
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
% Exceedance
Existing
Future
Future with BMPs


Lyncean Creek East
Flow (L/s)
140
120
100
80
60
40
20
0
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
10%
% Exceedance
Existing
Future
Future with BMPs


Leoran Brook
1400
1200
1000
800
600
400
200
0
Flow (L/s)
0%
5%
10%
15%
20%
25%
30%
% Exceedance
Existing
Future
Future w BMPs


184 Street Creek
1000
800
600
400
200
0
Title
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
Title
Existing
Future
Future with BMPs

Appendix D - Anniedale-Tynehead Stage 2 Engineering Corporate Report

CORPORATE REPORT

NO: **R077** COUNCIL DATE: **April 23, 2012**

REGULAR COUNCIL

TO: **Mayor & Council** DATE: **April 18, 2012**

FROM: **General Manager, Engineering** FILE: **6520-20 (A/T)**
1209-0006/01

SUBJECT: **Engineering Servicing Strategy and Related Financial Strategy for the Anniedale-Tynehead Neighbourhood Concept Plan (NCP) – Stage 2**

RECOMMENDATIONS

The Engineering Department recommends that Council:

1. Approve the engineering servicing strategy and the related financial strategy as documented in this report and as contained in the Anniedale-Tynehead Neighbourhood Concept Plan (NCP) as a means of managing the provision of engineering services for development in this NCP area;

2. Approve the road network for the NCP as illustrated on the map attached as Appendix III to this report;

3. Approve amendments to the Road Classification Map and Road Allowance Map as contained in the Surrey Subdivision & Development By-law, 1986, No. 8830 to reflect the road network for the NCP;

4. Authorize the City Clerk to bring forward for the required readings an amendment by-law to Surrey Subdivision & Development By-law, 1986, No. 8830 to address necessary amendments to the Road Classification Map and Road Allowance Map;

5. Authorize staff to bring forward amendments to the City's 10-Year (2012-2021) Servicing Plan for the Development Cost Charge (DCC)-eligible infrastructure related to water, stormwater, sanitary sewer, and transportation for the NCP as documented in Appendix VII attached to this report; and

6. Authorize staff to bring forward amendments to Surrey Development Cost Charge By-law, 2012, No. 17539, to establish area-specific DCC rates for this NCP area as described in this report.

INTENT

The purpose of this report is to provide an overview of and obtain Council approval of the engineering servicing strategy and the related financial strategy for the Anniedale-Tynehead NCP in support of the Anniedale-Tynehead NCP– Stage 2 Final Report, which is to be forwarded for consideration by Council at the same meeting as this report is to be considered.

BACKGROUND

Council approved-in-principle the Stage 1 Land Use Concept Plan for the Anniedale-Tynehead NCP area at its Regular meeting on October 4, 2010 (Corporate Report No. R212;2010). That report noted that there were a number of engineering and financial issues to be resolved as part of the Anniedale-Tynehead NCP - Stage 2 process. The Stage 2 report for the Anniedale-Tynehead NCP has been completed based on the Council-approved Land Use Concept Plan.

DISCUSSION

An engineering servicing analysis and financial plan for the Anniedale-Tynehead NCP has been completed. A copy of this Stage 2 servicing strategy is attached as Appendix I to this report.

Only those works that normally form part of the City's DCC program, such as major trunk sewer and water grid mains, collector and arterial roads, and major stormwater management infrastructure, are included in the NCP servicing strategy. Local engineering servicing will be addressed on a site-by-site basis during the development application review process, which is the usual practice of the City for development in NCP areas.

The following provides a description of each of the principal elements of the Engineering Servicing Strategy for the Anniedale-Tynehead NCP area.

Water

The area is currently serviced by private wells and a few localized small-diameter City water mains. The existing water infrastructure has insufficient capacity to service the NCP. The 96 Avenue feeder main that runs through the area supplies the Port Kells industrial area to the north side of Highway 1.

New water supply sources and distribution and feeder mains are required to support the proposed land uses and densities within the NCP area, as illustrated in Appendix II. The design of the proposed water distribution network will allow for the phased development of the area.

The topography of the area requires that two separate pressure zones be established. Lands located at higher elevations of the NCP area will be serviced by a high pressure zone (135m), as illustrated in Appendix II. To service this high pressure zone, a new connection to the existing feeder main will be provided at Cherry Hill Crescent and 168 Street located on the north side of Highway 1. The remainder of the NCP area falls within the lower pressure zone (90 m) which will be supplied by a new reservoir Metro Vancouver will construct next to the Fleetwood Pumping Station at 154 Street and 90 Avenue in Meagan Anne MacDougall Park. This reservoir is projected to be in service in 2017. To accommodate development proposals as and when they are received throughout the NCP area in the interim, the Cherry Hill connection can be utilized to supply some of the low pressure zone on an interim, first-come/first-served basis, which will be prioritized by a completed building permit. Depending on the pace of development in the NCP area, the City may not be able to accommodate every development application that it receives, and some development applications may need to be deferred until the new reservoir and related supply network are constructed.

Transportation

The transportation plan for the NCP is based on the guiding principles contained in the City's Transportation Strategic Plan. It involves a modified grid road system that takes into account property lines, tree and environmental protection, greenway connections and drainage infrastructure, all as illustrated in Appendix III. The modified grid system provides a level of street connections comparable with other NCPs that have been approved over the last few years including East Clayton, Sunnyside Heights and Orchard Grove and establishes block sizes in the range of 100 by 200m, which are considered reasonable for development outside of City Centre and Town Centres. The interconnectedness of the street system creates a more livable urban community and supports the objectives of the City's Transportation Strategic Plan.

Regional Traffic

The NCP area is at or adjacent to the junction of three major regional transportation corridors - Highway 15, Highway 1 (under Ministry of Transportation and Infrastructure jurisdiction) and 96 Avenue/Golden Ears Way (under TransLink jurisdiction). As these corridors are important regional connections, both agencies have strict restrictions on providing additional vehicular connections to these highways. The NCP traffic analysis demonstrated the following key findings:

1. The land use in the Anniedale Triangle north of Golden Ears Way and east of Highway 15 could not support commercial or business park land use designations due to there being only one permitted access point to the area off Golden Ears Way (GEW) at 180 Street and an access point by way of an overpass over GEW to allow a connection of 96 Avenue with the new Anniedale Road collector.
2. An overpass of Highway 15 at 94 Avenue (Ridgeline Drive) is required to provide improved connectivity between the Anniedale and Tynehead communities. This will also help to reduce the impact of NCP-development-related traffic on the adjacent arterial roads and highways.
3. To meet standards for acceptable levels of service, volume to capacity ratios and delay performance targets, a grade separated interchange may be required at the intersection of Highway 15 and 96 Avenue/Golden Ears Way prior to build out of the NCP. A supplemental study was undertaken for this intersection to determine the preferred interchange configuration. The Ministry and TransLink were involved in this study, but there are no commitments for funding. The planned road allowance necessary for the interchange footprint is well beyond the typical fronting obligation required of developments. The cost of the land required for the interchanges is therefore planned to be recovered through DCCs generated from this NCP.

Walking & Cycling

Local, collector and arterial roads will have sidewalks on both sides and will be complemented by a good system of Multi-Use Pathways. Greenways are also planned for the area including the continuation of the Port Kells Greenway, which will connect to East Clayton, and the Green Timbers Greenway, which will connect to the Guildford and Newton communities. All of the planned collector and arterial roads will have bike lanes. In summary, the network of greenways, pathways, and the public road system will support effective circulation routes for walking and cycling within the community and to/from adjacent communities.

