FINAL REPORT

Upper Serpentine Integrated Stormwater Management Plan

May 2015

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City of Surrey

Upper Serpentine

Integrated Stormwater Management Plan (ISMP)

City Project #4813-0706

Final Report

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Executive Summary

An ISMP is not just a plan, it represents an opportunity.

An Integrated Stormwater Management Plan (ISMP) is an opportunity to examine the interrelationships between drainage servicing, land use planning, and environmental protection. Its purpose is to outline an approach to support and promote the growth of a community in a way that maintains, or ideally enhances, the health of a watershed. By applying an integrated approach, an ISMP can be used to link watershed and stream health to land use and policy decisions. Further, as a policy level document, an ISMP is a powerful tool that can help a community achieve its vision.

Over the past decade the City has undertaken integrated stormwater plans for a number of watersheds and catchments. This ISMP is for the 2,600 hectare Upper Serpentine River Watershed. Extensive urban development in the watershed has placed great stress on the Serpentine River and its tributaries, though they retain the potential to be environmental treasures for Surrey. Into the future, further stream degradation will occur if development occurs unrestrained. But actions initiated now, as a part of this integrated stormwater management plan, can chart a path that will make the Serpentine River the treasure it deserves to be.

Formulation of the vision, goals and initiatives that form this ISMP was accomplished through four key questions or themes:

- What does the watershed look like today?
- What could be a vision for a healthy watershed?
- How do we achieve health in the Upper Serpentine watershed?
- How do we keep the watershed healthy over time?

To explore these areas, technical analysis (engineering; environmental; planning) was completed to establish conditions now, identify opportunities for significant both restoration and enhancement, and test possible ways to move forward into the future. Interdepartmental engagement was used to make key decisions about the direction of the plan, specifically regarding the focus on the use of green infrastructure as the keystone for watershed health, and initiate conversation that will support implementation of the ISMP into the future.

The result is a series of 17 long-term goals for the Upper Serpentine; the groundwork for achieving these goals was set during development of this ISMP:

Goal # 1 – Capitalize on Development Opportunities to Apply Stormwater Best Management Practices

Goal # 2 – Outline Prescriptive Stormwater Management Requirements for Single Family, Duplex and Small Multi-Family Developments

Goal # 3 – Capitalize on Road Improvement Opportunities to Apply Stormwater Best Management Practices

Goal # 4 – Enable Effective Stormwater Detention, Water Quality Treatment and Conveyance in Existing Developed Areas

Goal # 5 – Consider Climate Change Implications

Goal # 6 – Identify Interim Measures to Improve Watershed Health

Goal # 7 – Track Implementation Progress and Adapt as Development Proceeds

Goal # 8 – Define Riparian Setbacks Requirements based on Holistic Approach

Goal # 9 – Identify Land Requirements to Preserve High Value Habitat or for Community Stormwater Facilities

Goal # 10 – Address Habitat Issues Arising from Existing Land Use Activities

Goal # 11 – Align ISMP with Land Use Planning Initiatives in the Watershed

Goal # 12 – Identify Appropriate Regulatory Framework to Guide ISMP Implementation

Goal # 13 – Focus Priority Setting based on Funding Reality

Goal # 14 – Identify Amendments to Existing Funding Models to Improve Support for Integrated Stormwater Management

Goal # 15 – Highlight Alternative Funding Mechanisms

Goal # 16 – Support Internal Organizational Awareness and Capacity Building

Goal # 17 – Describe Public and External Stakeholder Outreach Initiatives

The ISMP recommends investing in $47.2 million in infrastructure improvements, mostly pipe upgrades and water quality treatment facilities, plus $3.1 million for in-stream improvements such as aquatic habitat enhancement work. As importantly, the ISMP recommends application of low impact development or green infrastructure stormwater management features as integral to all new, infill and re-development that occurs in the watershed, as well as a part of public road improvements.

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GLOSSARY

AMF – Adaptive Management Framework

Aquatic – of or relating to life or growth in water (see benthic and terrestrial).

BBAMP – Boundary Bay Assessment and Monitoring Program

Benthic - of or relating to the bottom of a watercourse, lake or pond (see aquatic and terrestrial).

Detention pond – a constructed stormwater management facility, normally considered grey infrastructure, which reduces peak runoff discharges by temporarily detaining water. Detention ponds may be either dry or wet between storms, the latter having permanent ponding area(s). When properly designed and maintained all detention ponds provide some water quality treatment, though wet facilities generally provide a greater level of treatment. Some dry detention ponds are used for other purposes (e.g. sports fields) between rain events.

Evapotranspiration – the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants.

Dyke - an embankment for controlling or holding back the waters of a river (or the sea); alternate terms are dike and levee.

Green (drainage) infrastructure - stormwater management systems that highlight the use of natural processes of the hydrologic cycle. Green infrastructure uses soil, vegetation, wetlands, and open space to replicate or imitate the natural environment, incorporating networks of green roofs, street trees, rain gardens, vegetated swales, pocket wetlands, infiltration planters, rain barrels, porous pavements, and riparian buffers into the urban landscape.

Grey (drainage) infrastructure - stormwater management systems that emphasize the capture and conveyance of runoff away from urban areas as efficiently as possible. Sometimes called “traditional drainage design”, grey infrastructure uses pipes, culverts, ditches, detention ponds and manufactured water quality treatment structures to provide drainage services, including flood control and (in some cases) runoff treatment.

Hydraulics – briefly, how water moves from one point to another in watercourses and pipes, specifically with respect to flow depth and velocity (compare with hydrology).

Hydrology – briefly, how much precipitation is converted to runoff on the land surface over time (compare with hydraulics).

Impervious surface – hard surfaces in the urban landscape that severely restrict or completely eliminate natural infiltration into soils; impervious surfaces include roads, parking lots, sidewalks and buildings.

Infiltration – the seepage of water into soil or rock; similar or related terms include percolation and (groundwater) recharge.

ISMP – Integrated stormwater management plan.

Low Impact Development (LID) – an approach to rainwater management that promotes mimicking the natural water balance of a property or site, particularly through the use of soil and vegetation to capture runoff where the rain falls; low impact development is one key aspect of green infrastructure.

Stormwater - as used in this ISMP, precipitation (rain; snow) that has become surface water; similar or equivalent terms include rainwater, (urban) runoff and drainage.

Terrestrial - of or relating to land as distinct from water (see aquatic and benthic).

Watercourse – a channel, whether natural or human-made that carries runoff; similar terms include river, stream, creek, brook, ditch and canal.

Watershed – the region or area drained by a river, stream or other watercourse; similar terms include catchment or basin.

1 INTRODUCTION

1.1 What is an Integrated Stormwater Management Plan (ISMP)?

An ISMP is a comprehensive plan that examines the interrelationships between drainage servicing, land use planning, and environmental protection. Its purpose is to outline an approach to support and promote the growth of a community in a way that maintains, or ideally enhances, the health of a watershed. By applying an integrated approach, an ISMP can be used to link watershed and stream health to land use and policy decisions. Further, as a policy level document, an ISMP can be a powerful tool that can help a community achieve its vision.

This ISMP has been prepared to support the Upper Serpentine Watershed.

1.2 Upper Serpentine Watershed Description

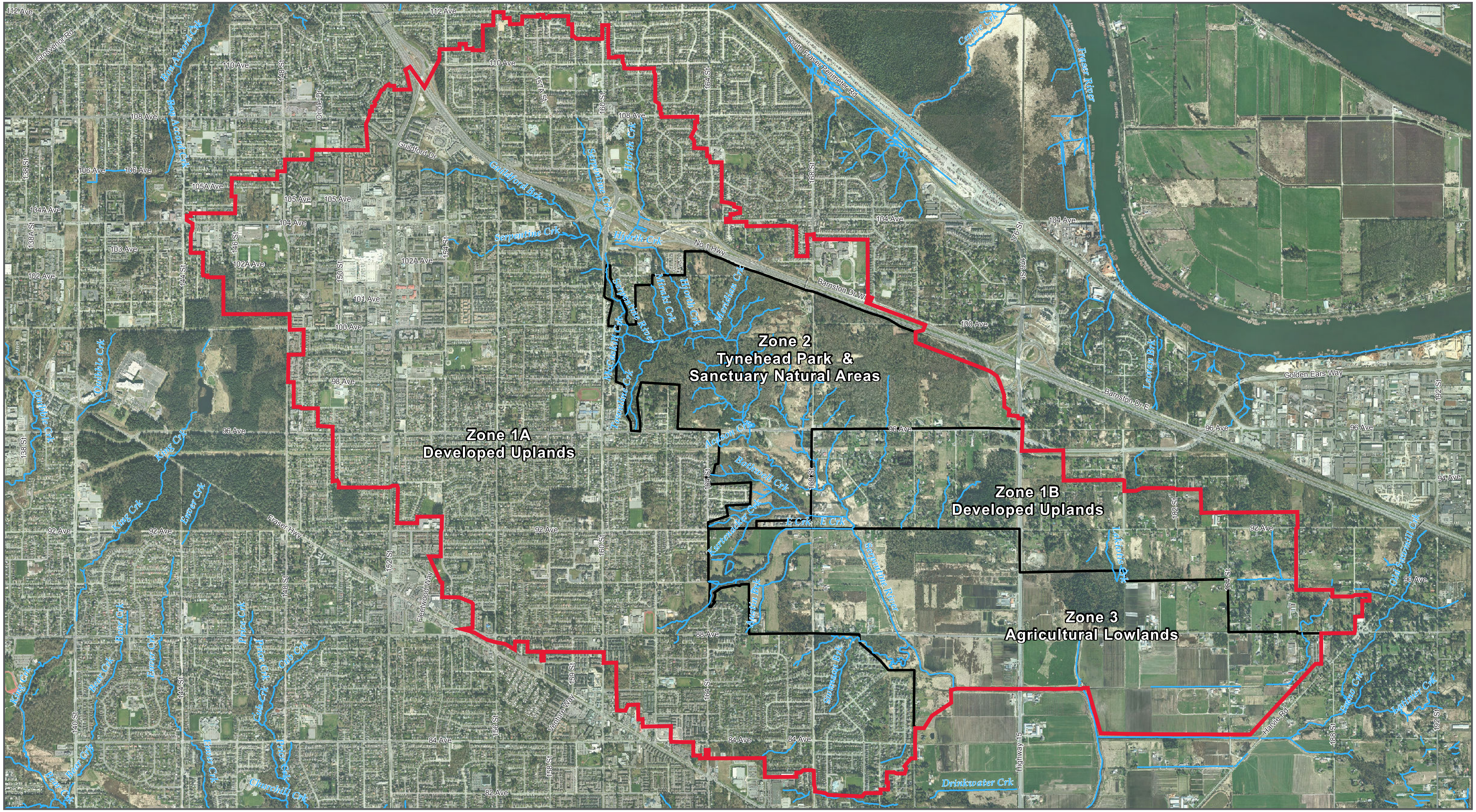
The Upper Serpentine watershed (Study Area) is situated near the northern limits of the City and is 2,618 hectares (ha) in size. The Study Area is roughly bounded by 112 Avenue to the north, 189 Street to the east, 86 Ave to the south and 144 Street to the west, as shown on **Figure 1.1**.

The Study Area encompasses the headwaters of the Serpentine River, a major river system that conveys water from several watersheds within the City to Mud Bay. In addition to the Serpentine River, a number of named and un-named tributaries feed into the river system within the Study Area limits, including:

- Guildford Brook
- Hjorth Creek
- McCaskill Creek
- Townline Creek
- Miraki Creek
- Meridian Creek
- Bunting Brook
- Acason Creek
- Bothwell Creek
- Kurtenacker Creek
- Godwin Creek
- Fern Creek
- E Creek
- Austin Brook
- Swanson Brook
- Lakiotis Creek

The Upper Serpentine River and its tributaries are mainly contained within defined ravines throughout the uplands area (north of 92nd Avenue). South of 92nd Avenue, the Serpentine River transitions from an upland watercourse to a lowland watercourse; the river is channelized and bounded by dikes south of the 90th Avenue right-of-way downstream to Mud Bay. Thus, while the Study Area contains mostly upland creek systems, there is a small portion of the Study Area that also contains creeks with lowland drainage characteristics.

Topography ranges from 100 metres above sea level near the western limits of the Study Area to 1 metre in the agricultural fields near the southeastern limits. Existing topography is shown on **Figure 1.2**.



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Author: SF
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Revision: A
Date: 2015 / 5 / 12

0 400 800 1,200 1,600 m

Scale: 1:27,500

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Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

2013 aerial and watercourses provided by the City of Surrey, Jan. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Watershed Zone Boundary
- Watercourse

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Upper Serpentine
Integrated Stormwater Management Plan

Figure 1.1 -
Study Area

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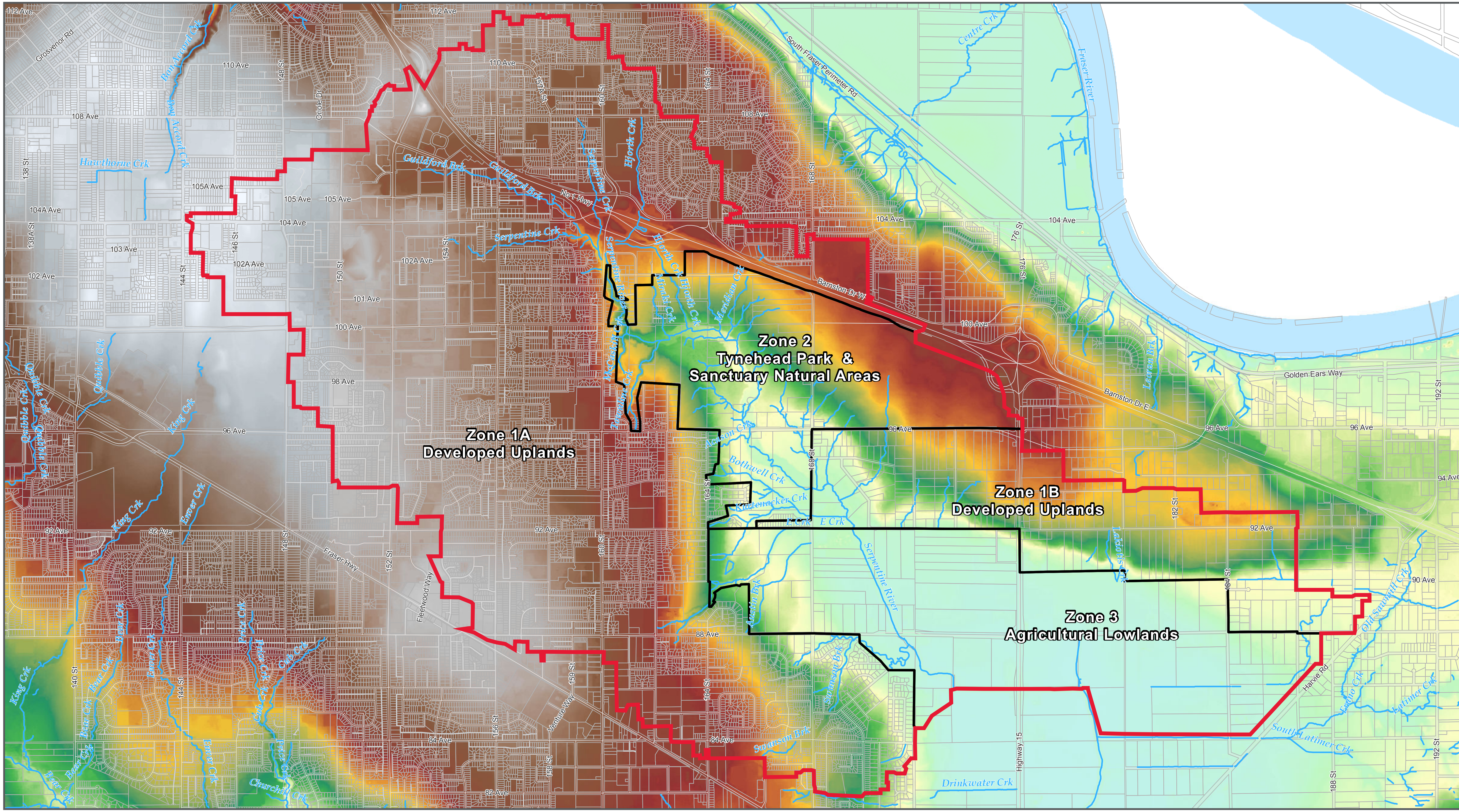

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0 400 800 1,200 1,600 m

Scale: 1:27,500

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Coordinate System:
NAD 1983 UTM Zone 10N

Data Sources:
Study area delineated by Urban Systems, Feb. 2014
Topographic, cadastral, road centreline and water course data provided by the City of Surrey, Jan. 2014

Legend

Study Area Boundary
Watershed Zone Boundary
Watercourse
Road Centreline
Cadastral

Topography
126 m, 95 m, 75 m, 60 m, 45 m, 30 m, 15 m, -1 m

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Upper Serpentine Integrated Stormwater Management Plan

Figure 1.2 - Existing Topography

For the purposes of the ISMP, the Study Area has been divided into four zones, with each zone having similar land use, drainage and environmental characteristics:

- Zone 1A – Developed Uplands (Urban)
- Zone 1B – Developed Uplands (Rural)
- Zone 2 – Tynehead Park and Sanctuary Natural Areas
- Zone 3 – Agricultural Lowlands

The zone boundaries are shown on **Figure 1.1**.

1.3 Communications and Engagement Strategy

Clear communications and engagement of City staff, external stakeholders and the general public is critical to the success of an ISMP, particularly when it comes to the implementation of ISMP recommendations.

1.3.1 Guiding Principles

A Communications and Engagement Strategy was developed at the onset of the Upper Serpentine ISMP. The strategy was developed to create awareness around the project and provide opportunities for external stakeholders to contribute to the project. Internally, the strategy provides the resources and opportunities necessary for City staff on the ISMP project team to work collaboratively towards an implementable ISMP for the Upper Serpentine Watershed.

Both internal and external stakeholders have been identified within the strategy. Externally, stakeholders include those who live, work, and recreate within the Study Area. Internally, stakeholders include City staff from various departments that make up the City's ISMP Team.

The strategy outlines a number of tools and techniques, as well as a timeline, to communicate and engage both the internal and external stakeholders identified within the plan. The Communications and Engagement Strategy can be found in full in **Appendix B**.

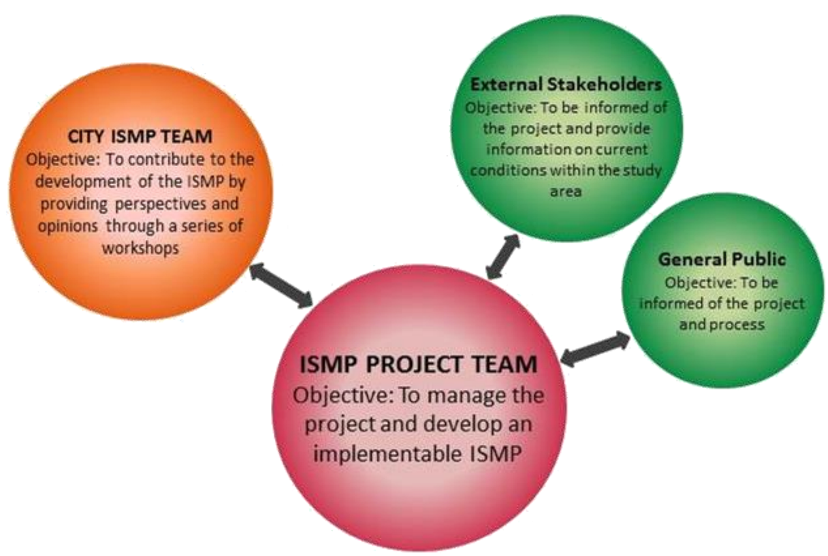


Figure 1.3: Communication and Engagement Flowchart

1.3.2 INTERNAL

1.3.2.1 ISMP Team

The ISMP Team for the Upper Serpentine Watershed is made up of a diverse group of City staff from various departments including: Engineering; Environment; Planning and Development; Parks, Culture and Recreation; Technology and Finance; Transportation; Building; and the Sustainability Office. City Staff were supported by an external consulting team consisting of Urban Systems (engineering, planning and landscape architecture), Dillon Consulting (environmental) and Thurber Engineering (geotechnical) on this project.

1.3.2.2 Staff Workshops

Over the course of the project, the ISMP Team participated in three workshops in order to collaboratively make important decisions to guide and shape the Upper Serpentine Watershed ISMP. Workshops were outcome-focused, ensuring that directions were set and decisions were made prior to advancing the ISMP. Workshops were supported by online surveys distributed to City staff; feedback from these surveys helped to shape the content of the workshops. Workshop summaries and online survey results are included in **Appendix B**.

Workshop # 1 included discussions about what an ISMP is intended to do and why ISMPs are important to the City. Team members highlighted various challenges and opportunities for the Study Area from their own unique perspectives. The group also toured the watershed, where they visited distinct areas that highlighted some of the positive work being done in the watershed as well as opportunities for improvements. At the completion of Workshop # 1, the ISMP Team identified four key themes to focus on in this ISMP; these are highlighted in **Section 2.4.1**.

Workshop # 2 focused on identifying core concepts to include in a Vision Statement for the Upper Serpentine Watershed. The ISMP team's discussion on values and tradeoffs confirmed that the ISMP should move beyond simply maintaining current watershed health; the ISMP should strive to improve watershed conditions in the future. Based on the workshop feedback, a vision for the Upper Serpentine Watershed, along with related goals and objectives were developed and agreed upon by the ISMP Team; these are highlighted in **Section 3**.

Focused priority setting, and identifying and evaluating scenarios that produced highest value for the watershed for a given level of investment were discussed in Workshop # 3.

These workshops were invaluable in articulating the City's preferences and values for the Upper Serpentine watershed, setting direction over the course of the project, and creating ownership amongst City staff moving forward with ISMP implementation.