Transit

TransLink's South of Fraser Area Transit Plan identifies each of the Frequent Transit Network (FTN) routes, Conventional routes and Community Shuttle routes in the NCP area. The arterial and collector roads will accommodate the delivery of effective public transit service in the NCP area. Each of 96 Avenue, 180 Street and 92 Avenue are planned for FTN service with the NCP designating adjacent lands with land uses and densities that reflect this level of transit service.

Commercial Traffic & Trucks

The NCP area is currently served with three existing Designated Truck Routes; these being, Highway 15, 96 Avenue/Golden Ears Way, and 88 Avenue west of Highway 15. Pending the implementation of the 192 Street interchange at Highway 1 by Transportation Investment (TI) Corp./Ministry of Transportation and Infrastructure (MoTI), it is expected that 88 Avenue from Highway 15 to 200 Street in Langley and 192 Street between Golden Ears Way and 88 Avenue should become designated truck routes as well in conjunction with improvements to these roads.

General Purpose Traffic / Vehicles

The modified grid road network is designed to provide connectivity within the NCP area and with the transportation network in areas adjacent to the NCP. It will also distribute traffic reasonably throughout the neighbourhood so as to minimize impacts on any particular street. Some of the local residential roads are shown as 'Flex Roads' to highlight the need for connectivity but allow flexible alignments and/or cross sections to address tree protection or other matters that are important to building a great neighbourhood. On-street parking will be permitted on both sides of most of the local and collector roads within the NCP. A number of unique cross sections were developed for the NCP in recognition of the Agricultural Land Reserve and utility corridors and to maximize opportunities for environmental protection.

The existing arterial roads in the NCP area are 96 Avenue, 192 Street, 88 Avenue, and 168 Street. The traffic analysis undertaken in support of the NCP demonstrates that each of these roads should be upgraded to an ultimate four-lane cross section during the process of building out the NCP. Additionally the analysis concluded that several changes need to be made to the City's R-91 Road Classification Map (Schedule D to Subdivision & Development By-law, No. 8830) to accommodate the traffic volumes that are expected as this NCP area develops. The changes to the collector road system are focused on providing service for the proposed land uses and to ensuring the appropriate connectivity between local roads within the various areas of the NCP and to the arterial road network within and adjacent to the NCP area.

The following streets are to be reclassified as arterials in support of the development in the NCP area:

- 180 Street between Golden Ears Way and 88 Avenue;
- 184 Street between 92 Avenue and 80 Avenue, to provide connections between the NCP area and Clayton;
- 92 Avenue between 180 Street and Harvie Road; and

- 90 Avenue between Harvie Road and 192 Street.

Both 92 Avenue and 90 Avenue will need to be widened to four lane roads as development in the NCP area occurs with a view to accommodate traffic to/from 192 Street. 92 Avenue will accommodate on-street parking until such time as traffic volumes and related delays warrant its removal to facilitate traffic flow. 180 Street has connections with 88 Avenue and 184 Street has connections with East and West Clayton, Cloverdale, and Campbell Heights. Both of these arterial roads run through the Agricultural Land Reserve. A meeting was held with the Agricultural Advisory Committee (AAC) in June 2010 to inform them of the road network planned for this NCP area. Any future road widening within the ALR would be reviewed in advance with the AAC and will require ALC approval.

Lot Consolidation Areas

There are a number of parcels and irregularly shaped lots within the NCP area that should be consolidated for the purposes of development. These are illustrated in Appendix IV and will provide for efficient development by eliminating remnant parcels that would otherwise be more difficult to develop due to encumbrances such as significant stands of trees or transportation infrastructure. Consolidation will assist in ensuring that dedications for road connections within the NCP area and the construction costs of these connections are distributed equitably. Generally, these costs should be shared between benefitting properties in a land assembly area based on the probable unit yield of each property. The assembly areas shown on the map can be larger than those illustrated.

Sanitary Sewer

There is no City sanitary sewer system in the NCP area at this time. Individual property owners rely on the use of in-ground disposal systems for sewage disposal.

Four new pumping stations along with three low pressure systems and a network of gravity sewers and forcemains are required to service the NCP area, all as illustrated in Appendix V.

In general the proposed sewer system is designed to flow by gravity to a series of pump stations which will pump the sewage to a gravity trunk sewer that will discharge into the MV North Surrey Interceptor at 104 Avenue and 173 Street north of Highway 1.

Due to the topography of the area the 184 Street pump station, and a portion of the collection network, is located south of the NCP area on residential land (zoned RA) located within the Fraser Sewerage Area and outside of the Agricultural Land Reserve.

The approach to servicing the area with multiple pumping stations and forcemains will allow for the phased development of the area. One area of exception is located in Anniedale where a proposed pump station was eliminated in order to lower servicing costs. By doing so, development within this subcatchment is dependent on the construction of a pump station and associated infrastructure in the neighbouring downstream catchment being constructed.

Stormwater

The area is currently serviced to a rural/agricultural standard with open ditches, culverts, a pump station, and a few storm sewers which drain to either the Fraser River or the Serpentine River.

In addition to the above-referenced system, TransLink owns and operates a small storm sewer system that services Golden Ears Way and which drains east then north under Highway 1 to discharge to the Fraser River.

Based on the characteristics of the watershed and the receiving watercourses, the stormwater objectives for the NCP are:

- Protect downstream lands from exacerbated flooding;
- Protect receiving watercourses from erosion;
- Maintain base flows in creeks;
- Maintain water quality in creeks, ditches and storm systems;
- Safely convey runoff to the river systems; and
- Protect the natural environment adjacent to watercourses.

The servicing plan consists of both offsite and onsite measures that together meet the above-stated stormwater objectives. The following is a brief description of the measures recommended in the NCP.

1. *On-Site Stormwater Management Controls*

On-site stormwater management controls are to be incorporated into each development site within the NCP area with the intention of maximizing infiltration and evapo-transpiration of rainwater. The following table summarizes the intended on-site controls by land use.

Land Use	On-Site Stormwater Management Control Requirements
Single-family Residential	• A minimum 300mm depth of amended topsoil on residential lawn areas, and • Discharge roof leaders directly to lawns (no hard pipe connections to the storm sewer system).
Multi-family Residential, Commercial, Industrial and Institutional	• Capture and retain on site 50% of the Average Annual Return rainfall event (35mm in 24 hours = 350 cubic metres per hectare of impervious surface), and • Provide oil/water separators in parking lots.

2. *Stormwater Management Ponds*

The stormwater management strategy for the NCP includes the implementation of two stormwater detention ponds and six water quality ponds all as illustrated in Appendix VI.

The stormwater detention ponds will mitigate peak flows in watercourses related to major rain events. The stormwater detention ponds will also mitigate downstream flooding related to runoff from new development within the NCP area. The design of the ponds relies upon the successful implementation of on-site stormwater controls as referenced above.

The water quality ponds act to provide adequate base flows to natural watercourses to support fish life while mitigating erosion and maintaining or enhancing water quality for aquatic purposes and downstream users. The footprint for each water quality pond is approximately 0.5 hectares.

Sites have been selected for each pond based on best fit/lowest cost principles and are supported by the Citizens Advisory Committee (CAC). Any development applicant will retain the opportunity to further study the sub-catchment area for any pond for the purpose of identifying an alternate acceptable location for the pond but regardless of the location of each pond within each sub-catchment, the land for each pond must be secured in favour of the City before development proceeds within its catchment area, which is consistent with City Policy. Similarly, the pond must be constructed in advance of any development proceeding within the NCP area (i.e., be constructed in parallel with the construction of engineering servicing for the first development site in the NCP).

3. *Additional Secondary Measures*

In addition to the primary measures as referenced above, exfiltration-type storm sewer systems within roadways, infiltration-enhanced boulevards and rain gardens in traffic calming bulges are also part of the stormwater servicing plan for this NCP and will be constructed where site conditions allow.

Impacts on the Serpentine and Nicomekl Lowlands Flood Control Project

The purpose of the Serpentine and Nicomekl Lowlands Flood Control Project is to control flooding within the agricultural floodplain along these rivers in support of agricultural activities on the floodplain lands. The standard that is being applied in relation to flood control is referenced as the ARDSA Criteria (Agri-Food Regional Development Subsidiary Agreement). This standard seeks to:

- Restrict flooding to a maximum of 5 days in duration for the 10-year return, 5-day winter storm (November 1 to February 28).
- Restrict flooding to a maximum of 2 days in duration for the 10-year return, 2-day growing season storm (March 1 to October 31).
- Maintain a minimum baseflow level of 1.2 m below adjacent ground level in ditches between storm events during the growing season.

Development in the Anniedale-Tynehead NCP area will not negatively impact the ARDSA Criteria in relation to the lowlands in the Serpentine River floodplain.

Infrastructure Summary and Financial Analysis

The following table summarizes the projected DCC revenues and construction costs for the infrastructure projects that are required to service development within this NCP area. The revenues are based on the current DCC rates that came into effect on March 15, 2012. The revenues include the DCC municipal assist factor for each utility.

Services	Estimated DCC Revenues	DCC Expenditures on Eligible Works in the NCP Area	Shortfall
Sanitary Sewer	$17,100,000	$28,800,000	$11,700,000
Water	$13,100,000	$20,100,000	$7,000,000
Drainage	$21,800,000	$26,600,000	$4,800,000
Non-Arterial Roads	$14,400,000	$21,500,000	$7,100,000
Arterial Roads	$66,200,000	$75,000,000	$8,800,000

As is documented in the preceding table, the estimated DCC revenues from the NCP area cannot support the financing of projects in any of the engineering services.

Appendix VII provides the list of the sanitary sewer, water, drainage and transportation infrastructure projects, respectively, to support development within this NCP area and that are eligible to be included in the City's 10-Year Servicing Plan. It also provides for each project the component of its total cost that will need to be covered by DCCs.

Financing Alternatives

The costs to service this NCP area are very high due to the limited amount of infrastructure in and around the area, its topography, and its location. At the time of approval of the Stage 1 component of the NCP, Council was advised that any financial strategy for servicing this NCP area may need to include an area-specific DCC program, such as similar programs that have been developed for Campbell Heights and the Highway 99 Corridor.

Establishing area-specific DCC rates provides an equitable way to distribute the costs of needed infrastructure. An area-specific DCC program is also administratively simple to implement and manage in comparison to other approaches to finance the installation of engineering services. Staff has concluded that an area-specific DCC program should be developed for this NCP area.

The following table provides a comparison of current DCC rates in Surrey with an estimate of area-specific DCC rates for the Anniedale-Tynehead NCP area. These were developed in accordance with guidelines contained in the DCC Best Practices Guide as published by the Ministry of Community, Sport and Cultural Development.

Land Use	Existing DCC Rate (effective March 15, 2012)	Proposed Area-Specific DCC Rate	Proposed as a % of Existing
SF (RF, RF-12, RFC)	$26,248 / lot	$36,356 / lot	139%
SF Small Lot (RF-9, RF-SD)	$22,779 / lot	$31,494 / lot	138%
RM-10, RM-15 & RM-30	$14.90 / sq. ft.	$19.63 / sq. ft.	132%
RM-45 and RM-70	$16.46 / sq. ft.	$21.91 / sq. ft.	133%
Commercial (ground floor)	$9.37 / sq. ft.	$13.66 / sq. ft.	146%
Industrial	$72,879 / acre	$108,017 / acre	148%

The initial developers in this area will be required to construct a considerable amount of infrastructure to service the overall NCP. These developers will then typically enter into a DCC Front-ending Agreement with the City by which they will recover over time from the DCC revenues collected by the City from other development within the NCP area the costs that they incurred in constructing the eligible front-ended engineering servicing works. This approach has been successfully applied in other NCP areas in Surrey.

Implementation

In January 2012, Council adopted an updated 10-Year (2012-2021) Servicing Plan and related DCC By-law. The Servicing Plan is reviewed annually. The most recent Servicing Plan review was undertaken in late 2011 and the related adjustments to the DCC rates took effect on March 15, 2012.

The City's 10-Year (2012-2021) Servicing Plan needs to be revised to include DCC-eligible infrastructure projects for this NCP area as documented in Appendix VII, and the City's DCC By-law needs to be amended to include area-specific DCCs for this NCP area. Subject to Council's approval of the recommendations of this report, staff will forward for Council's consideration a Corporate Report including recommendations related to amending the City's 10-Year (2012-2021) Servicing Plan and DCC By-law in accordance with the above-stated intentions.

SUSTAINABILITY CONSIDERATIONS

The approval of the engineering servicing strategy and the related financial strategy for the Anniedale-Tynehead NCP will assist in achieving the objectives of the City's Sustainability Charter; more particularly the following action items:

- EC3: Sustainable infrastructure maintenance and replacement;
- EC4: Sustainable Fiscal Management Practices;
- Ec7: Sustainable Building and Development Practices;
- EC9: Quality of Design in New Development and Redevelopment;
- EN8: Sustainable Engineering Standards and Practices;
- EN9: Sustainable Land Use Planning and Development Practices;
- EN12: Enhancement and Protection of Natural Areas, Fish Habitat and Wildlife Habitat;
- EN13: Enhancing the Public Realm;
- EN15: Sustainable Transportation Options;
- EN16: Land, Water and Air Quality Management;
- EN17: Enhance Biodiversity; and
- SC 13: Create a fully accessible City.

CONCLUSION

The strategies articulated in this report will support the land uses and related development as proposed in the Anniedale-Tynehead NCP. The financial strategy as proposed is consistent with the "development-pay" principle, which requires that each NCP area be financially self-sufficient.

Based on the above discussion, the Engineering Department recommends that Council:

- Approve the engineering servicing strategy and the related financial strategy as documented in this report and as contained in the Anniedale-Tynehead Neighbourhood Concept Plan (NCP) as a means of managing the provision of engineering services for development in this NCP area;

- Approve the road network for the NCP as illustrated on the map attached as Appendix III to this report;

- Approve amendments to the Road Classification Map and Road Allowance Map as contained in the Surrey Subdivision & Development By-law, 1986, No. 8830 to reflect the road network for the NCP;

- Authorize the City Clerk to bring forward for the required readings an amendment by-law to Surrey Subdivision & Development By-law, 1986, No. 8830 to address necessary amendments to the Road Classification Map and Road Allowance Map;

- Authorize staff to bring forward amendments to the City's 10-Year (2012-2021) Servicing Plan for the Development Cost Charge (DCC)-eligible infrastructure related to water, stormwater, sanitary sewer, and transportation for the NCP as documented in Appendix VII attached to this report; and

- Authorize staff to bring forward amendments to Surrey Development Cost Charge By-law, 2012, No. 17539, to establish area-specific DCC rates for this NCP area as described in this report.