1.3.3 EXTERNAL

1.3.3.1 Stakeholders

Two categories of external stakeholders were identified within the Communication and Engagement Plan; Agencies/Government Organizations and Special Interest Groups. These stakeholders were engaged to provide information about current conditions in the Study Area. Information was solicited through a digital poster that was emailed all external stakeholders. The digital poster included background information on the ISMP to create awareness around the project as well as information on how stakeholders can contribute to the process.

Stakeholders who asked to be kept informed of the ISMP's progress were provided updates at key milestones in the project.

1.3.3.2 General Public

The Communication and Engagement Strategy targeted the general public through online forums. A project page within the City of Surrey's website was created as a central location for all project-related information. Content was developed and posted to the project page for each phase of the project to keep interested community members informed on the ISMP's progress. The City's social media channels were also utilized to aid the project team in creating awareness for the project, promote opportunities for input, and direct traffic to the project page.

1.4 Report Outline

The ISMP has been organized into four stages; the purpose and key outcomes of each stage are highlighted in **Table 1.1** below.

Table 1.1: ISMP Stages

STAGE	TITLE	PURPOSE AND OUTCOMES
Stage 1	The Upper Serpentine Watershed Today (Inventory of Existing Systems)	• Summarize key features and properties of the Study Area • Highlight opportunities and constraints • Identify key issues for the ISMP to address
Stage 2	Vision for a Healthy Watershed in the Future (Vision, Goals and Objectives)	• Summarize anticipated future land uses in the Study Area • Articulate a vision (supported by goals and objectives) for the watershed that meets the City's and community's needs, and guides the ISMP process
Stage 3	Achieving a Healthy Watershed (Assessment, Analysis and Implementation)	• Identify, assess and present the recommended servicing approach(es) for future development conditions • Outline performance targets and design criteria • Develop a clear framework for implementation • Prepare cost estimates for recommended works
Stage 4	Keeping the Watershed Healthy (Monitoring and Adaptive Management)	• Identify performance indicators for key ISMP components • Outline monitoring and assessment programs • Describe an adaptive management process that the City can use to modify the implementation strategy if, through monitoring and assessment program results, the City determines that the ISMP vision, goals and objectives are not being met

2 THE UPPER SERPENTINE WATERSHED TODAY

2.1 Regulatory Framework

2.1.1 REGIONAL

As a member municipality of Metro Vancouver, the City has committed to meeting its obligations under the regional Integrated Liquid Waste and Resource Management Plan (ILWRMP; 2010). The plan endorses the view that stormwater is a resource that, when managed properly, can be utilized to protect and enhance watershed health. The ILWRMP outlines an approach to integrated stormwater management planning that considers drainage, environment and land use planning functions within a watershed. The intent is to address potential stormwater management impacts on a community and its values, such as population growth and densification, recreation, agriculture, fisheries, wildlife, flood protection, transportation, and other related issues. Member municipalities are required to undertake ISMPs for all urban and semi-urban watersheds by 2014 (with a conditional extension to 2016 for municipalities that can show they are complying with the Minister of Environment's ILWRMP approval conditions). The City is well underway with their ISMP programming and is on track to meet the ILWRMP deadline.

2.1.2 CITY OF SURREY

The City has a comprehensive suite of bylaws, policies, guidelines and other tools to support stormwater management, environment and land use planning initiatives. Primary documents of interest are briefly summarized below.

Sustainability Charter – The Sustainability Charter (2008) is the City's overarching policy document that promotes social, cultural, environmental, and economic sustainability. Through the Environmental Sustainability Pillar, the Charter encourages the use of sustainable stormwater management practices and promotes overall environmental protection. Several initiatives identified in the 2008 Charter are complete or underway; thus the City recently initiated a process to update the Charter. The updated Sustainability Charter is anticipated to be completed by Spring 2015.

Official Community Plan – The Official Community Plan (OCP) states the objectives and policies that guide the City's long-term planning decisions. It provides a comprehensive look at the City's physical structure, land use management, community growth and development, transportation systems, City-provided services and amenities, environmental protection and social issues. The City is currently updating their OCP. The 2013 draft Plan Surrey OCP went through a public hearing process and 3rd reading at City Council in March 2014. Following 3rd reading the OCP will be submitted to Metro Vancouver for review and approval. It is anticipated that final adoption of the updated OCP will take place in the Summer / Fall of 2014.

Climate Adaptation Strategy – The Climate Adaptation Strategy (CAS), developed in accordance with the Sustainability Charter, identifies the City's risks in areas related to drainage and flooding, tree mortality and ecosystem change, energy security, and agricultural viability due to climate change impacts. With these risks in mind, the strategy outlines a comprehensive action plan to increase the City's resilience in the areas of flood management and drainage, infrastructure, ecosystems and natural areas, urban trees and landscaping, human health and safety, and agriculture and food security.

Zoning Bylaw – The Zoning Bylaw defines land use classes in the City and identifies permitted uses, densities, lot coverage and setbacks, building heights, off-street parking and landscaping requirements for each class.

Erosion and Sediment Control Bylaw – The City's Erosion and Sediment Control (ESC) Bylaw regulates construction-related activities that could negatively affect the City's drainage system.

Stormwater Drainage Regulation and Charges Bylaw – This bylaw regulates the conditions under which connections and discharges can be made to the City's drainage systems (including watercourses). The bylaw also outlines user charges to connect to the City's system.

Drainage Parcel Tax Bylaw – This bylaw permits the City to apply a charge on all lands that are directly or indirectly serviced by the City's drainage system. The charge is a flat rate based on parcel class (all parcel classes are charged the same rate except for Class 9 – Agricultural, which has a lower rate). Monies are used to maintain and upgrade the City's drainage system.

Subdivision and Development Bylaw – This bylaw defines levels of service and outlines funding mechanisms (i.e., development cost charges, or DCC's) to fund infrastructure that supports the community on a neighbourhood or regional basis. It also requires developers to set aside lands for stormwater management purposes and park space as required.

Design Criteria Manual – The Design Criteria Manual (Schedule A of the Subdivision and Development Bylaw) provides the basis for utility design throughout the City, including stormwater infrastructure.

Soil Conservation and Protection Bylaw – This bylaw outlines permitting requirements and fees for the removal or deposit of soil in the City, with consideration given to potential drainage impacts and mitigation measures, amongst other requirements.

Building Bylaw – The Building Bylaw outlines on-site requirements for the capture and safe conveyance of stormwater runoff.

Tree Cutting and Tree Preservation Bylaws – The Tree Cutting Bylaw focuses on the protection and preservation of trees situated on publicly owned lands. The Tree Preservation Bylaw defines the requirements for "protected" trees and is applied City-wide.

Floodplain Development Policy – This policy establishes conditions and criteria for evaluating development proposals within the floodplain area (200 year) of the Serpentine and Nicomekl Rivers. The policy states that new development will not be permitted within the floodplain except where indicated in existing zoning or land use planning documents.

Ecosystem Management Study – This study, a recommended initiative of the Sustainability Charter, outlines the strategic management of environmentally significant lands and ecosystems in the City. The study includes an inventory of environmental features and ecological assets along with vegetation types and structures, as well as mapping that delineates ecosystem hubs, sites and corridors throughout the City.

Biodiversity Conservation Strategy – This strategy grew out the Ecosystem Management Study (EMS) completed several years ago for the City. Now adopted by Council, it provides a policy framework establishing biodiversity goals, targets and conservation priorities in the City. Together with the EMS, the BCS will provide strategic guidance on City-wide environmental initiatives in the future.

2.1.3 Provincial / Federal

Several Provincial statutes, regulations, and policies may have an influence on the ISMP, including:

- Agricultural Land Commission Act
- Dike Maintenance Act
- Drainage, Ditch and Dike Act
- Drinking Water Protection Act
- Environment and Land Use Act
- Environmental Assessment Act
- Environmental Management Act (and Waste Discharge Regulation)
- Fish Protection Act (and Riparian Areas Regulation)
- Fisheries Act
- Integrated Pest Management Act
- Water Act (and Water Regulation, Groundwater Protection Regulation)
- Water Protection Act
- Riparian Areas Regulation

The Province has also published the following manuals and guidelines:

- Stormwater Planning: A Guidebook for British Columbia (2002)
- Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia (2010)
- Develop with Care 2012: Environmental Guidelines for Urban and Rural Land Development in British Columbia (2012)
- Sea Level Rise Adaptation Primer (2013)

The Federal Government has passed various statutes that may be relevant to watershed health and stormwater management, including:

- Fisheries Act
- Canada Water Act
- Pest Products Control Act
- Canadian Environmental Protection Act
- Species at Risk Act

- Canada Wildlife Act
- Canada Marine Act
- Land Development Guidelines

The Federal Government has also established draft development guidelines to protect fish: "Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat".

2.2 Land Use

2.2.1 Existing

The Zone 1A Developed Uplands area is highly urbanized, with single family and multi-family residential, commercial, light industrial, schools, community centres, and parks and open spaces comprising the primary land uses, as shown on **Figure 2.1**. Highway 1 transects this zone near its northern limit. Densities are generally higher south of the highway; major developments in this area include the Guildford Town Centre shopping mall at 152 Street and 104 Avenue, and a large auto mall near 154 Street and Guildford Drive. Single family residential homes, along with schools, community centres, parks and open space, represent the primary land uses north of the highway.

Zone 1B consists of rural land uses, including large acreages with single family homes and hobby farms, as highlighted on **Figure 2.1**. Generous tracts of open space and tree stands are also present in this zone.

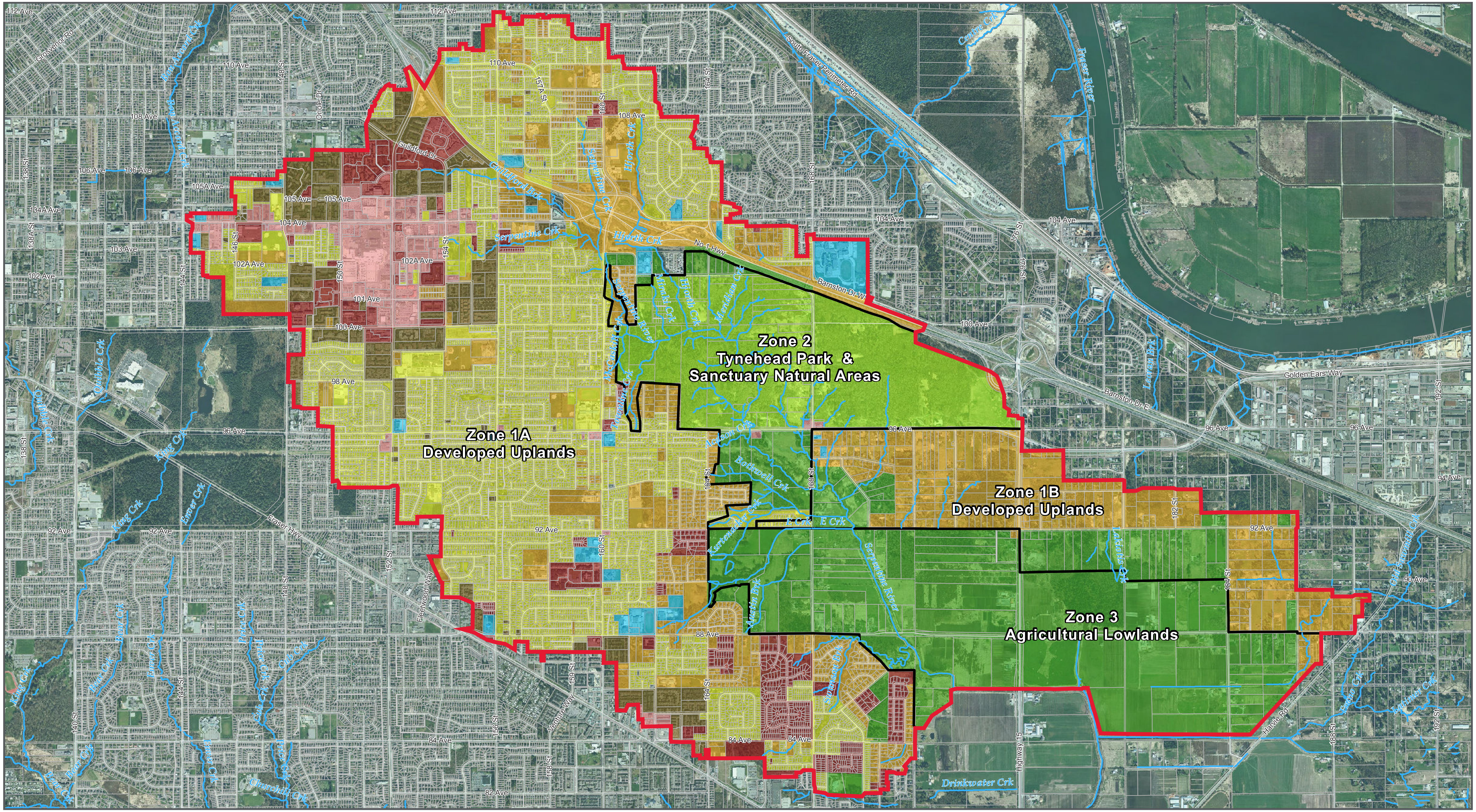
Metro Vancouver's Tynehead Regional Park is located in Zone 2. This passive-use park contains significant tracts of treed and natural areas, an extensive trail network, and picnic and open field areas. The Tynehead Hatchery, also located in the park, plays a vital role in supporting the aquatic health of the Upper Serpentine system; the hatchery releases 250,000 salmon fry annually into the Upper Serpentine River and qualitatively monitors stream health from a fisheries and aquatic perspective. Tynehead Regional Park is also a regional hub for wildlife, and is well utilized by the community for recreational purposes.

Agricultural uses dominate Zone 3 in the Study Area. Active farming operations in this lowland area include forage uses, along with blueberry and vegetable crops. A few fallow (uncultivated) fields are also present.

The existing total impervious area (TIA) for each zone (and the watershed) was computed based on 2013 aerial photography provided by the City. Results are highlighted in **Table 2.1** below.

Table 2.1: Total Impervious Area Summary (Existing Conditions)

Zone	Description	Total Area (ha)	Impervious Area (ha)	% Impervious
1A	Developed Uplands (Urban)	1,582	699	44.2%
1B	Developed Uplands (Rural)	313	31	9.9%
2	Tynehead Park & Sanctuary Natural Areas	324	20	6.2%
3	Agricultural Lowlands	399	31	7.8%
	Total Area (ha)	**2,618**	**781**	**29.8%**



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0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

2013 aerial provided by the City of Surrey, Jan. 2014
Tynehead Park boundary from Metro Vancouver website, Jan. 2014
Study area delineated by Urban Systems, Feb. 2014
Land use and watercourse data provided by the City of Surrey, Jan. 2014

Legend

- Study Area Boundary
- Watershed Zone Boundary
- Watercourse
- Cadastral
- Single Family
- Acreage Residential
- Multi-Family Residential
- Institutional
- Commercial
- Comprehensive Development
- General Agriculture
- Regional Park
- Industrial

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Figure 2.1 - Existing Land Use

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2.2.2 FUTURE

Generalized future land use classifications in the City are provided in the City's 2013 draft Plan Surrey Official Community Plan (OCP), shown on Figure 2.2. Within the Study Area, the OCP indicates that the Zone 1A Developed Uplands will remain urban, with higher density development concentrated in the Guildford and Fleetwood Town Centre areas (see further discussion below). The Zone 1B Developed Uplands, along with Zone 2 and Zone 3, are designated as suburban, conservation and agricultural, respectively, in the draft OCP.

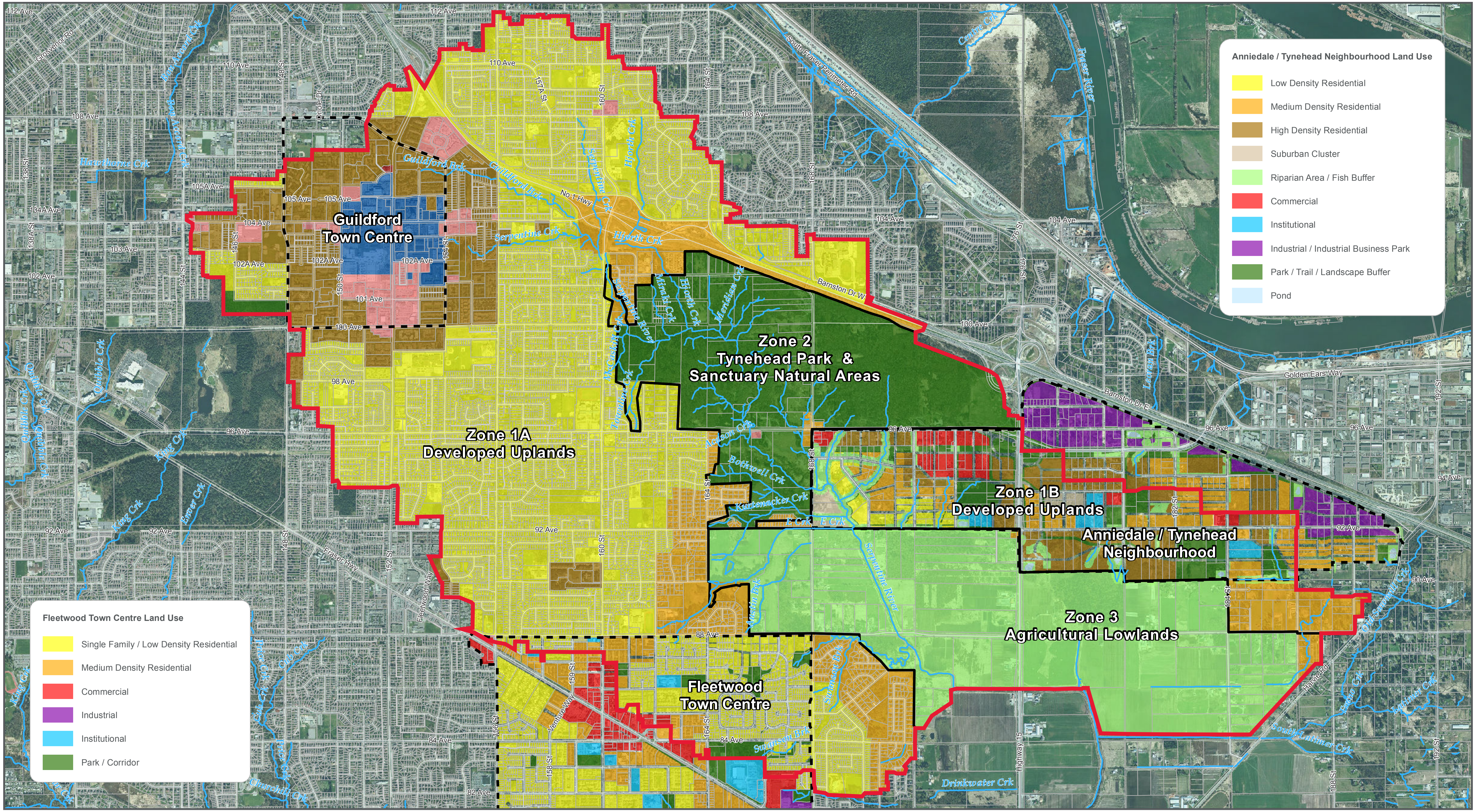
Future development within the Zone 1B Developed Uplands is further defined by the Anniedale-Tynehead Neighbourhood Concept Plan (NCP). The NCP area is roughly bounded by Highway 1 to the north, 190 Street to the east, 90 Avenue to the south and 168 Street to the west, as shown on **Figure 2.2**. The NCP calls for the transformation of this area from suburban uses into a comprehensive development zone with a variety of uses, including low to high density cluster developments, low to high density residential, commercial, light industrial, schools and parks. An extensive trail network, along with landscape and riparian buffers are also proposed.

The Anniedale-Tynehead NCP was developed with green infrastructure opportunities in mind. Subsurface infiltration galleries and bioswales are proposed along main road corridors to address roadway-generated runoff. Stormwater quantity / quality treatment ponds are also to be located throughout the neighbourhood area to control and treat runoff prior to discharge to the Serpentine River. Further, the focus on cluster development throughout much of the NCP area is intended to promote the retention of dedicated green space / natural areas, which are beneficial from both the stormwater and environmental perspectives.

Currently, there are no sanitary sewers and limited watermains in the NCP area. Given the costs associated with extending these utility networks, it is anticipated that growth and development in the Anniedale-Tynehead NCP area will occur over the longer term.

Future land use within the southern portion of Study Area (south of 88 Avenue, between 156 Street and 168 Street) is described in the Fleetwood Town Centre Plan (TCP), adopted in 2000. The TCP, shown on **Figure 2.2**, currently calls for an increase in densification, with commercial, light industrial, institutional and multi-family residential development concentrated along the Fraser Highway and 160 Street corridors. Outside of these corridors, the plan calls for single family and low density multi-family housing, along with schools and park space. The Fleetwood TCP is currently being updated by City staff and is scheduled for completion in the near future; development of a drainage servicing plan has not yet begun.

The City intends to initiate a detailed planning process for the Guildford Town Centre area in 2015. The proposed plan limits are shown on **Figure 2.2**. This initiative will focus on redevelopment and densification opportunities within the Study Area's primary Town Centre. The draft OCP states that the "Guildford Town Centre is characterized by overall low-density commercial development, a few stand-alone high density commercial developments and older, walk-up style apartment buildings. Higher density residential and commercial development is expected to increase given its proximity to the TransCanada Highway (Highway #1)." Therefore, it is anticipated that future high density growth and redevelopment will be focused in this area.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 5 / 12

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:
NAD 1983 UTM Zone 10N

Data Sources:
2013 aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Road Centreline
- Cadastral
- Town Centre / NCP Area
- Watershed Zone Boundary
- Watercourse

Official Community Plan

- Agricultural
- City Centre
- Commercial
- Conservation
- Industrial
- Multiple Residential
- Suburban
- Town Centre
- Urban

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Figure 2.2 -
Future Land Use

U:\Projects_VAN\1072\0211\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report_Figure_Revisions_2015_05_12\Figure_2_2_Future_Land_Use_Rev_A.mxd Last updated by sfadum on Tuesday, May 12, 2015 at 3:18:24 PM

The future total impervious area (TIA) for each zone (and the watershed) was computed based on the OCP, the Anniedale-Tynehead NCP and the Fleetwood TCP, as applicable. Since detailed land use information from the Fleetwood TCP Update and Guildford Town Centre Plan were not available at the time the ISMP was being developed, available information was used for these areas; in any case, differences between the information used for the ISMP and as adopted for Fleetwood and Guildford will not be significantly different than listed here. Results are tabulated in **Table 2.2** below.