Vincent Lalonde, P.Eng.
General Manager, Engineering

DM/JA/JLU/brb

Appendix I - Stage 2 Servicing Strategy
Appendix II - Water Servicing Strategy
Appendix III - Transportation Network
Appendix IV - Lot Consolidation Areas
Appendix V - Sanitary Servicing Strategy
Appendix VI - Stormwater Servicing Strategy
Appendix VII - 10-Year Servicing Plan Projects

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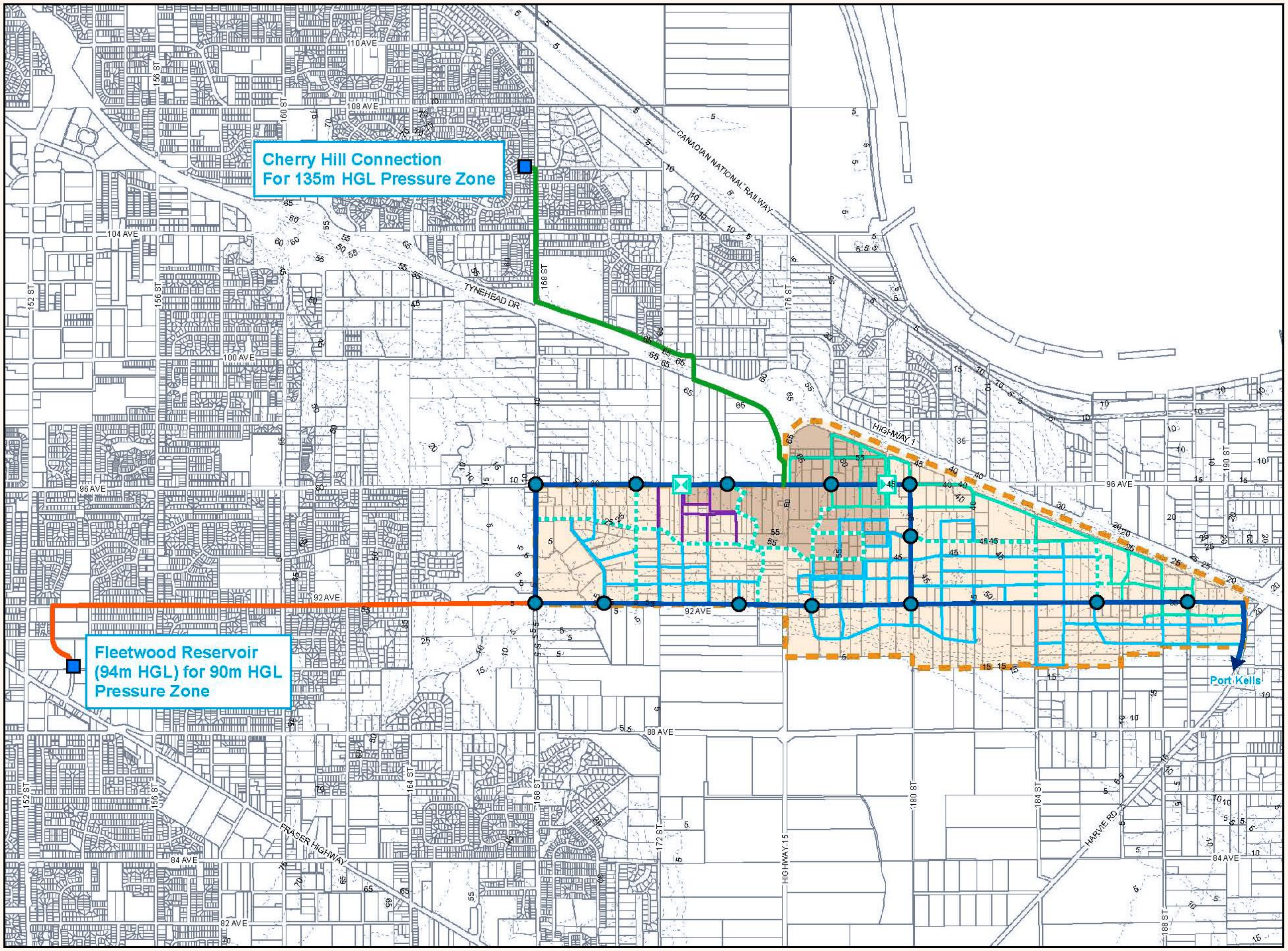

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Legend

- NCP Area
- 135m HGL Pressure Zone (all other areas 90m HGL)
- 200 Ø
- 250 Ø
- 300 Ø
- Water Main upsized to 300 Ø (see note below)
- Proposed Feeder Main
- Cherry Hill Supply Main
- Fleetwood Supply Main
- PRV
- Contour (5m Interval)
- Assumed (modeled) Local System Connections to Trunk Main (Actual connection points to be confirmed as part of design).

Note: In recognition that the ultimate looped system will be constructed over time, with some areas requiring larger pipes to provide adequate service and fire protection in the interim, some local water mains have been upsized from minimum sizes to account for staged development.

APPENDIX II

WATER SERVICING STRATEGY

0 250 500 1,000
Metres

URBANSYSTEMS.