Table 2.2: Total Impervious Area Summary (Future Conditions)

Zone	Description	Total Area (ha)	Impervious Area (ha)	% Impervious	Increase Over Existing Conditions
1A	Developed Uplands	1,582	1,013	64.0%	+19.8%
1B	Developed Uplands	313	149	47.7%	+37.8%
2	Tynehead Park & Sanctuary Natural Areas	324	47	14.5%	+8.3%
3	Agricultural Lowlands	399	85	21.4%	+13.6%
	Total Area (ha)	**2,618**	**1,295**	**49.5%**	**+19.7%**

The extent of future impervious areas is based on application of current zoning requirements for the various land uses. This leads to a rather high potential impervious cover in agricultural lowlands. Further discussion can be found in **Section 4.1.3.1**.

2.3 Existing Systems Inventory

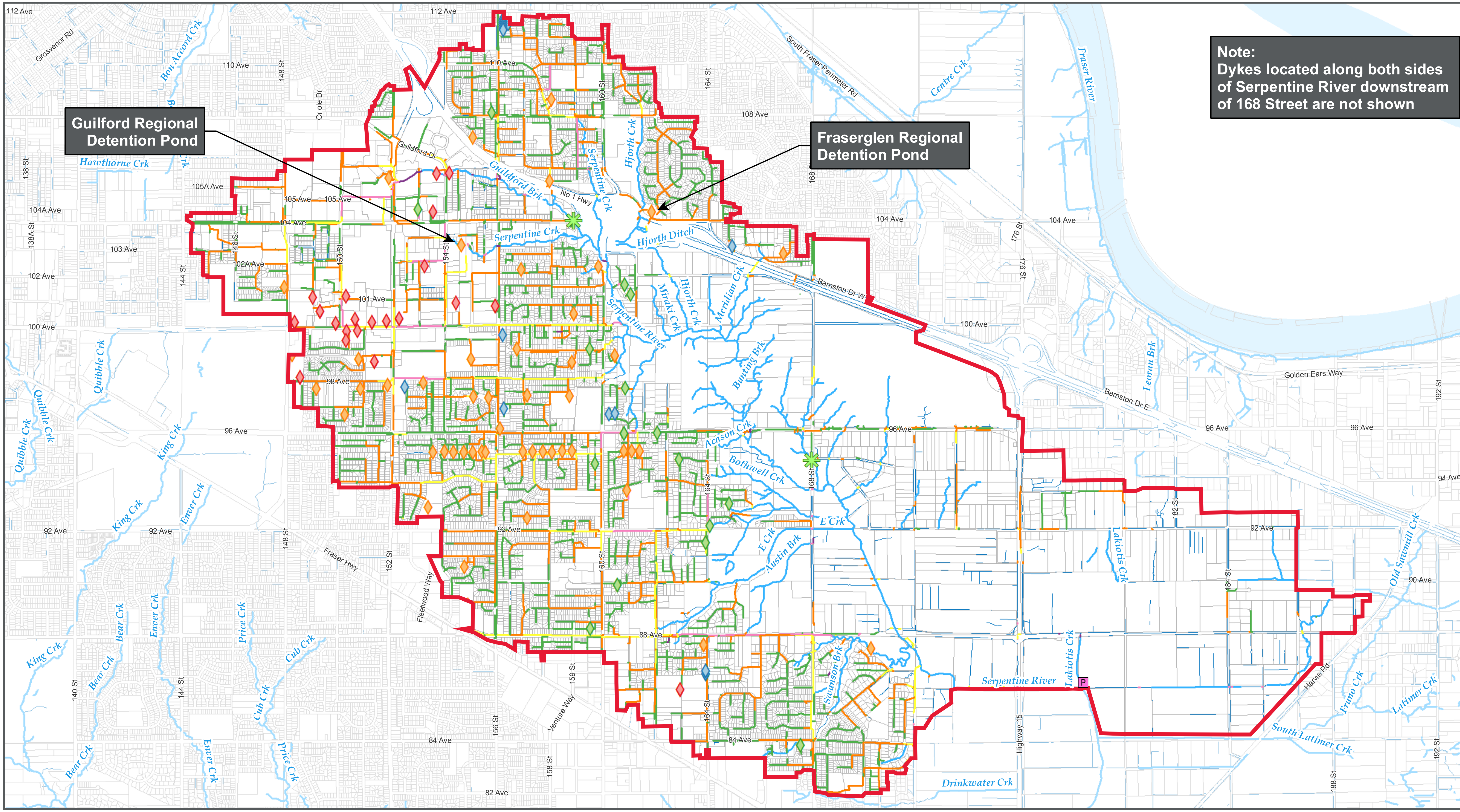
2.3.1 Stormwater / Drainage

Stormwater runoff generated by developed areas in Zone 1A is captured and conveyed by an extensive storm sewer network, as shown on **Figure 2.3**. This network in turn discharges flow to the numerous creeks that originate within Zone 1A, along with some direct outfalls to the Serpentine River itself. The storm sewer network is intended to convey flows up to the 5 year return period event, with excess flows routed overland (along roadways and dedicated rights-of-way) to the creeks. This drainage servicing approach is typical for urbanized areas throughout the City.

In contrast, rural portions of the Study Area (Zones 1B, 2 and 3) are predominantly serviced by an open ditch network, with culverts to convey flows beneath roadways and driveways. Stormwater runoff typically flows overland and/or via shallow groundwater (interflow) pathways for a distance prior to reaching the ditch system. Ditches in turn discharge flow to the tributary creeks or to the Serpentine River directly. Flows in excess of the ditch capacity will overtop the ditches and flow overland along roads or potentially over private property. The ditch system within the Lakiotis Creek catchment discharges flow to the Serpentine River via a drainage pump station (and flood box) located at the confluence of the Serpentine River with Lakiotis Creek, as shown on **Figure 2.3**. The pump station discharges runoff across the dykes which line both sides of the Upper Serpentine south from about midway between 92 and 88 Avenues, providing flood protection for Surrey's lowlands.

According to the City's GIS database, there are 65 municipal stormwater detention facilities scattered throughout Zone 1A, with an additional 35 privately-owned detention facilities. The vast majority of these are dry ponds that were implemented to service local catchment areas in the immediate vicinity of each pond. The ponds were generally designed with a downstream flow control structure (i.e., orifice) that activates the pond only when the capacity of the orifice is exceeded (orifices are typically designed for the 5 year storm event). Previous studies and reviews have shown that many of these ponds have resulted in minimal benefit to the creeks under frequent, low intensity events (i.e., less than the 5 year event) as the ponds are rarely activated; however, under more extreme events they may provide some benefit. Frequent, low intensity events constitute roughly 90% of the annual rainfall volume in a watershed in the Lower Mainland, and have a direct influence on creek health, including aquatic organisms, bank stability, etc. The City has previously undertaken works to improve the performance of some of the ponds in the Study Area, including those located within the BC Hydro right-of-way between 95 Avenue and 95A Avenue; however, resulting benefits on a watershed health basis appear to be minor for frequent, low intensity events.

There are two regional municipal stormwater detention facilities in the northern portion of Zone 1A; Guildford Pond and Fraserglen Pond, as shown on **Figure 2.3**. Guildford Pond, located within Guildford Heights Park at 154 Street and 103A Avenue, was constructed in 2002. This wet pond services a large, highly urbanized catchment that includes a portion of the Guildford Town Centre area. Outflows from the pond discharge to the upper reaches of the Serpentine River. The adjacent sports field in the park also serves as an emergency storage basin during extreme rainfall events when the pond's capacity is exceeded. Together, the pond and adjacent sports field represent the largest stormwater detention facility in the Study Area. Fraserglen Pond, built in 1984, is a smaller regional pond located at the northwest corner of Fraserglen Drive and 104th Avenue. This wet pond services a large urban catchment area north of Highway 1, and ultimately discharges to Hjorth Creek.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:
NAD 1983 UTM Zone 10N

Data Sources:
Town centre, NCP boundaries provided by the City of Surrey, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014
Monitoring station locations from Flow Works website, Mar. 2014

Legend

Study Area Boundary
Cadastral
Watercourse
Ditch
Storm Main (<= 300mm)
Storm Main (>300mm - 600mm)
Storm Main (>600mm - 900mm)
Monitoring Station
Storm Main (>900mm - 1200mm)
Storm Main (>1200mm)
Existing Pump

Detention Ponds

	Above Ground	Below Ground
Municipal	(49)	(17)
Private	(21)	(17)

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Figure 2.3 - Existing Drainage Infrastructure

U:\Projects_VAN\1072\0211\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report_Figure_Revisions_2015_03_26\Figure_2_3_Existing_Drainage_Infrastructure_Rev_A.mxd Last updated by sfadum on Thursday, April 2, 2015 at 4:05:34 PM

There are no municipal stormwater detention facilities in Zones 1B, 2 or 3 within the Study Area limits.

The City has a hydrometric station on the Serpentine River at the 104 Avenue crossing, which has flow and water level data available for the 1996 to 2012 period. The City also maintains a water level gauge on the Serpentine River at the 168 Street crossing, which has been active since 1996. Both monitoring sites are shown on **Figure 2.3**. These stations provide valuable information on seasonal base flows as well as the river's response to rainfall events. Limited rainfall data (late 2012 to present) is available for the Hemlock Municipal Yard Rain Gauge (which is located within the Study Area); the Surrey Kwantlen Park rain gauge, on the other hand, is located just east of the Study Area and has a significantly longer period of record (1997 to present).

The City has been conducting ravine stability assessments for all major watercourses in the City for over a decade. Each biannual assessment tracks trends and changes in ravine bank stability over time, and identifies and ranks erosion sites based on perceived risk to public safety, structures and/or infrastructure. The last available assessment, completed in 2011, identified one high risk site and numerous medium and low risk sites along watercourses within the Study Area; the high risk erosion site is shown on **Figure 2.3**. The City recently initiated an update to the ravine stability assessment, but it was not available at the time of preparing this report.

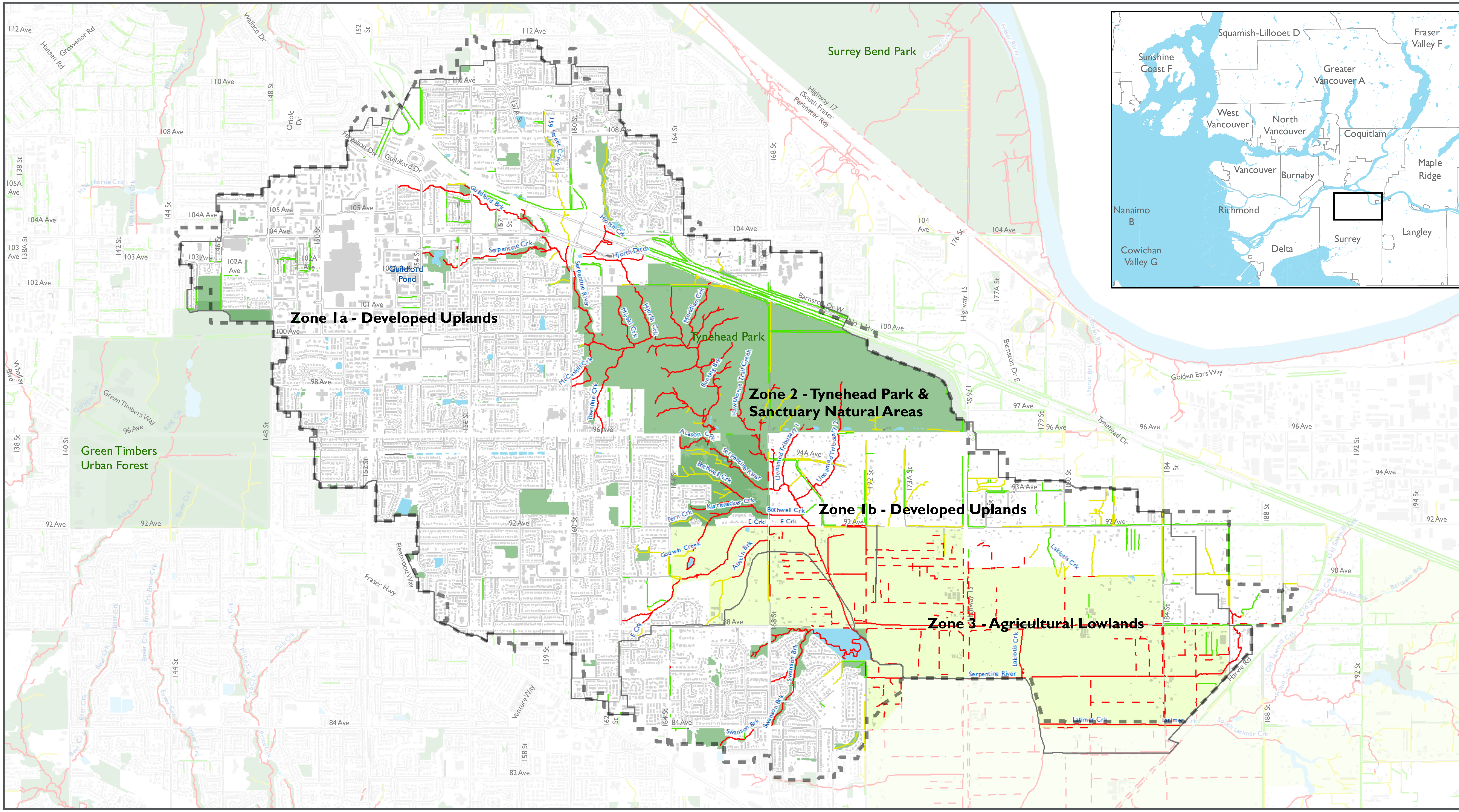
The 2011 high risk site, located near the confluence of Guildford Brook and the Serpentine River, is downstream of Guildford Pond and a highly urbanized development area. The site was reviewed in the field as part of the ISMP. Based on that site review, aside from minor weathering and ravelling of the bank face, the site appears to be relatively stable compared to the 2011 assessment results. Vegetation is establishing in the slough material and in some areas of the head scarp. Erosion is still evident at the creek water level with some minor sloughing of the bank; however, there does not appear to be recent retrogression of the crest of slope.

Sediment generated by erosion and scour processes along the upland segments of the watercourses are typically settled out in the lowland portion of the Serpentine River; as a result, an on-line sediment trap was constructed immediately south of the 88 Avenue crossing to collect sediment transported in the river. In 2007, the City installed a flow bypass pipe to aid sediment trap dredging activities during times of low flow in the river.

2.3.2 Aquatic

Existing watercourse classifications, based on the City's Watercourse Classification system, are shown on **Figure 2.4**. The Serpentine River and several of its tributaries in the upland areas are considered Class A watercourses, indicating that salmonids are present year round (or could be present if access enhancements were undertaken).

Figure 2.5 highlights those sections of Class A watercourse that provide spawning, rearing or migratory habitat for salmonids. Barriers and obstacles to fish access are also indicated on **Figure 2.5**. The spawning/rearing/migratory designations shown may not be the appropriate designation for some sections of the Class A channels, particularly within the upstream reaches. Gradient barriers may prevent upstream access for fish and, as such, further study is warranted to confirm access potential and classification.



Project #: 14-8893
Author: ECH
Checked: NG/ML
Status: FINAL
Revision: A
Date: 2015 / 3 / 24

0 250 500 750 1,000 m
Scale: 1:29,000
N

Coordinate System:
UTM Zone 10N Nad83

Data Sources:
City of Surrey Open Data, ESRI Base Layers, Dillon Consulting Limited, Urban System

Legend

Watercourse Classification			
A	B	Upper Serpentine Watershed	Parks and Natural Areas
A(O)	C	Watershed Zones	Agricultural Land Reserve
		Waterbodies	Building Footprints

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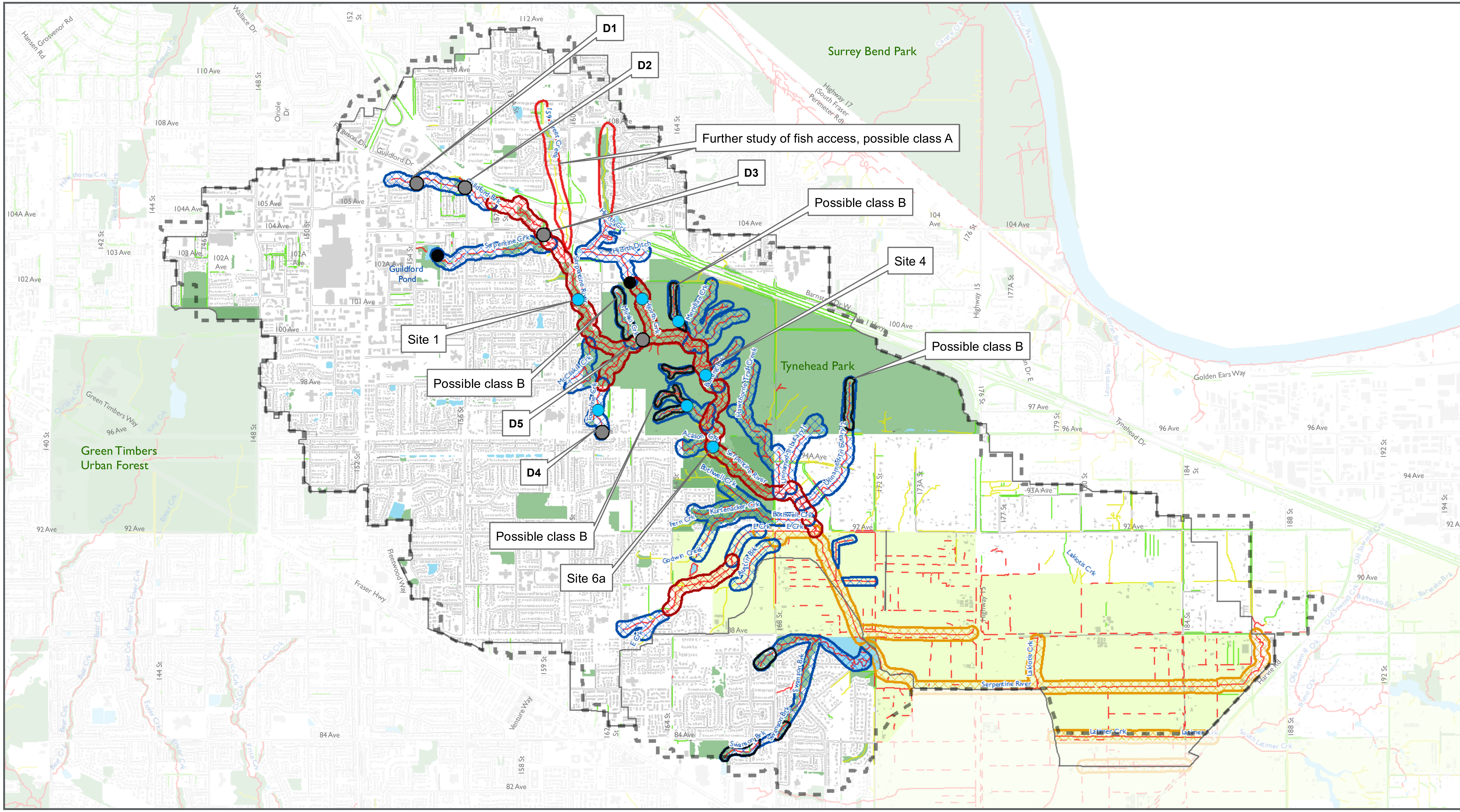
Figure 2.4 - Study Area and Watercourse Classification



![Dillon Consulting logo]

Project #: 14-8893
Author: ECH
Checked: NG/ML
Status: Final
Revision: A
Date: 2015 / 3 / 24

0 250 500 750 1,000 m

Scale: 1:28,000

N

Coordinate System:
UTM Zone 10N Nad83

Data Sources:
City of Surrey Open Data, ESRI Base Layers, Dillon Consulting Limited, Urban System

D1 Gravel Deployment
Fish Barriers
Historic Benthic Sampling (1985[4])

Habitat Utilization Potential for Salmonids
Migratory Only
Rearing Only
Spawning and Rearing

Possible Watercourse Reclassification
Possible Class B (Further Study)
Possible Class A (Further Study)
Upper Serpentine Watershed

Watercourse Classification
A
A(O)
B
C

Waterbodies
Parks and Natural Areas
Agricultural Land Reserve

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Figure 2.5 - Fish Habitat Suitability

G:\GIS\148893 Upper Serpentine ISMP\Figure 2.5 - Fish Habitat Suitability.mxd Last updated by 42MZO on Tuesday, March 24, 2015 at 2:27:50 PM

Although the habitat usage for Class A(O) channels has not been indicated on **Figure 2.5**, all of these channels are considered to provide rearing habitat only. Other habitat is provided by a series of Class B channels in the Zone 1B Developed Uplands area, between Zones 2 and 3. These channels generally convey flow south to the Class A(O) drainage network in the agricultural lowlands.

Aquatic habitat has been compromised by development and limited detention within the Zone 1A Developed Uplands, particularly in the Guildford area and areas north of Highway 1. Sections of the watercourses have been reconstructed on linear alignments such that their complexity is reduced. Limited detention in the upstream catchments results in peak flows being discharged to the creek systems with little to no attenuation; resultant peak flows have scoured gravel from some sections such that spawning potential has been severely impacted or is no longer existent. In response to this, the City initiated a gravel deployment program in several locations in the summer of 2013, as shown on **Figure 2.5**. Placement of additional gravel was initiated at locations D2 through D4 in the summer of 2014. It appears the some of the gravel remains at the deposition points; however, the majority appears to have been conveyed downstream as would be expected. The City has not yet initiated a detailed assessment of where this supplemental gravel may have been deposited downstream. The long-term benefit of the program is expected to include improved substrates for both salmonid spawning and benthic invertebrate habitat.