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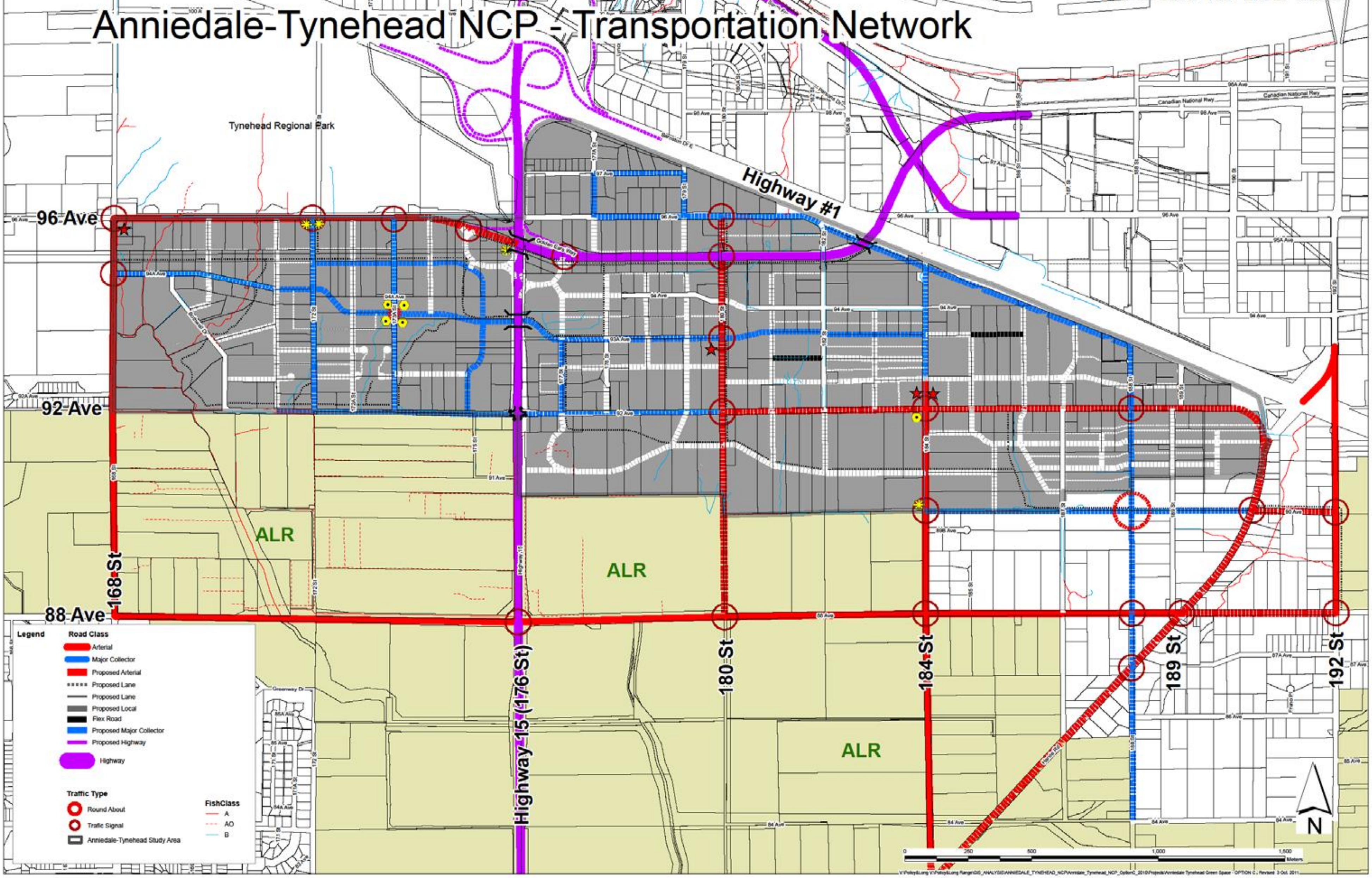
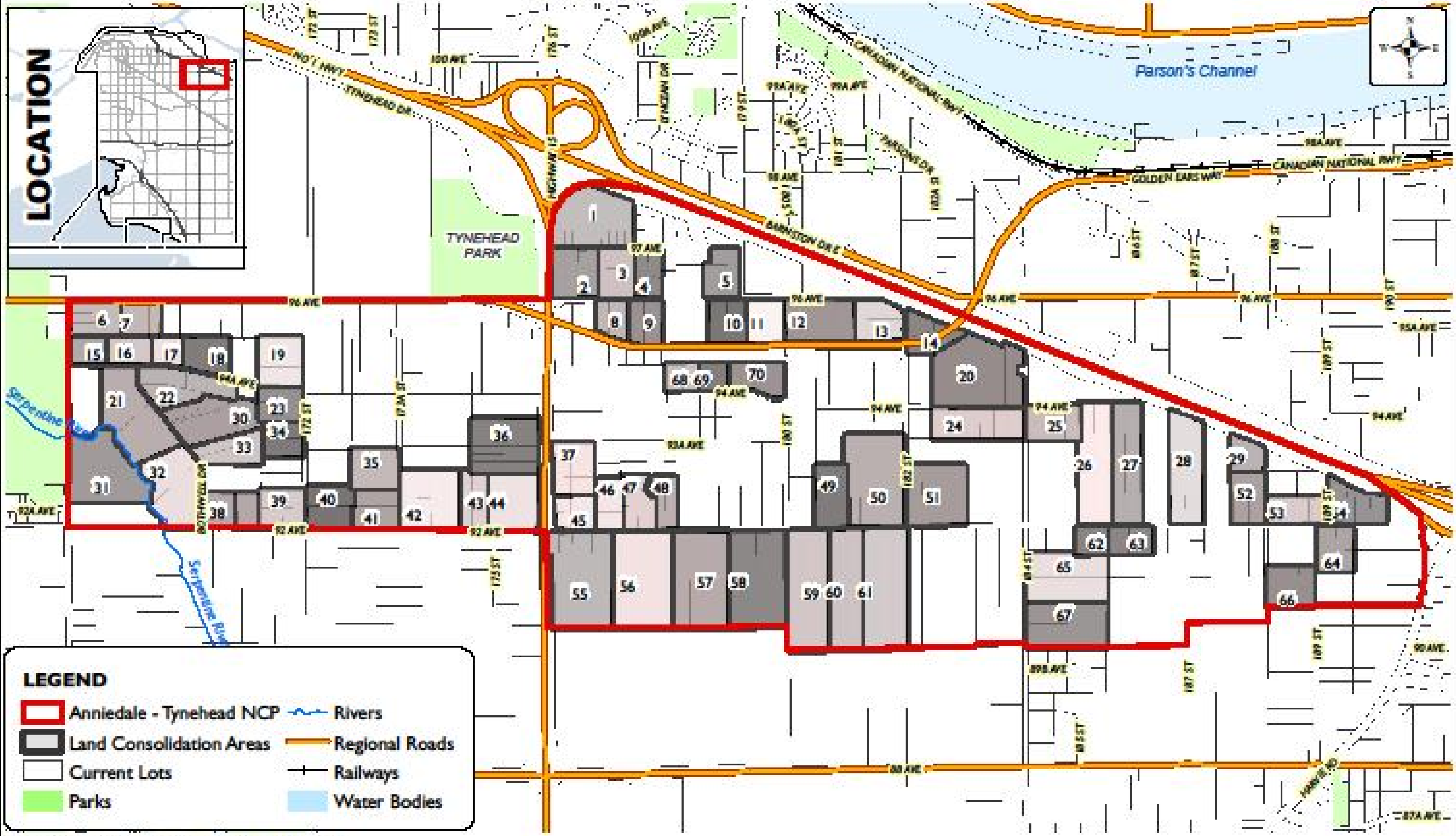
APPENDIX III



APPENDIX IV
SITE MAP



Produced by GIS Section: March 27, 2012, CS

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ANNIEDALE - TYNEHEAD NCP
LOT CONSOLIDATION AREAS

ENGINEERING DEPARTMENT

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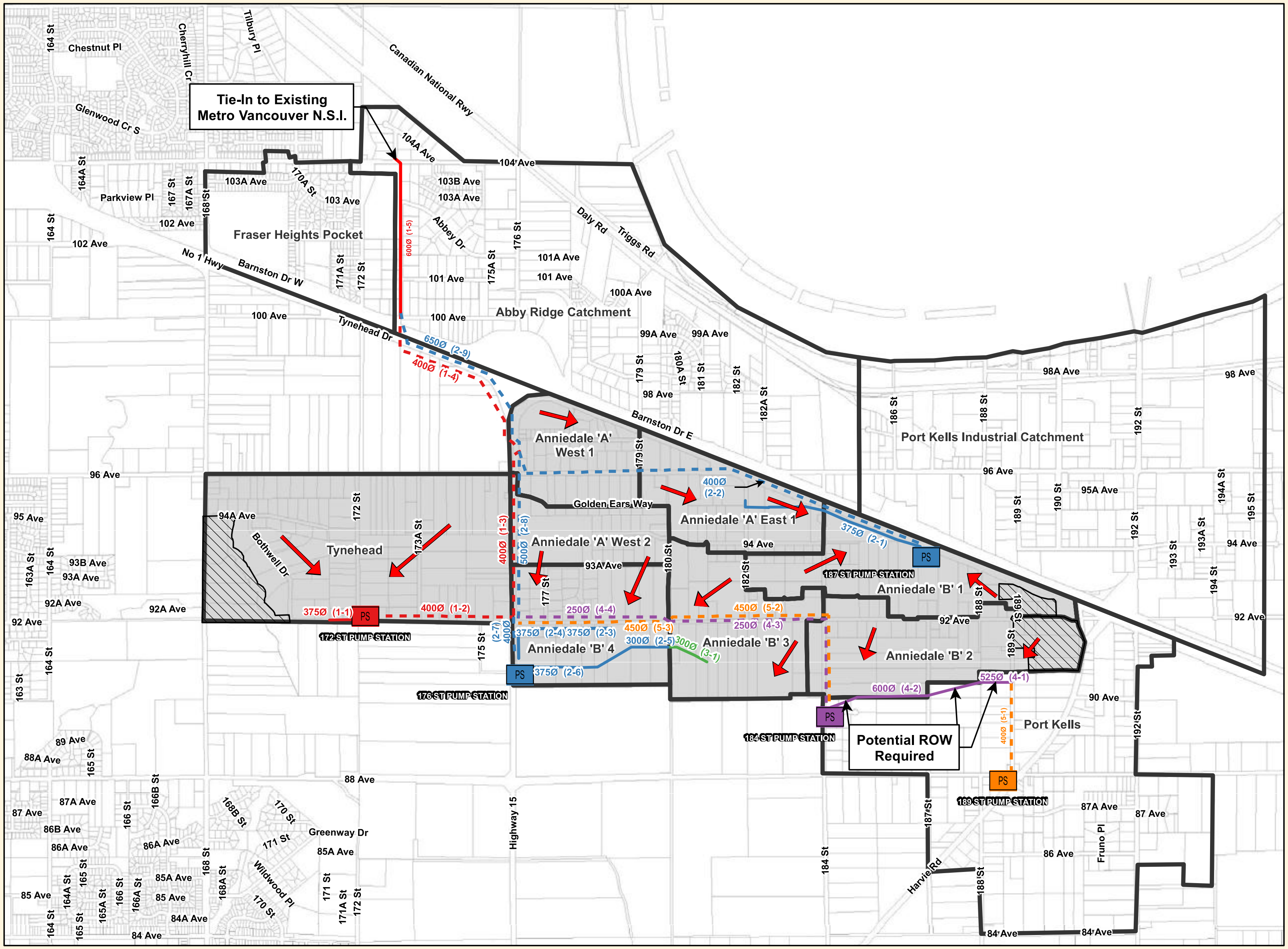