Riparian setbacks have been restricted in places in Zone 1A and access from local properties has rendered these channels sensitive to disturbance by people.

The most significant, intact aquatic habitat in the Study Area is located in Zone 2. Numerous small Class A tributaries discharge to the Serpentine River mainstem, with each channel providing rearing habitat for salmonids. Some tributaries also provide spawning habitat; however, the most significant spawning potential is found within the Serpentine River itself. The channels are commonly found on their original alignments and display high complexity with a varied substrate, instream woody debris, and sections of pool, riffle, and run habitat. The riparian vegetation assemblage is largely intact with limited presence of invasive species (such as Himalayan blackberry). This vegetation provides shade, stability, and cover for fish. Some of the channels have been more impacted by development than others, particularly the area around 168th Street and to the east. Some Class A channels may warrant further investigation to confirm fish access and, as such, verify whether the Class A designation is accurate.

Aquatic habitat in the Zone 3 Agricultural Lowlands is provided by the Serpentine River, numerous tributary Class A watercourses, and a series of linear Class A (O) ditches. Habitat is limited to migratory or rearing habitat with some small sections of potential spawning habitat present. The channels tend to be lower gradient with substrates dominated by silts and organics. They are often channelized and have been reconstructed along linear alignments such that instream complexity is reduced. Riparian vegetation has often been cleared to at or near the top-of-bank such that there is limited shade. As a result, water quality would be expected to be reduced, further limiting the value of the habitat to salmonid species. Water quality would be particularly impacted in the Class A (O) sections of channel where flow is very low.

Further information on aquatic resources can be found in **Appendix C**.

2.3.3 Vegetation

The entire study area is located within the Coastal Western Hemlock (CWH) biogeoclimatic zone. The CWH is characterized by mild and wet winters with sunny and dry summers. Western hemlock is the dominant tree species in undisturbed areas and climax vegetation communities.

Vegetation in the Zone 1A Developed Uplands is predominantly found within landscaped properties. Native species would be generally restricted to riparian corridors, park land and wildlife corridors. Native species are more prevalent in Zone 1B, although there is still a significant invasive species presence.

Tynehead Park (Zone 2) consists mainly of young forests, with some sections of old forest and unmanaged herb, grass, and shrub land. Riparian vegetation in Tynehead Park contained little to no invasive vegetation at the time of assessment in support of the ISMP. Vegetation in upland areas within the park was more characteristic of disturbed areas, with invasive species present.

Vegetation (i.e. excluding crops) in the agricultural lowlands (Zone 3) is quite limited with only a small section of forest consisting of a mixed deciduous/coniferous canopy with an understory of both native and invasive species south of 92nd Avenue. The majority of the significant vegetation has been cleared for agriculture. Riparian vegetation is often lacking near the top-of-bank of the majority of the linear channels and ditches.

Further information on vegetation resources can be found in **Appendix C**.

2.3.4 Wildlife / Terrestrial

Figure 2.6 highlights the existing terrestrial habitat of the Study Area, including wildlife corridors. Wildlife corridors are defined as:

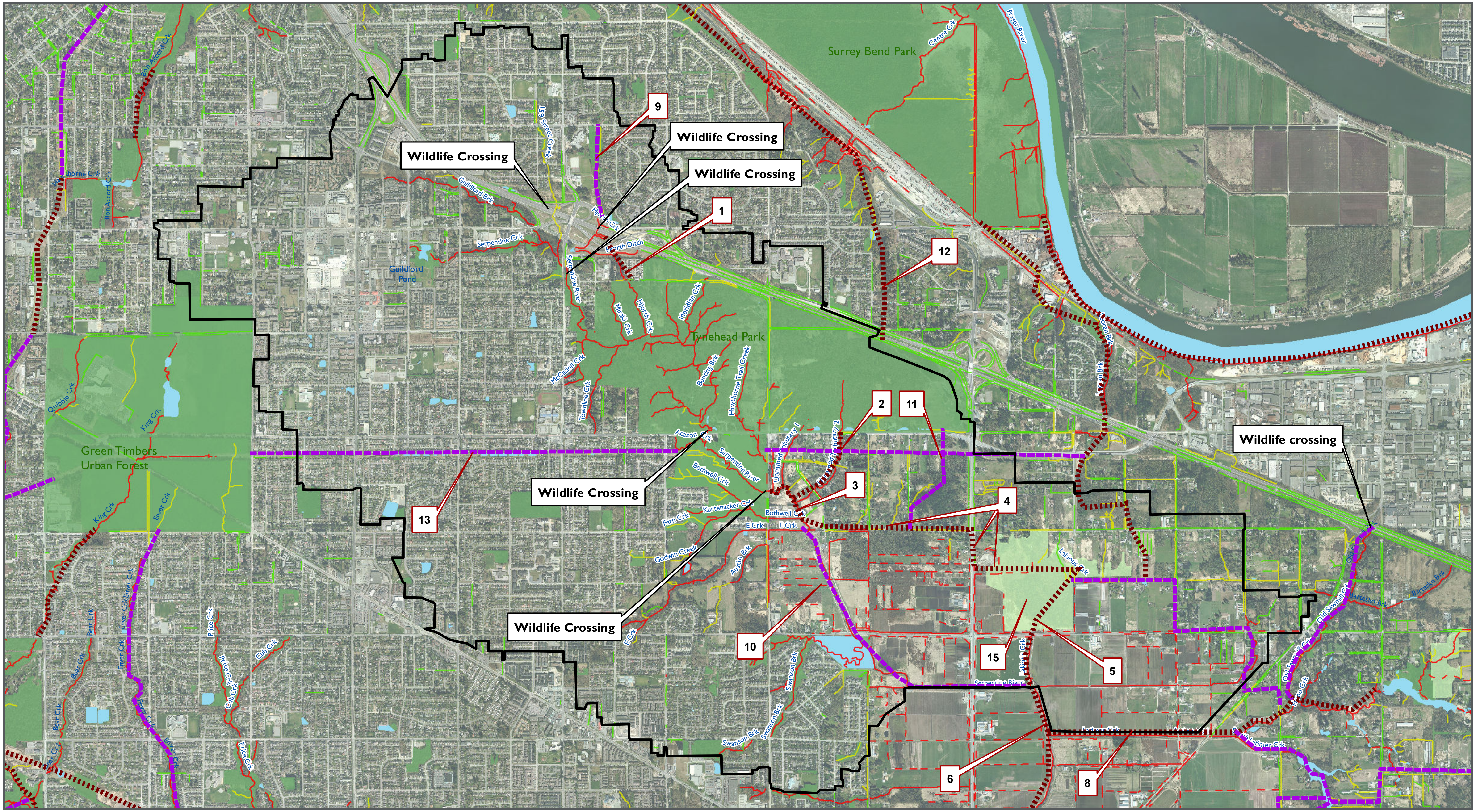
- ***Regional:*** 50 - 100 metres wide; provides movement for a wide range of species, including those less tolerant of human disturbance; limited recreation opportunities; connects large habitat areas.
- ***Local:*** 10 - 50 metres wide; provides movement for species more tolerant of human disturbance (e.g., BC hydro ROW, greenways through developed areas); connects smaller sites.

Wildlife corridors are important for maintaining biodiversity because they allow species to disperse and colonize new areas, which helps maintain genetic diversity among populations. Large corridors are ideal because they are better suited to species that are less tolerant of human disturbance and they support a greater diversity of species.

Terrestrial habitat in Zone 1A Developed Uplands is limited to small patches of forested areas (e.g., northwest of 160th Street and 92nd Avenue), riparian corridors, landscaped properties and manicured urban parks. Given the level of development, terrestrial habitat value has been severely compromised and wildlife utilization is expected to be limited to urban generalist species. Local corridors include the riparian zones of named creeks, a BC Hydro right-of-way between 95 Avenue and 95A Avenue, Hjorth Creek north of Highway 1, Guildford Brook and Serpentine Creek.

Habitat in Zone 1B is somewhat impacted with large single family lots providing more intact habitat, particularly on the south–facing slope transitioning down to Zone 3. The intact habitat also has more linkages to regional and local wildlife corridors than that experienced in Zone 1A.

Tynehead Park (Zone 2) is the largest natural area in the Upper Serpentine watershed and represents the most significant hub for wildlife in the Study Area. It is largely undisturbed and provides a variety of habitats (stream, riparian, upland wooded areas) for numerous species. Wildlife corridors link Tynehead Park to other large hubs nearby. A major corridor exists between the east portion of Tynehead Park and a small natural area east of 172nd Street to the north, which connects to Surrey Bend Park. The Quibble Creek Greenway that runs south from Green Timbers Urban Forest connects with the Serpentine River south of 72nd Avenue, and both of these corridors ultimately provide connectivity to Mud Bay. The Serpentine River also acts as a regional corridor for wildlife to move between Tynehead Park and agricultural areas to the south.



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Project #: 14-8893
Author: ECH
Checked: NG/ML
Status: Final
Revision: A
Date: 2015 / 3 / 24

0 250 500 750 1,000 m

Scale: 1:28,000

N

Coordinate System:
UTM Zone 10N Nad83

Data Sources:
City of Surrey Open Data, ESRI Base Layers, Dillon Consulting Limited, Urban System

Wildlife Corridors	Watercourse Classification
Regional	A
Local	A(O)
1 Corridor Number	B
	C

Upper Serpentine Watershed
Parks and Natural Areas
Waterbodies
High Priority Unprotected Habitat Areas

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Figure 2.6 - Terrestrial Habitat

Significant terrestrial habitat in the Agricultural Lowlands is essentially limited to patches of grassland and forest, as well as narrow riparian zones. Most of the area is developed for agricultural or residential use, and the habitat in the area is fragmented. There is limited habitat for larger wildlife and species presence is expected to consist of a variety of bird species, some amphibian and reptiles, and mammalian urban generalists adapted to disturbed habitats. Agricultural row crops and turf grass (areas of manicured grass) are expected to have a particularly low biodiversity compared to the other habitat types in the watershed. The primary terrestrial habitat would be the Serpentine River which would act as a corridor for wildlife moving to and from the large hub at Tynehead Park.

As would be expected, wildlife presence is influenced by existing land use and linkages through the Study Area. Large intact blocks of native vegetation are able to support a much greater biodiversity than the fragmented habitat often found in an urban setting. In addition, a greater biodiversity of species would be expected where wildlife corridors connecting sections of intact habitat area present. For this reason, Zone 2 supports the greatest native biodiversity for wildlife in the Study Area. It is of sufficient size to support populations, or at least the presence, of a number of wildlife species, including larger mammals that would typically avoid high-density areas. The numerous regional and local wildlife corridors help bolster this biodiversity through connections to other large habitat blocks such as Green Timbers and Surrey Bend. Despite the presence of these corridors, the other zones show a reduced wildlife presence given the fragmented nature of the habitat and the general lack of intact forested blocks. This is particularly observed in the highly developed Zone 1A.

Further information on wildlife and terrestrial resources can be found in **Appendix C**.

2.3.5 Habitat Health

Habitat health varies significantly throughout the Study Area, principally as a result of past land use activities. The clearing of vegetation to accommodate development not only impacts terrestrial habitat through direct loss, it also can serve to increase urban runoff which, without controls, can have a severe negative impact to aquatic habitat both at and downstream of the Study Area as a result of erosive flow and decreased water quality.

2.3.5.1 Zone 1A

Zone 1A is the most severely impacted habitat in the Study Area. It has been developed for residential and commercial purposes. As referenced, terrestrial habitat is generally limited to parks, school fields, landscaped properties and local wildlife corridors (identified as Nos. 9 and 13 on **Figure 2.6**). While some wildlife presence is expected, it would be limited to urban generalist species. In addition, landscaped properties would most likely include a high percentage of non-native or possibly even invasive plant species. As a result, the native biodiversity of the terrestrial habitat would be quite low.

Aquatic habitat is quite limited and restricted to a few channels in Guildford, near Highway 1 and 160th Street, and in the south central portion of the Study Area. Development has significantly reduced the riparian zones for these watercourses. In addition, the development of the majority of the upland area has resulted in highly erosive flow within the Serpentine River mainstem and some of its tributary channels. This has combined to scour spawning gravel from large sections of the channels, particularly in Guildford Brook and Serpentine Creek. As a result, habitat value of these watercourses has been severely compromised.

The lack of significant terrestrial habitat and the impacted nature of the aquatic habitat have resulted in an overall habitat value in Zone 1A of poor.

2.3.5.2 Zone 1B

Although developed for residential purposes, Zone 1B tends to have much larger properties and lower density than Zone 1A. As a result, the terrestrial vegetation is considerably more intact with a higher percentage of native vegetation present. Wildlife corridors, both regional and local, facilitate movement through the Study Area as well as to large hubs located north of Highway 1 and to the south within the Serpentine River lowlands. Wildlife presence is expected to include not only the urban generalists found on Zone 1A but would also likely include large mammals such as deer or bear on occasion. As a result, native biodiversity for both the plant and animal communities is expected to be moderate to high.

Aquatic habitat is primarily present as a series of linear channels, often oriented along property lines and roadsides. Accessible fish habitat is limited to the Serpentine River mainstem and a number of tributary channels that discharge to the river between 92nd and 96th Avenues. The large terrestrial blocks benefit fish habitat by buffering channels from erosive flow and poor water quality. Despite these benefits, fish presence is limited, perhaps due to steep local topography at some locations. Regardless, the buffering effects of the terrestrial vegetation has a benefit to both water quality and, where present, fish populations.

The intact terrestrial patches and the buffering of the aquatic habitat have resulted of an overall health rating of moderate for Zone 1B.

2.3.5.3 Zone 2

As referenced, from both a terrestrial and aquatic perspective, Zone 2 provides the most significant habitat in the Study Area. It is a large intact forested block that supports a highly diverse assemblage of native plant and animal species. The intact habitat serves to attenuate rainfall such that erosive flow in the network of creeks in the area is reduced, although this does not assist significantly with flow entering the zone from upstream areas. The entirety of Tynehead Park serves as the primary terrestrial habitat hub for the area and plays and important part in linking to other large, intact hubs such as Green Timbers Urban Forest and Surrey Bend. Wildlife presence includes species not normally observed in many urban settings including black bear, black-tailed deer and river otter.

The numerous tributary channels located within Tynehead Park are commonly found on their original alignments and for the most part support complex, accessible fish habitat. While the mainstem of the Serpentine River is severely impacted due to erosive flows originating in Zone 1A, it is still some of the most complex habitat to be found in Surrey, with great potential to support populations of a variety of salmonid species.

Overall, the health of the habitat within Zone 2 is high due to the complex aquatic habitat and the large terrestrial habitat block of Tynehead Park.

2.3.5.4 Zone 3

Overall habitat value within Zone 3 has been compromised by agricultural land use. Significant blocks of terrestrial vegetation are limited which diminishes overall biodiversity for both plants and wildlife.

However, some diversity of wildlife presence is still expected given the reduced presence of large numbers of people.

Riparian vegetation is often cleared to near the top-of-bank on most watercourses. In addition, the channels are flat and aligned along roadside or property lines for the most part. This would tend to reduce the complexity of the habitat as well as negatively affect water quality. As such, salmonid presence would likely be restricted to the overwintering period.

The lack of significant terrestrial habitat and reduced quality of the aquatic habitat is indicative of low to moderate health.

2.3.6 Soils and Groundwater

The Study Area uplands are generally underlain by Capilano Sediments with localized pockets of Vashon Drift of Pleistocene Age. The predominant soils are generally fine grained (predominantly shallow fills, topsoil or clay/silt caps over dense, till-like, silty sand soils) as indicated by both the available mapping and test hole and water well records. The lowland test holes and water wells recorded peat deposits over clays, also in agreement with published information. Surficial geology, along with test hole and well locations, are shown on **Figure 2.7**.

The entire upland portion of the Study Area has been classified by the BC MoE Water Protection and Sustainability Branch as the IIIC Newton Upland Aquifer. The qualifier "III" refers to a light development aquifer subclass, indicating demand is relatively low compared to productivity, and the qualifier "C" indicates a low vulnerability subclass. The portion of the Study Area occupied by the Salish Sediments, i.e. the lowlands, does not appear to have an aquifer classification.

Groundwater was encountered in several of the reviewed test holes, at depths typically ranging from 2 to 4 metres. Artesian flows were recorded at three test holes, and shallow water levels in two other locations; these generally occurred at lower elevations and/or within the lowlands to the southeast.

Based on the results of the desktop geotechnical assessment, the relatively low permeability upland native soils are likely to offer moderate to low infiltration potential and elevated surface run-off potential. Natural drainages are likely to be semi-flashy and relatively quickly convey flows from upland to lowland areas. Under periods of prolonged rainfall, the lowland, flat lying, surficial peat and organic silt soils overlying low permeability clays are likely to promote elevated groundwater levels. The lowlands will become saturated in response to prolonged periods of rainfall and offer minimal to no storage, resulting in surface water ponding.

Further information on soil and groundwater conditions can be found in **Appendix D**.

NOTES:

1. SURFICIAL GEOLOGY EXTRACT FROM GEOLOGICAL SURVEY OF CANADA 1:50,000 SCALE MAP SHEET 1484A SURFICIAL GEOLOGY NEW WESTMINSTER (1977).
2. REFER TO REPORT TEXT FOR TEST HOLE DETAILS.

LEGEND:

- ARTESIAN WELL
- WELL
- TEST HOLE
- TEST PIT
- ISMP STUDY AREA

URBAN SYSTEMS LTD.

Figure 2.7
SURFICIAL GEOLOGY

UPPER SERPENTINE INTEGRATED STORMWATER MANAGEMENT PLAN — SURREY, B.C.

THURBER ENGINEERING LTD.

ENGINEER:	CHECKED:	DRAWN:	
AGB	DWH	NAK	
DATE: FEB. 3, 2014	SCALE: 1:30,000	PROJECT No: 17-610-183	FIG: 2

REV	DESCRIPTION	DATE	BY
1	REVISED ISMP STUDY AREA ISSUED WITH THURBER ENGINEERING DEC. 10, 2014 REPORT	DEC.10, 2014	AGB
0	WITH THURBER ENGINEERING LIMITS, FEB. 3, 2014 REPORT	FEB. 3, 2014	NAK

REVISIONS

2.4 Watershed Enhancement Opportunities

2.4.1 Key Themes

Based on City staff feedback during Workshop # 1, site visit observations, external stakeholder input and relevant background information, four themes have emerged as key issues to address in the Upper Serpentine ISMP. While all of the enhancements noted in the following sections will be considered and included where appropriate, the ISMP should strive to address the key themes noted below:

- Develop a solid, scientific-based rationale for riparian (i.e., land situated adjacent to rivers, streams or other water features) setbacks based on a comprehensive suite of considerations.
- Consider a range of “grey” to “green” drainage infrastructure requirements to address future development, with particular focus on the Guildford Town Centre planning area and Zone 1A.
- Consider climate change impacts when assessing various future servicing scenarios.
- Provide recommendations for improvements to the City’s Drainage Parcel Tax that better reflects development usage of the municipal drainage system.

These themes, along with other watershed enhancement opportunities, are discussed below.

2.4.2 Stormwater Management

Watercourses within the Zone 1A Developed Uplands are stressed, particularly from a peak flow, water quality and environmental perspective. It is evident that, while the Guildford and Fraserglen detention ponds provide some benefit, stormwater runoff from the majority of developed areas in this zone receives little to no attenuation or water quality treatment prior to discharge to the creek systems. There are several sites along the watercourses where ongoing erosion is a concern, and despite the City’s gravel deployment program many areas appear to still lack sufficient gravels for spawning[1], suggesting that high velocities and runoff volumes are continuing to scour the creek beds. Further, there are known historic and current water quality concerns given the type and density of development in the catchment; pollutants may not be properly captured and treated by the current facilities. Thus, watershed health would be improved if additional detention and water quality treatment is provided in Zone 1A.

Two approaches (or a combination of the two) could be followed to meet detention and water quality treatment objectives in Zone 1A; implementation of regionally based, municipal-owned facilities, or multiple private on-lot facilities associated with individual developments. Advantages of a regional facility approach include municipal ownership and management of the facility, the potential to capture and treat runoff from areas that are not expected to redevelop in the near future, and the ability to integrate the facility within park space or other public settings to achieve complementary goals and objectives. Disadvantages include the lack of existing park space of sufficient size to support a regional facility, high land costs to secure site(s) of sufficient size for a regional facility, and the inability to expand existing local detention facilities into regional facilities due to space constraints., It may be possible in some cases to eliminate some of the smaller, localized facilities, using proceeds of the sales to facilitate regional solutions. However, the revenues from such sales may be partially offset by the cost of rerouting storm

[1] Tynehead Hatchery staff, pers. comm.

drains from the old sites to new regional sites. Finally, it may be possible in some cases to retrofit existing local ponds to achieve water quality objectives, which may not have been part of the original design of the facilities.

Placing the onus on private development to provide detention and water quality treatment has several advantages, including reduced liability and costs for the City, eliminates the need to secure public amenity space for a facility, and may simplify negotiations with development applicants as there is more flexibility in the type of facility implemented to achieve ISMP performance targets. However, the long term operation and maintenance of privately owned facilities is often more difficult to enforce, even if requirements are on title (e.g., restrictive covenants) or financial penalties are imposed (e.g., fines or reimbursement fees if the City has to undertake remedial actions). The approach to detention and water quality treatment for Zone 1A should be determined through the ISMP and ultimately used as an input in the Guildford Town Centre Plan update (see **Section 4.4.4**).