Legend

PHASE	GRAVITY	FORCEMAIN
1	red solid	red dashed
2	blue solid	blue dashed
3	green solid	green dashed
4	purple solid	purple dashed
5	orange solid	orange dashed

- General Flow Direction
- PS Pump Station
- Anniedale / Tynehead Development Areas
- Low Pressure Sewer Areas

0 250 500 1,000

Metres

APPENDIX V

SANITARY SERVICING STRATEGY

URBANSYSTEMS.

THE ACCURACY & COMPLETENESS OF INFORMATION SHOWN ON THIS DRAWING IS NOT GUARANTEED. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

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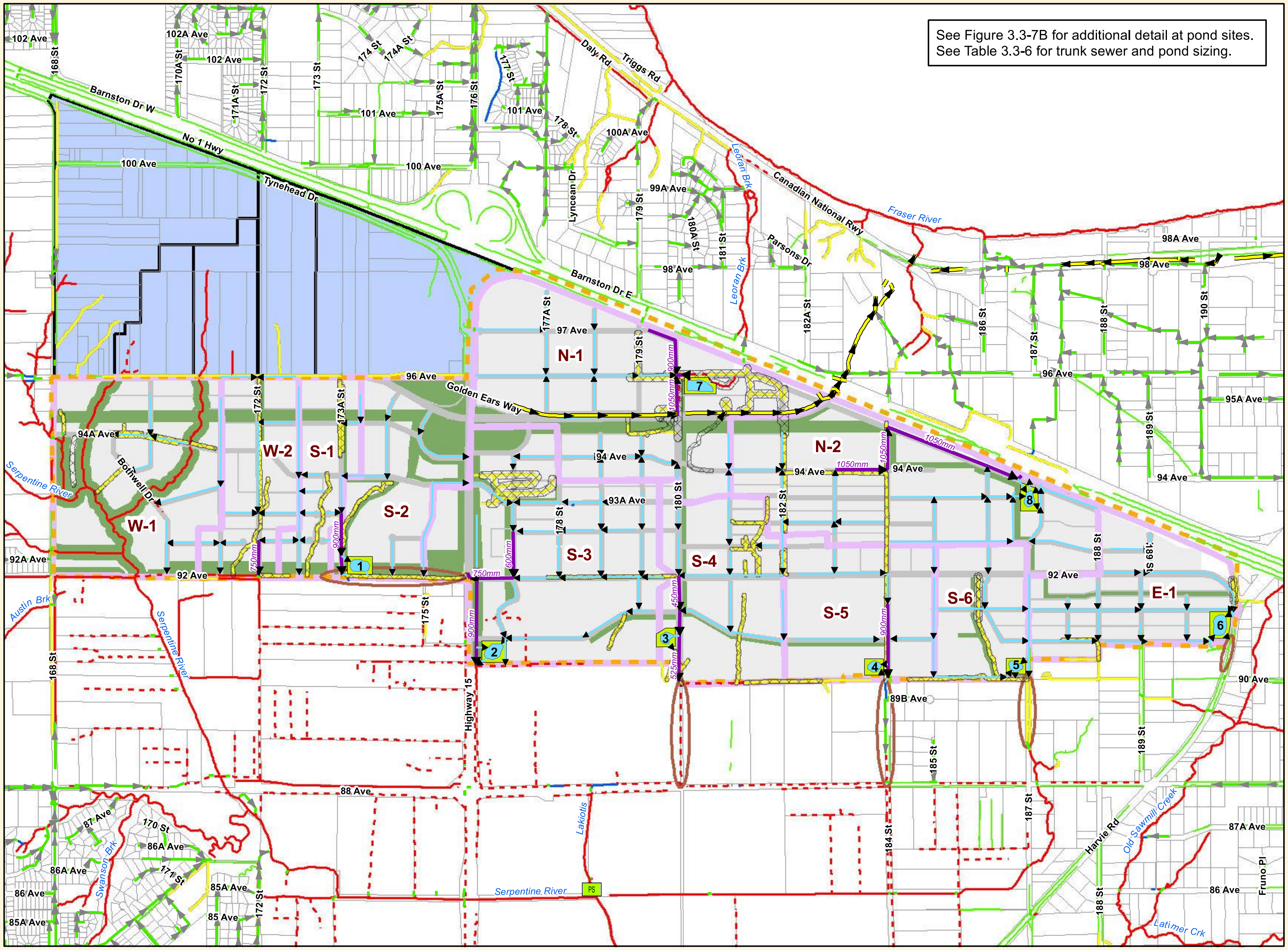

Legend

NCP Land Uses
- NCP Boundary
- NCP Area
- Future Road Network
- Proposed Trails, Buffers & Riparian Areas
- 15m and 30m Watercourse Class B Buffer

Watercourse Classifications
- Class A (red-coded)
- Class A(O) (red-dash)
- Class B (yellow-coded)
- Class C (green-coded)
- Unclassified

Existing Drainage Infrastructure
- Existing Pump Station
- Existing Storm Sewer (outside NCP)
- Existing Storm Sewer (Translink)

Proposed Drainage Infrastructure
- Proposed Sub-Catchments
- Contributing Catchments Outside NCP Area
- Proposed Trunk Storm Sewer
- Potential Local Storm Sewer Network
- Proposed Pond
- Land Required for Pond
- Ditch Improvement Reaches

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APPENDIX VI

STORMWATER SERVICING STRATEGY

URBANSYSTEMS.

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Metres

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APPENDIX VII

10-Year Servicing Plan Projects

The projects listed in the following tables are eligible for the inclusion into the 10-Year Servicing Plan.