Recommended "grey" drainage infrastructure (i.e., detention and water quality facilities, storm sewer upgrades) should be complemented by "green" drainage infrastructure where opportunities exist. Likely candidate locations for green drainage infrastructure include the public road right-of-ways as well as private developments. Green infrastructure could include physical elements such as landscape-based retention / water quality treatment facilities, subsurface engineered facilities, porous pavement and green roofs, as well as planning based elements such as impervious area reduction, easing of on-lot parking requirements, encouraging cluster-style developments that retain high value natural areas, and encouraging vertical-oriented development (including underground parking structures) over lower density or suburban development. This approach would have the greatest influence on watershed health if implemented through the Guildford Town Centre Plan update.

Roadways represent a significant portion of total impervious area in the Study Area. Stormwater management objectives could be realized if focus was placed on maximizing opportunities within the road rights-of-way. For example, roadway improvements identified in the City's 10 year capital plan should be reviewed for opportunities to incorporate green infrastructure elements as described above. Potential projects within the Study Area include 160 Street widening between 96 Avenue and 104 Avenue, and intersection improvements along 168 Street and 96 Avenue. For roads not in the 10 year capital plan, an enhanced sweeping program could be initiated to mitigate water quality concerns. The City should lead by example by incorporating innovative stormwater management approaches to address roadway generated stormwater runoff, and encourage, or perhaps even require, private roads to do the same.

The City has already undertaken several initiatives to further their understanding of climate change impacts on municipal-owned systems. While sea level rise and land subsidence are not anticipated to greatly influence the Study Area, changes in rainfall pattern distributions and amounts will likely have an impact on how future drainage infrastructure is designed. ISMP drainage infrastructure recommendations should align with an adaptive management mindset and strive to incorporate design resiliency to account for future climate change predictions.

The City has had a Drainage Parcel Tax (DPT) in place since 2001. The DPT provides a dedicated revenue source to fund drainage related initiatives and projects in the City. Currently, the DPT is an annual fee that is based on parcel class; essentially all properties are charged a flat fee regardless of lot size, stormwater runoff contribution, etc. For example, a condominium is currently charged the same fee as a large scale commercial development, although the commercial development would arguably have a substantially greater impact on the municipal drainage system than the condominium, due to its larger impervious area and multiple connection points to the municipal system. The DPT structure could be reviewed for opportunities to refine it to better reflect different types of development and their usage of the municipal drainage system.

2.4.3 Environment

The aquatic and terrestrial habitat supported in the Study Area ranges from mostly intact (Tynehead Park) to severely impacted (Guildford). Efforts to enhance habitat should focus on preservation of highly diverse natural habitat while at the same time introducing measures to protect habitat from the potentially harmful effects of upstream inputs (e.g., peak stormwater flows).

In particular, the City could explore the introduction of wider setbacks on the creeks beyond that currently required under the provincial Riparian Areas Regulation (RAR). RAR setbacks are based on a multiple of the width of the channel between defined minimum and maximums. They do not exceed 30 metres and are often less if the channel width is not significant. However, riparian corridors are often preferentially used by wildlife to access intact habitat hubs. According to the City's Biodiversity Conservation Strategy, local wildlife corridors can range anywhere from 10-50 metres in width while regional corridors typically range from 50-100 metres in width for species that are less tolerant of human disturbance. The introduction of wider corridors around the current creek setbacks would allow for more wildlife access not only through the watershed but to other intact habitat hubs throughout the City. Riparian corridors could be further supported by the establishment of backyard setbacks / fencing to discourage creek access in sensitive areas. It is noted that Council has recently approved the development of a riparian area bylaw, anticipated to be ready by summer 2015. The final bylaw will likely meet or exceed the requirements of the RAR and give strong consideration to the BCS-recommended corridors and account for slope stability issues.

Other habitat enhancement opportunities include:

- Remove invasive species from riparian corridors and replace with native vegetation;
- Plant street trees in Guildford to create small "habitat islands" suitable for use by small birds;
- Naturalize specific sections of Tynehead Park (e.g., the area dominated by Sitka spruce);
- Assess corridor enhancement opportunities within the existing BC Hydro ROW (between 95 Avenue and 95A Avenue) to promote biodiversity;
- Create fish access to Guildford Pond;
- Expand the existing gravel deployment program by increasing volume of material deployed and/or the number of deployment locations (further detailed study is required);
- Reconstruct channels east of 168th Street and enhance fish access;
- Remove barriers from creeks with known fish presence (e.g., 159 Street Creek and Hjorth Creek; see **Figure 2.5**); and,
- Initiate a public awareness campaign focusing on stormwater and environmental issues in the watershed (with particular focus on riparian corridors held in private ownership in the Study Area).

2.4.4 Planning

Completing the Upper Serpentine ISMP in advance of the Guildford Town Centre Plan (GTCP) update provides the opportunity to fully consider and integrate stormwater management and environmental objectives into the planning process. One approach brought forward by City staff during Workshop # 1 was to identify water and environmental protection for the Serpentine River and its tributaries as a central theme and foundational element of the GTCP. Using this central theme as the basis for planning decisions, the GTCP could further support the range of “grey” to “green” drainage infrastructure identified by the ISMP, initiate and support public education and awareness campaigns (as well as partnerships with local stakeholder groups and/or schools) targeted towards preserving watershed health, and provide a unique marketing platform to attract potential development interests. Further discussion is needed amongst the ISMP team to articulate how a water and environmental conservation theme might weave itself through the GTCP planning process.

While the Anniedale-Tynehead NCP recommended a green infrastructure drainage servicing approach, the anticipated long-term time horizon for development in this area provides an opportunity to review the plan to ensure that it is consistent with ISMP goals and objectives. Adjustments to the proposed drainage servicing approach can be considered to align the NCP with the ISMP, should there be conflicts. The Fleetwood Town Centre Plan update is currently underway, and City staff involved in this update have been made aware that the ISMP is underway and should seek opportunities to align the two plans where possible.

Outside of these dedicated area plans, increased development density in the Study Area can be expected along existing and future rapid transit corridors (i.e., Fraser Highway, 152 Street and 104 Avenue). The ISMP should focus and identify opportunities to achieve goals and objectives through future development in close vicinity to these corridors.

3 VISION FOR A HEALTHY WATERSHED

3.1 What does a Great Vision Statement Look Like?

A great vision statement contains clear, carefully chosen language that describes what a business, project or initiative will ideally do or look like in the future. It is aspirational, without being so ambitious that it cannot be translated into the actions necessary to achieve it. It is also grounded, without being so practical that it does not inspire those tasked with attaining it. It must be meaningful, and appeal to both emotion and logic, to both the individual and the collective. A great vision can have enormous power; even those that seem very simple are beautifully rich in what they contain.

Great vision statements require context to be meaningful. They consider the past, the present and the future; they explore possibilities, and touch on why something will be different in the future. Without context, there is no benchmark for measuring a vision's success.

Vision statements, in turn, must be supported by tangible goals and objectives. The goals and objectives describe how the vision will be achieved. Together, the vision, goals and objectives highlight the "what", the "why" and the "how" of the future state of a business, project or initiative.

3.2 Surrey Vision Statements

A vision for the future of the Upper Serpentine watershed must support, and be supported by, other visions that guide broader initiatives in the City. Vision statements for related City initiatives are summarized below.

> *"The City of Surrey will continually become a greener, more complete, more compact and connected community that is resilient, safe, inclusive, healthier and more beautiful."*
>
> **- PlanSurrey Draft Official Community Plan, 2013**

> *"Surrey values and protects its natural environment through stewardship of its rich tree canopy, and enhancement of its natural areas and biodiversity.*
>
> *It is a safe City, with a vibrant City Centre and livable communities that provide a range of affordable and appropriate housing options.*
>
> *Surrey leads the way in sustainable design, "green" buildings and "green" infrastructure. It provides transportation choice, with a focus on the efficient movement of people and goods, not just vehicles. Surrey incorporates "Triple Bottom Line Accounting" into its*

operations, incorporates and encourages alternative energy sources, and strives for carbon neutrality and no net impact from waste.

It is a city that fosters local employment opportunities and "green" businesses including a sustainable agricultural base and local food security.

Surrey has a network of widely accessible community health and social services, parks, recreation, library and cultural opportunities that promote wellness and active living.

The City embraces its cultural diversity, and promotes tolerance, social connections and a sense of belonging."

- Sustainability Charter, 2008

"Our Community, the City of Surrey, will be resilient in the face of a changing climate. Through bold leadership and careful forethought, Surrey will take timely action to reduce the risks of climate change and thereby minimize social, environmental, and economic costs in the future. In partnership with key stakeholders, and through the integration of adaptation in City policy, Surrey will remain a vibrant, flexible, and prosperous community for centuries to come."

- Climate Adaptation Strategy, 2013

"Anniedale-Tynehead is a unique, diverse, and thriving complete community that complements its surroundings, contributes to the healthy growth of Surrey, and builds on its strategic location in the region. The Anniedale-Tynehead community is a model of sustainable development that integrates the natural environment, interconnects neighbourhoods, provides a diversity of housing and employment choice, and ensures a legacy of quality places."

- Anniedale-Tynehead Neighbourhood Concept Plan, 2012

There are several common themes infused in these vision statements. These themes reflect the community's core values; what is treasured most about the City where community members work, live and play. The common themes are:

- Strong, consistent City leadership;
- Community stewardship, supported by the City and strategic partnerships / alliances;
- Protection of the natural environment;
- Promotion of sustainable, "green" techniques at a variety of spatial scales, to serve a multitude of purposes and functions;
- Flexibility; incorporate the ability to adapt over time in response to external and/or unknown factors; and,
- Monitor progress as changes are implemented over time and adjust if needed.

With these common themes in mind, a vision statement was developed for the Upper Serpentine ISMP.

3.3 Upper Serpentine ISMP Vision

Change does not happen overnight. Rather, change is an organic process; a result of little things that, when implemented over time, culminate in measurable improvements. For the Upper Serpentine watershed, change will occur by staying true to the core values of the watershed and the community, maintaining consistency when faced with outside pressures, being flexible and adaptable to adjust as program components are implemented and measured, and capitalizing on opportunities as they arise.

The vision statement that guides the Upper Serpentine ISMP is:

> *In 30 years, the Upper Serpentine Watershed will be the Lower Mainland's leading example of how to capitalize on growth to significantly improve a watershed's health. Biodiversity, fish and aquatic communities, and other ecological resources are self-sustaining due to the high integrity and interconnectivity of riparian habitat, creeks, parks, landscape buffers and natural areas that connect to the broader ecological network, supported by enhanced water quality in the creeks.*
>
> *Protection of the Upper Serpentine and the natural environment are the community's central themes, and are the basis of all land use planning in the watershed. Development is supported by innovative, green and cost effective servicing approaches that promote naturalized systems, reduce stresses on receiving systems, have the flexibility to*

adapt to changing climate conditions, and align with the aesthetic ideals expressed by the community.

This successful model of community growth and environmental protection has been achieved as a result of the City's leadership, supported by the strong stewardship ethic of an engaged community, strategic partnerships and alliances with various groups and levels of government.

Goals and objectives to support the Upper Serpentine ISMP vision are described in the following section.

3.4 Goals and Objectives

The goals and objectives for the Upper Serpentine ISMP should describe how the vision will be achieved. As such, goals and objectives must be S.M.A.R.T.; that is, they must be Specific; Measurable; Attainable; Realistic; and Timely. Some of these goals will be realized within the scope and context of the current integrated planning, while others will be realized over time as the ISMP is implemented.

Goals and Objectives for the Upper Serpentine ISMP are outlined in the following sections. These evolved over the course of preparing this ISMP.

3.4.1 Stormwater Management

Goal # 1 – Capitalize on Development Opportunities to Apply Stormwater Best Management Practices

Future development in the Upper Serpentine watershed will primarily be focused within the three main planning areas (Anniedale-Tynehead, Guildford Town Centre and Fleetwood Town Centre), as well as along existing and future rapid transit corridors (i.e., Fraser Highway, 152 Street and 104 Avenue). The City requires that future developments include provisions for stormwater management. To assist in identifying stormwater management requirements for future developments in the Upper Serpentine watershed, the ISMP will identify performance targets for onsite stormwater management source controls to address peak flow attenuation, volume reduction and water quality treatment.

Recognizing that the ultimate form, density and spatial distribution of future development may be different from that assumed in the ISMP, the ISMP will identify performance targets based on general classes of land use rather than outlining prescriptive measures on a site-by-site basis. This will allow a developer to select the most appropriate suite of measures to meet the ISMP targets while conforming to site specific needs and constraints. A listing of potential source controls for each generalized land use class will be provided.

Performance targets and the list of potential source controls can be directly incorporated into the Guildford Town Centre and Fleetwood Town Centre planning processes. Existing stormwater management performance targets, features and facilities recommended in the Anniedale-Tynehead

Neighbourhood Concept Plan (NCP) will remain as is, as this NCP already incorporates a sustainable, green infrastructure approach to stormwater management.

Goal # 2 – Outline Prescriptive Stormwater Management Requirements for Single Family, Duplex and Small Multi-Family Developments

To simplify the design and approval process for small scale development / redevelopment projects (less than 2,000 m^2) involving single family, duplex and small multi-family developments, the ISMP will outline prescriptive stormwater management requirements for these development types. Requirements will consist of site adaptive planning approaches, source controls and non-structural controls that can be applied to meet the City's stormwater management requirements, without the need for the owner / developer to retain professional engineering design assistance. Where appropriate, the ISMP will also include recommendations for future work to develop design details for recommended components.

Goal # 3 – Capitalize on Road Improvement Opportunities to Apply Stormwater Best Management Practices

Road right-of-ways currently constitute 17% of the total area in the Upper Serpentine watershed. As roads are a significant source of stormwater quantity and quality issues, the ISMP will identify opportunities (in accordance with the City's 10 year roads capital works plan, along with future roads identified in applicable planning processes) to integrate site adaptive planning approaches, source controls and non-structural controls to reduce the detrimental impacts of roadway generated stormwater runoff in the watershed. Secondary opportunities, where roads may be affected due to a City-owned utility upgrade will also be considered.

The ISMP will also outline an enhanced maintenance program for roads targeted at addressing water quality issues, with particular focus on roads that are not in the City's 10 year roads capital works plan.

Goal # 4 – Enable Effective Stormwater Detention, Water Quality Treatment and Conveyance in Existing Developed Areas

Development changes outside of the Anniedale-Tynehead, Guildford Town Centre and Fleetwood Town Centre planning areas are anticipated to mainly consist of small scale redevelopment, infill and densification projects. Imposing stringent detention and water quality requirements on these types of developments in the near term may only have a limited impact on improving overall conditions in the creeks. Further, while some developed areas have small neighbourhood-scale stormwater detention facilities, due to their design intent many of these facilities provide little to no attenuation benefits for small, frequent rainfall events, and none of these facilities were designed specifically to provide stormwater quality treatment.

Focusing primarily on Zone 1A, the ISMP will identify an approach for effective stormwater detention, water quality treatment and conveyance in existing developed areas. Community detention / water quality treatment facilities will be identified for tributary subcatchments that currently do not contain neighbourhood-scale facilities. For subcatchments with neighbourhood-scale facilities, the effectiveness of the facilities will be qualitatively assessed. A minimum threshold for contributing catchment area will be applied and neighbourhood-scale detention facilities that do not meet the threshold will be deemed ineffective and will be recommended for possible removal (with the land sold for the City's benefit) or repurposed for water quality treatment. Remaining facilities will be reviewed for retrofit opportunities to increase storage capacity and/or provide water quality treatment. If neither objective is feasible, the ISMP may identify options for community detention / water quality treatment facilities in these subcatchments as well.

Existing and future community stormwater detention / water quality treatment facilities will be located and sized / optimized to balance watershed needs, land requirements (utilizing existing City-owned parcels where possible), and fish access, and will aim to mitigate erosion, velocity and water quality issues previously identified in the watercourses. Per the City's requirements, new community (trunk) facilities will have a minimum catchment area of about 20 hectares.

Drainage conveyance infrastructure will also be reviewed to assess capacity constraints for future development conditions with recommended detention facilities in place. The ISMP will identify any upgrades necessary to establish safe and effective conveyance of stormwater runoff.

Goal # 5 – Consider Climate Change Implications

While sea level rise and land subsidence are not anticipated to influence the Study Area, predicted shifts in rainfall pattern distributions and amounts will likely have an impact on how future drainage infrastructure in the Upper Serpentine watershed is designed. For future development conditions, the ISMP will identify drainage infrastructure requirements under a climate change scenario involving rainfall variations. This will be compared with results generated under a non-climate change scenario to establish the range of potential drainage infrastructure requirements. Infrastructure recommendations will consider both conditions to arrive at an appropriate design recommendation that reflects an adaptive management mindset, cost considerations, design life and design resiliency.

Goal # 6 – Identify Interim Measures to Improve Watershed Health

Development pressures in the watershed vary; overall, however, significant advances in development are anticipated over a medium to long term time horizon. The watershed is exhibiting stresses now, therefore, the City cannot wait until development opportunities arise to begin addressing issues in the watershed. The ISMP will recommend interim measures that could be applied by the City, residents, businesses, partners and external stakeholders to begin to improve watershed conditions in the short term. Interim measures may include educational, adaptive planning, or physically based approaches.

Goal # 7 – Track Implementation Progress and Adapt as Development Proceeds

The ISMP will outline a comprehensive monitoring and adaptive management program, which will allow the City to track whether ISMP goals and objectives are being met as development proceeds; and if not, what corrective actions to take. Program costs, timelines and responsibilities will be identified.

3.4.2 Environment

Goal # 8 – Define Riparian Setbacks Requirements based on Holistic Approach

Currently, the City is developing a new Riparian Area Bylaw to support biodiversity, habitat integrity, wildlife usage, native plant community health, instream quality and complexity, and slope stability. These concerns are fully consistent with and supportive of the ISMP and its goals. Language and rationale to support the City's proposed Riparian Areas Bylaw will be provided.

Goal # 9 – Identify Land Requirements to Preserve High Value Habitat or for Community Stormwater Facilities

The ISMP will identify land acquisition requirements to support the implementation program. Acquiring land may be necessary to preserve high value habitat (e.g., large, intact forested parcels), enable construction of community stormwater detention / water quality treatment facilities, reclaim key riparian corridors under City ownership, etc.

Goal # 10 – Address Habitat Issues Arising from Existing Land Use Activities

The Upper Serpentine River and many of its tributaries are already experiencing stresses and degradation as a result of past and current land use activities in the watershed. The ISMP will identify sections of watercourses where the habitat value has been impacted, and will list potential approaches for rehabilitation. Limitations and assumptions for potential approaches will be discussed.

3.4.3 Planning

Goal # 11 – Align ISMP with Land Use Planning Initiatives in the Watershed

Completing the ISMP in advance of the Guildford Town Centre and Fleetwood Town Centre Plans offers a unique opportunity to infuse integrated stormwater management approaches directly into the planning process. The ISMP will suggest adaptive planning and development approaches that better support stormwater management and environmental conditions in the watershed, and emphasize protection of the Upper Serpentine and the natural environment as central themes in the plans. Recommendations such as capital improvement works, onsite stormwater management requirements, identification of high value habitat and natural areas, impervious area and on-lot parking targets, and education and awareness campaigns could all be brought forward into the plans at the City's discretion.

Goal # 12 – Identify Appropriate Regulatory Framework to Guide ISMP Implementation

The ISMP will identify any necessary amendments to existing relevant bylaws and policies to guide and support the implementation program. New bylaws or policies may also be identified, should current bylaws and policies not cover specific areas required for ISMP implementation.

3.4.4 Finance

Goal # 13 – Focus Priority Setting based on Funding Reality

The City has a finite amount of money to implement the Upper Serpentine ISMP program. Through consultation with City staff, the ISMP will define the funding reality for the City, including sources and amounts, and prioritize recommendations that align with the funding reality to achieve the greatest value / improvement to the watershed per dollars spent. High priority recommendations will focus on actions that directly support the ISMP vision. Opportunities to leverage resources from other areas where multiple objectives could be achieved will also be identified.

Goal # 14 – Identify Amendments to Existing Funding Models to Improve Support for Integrated Stormwater Management

The ISMP will review the existing funding sources available to the City and identify whether amendments are needed to better support integrated stormwater management. In particular, opportunities to amend the City's Drainage Parcel Tax to more accurately reflect demands from various land uses on the City's municipal drainage system could be considered in the future.

Goal # 15 – Highlight Alternative Funding Mechanisms

Some communities, particularly those in the Pacific Northwest, have enacted innovative funding models to support sustainable community development and integrated stormwater management. The ISMP will identify options for alternative funding mechanisms for the City, with particular focus on homeowner incentive programs and front ending green infrastructure costs.

3.4.5 Leadership, Stewardship and Engagement

Goal # 16 – Support Internal Organizational Awareness and Capacity Building

Several ISMP recommendations will need to be led by City staff within and outside of the ISMP team. Through consultation with City staff, the ISMP will identify responsibilities within the organization for leading or implementing relevant portions of the ISMP program, and identify education, training or additional resources that might be needed to support the implementation of ISMP recommendations.

Goal # 17 – Describe Public and External Stakeholder Outreach Initiatives

The public and external stakeholders have a crucial role to play in improving watershed health conditions for the Upper Serpentine watershed; however, most residents, businesses, and other users in the community do not know how they influence the watershed or how they could help to protect it. The ISMP will identify a suite of outreach initiatives to advance education and awareness of issues in the Upper Serpentine watershed. Each initiative will identify target audience(s), key messages, desired outcomes, and how the initiative supports the ISMP vision of creating an engaged community in the Upper Serpentine watershed. Wherever possible, the initiatives should utilize, link with or expand existing outreach efforts of the City, such as the storm drain marking challenge, "Take the DIP" water quality testing program and Salmon Habitat Restoration Program (SHaRP).

4 Achieving a Healthy Watershed

4.1 Hydrologic / Hydraulic Assessment and Analysis

4.1.1 *Model Development*

In support of the ISMP, a detailed hydrologic / hydraulic model was developed for the Study Area using the PCSWMM modeling software program. The model was used to assess the hydrologic characteristics of the Study Area, along with the hydraulic performance of trunk drainage infrastructure (i.e., storm sewers, culverts, ditches, regional ponds and watercourses).

The model was developed using available information from the City (i.e., GIS, LiDAR, as-built drawings, aerial photography, etc.), supplemented by site visit observations and relevant background reports. The model represents a scale commensurate with the City's standard trunk system measure (i.e., the lower limit of modeled infrastructure is based on a 20 hectare contributing catchment area). Rainfall data from the Surrey Kwantlen Park rain gauge was used as the basis for the storm frequency values. Existing conditions impervious cover by subcatchment throughout the watershed was based on processing of the aerial photography; **Figure 4.1** shows the results, which were previously summarized in **Table 2.1**. Details on model input parameters can be found in **Appendix E**.

There are 66 City-owned and maintained detention ponds and another 38 privately-owned and maintained detention ponds within the watershed (see **Figure 2.3**). Within the scope of this high level hydrologic modeling, only the two regional detention ponds at Fraserglen and Guildford were included. Except for the regional detention facilities, many of these ponds do not activate until storm events exceed at least the 5-year frequency peak discharge. Implications of this modeling decision are discussed in **Section 4.1.2**.

The City's dyking system along the Upper Serpentine, including the Upper Serpentine Pump Station at the confluence with Lakiotas Creek, is incorporated into the modeling. Also, several storm sewer diversions located in various parts of Zone 1A have been accounted for in the model.

To establish a reasonable base flow for the model, measured flow data from the 104 Avenue hydrometric station was reviewed. Over the period of record that was reviewed (2008 to 2012), the average measured base flow was 17 L/s. This translates to a unit base flow of 0.07 L/s/ha for the contributing catchment area at 104 Avenue. This unit base flow was applied to all of the modeled subcatchments to approximate base flow contributions throughout the Study Area.

The model was calibrated using flow data from the 104 Avenue hydrometric station, which has a contributing area of 243 ha, or about 10% of the total study area. The rainfall time series for the period December 6–10, 2010, was selected as the calibration event as it contains a representative range of low to moderate rainfall depths over the period of record reviewed (2008 – 2012). Various parameters, including the sub-catchment width, subarea routing, pervious and impervious depression storage, and minimum and maximum infiltration rates were adjusted to achieve a reasonable correlation between the modeled and measured flow rates (see **Appendix E**). The calibrated model was then run using three months of rainfall data (Winter 2011) to verify that the model was reasonably approximating measured flow rates over this time period.

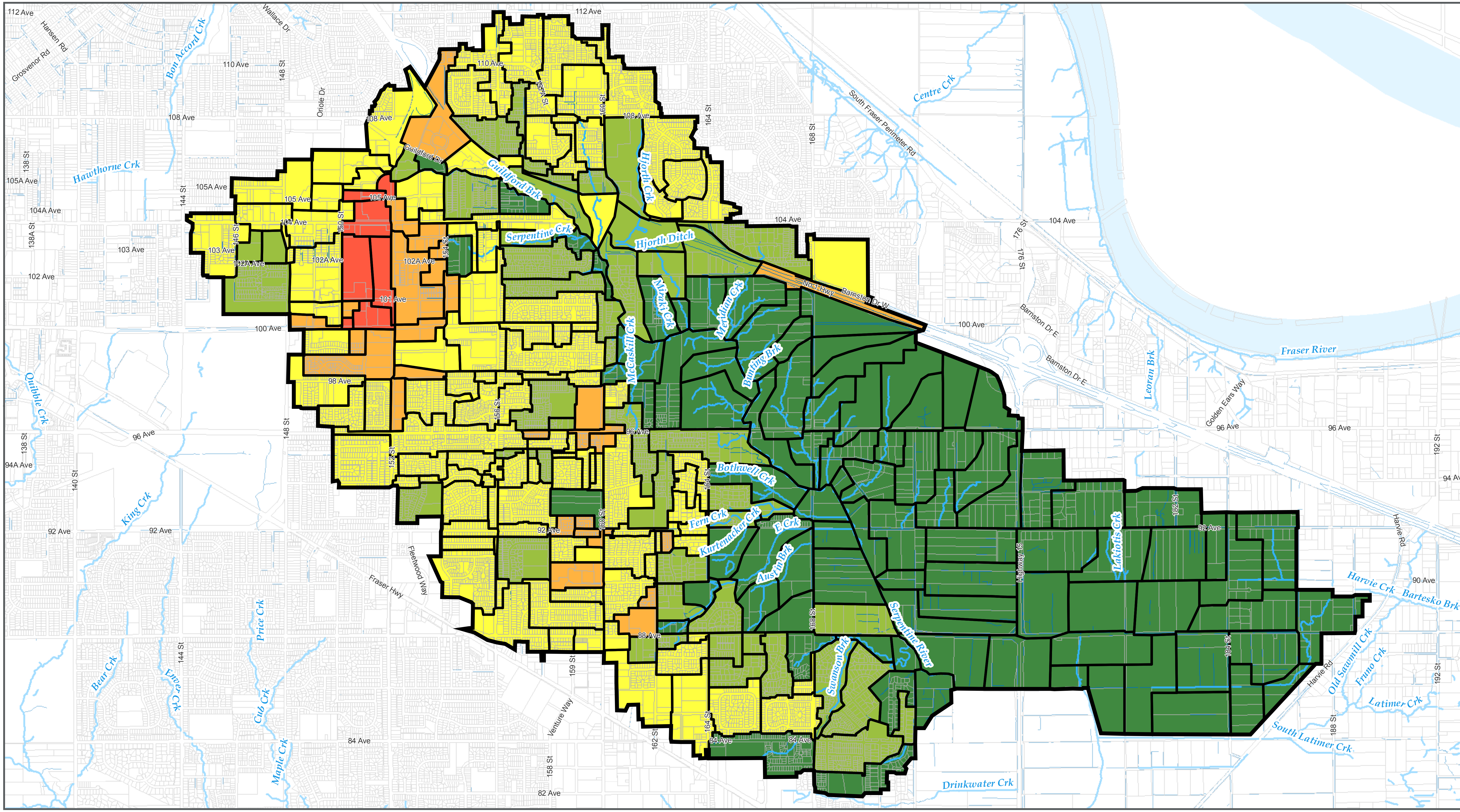
It is noted that, for longer time series simulations (i.e., the calibration and verification events), the model predicts a steeper recession limb on the hydrograph than that shown in the measured flows towards the end of the simulation run (see **Appendix E**). Since the primary purpose of the modeling effort is to evaluate hydraulic performance of drainage infrastructure, the PCSWMM model does not include active groundwater or 2D overland routing modules. However, the measured flows account for groundwater seepage and overland flow contributions to the creek systems during prolonged rainfall events, which cannot be replicated in the model unless the groundwater module is used. The differences between the modeled and measured hydrograph recession limbs do not affect the hydraulic performance assessment, therefore the calibration and verification effort is considered acceptable for this modeling exercise.

To assess the hydraulic performance of the municipal drainage system, the calibrated model was run for the 2, 5 and 100 year design events (1, 2, 6, 12 and 24-hour durations). These return periods were chosen to allow evaluation of several aspects of stormwater management:

- The 2-year return design event was used to assess conditions in creeks and river with respect to erosion, which is one indicator of watercourse and aquatic habitat health;
- The 5-year return design event was used to assess general flood protection within those areas with storm sewers; the City's standard servicing criteria is to convey the 5-year peak discharge within storm sewers; and
- The 100-year return design event was used to assess severe flood conditions; the City's standard servicing criteria is to convey the 100-year peak discharge safely and/or maintain the hydraulic grade line (HGL) in storm sewers below minimum basement elevations (MBE) to prevent flooding at houses and buildings.

The development of the existing and future conditions models are discussed in the sections that follow as are the results. The 12-hour duration produced the critical peak flows for the Study Area and thus all discussion (including the figures and tables) that follows uses the 12-hour duration model results.

Appendix E provides additional details of model development and use.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 5 / 12

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Study area and catchments delineated by Urban Systems, Feb. 2014
All other data provided by City of Surrey, Feb. 2014

Legend

Study Area Boundary (2616.5 ha)
Cadastral
Watercourse
Ditch

Existing Impervious %

<= 20%
> 20% - 40%
> 40% - 60%
> 60% - 80%
> 80%

CITY OF SURREY
the future lives here.

Upper Serpentine Integrated Stormwater Management Plan

Figure 4.1 - Existing Impervious Coverage

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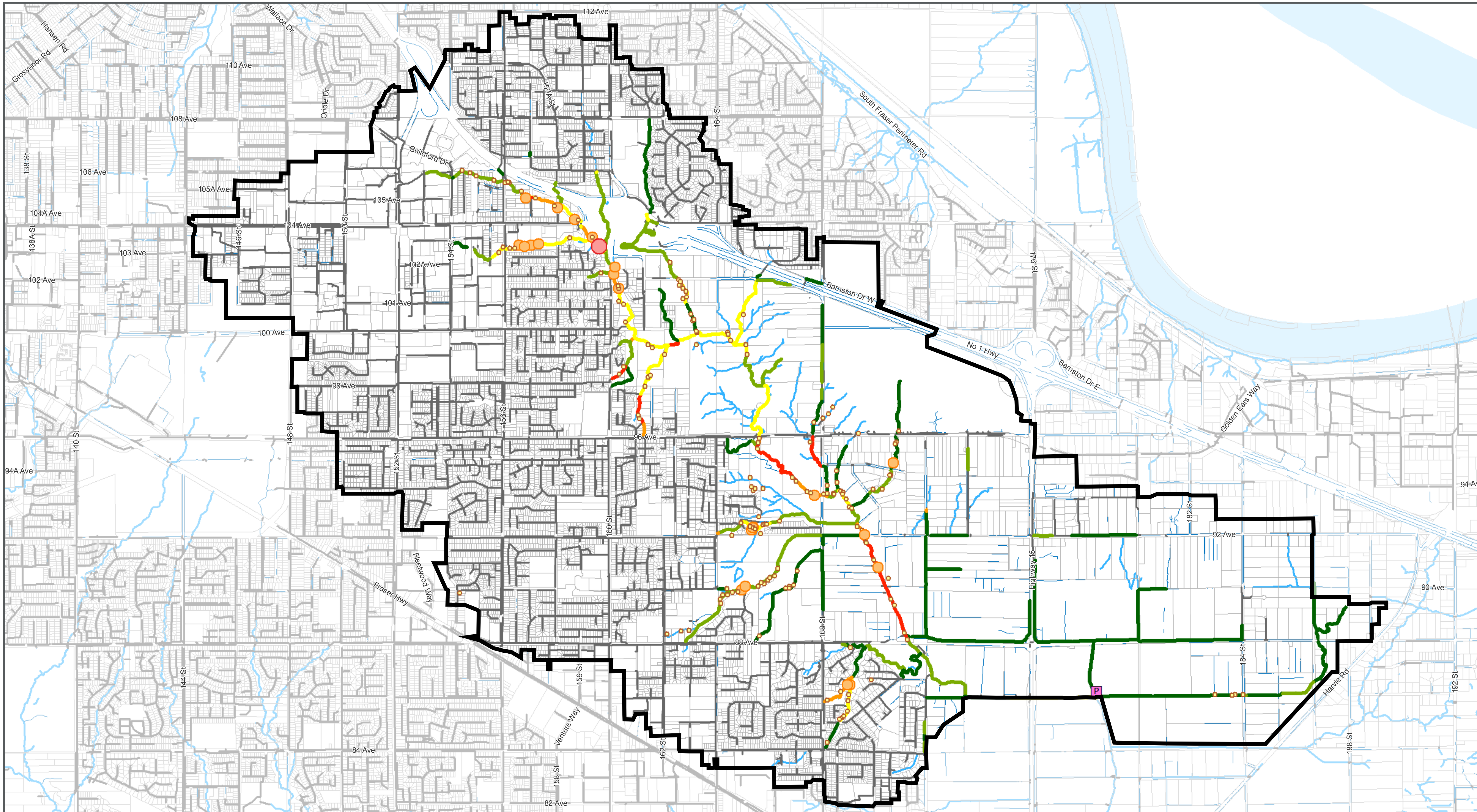

URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: B
Date: 2015 / 5 / 12

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary (2616.5 ha)
- Cadastral
- Watercourse
- Ditch
- Existing Storm Main
- P Existing Pump Station

Open Channel Velocity

- <= 0.5 m/s
- > 0.5 m/s - 1 m/s
- > 1 m/s - 1.5 m/s
- > 1.5 m/s - 2 m/s
- > 2 m/s

Erosion Site

- Low Risk
- Medium Risk
- High Risk

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Figure 4.2 - Existing Watercourse Velocities - 2 Yr Event

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4.1.2 Existing Conditions

Figure 4.2 shows the existing velocity conditions for the 2-year frequency storm event within the River and its tributaries, plotted with the 2011 ravine stability assessment results. As shown, there is a fairly strong correlation between stream reaches with velocity greater than 1 m/s and the location of erosion sites. The 2-year frequency storm event has been used since it generally approximates the “channel-forming” hydraulic condition in many open watercourses and thus is a reasonable indicator of prevailing erosive conditions. Due to the coarse level of hydraulic analysis performed for the ISMP, the model estimates average flow velocities for watercourse reaches that extend well beyond the localized erosion sites identified in the City’s ravine assessments; this masks the severity of erosion or the direct link between velocity and bank erosion at specific sites. It does however allow comparison between existing and future conditions, as will be discussed later in the report (**Section 4.1.4.2**).

Figure 4.3 highlights the predicted drainage system performance for the 5-year 12-hour (minor) design event, based on the PCSWMM model results. As previously noted, except for the two regional detention ponds, none of the watershed’s existing detention ponds (also shown on Figure 4.2) were included in the scope of the modeling. This means that some surcharging in the storm sewers may in fact be relieved by these ponds and that estimated peak discharges are over-estimated. Review of the modeling results shown in Figure 4.3 indicates that most of the predicted surcharged pipes and nodes are located in areas for which existing detention ponds will provide relief. This is notably the case for the trunk systems along 92, 95, 96, 98 and 100 Avenues, including tributary streets, west of 160 Street. It is also the case for the areas north of Hwy 1. As corroboration, City staff has indicated there have been few if any recorded or (recent) historic complaints in these areas.

Several nodes at the very upstream end of storm sewers and watercourses are highlighted as surcharging on **Figure 4.3**. This is an artifact of the modeling process, a result of limiting the model to the trunk systems. Similarly, highlighted surcharging along some of the open watercourses is a result of using idealized channel cross sections and/or having insufficient detail at some culverts. For example, this is the case for the ditch along 92 Avenue west of Hwy 15. Surcharging and flooded is noted to the west of the Serpentine just south of 88 Avenue is expected. This is a wetland area / naturalized channel area intended to provide flood storage along the river.

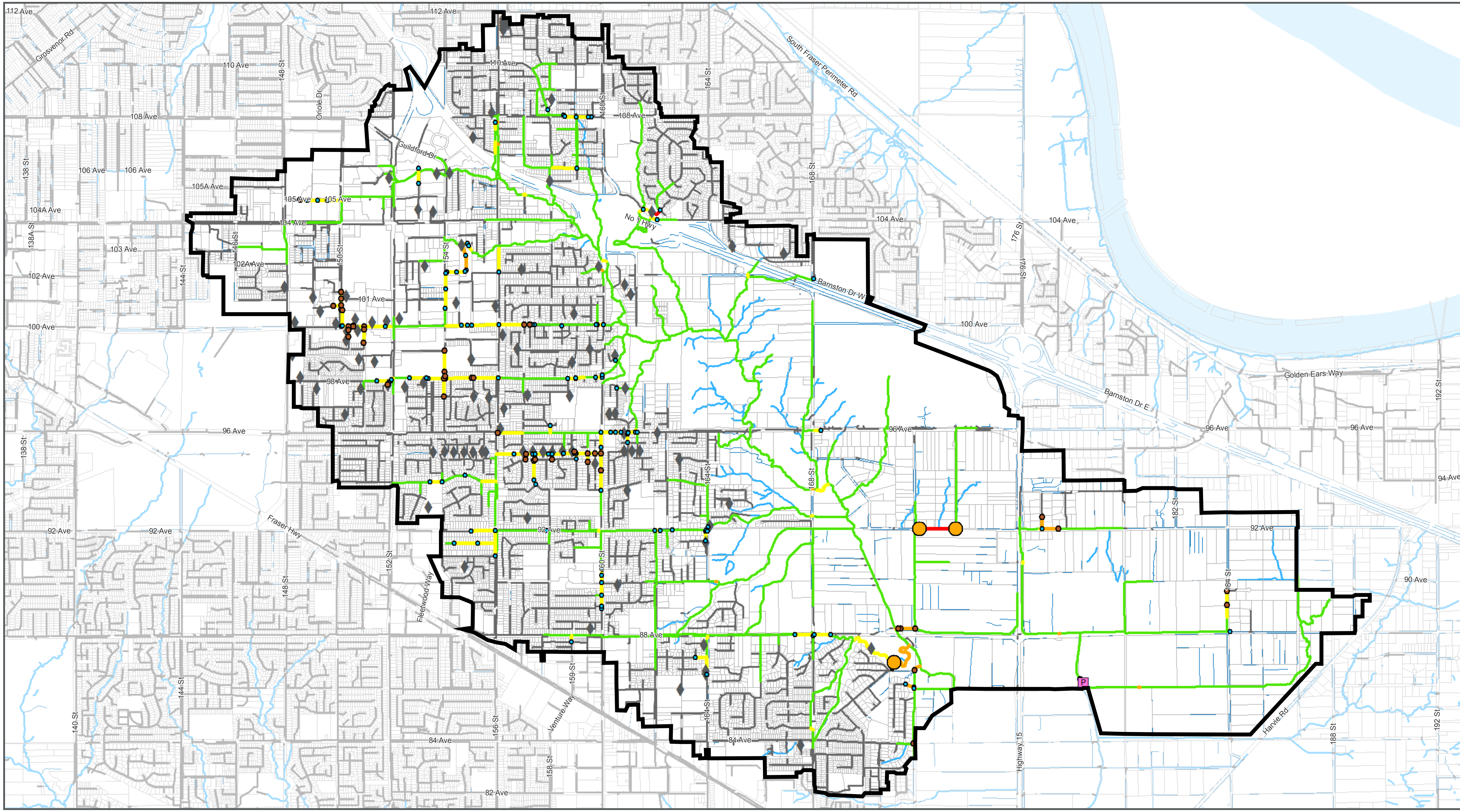
On balance, there appear to be only a few sections of existing storm sewers that may be currently undersized and thus not providing the City’s desired 5-year servicing level. These are:

- 105 Avenue west of 150 Street;
- 94 Avenue west of 156 Street;
- 105A Avenue between 158 and 159 Street; and
- 160 Street south of 90 Avenue.

More detailed hydraulic analysis, specifically the inclusion of existing detention storage, would yield more information on these locations and likely will eliminate some of these areas as problematic. The City should consider pursuing the addition of these details to enhance its understanding of the watershed.

Some flooding was identified in open creeks or ditches tributary to the Serpentine. These are largely artifacts of the data available for the modeling, specifically, insufficient detail concerning ditch geometry. To date, no specific concerns have been received from the City regarding flooding along 92 Avenue where several such issues were simulated by the model. In the case of the area west of the River immediately south of 88 Avenue, the simulated flooding is in fact intended in this “naturalized” creek and wetland area. Until or unless the City becomes aware of specific flooding issues in these areas, no additional modeling or investigations are required at this time for these open channel areas.