Water

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
1,060 of 450mm diameter 168 Street: 106 Avenue - Hwy 1	$901,000		$901,000
1,060 of 450mm diameter Hwy 1: 168 Street - 173 Street	$901,000		$901,000
1,060 of 450mm diameter Hwy 1: 173 - Hwy 15/96 Avenue	$901,000		$901,000
350m of 450mm diameter 96 Avenue: Hwy. 15 - 178 Street	$297,500		$297,500
505m of 300mm diameter 96 Avenue: Hwy. 15 - 173A Street	$373,700		$373,700
PRV station 96 Avenue/173 Street	$115,000		$115,000
MV Connection Cherry Hill Cresc./168 Street	$102,500		$102,500
	135m Pressure Zone Total Estimate		**$3,591,700**
PRV station 96 Avenue/180 Street	$115,000		$115,000
550m of 750mm diameter 153 Street: 90 - 92 Avenue	$935,000		$935,000
3,000m of 750mm diameter 92 Avenue: 153 - 168 Street	$5,100,000		$5,100,000
2,405 of 750mm diameter 92 Avenue: 168 - 180 Street	$4,088,500		$4,088,500
955m of 600mm diameter 92 Avenue: 180 - 185 Street	$1,260,600		$1,260,600
780m of 450mm diameter 92 Avenue: 185 - 189 Street	$663,000		$663,000
760m of 350mm diameter 168 Street: 96 - 92 Avenue	$585,200		$585,200
770m of 350mm diameter 180 Street: 96 - 92 Avenue	$592,900		$592,900
440m of 300mm diameter 96 Avenue: 177 - 180 Street	$325,600		$325,600
1,095m of 300mm diameter 96 Avenue: 173 - 168 Street	$814,000		$814,000
9,345m of 300mm diameter upsizing mains 200 to 300mm diameter	$1,869,000		$1,869,000

1,595m of 300mm diameter upsizing mains 250 to 300mm diameter	$159,500		$159,500
		90m Pressure Zone Total Estimate	**$16,508,300**
		GRAND TOTAL	**$20,100,000**

Sanitary Sewer

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
355m of 375mm diameter 92 Avenue: 171 - 172 Street	$85,200		$85,200
835m of 400mm diameter 92 Avenue: 176 - 172 Street	$810,785		$810,785
Tynehead forcemain odour control Hwy 15	$60,000		$60,000
980m of 400mm diameter Hwy 15: 96 - 92 Avenue	$951,580		$951,580
1150m of 400mm diameter Hwy 1: 176 - 173 Street	$1,116,650		$1,116,650
800m of 600mm diameter 173 Street: Hwy 1 - 104 Avenue	$1,132,800		$1,132,800
Tynehead Trunk ROW Tynehead Park	$90,000		$90,000
Hwy 1 crossing Hwy 1/173 Street	$500,000		$500,000
South Port Kells odour control 173 Street	$660,000		$660,000
270m of 250mm diameter upsizing mains to 250mm diameter	$17,280		$17,280
160m of 300mm diameter upsizing mains to 300mm diameter	$21,760		$21,760
435m of 375mm diameter upsizing mains to 375mm diameter	$104,400		$104,400
Tynehead Pump Station 92 Avenue/172 Street	$3,300,000		$3,300,000
		Tynehead Sub-Total	**$8,850,455**
1000m of 375mm diameter Golden Ears Way: 182 - 187 Street	$240,000		$240,000
2140m of 400mm diameter Hwy 1: 187 - 176 Street	$2,077,940		$2,077,940
Anniedale A odour control 96 Avenue	$60,000		$60,000
265m of 375mm diameter 92 Avenue: 178 - 177 Street	$63,600		$63,600
390m of 375mm diameter 92 Avenue: 177 - 176 Street	$93,600		$93,600

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
690m of 300mm diameter 91 Avenue: 180 - 178 Street	$93,840		$93,840
135m of 375mm diameter 90A Avenue: 178 - 176 Street	$32,400		$32,400
200m of 400mm diameter Hwy 15: 91 - 92 Avenue	$194,200		$194,200
Anniedale B4 odour control Hwy 15	$60,000		$60,000
980m of 500mm diameter Hwy 15: 92 - 96 Avenue	$1,065,260		$1,065,260
1150m of 650mm diameter Hwy 15: 96 Avenue - 173 Street	$1,396,100		$1,396,100
Hwy 15 crossing Hwy 15 /97 Avenue	$200,000		$200,000
1,135m of 250mm diameter upsizing mains to 250mm diameter	$72,640		$72,640
350m of 300mm diameter upsizing mains to 300mm diameter	$47,600		$47,600
75m of 375mm diameter upsizing mains to 375mm diameter	$18,000		$18,000
Anniedale Pump Station Hwy 1/187 Street	$3,600,000		$3,600,000
Anniedale B4 Pump Station 176 Street/91 Avenue	$3,500,000		$3,500,000
		Anniedale A/B1/B4 Sub-Total	**$12,815,180**
220m of 300mm diameter 91 Avenue: 180 - 181 Street	$29,920		$29,920
Anniedale B3 Trunk ROW 91 Avenue	$225,000		$225,000
100m of 300mm diameter upsizing mains to 300mm diameter	$13,600		$13,600
		Anniedale B3	**$268,520**
890m of 525mm diameter 90A Avenue: 189 - 186 Street	$412,960		$412,960
190m of 600 diameter 90 Avenue: 186 - 184 Street	$107,920		$107,920
Anniedale B2 Trunk ROW 89 Avenue	$235,000		$235,000
400m of 250mm diameter 184 Street: 90 - 92 Avenue	$304,000		$304,000
920m of 250mm diameter 92 Avenue: 184 - 180 Street	$699,200		$699,200
850m of 250mm diameter 92 Avenue: 180 - 176 Street	$646,000		$646,000
Anniedale B2 odour control 90 Avenue	$60,000		$60,000

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
Anniedale B2 pump station 184 Street/89 Avenue	$4,400,000		$4,400,000
		Anniedale B2	**$6,865,080**
		GRAND TOTAL	**$28,799,235**

Drainage

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
160m of 1050mm diameter 180 Street: 96 Avenue - Golden Ears Way	$297,000		$297,000
65m of 1050mm diameter 96 Avenue/180 Street	$108,000		$108,000
250m of 900mm diameter 97 Avenue:179 - 180 Street & 180 Street: 97 - 96 Avenue	$347,000		$347,000
		Sub-Catchment N-1	**$752,000**
200m of 1050mm diameter 94 Avenue: 183 - 184 Street	$371,000		$371,000
150m of 1050mm diameter 184 Street: 94 - 95 Avenue	$279,000		$279,000
1050m of 1050mm diameter Hwy 1: 184 - 187 Street	$1,624,000		$1,624,000
		Sub-Catchment N-2	**$2,274,000**
150m of 900mm diameter 173A Street: 92 - 93 Avenue	$249,000		$249,000
350m of ditch improvement 92 Avenue: 173A - 176 Street	$47,000		$47,000
		Sub-Catchment S-2	**$296,000**
350m of 900mm diameter 176 Street: 90 - 92 Avenue	$809,000		$809,000
170m of 600mm diameter 177 Street: 93 - 92 Avenue	$217,000		$217,000
150m of 750mm diameter 92 Avenue: 176 - 177 Street	$220,000		$220,000
		Sub-Catchment S-3	**$1,246,000**
150m of 450mm diameter 180 Street: 91 - 92 Avenue	$134,000		$134,000
270m of 525mm diameter 180 Street: 91 - 92 Avenue	$266,000		$266,000
400m of ditch improvement & ROW 180 Street: 90 - 88 Avenue	$509,000		$509,000
		Sub-Catchment S-4	**$909,000**