Not surprisingly, surcharge and flooding conditions for the 100-year return period event are greater than the 5-year return period event, according to model results (see **Figure 4.4**; note the greater numbers of pipes experiencing surcharging and manholes experiencing some flooding). Most of the areas denoted as worsening from the 5-year return period event will yield street flooding. From a servicing standpoint, surcharge during the 100-year return event is only a concern if there is no safe conveyance path for the runoff and/or the hydraulic grade line in the sewer(s) is above the minimum basement elevation (MBE) such that basement flooding could occur. The current modeling lacks sufficient detail to guarantee meeting these conditions.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: SW
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Existing Storm Main
- Cadastral
- Existing Pump Station
- Watercourse
- Detention Pond
- Ditch

Model Nodes

- Flooding (<5 m³)
- Flooding (5 m³ - 10 m³)
- Flooding(>10 m³)
- Surcharging (No Flooding)

Model Conduits

- Surcharging (<6 hrs)
- Surcharging (6 hrs - 24 hrs)
- Surcharging (>24 hrs)
- Modelled Conduit or Watercourse

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Figure 4.3 - Existing System Performance - 5 Yr Event

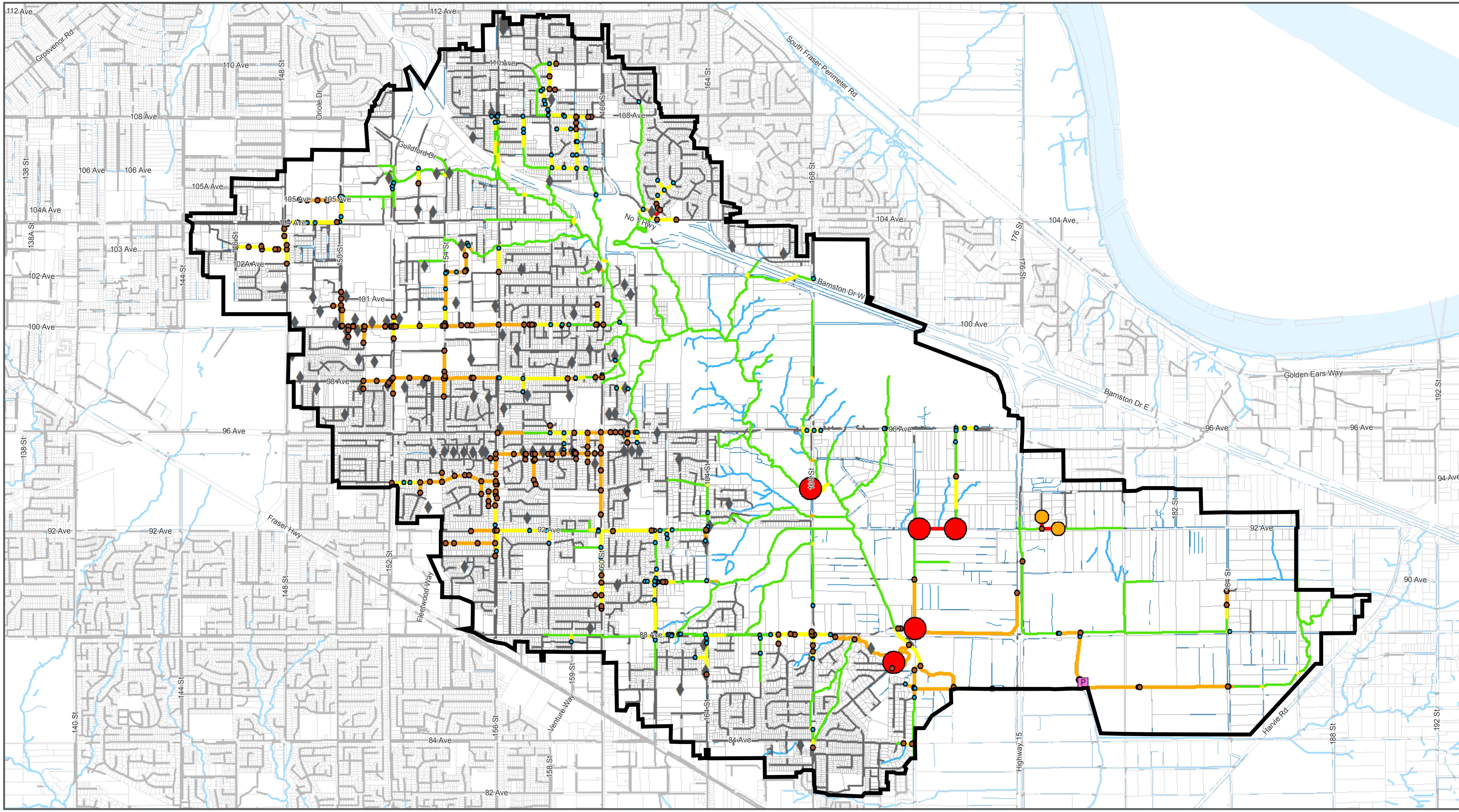
4.1.3 *Future Conditions and Climate Change*

4.1.3.1 Unmanaged Future Conditions

In order to gain some insight into the potential impacts of continued development and growth in the watershed in light of changes in rainfall due to climate change, an “unmanaged” future conditions model was developed by applying “full build out” impervious land percentages as per the City’s existing zoning bylaw. Previously, **Figure 2.2** showed future land use for the watershed; **Figure 4.5** shows the extent of the future development as represented by impervious area, while **Table 2.2** previously summarized the overall future impervious surface coverage in the watershed. The model assumes that future land will be developed to the maximum allowable land coverage under current zoning regulations and does not consider existing or future non-conforming land uses. For this “unmanaged conditions” analysis the current requirement for disconnected roof leaders on single family residential homes was ignored for future growth areas, an assumption that will end to over-estimate the impact of new development on peak runoff. After applying the new impervious conditions, the model was run with the same design events as the existing conditions model (see **Section 4.1.1**).

Figure 4.6 shows the resulting performance of the system without careful management of the effects of continued urban development on stormwater. As compared with the results shown on **Figure 4.3**, the existing storm sewer exhibits appreciable decline in its ability to convey runoff, easily seen in the much greater number of surcharging pipes and nodes and of nodes with nuisance flooding (< 5 m^3 of flooding). The decline does not appear to manifest as catastrophic failure, a result of the significant infrastructure already installed by the City in Zone 1A, but it does represent serious degradation of the system’s servicing level. Open watercourse flooding would be clearly worsened over existing conditions, notably for ditches in the Anniedale/Tynehead Neighbourhood along 92 Avenue east of the River and, evenly more dramatically, at the 168 Street culvert crossing of the Serpentine. As previously discussed, the extent to which the existing system of detention ponds would have mitigated some of these increases is not known.

These results highlight the critical role that stormwater management will play in maintaining a high level of service for the City’s storm systems.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: SW
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

Study Area Boundary
Cadastral
Watercourse
Ditch
Existing Storm Main
Existing Pump Station
Detention Pond

Model Nodes

Flooding (<5 m³)
Flooding (5 m³ - 10 m³)
Flooding (> 10 m³)
Surcharging (No Flooding)

Model Conduits

Surcharging (<6 hrs)
Surcharging (6 hrs - 24 hrs)
Surcharging (>24 hrs)
Modelled Conduit or Watercourse

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Figure 4.4 -

Existing System Performance - 100 Yr Event

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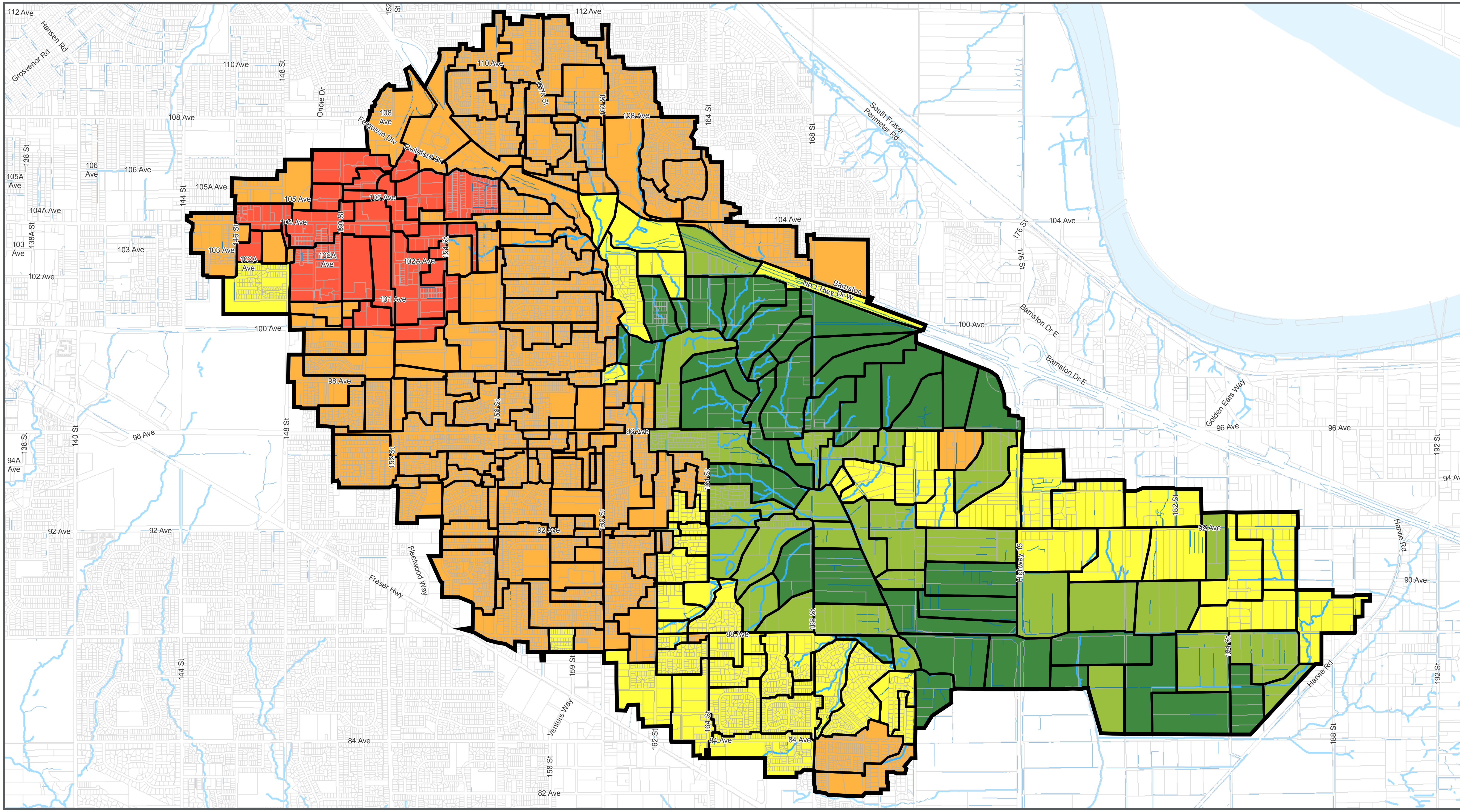

URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 5 / 12

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Study area and catchments delineated by Urban Systems, Feb. 2014
All other data provided by City of Surrey, Feb. 2014

Legend

- Study Area Boundary
- Cadastral
- Watercourse
- Ditch

Future Impervious %

- <= 20%
- > 20% - 40%
- > 40% - 60%
- > 60% - 80%
- > 80%

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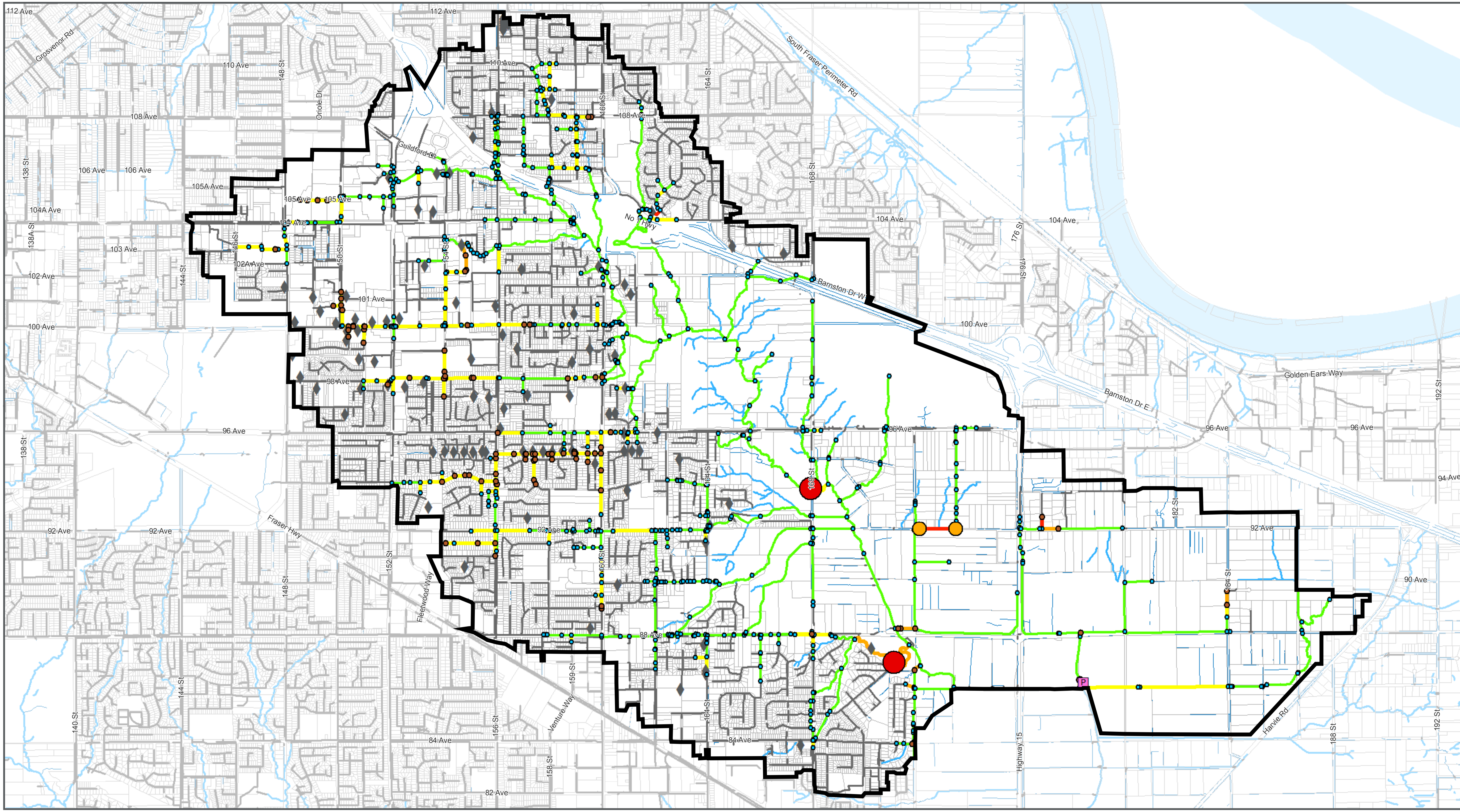
Figure 4.5 - Future Impervious Coverage



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Cadastral
- Watercourse
- Ditch
- Existing Storm Main
- Existing Pump Station
- Detention Pond

Model Nodes

- Flooding (<5 m^3)
- Flooding (5 m^3 - 10 m^3)
- Flooding(>10 m^3)
- Surcharging (No Flooding)

Model Conduits

- Surcharging (<6 hrs)
- Surcharging (6 hrs - 24 hrs)
- Surcharging (>24 hrs)
- Modelled Conduit or Watercourse

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Figure 4.6 - Future Unmanaged System Performance - 5 Yr Event

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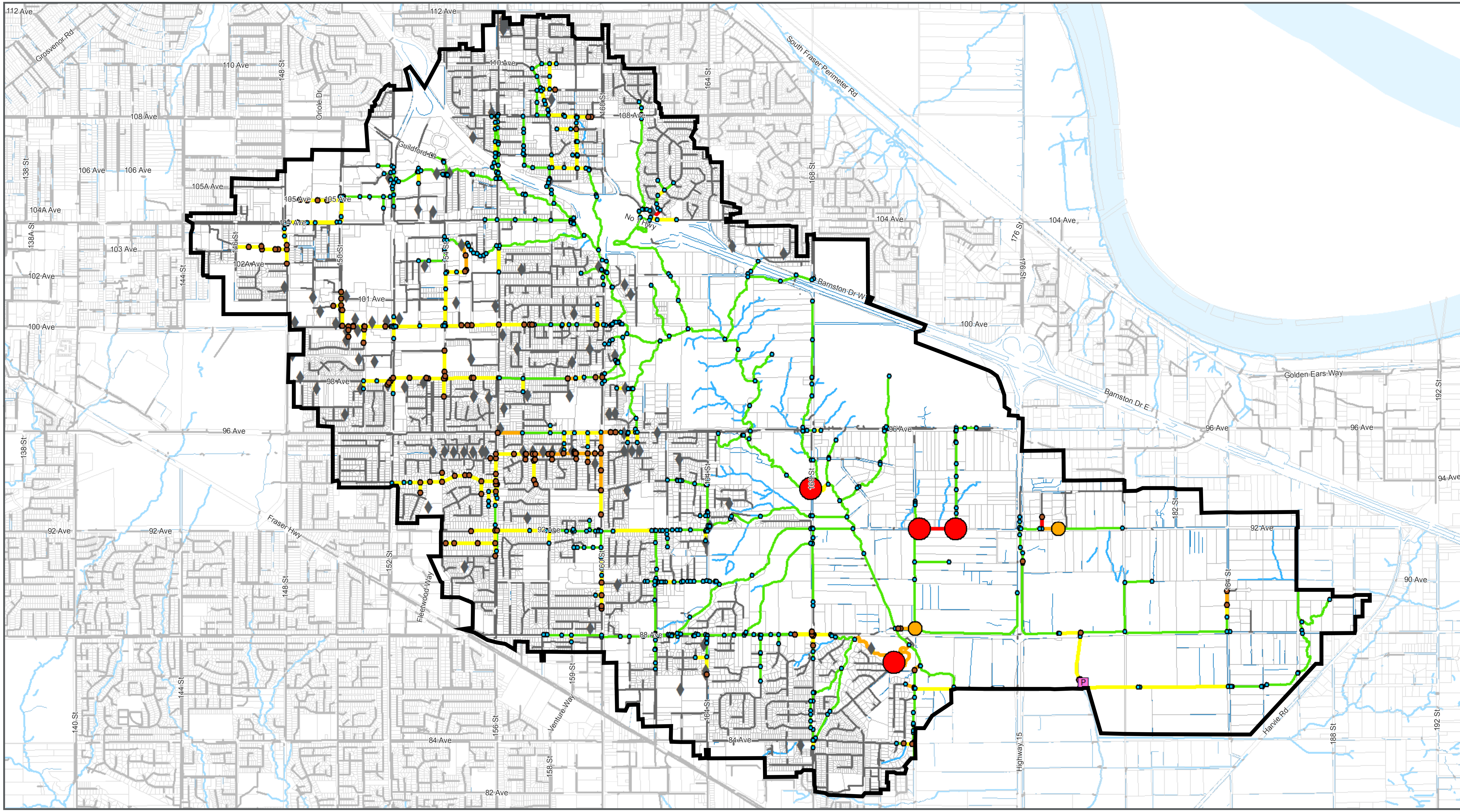
4.1.3.2 Climate Change Considerations

It is generally accepted that historic and on-going changes in global climate will affect rain patterns in the Lower Mainland. Although the precise magnitude of the impacts is not known, there is general agreement that short duration storm events will likely see heightened intensity.

In the absence of definitive understanding or agreement of future rain patterns and events, two "climate change" scenarios were tested for the unmanaged future conditions by increasing the rainfall depths in the City's current design storms by 10% then by 20%. **Figures 4.7** and **4.8** show the 10% and 20% rainfall increase scenarios, respectively, for the 5-year return storm event. When compared with the results shown on **Figure 4.6**, it is seen that rainfall increases of this magnitude would put increasing pressure on the storm trunk system, to the point that about 2/3 of all pipes in Zone 1A could potentially surcharge (pipes shaded with yellow or orange) and flooding at manholes (larger circles at the nodes) becomes a common occurrence. Some of this additional surcharging and flooding would be mitigated by the presence of the existing detention ponds, but not all of it. As will be discussed in the next section, application of green infrastructure can take up some slack but not all if rainfall intensities experience increases of the magnitude assessed here. Further detailed analysis could refine this general assessment but was not pursued within the scope of this ISMP at this time.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Cadastral
- Watercourse
- Ditch
- Existing Storm Main
- Existing Pump Station
- Detention Pond

Model Nodes

- Flooding (<5 m^3)
- Flooding (5 m^3 - 10 m^3)
- Flooding(>10 m^3)
- Surcharging (No Flooding)

Model Conduits

- Surcharging (<6 hrs)
- Surcharging (6 hrs - 24 hrs)
- Surcharging (>24 hrs)
- Modelled Conduit or Watercourse

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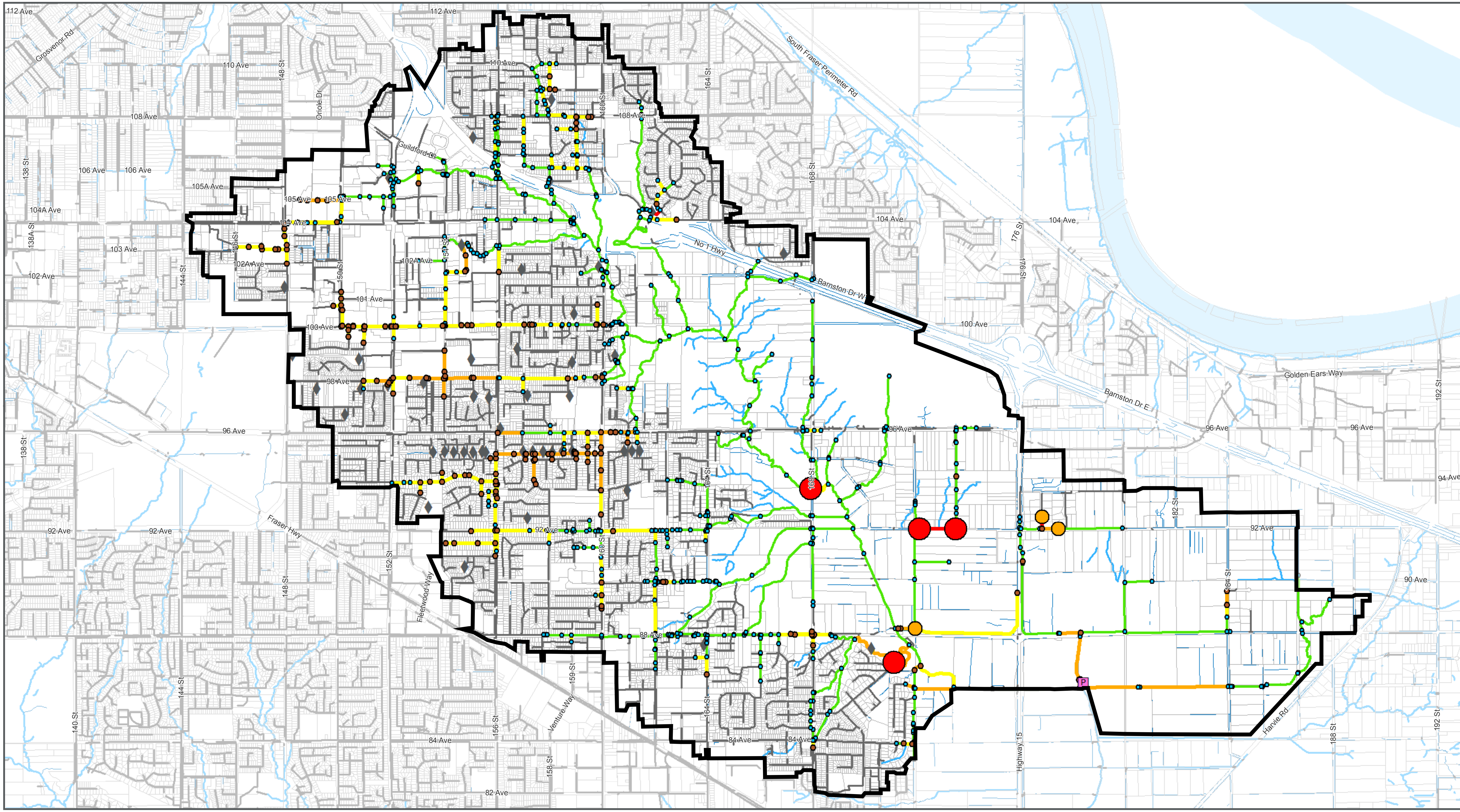
Upper Serpentine
Integrated Stormwater Management Plan
Figure 4.7 -
Future Unmanaged System Performance - 5 Yr Event + 10% Rainfall Increase



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Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

Study Area Boundary
Existing Storm Main
Cadastral
Existing Pump Station
Watercourse
Detention Pond
Ditch

Model Nodes

Flooding (<5 m^3)
Flooding (5 m^3 - 10 m^3)
Flooding(>10 m^3)
Surcharging (No Flooding)

Model Conduits

Surcharging (<6 hrs)
Surcharging (6 hrs - 24 hrs)
Surcharging (>24 hrs)
Modelled Conduit or Watercourse

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Upper Serpentine Integrated Stormwater Management Plan

Figure 4.8 -
Future Unmanaged System Performance - 5 Yr Event + 20% Rainfall Increase

4.1.4 STORMWATER MANAGEMENT SCENARIOS

4.1.4.1 Development of Stormwater Strategies

There are a variety of best management practices (BMPs) that can be applied to manage water quantity (and quality) of urban runoff. The BMPs run the gamut from planning methods to source controls to large -scale grey infrastructure. Recent focus within stormwater management in Surrey has been on the use of green infrastructure and source controls (sometimes called "low impact development" or LID) due to the potential to mimic natural pre-development hydrologic conditions, thus limiting negative impacts on watercourses. For example, following detailed 2-dimensional, coupled surface-subsurface modeling of the area, the Anniedale-Tynehead NCP drainage servicing plan (2011) recommended the use of three basic approaches for stormwater management, directed towards volume control and water quality enhancement[2]:

- Provide 300 mm of amended topsoil on all single family residential lawn areas;
- Discharge roof leaders in single family residential lots directly to lawns (not to the storm sewer), as per current practice in the City; and
- Capture and retain on site 50% of the Mean Annual Rainfall depth (that is, 35 mm in 24 hours, which is equivalent to 350 m^3 per hectare of impervious surface) on all high density and multi-family residential, commercial and industrial lots.