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
290m of 900mm diameter 184 Street: 91A Avenue - 90 Avenue	$482,000		$482,000
400m of ditch improvement 184 Street: 90 - 88 Avenue	$54,000		$54,000
		Sub-Catchment S-5	**$536,000**
150m of 750mm diameter 172 Street: 93 - 92 Avenue	$220,000		$220,000
		Sub-Catchment W-2	**$220,000**
100m of ditch improvement Harvie Rd: 91 -90 Avenue	$14,000		$14,000
		Sub-Catchment E-1	**$14,000**
200m of ditch improvement 92 Avenue: 173 - 173A Street	$27,000		$27,000
		Sub-Catchment S-1	**$27,000**
250m of ditch improvement 187 Street: 89 - 90 Avenue	$34,000		$34,000
		Sub-Catchment S-6	**$34,000**
		GRAND TOTAL	**$6,308,000**

Drainage - Ponds

Project	Project Cost	Non-Growth Component (DCC)	Ultimate Growth Component (DCC)
Anniedale 7 detention pond 96 Avenue/180 Street (N-1)	$4,888,000		$4,888,000
Anniedale 8 water quality pond 187 Street/Hwy 1 (N-2)	$2,217,000		$2,217,000
Anniedale 6 detention pond 96 Avenue/Harvie Rd (E-1)	$3,279,000		$3,279,000
Tynehead 1 water quality pond 173A Street/92 Avenue (S-2)	$2,122,000		$2,122,000
Anniedale 2 water quality pond 90 Avenue/Hwy 15 (S-3)	$2,967,000		$2,967,000
Anniedale 3 water quality pond 180 Street/92 Avenue (S-4)	$1,738,000		$1,738,000
Anniedale 4 water quality pond 184 Street/90 Avenue (S-5)	$1,679,000		$1,679,000
Anniedale 5 water quality pond 90 Avenue/187 Street (S-6)	$1,439,000		$1,439,000
		GRAND TOTAL	**$20,329,000**

Transportation

Project	Project Cost	Ultimate Anniedale-Tynehead Growth Component (DCC)	External Funding	Development Obligation
ARTERIALS				
Highway 15 at Golden Ears Way Interchange	$48,263,000	$12,065,750	$36,197,250	
Highway 1 at 192 Street Interchange	$20,000,000	$5,000,000	$15,000,000	
088 Avenue - 168 Street to 192 Street (Ultimate Arterial Widening)	$43,530,500	$10,882,625	$32,647,875	
090 Avenue - Harvie Road to 192 Street (Ultimate Arterial Widening)	$3,030,300	$1,515,150	$1,515,150	
092 Avenue - 180 Street to Harvie Road/90 Avenue (Interim Arterial Upsizing) Special Section II	$16,016,000	$16,016,000		
168 Street - 88 Avenue to 96 Avenue (Ultimate Arterial Widening)	$10,914,800	$5,457,400	$5,457,400	
180 Street - 88 Avenue to 96 Avenue (Ultimate Arterial Widening & New Arterial) Including Special Section HH	$11,425,400	$11,425,400		
184 Street - 80 Avenue to 93 Avenue (Ultimate Arterial Widening & New Arterial)	$15,082,860	$7,541,430	$7,541,430	
192 Street - 80 Avenue to 92 Avenue (Ultimate Arterial Widening)	$5,573,100	$2,786,550	$2,786,550	
Arterials - Roads & Structures Sub-Total	**$173,835,960**	**$72,690,305**	**$101,145,655**	**$ -**

ARTERIAL INTERSECTION IMPROVEMENTS				
88 Avenue at 180 Street (Traffic Signal)	$180,700	$45,175	$135,525	
88 Avenue at 184 Street (Traffic Signal)	$180,700	$45,175	$135,525	
88 Avenue at 188 Street (Traffic Signal)	$180,700	$45,175	$135,525	
88 Avenue at 192 Street (Traffic Signal) 10 YSP or at Harvie Road?	$180,700	$45,175	$135,525	
90 Avenue at Harvie Road (Traffic Signal)	$180,700	$90,350	$90,350	
90 Avenue at 192 Street (Traffic Signal)	$180,700	$90,350	$90,350	
92 Avenue at 180 Street (Traffic Signal)	$180,700	$180,700		
92 Avenue at 184 Street (Traffic Signal)	$180,700	$180,700		
96 Avenue at 173A Street (Traffic Signal)	$180,700	$90,350	$90,350	
92 Avenue at 188 Street (Traffic Signal)	$180,700	$180,700		
168 Street at Ridgeline Dr (94A Avenue) |Traffic Signal	$180,700	$90,350	$90,350	
180 Street at Ridgeline Dr (93A Avenue) | Traffic Signal	$180,700	$180,700		
180 Street at 96 Avenue | Traffic Signal	$180,700	$180,700		
184 Street at 90 Avenue | Traffic Signal	$180,700	$90,350	$90,350	
184 Street at 80 Avenue | Traffic Signal	$180,700	$90,350	$90,350	
192 Street at 80 Avenue | Traffic Signal	$180,700	$90,350	$90,350	
Arterials - Traffic Signals Sub-Total	**$2,891,200**	**$1,716,650**	**$1,174,550**	**$ -**

ARTERIALS TOTAL	**$176,727,160**	**$74,406,955**	$102,320,205	**$ -**

Project	Project Cost	Ultimate Anniedale-Tynehead Growth Component (DCC)	External Funding	Development Obligation
COLLECTOR UPSIZING, STRUCTURES & INTERSECTION IMPROVEMENTS				
Anniedale Road Overpass of GEW | Structure	$3,360,000	$3,360,000		
Ridgeline Dr (94 Avenue) overpass at Highway 15 | Structure	$4,670,000	$4,670,000		
Ridgeline at 173A Street | Roundabout | Intersection Improvements	$500,000	$500,000		
90 Avenue at 188 Street | Roundabout | Intersection Improvements	$500,000	$250,000	$250,000	
90 Avenue - 184 Street to 187 Street (Upsizing) ** 187 Street to Harvie Road in SPK	$1,806,800	$600,600		$1,206,200
92 Avenue - 172 Street to 176 Street (Upsizing & South Side) Special Section CC	$2,270,580	$613,470		$1,657,110
92 Avenue - 176 Street to 180 Street (Upsizing)	$31,122,000	$653,562		$30,468,438
Ridgeline Dr - 168 Street to 184 Street (Upsizing & South Side of 94A Avenue) Special Section AA Included	$13,175,760	$2,966,270		$10,209,490
95 Avenue - 172 Street to 175 Street (Upsizing) Special Section DD	$1,107,600	$147,638		$959,962
96 Avenue - 177A Street to 181A Street (Upsizing)	$2,511,600	$527,440		$1,984,160
Anniedale Road - 181 Street to 188 Street (Upsizing & East Side) Special Section GG	$6,366,360	$3,188,640		$3,177,720
97 Avenue & 177A Street & 179 Street in Anniedale Triangle (Upsizing)	$2,987,400	$679,770		$2,307,630
172 Street - 92 Avenue to 96 Avenue (Upsizing)	$2,870,400	$602,780		$2,267,620
173A Street - 92 Avenue to 96 Avenue (Upsizing)	$2,870,400	$602,780		$2,267,620
175 Street - 92 Avenue to 95 Avenue (Upsizing) Including Special Section EE	$1,544,400	$532,116		$1,012,284
177 Street - 92 Avenue to Ridgeline Dr (93A Avenue) (Upsizing)	$1,004,640	$210,970		$793,670
184 Street - 92A Avenue to Anniedale Road (Upsizing)	$1,474,200	$309,582		$1,164,618
188 Street - 90A Avenue to Anniedale Road (9300 Block) (90A Avenue south SPK)	$3,533,400	$742,010		$2,791,390
COLLECTORS TOTAL	**$83,675,540**	**$21,157,628**	**$250,000**	**$62,267,912**