A series of scenarios progressively applying these three concepts were simulated for the future land use condition in the Upper Serpentine watershed:

- Scenario 1 (existing minimum commitment scenario): Apply recommended Anniedale-Tynehead NCP servicing (noted above) to that area only; all other new residential development has roof leaders discharging directly to lawns[3].
- Scenario 2: Same as Scenario 1 except pervious surfaces in new newly developed areas (including infill areas) must have 300 mm of amended topsoil, regardless of land use type.
- Scenario 3: Same as Scenario 2 except that amended topsoil requirement is increased to 400 mm[4] and, in the Anniedale-Tynehead Neighbourhood only, the rainwater retention requirement is increased to 400 m^3/ha impervious surface[5].
- Scenario 4 ("full-scale LID scenario"): Same as Scenario 4 except that the greater rainfall retention requirement of 400 m^3/ha is extended to cover all[6] new high density and multi-family residential, commercial and industrial development as well.

The results of these simulations are discussed in the next section.

---

[2] It is noted that the Anniedale-Tynehead neighbourhood servicing plan does include several detention ponds; however, these ponds manage runoff being conveyed north towards the Fraser River, not south towards the Serpentine River. Several water quality control ponds are proposed for inclusion in Anniedale-Tynehead as well, but these do not significantly reduce peak discharge rates. Appendix G provides a complete listing of stormwater management features proposed for that neighbourhood which drain into the Serpentine River system.

[3] For modeling, a 100% compliance rate was assumed for discharging roof leaders directly to lawns.

[4] The use of 400 mm of amended soils was proposed at Workshop #3.

[5] The use of 400 m^3 storage was proposed at Workshop #3.

[6] For modeling purposes, this requirement was only applied to catchments in which the total impervious cover was increasing by at least 10%. This simplified the effort to determine the required volume of storage within the scope of this ISMP.

4.1.4.2 Discussion of Results

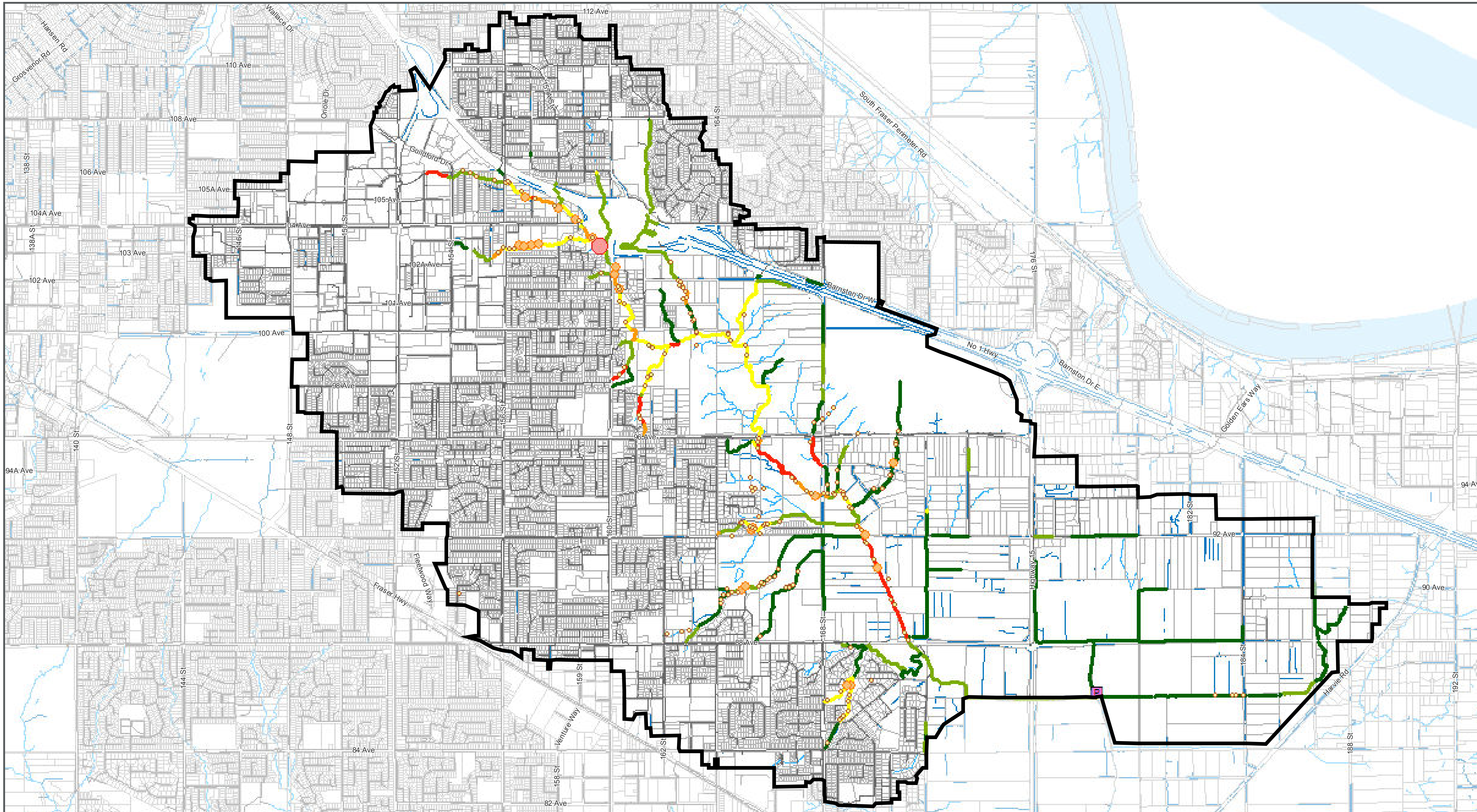
While large storm events will produce high flows in creeks and may yield significant erosion in some locations along the creeks, it is generally the more frequent events that will tend to shape watercourses over time. Thus, the 2-year frequency rain event can be used as an approximate upper limit to these more frequent events, allowing comparison of the erosion potential of various stormwater management scenarios. While velocity can be used as one indicator of erosion potential (for example, as shown on **Figure 4.2**), given the extent of current development around the watershed and the relatively coarse level of modeling detail possible within the scope of this ISMP, it was not found to be sufficient for easily evaluating changes over time. For example, **Figure 4.9** shows the watercourse velocities (plotted with locations of existing erosion sites) for the full LID scenario (Scenario 4). As can be seen, the differences from existing condition appear to be very minimal.

Erosion being a function of velocity, depth and duration of flow in the stream, total runoff volume[7] for the 2-year event is a reasonable surrogate for assessing erosion potential. **Table 4.1** shows the total volume of runoff generated by the 2-year frequency event for all scenarios at 15 locations around the watershed; **Figure 4.10** shows the 15 reporting locations. The first four results columns show the impact of growth ("future unmanaged" conditions) and potential worsened storm conditions due to climate change ("future unmanaged + 10% rainfall increase"; "future unmanaged + 20% rainfall increase"). Not surprisingly, the combination of the increase in impervious area and the more intense "climate change" storms yields larger 2-year event runoff volumes, about 11% and 26% greater, respectively, across the watershed.

The last four results columns in **Table 4.1** show how the runoff volume can be reduced to less than or equal to existing conditions using LID, yielding overall improved watershed health. This most dramatically occurs with green field development, as seen at Location 14 (Lakiotis Creek at the Serpentine pumping station), which includes the runoff from the Anniedale/Tynehead neighbourhood. In this case, Scenario 1 already incorporates the current LID-based recommendations from the servicing plan for Anniedale/Tynehead to yield a 26% reduction in runoff as compared to existing conditions. As shown a potential for nearly 50% volume reduction at this location can be realized through progressively greater application of soils and retention storage (Scenario 4, "full LID"). The extensive existing development in many of the other catchments blunts the ability to reduce volumes at other locations but it does appear possible to achieve significantly improved watercourse conditions across the board, as shown in the final column of this table.

A more complete or detailed picture of erosive conditions could be developed by using a continuous simulation model rather than the 2-year design event; as well, a finer look at watercourse geometries could allow consideration of erosion at specific sites along the watercourses.

[7] Runoff volume is also function of velocity, depth and duration.



URBAN systems

Project #: 1072.0211.01
Author: SF
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Status: Final
Revision: B
Date: 2015 / 4 / 10

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Existing Storm Main
- Cadastral
- Existing Pump Station
- Watercourse
- Ditch

Open Channel Velocity

- <= 0.5 m/s
- > 0.5 m/s - 1 m/s
- > 1 m/s - 1.5 m/s
- > 1.5 m/s - 2 m/s
- > 2 m/s

Erosion Site

- Low Risk
- Medium Risk
- High Risk

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Figure 4.9 - Future "Full LID" Scenario Watercourse Velocities - 2 Yr Event

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Table 4.1: Comparison of Total Runoff Volume for 2-Year Return Storm Event

Location	Watershed Area (ha)	2yr 12hr Total Runoff Volume (ML)								
		Existing	Future Unmanaged	Future Unmanaged + 10% Rainfall Increase	Future Unmanaged + 20% Rainfall Increase	Scenario 1	Scenario 2	Scenario 3	Scenario 4	%Diff
1. Serpentine Creek (east branch) above confluence with Serpentine River	71.0	**27.9**	30.5	33.8	37.5	30.5	**27.6**	**26.6**	**26.3**	-5.8%
2. Guildford Creek just above confluence with Serpentine River	294.1	**114.6**	128.8	142.6	157.6	129.4	117.4	**113.5**	**112.5**	-1.8%
3. Serpentine Creek (west branch) above confluence with Guildford Creek	146.9	**37.3**	40.6	44.6	49.5	40.7	38.7	38.0	**37.6**	0.9%
4. Serpentine River below two Serpentine Creeks and Guildford Creek combine	522.7	**183.5**	204.4	226.0	256.5	205.9	187.0	**181.1**	**179.4**	-2.2%
5. Serpentine River at 100 Avenue	611.2	**239.5**	266.8	295.5	327.0	267.8	243.4	**235.3**	**233.2**	-2.7%
6. Hjorth Creek just above confluence with Serpentine River	108.2	**36.6**	40.8	45.9	51.5	41.0	**36.3**	**34.7**	**34.4**	-6.0%
7. Serpentine River at 96	1233.0	**462.3**	509.8	567.5	631.0	511.7	**461.1**	**444.4**	**440.7**	-4.7%
8. Bothwell Creek just above confluence with Serpentine River	168.6	**64.5**	69.6	76.8	84.4	69.5	**63.5**	**61.4**	**60.9**	-5.5%
9. E Creek near confluence with Serpentine River	156.2	**41.1**	45.1	50.6	56.7	45.0	**38.0**	**35.7**	**35.5**	-13.6%
10. Austin Brook just above confluence with Serpentine River	27.5	**9.1**	9.72	10.98	12.38	9.72	**8.39**	**7.94**	**7.91**	-12.7%
11. Serpentine River at 92	1750.0	**624.8**	685.7	763.7	851.0	674.4	**606.0**	**582.3**	**577.8**	-7.5%
12. Swanson Brook just above confluence with Serpentine River	313.9	**75.9**	81.7	91.7	103.3	80.8	**72.6**	**69.8**	**69.5**	-8.5%
13. Serpentine River at 85A	2192.6	**781.5**	855.0	959.3	1070.3	827.8	**739.2**	**707.0**	**702.1**	-10.2%
14. Lakiotis Creek at pump station to Serpentine River	406.2	**121.3**	144.7	163.2	183.7	**89.4**	**75.5**	**63.9**	**63.8**	-47.4%
15. Serpentine River below Lakiotis Creek	26185.6	**902.4**	998.7	1122.4	1254.9	918.7	**815.1**	**770.8**	**765.8**	-15.1%

KEY:

Main Serpentine River locations

Bold, black: Existing conditions results

Bold, blue: Scenarios yielding results less than or equal to Existing Conditions

%Diff: Percent change from Existing Conditions to Scenario 4

NOTES:

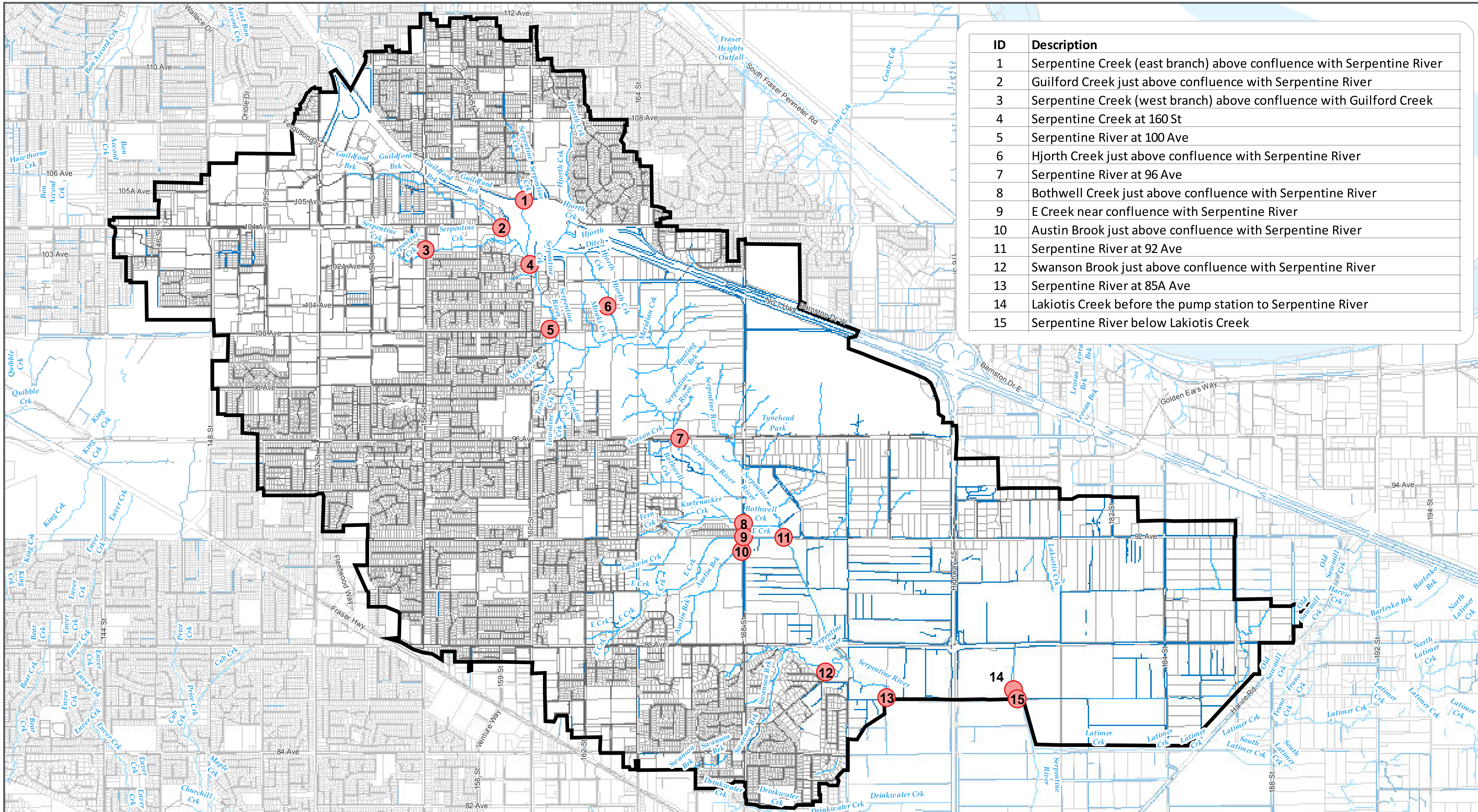
1. Except for the two regional ponds, none of the 104 existing detention ponds are included in the models; this applies to existing conditions as well as all scenarios.

2. Scenario descriptions:

Scenario:	*Existing*	*Future Unmanaged*	*Future Unmanaged + 10% Rainfall Increase*	*Future Unmanaged + 20% Rainfall Increase*	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*
Land Use Condition:	Existing	Future	Future	Future	Future	Future	Future	Future
Rainfall:	Per current standards	Per current standards	Rainfall depths increased by 10%	Rainfall depths increased by 20%	Per current standards	Per current standards	Per current standards	Per current standards
Roof Leader Disconnect for New Residential Areas:	*	No	No	No	Yes	Yes	Yes	Yes
Amended Soils Depth (mm):	n/a	n/a	n/a	n/a	300 (Anniedale only)	300 (all new development, incl infill)	400 (all new development, incl infill)	400 (all new development, incl infill)
Volume for Capture and Retention of 50% of Mean Annual Rainfall (MAR):	n/a	n/a	n/a	n/a	350 m3/imp ha (Anniedale only)	350 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale plus all areas >10% imp cover increase)

* Disconnected roof leaders assumed for all existing residential development, as per City standard (see text).

3. See Appendix E for fuller discussion of modeling.



ID	Description
1	Serpentine Creek (east branch) above confluence with Serpentine River
2	Guilford Creek just above confluence with Serpentine River
3	Serpentine Creek (west branch) above confluence with Guilford Creek
4	Serpentine Creek at 160 St
5	Serpentine River at 100 Ave
6	Hjorth Creek just above confluence with Serpentine River
7	Serpentine River at 96 Ave
8	Bothwell Creek just above confluence with Serpentine River
9	E Creek near confluence with Serpentine River
10	Austin Brook just above confluence with Serpentine River
11	Serpentine River at 92 Ave
12	Swanson Brook just above confluence with Serpentine River
13	Serpentine River at 85A Ave
14	Lakiotis Creek before the pump station to Serpentine River
15	Serpentine River below Lakiotis Creek

URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: B
Date: 2015 / 4 / 10

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Cadastral
- Watercourse
- Ditch
- Existing Storm Main

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Figure 4.10 -
Locations for Reporting Results

The less frequent, larger storm events are of course still important since the City's level of service for drainage is the 5-year frequency event. **Table 4.2** shows the peak discharge results for the 5-year frequency event at the same locations as **Table 4.1**. Although LID best management practices are focused on managing the more frequent rain events, LID can have a significant dampening effect on the runoff generated for larger storms, particularly in the less developed lower parts of the watershed. As shown, full LID Scenario 4 can yield an overall 9% reduction in peak 5-year event discharge at the watershed outlet (Location 15), though increases in peak discharge are seen in upper parts of Zone 1A which are currently highly developed. Comparison of **Figure 4.11** for the full LID Scenario 4 with the existing conditions results (**Figure 4.3**) shows that application of LID during infill and redevelopment could forestall the need for sewer upgrades. That is, although there are significantly more surcharged manholes around the drainage system, the number and duration of surcharging in individual pipes is about the same as currently experienced.

Table 4.2: Comparison of Peak Discharges for 5-Year Return Storm Event

Location	Watershed Area (ha)	Peak Discharge (5yr 12hr) (m^3/s)								
		Existing	Future Unmanaged	Future Unmanaged + 10% Rainfall Increase	Future Unmanaged + 20% Rainfall Increase	Scenario 1	Scenario 2	Scenario 3	Scenario 4	%Diff
1. Serpentine Creek (east branch) above confluence with Serpentine River	71.0	**1.36**	1.57	1.69	1.81	1.59	1.45	1.41	1.40	2.9%
2. Guildford Creek just above confluence with Serpentine River	294.1	**5.21**	6.59	7.18	7.83	6.73	6.05	5.91	5.87	12.6%
3. Serpentine Creek (west branch) above confluence with Guildford Creek	146.9	**1.67**	1.97	2.16	2.36	1.98	1.83	1.78	1.77	5.8%
4. Serpentine River below two Serpentine Creeks and Guildford Creek combine	522.7	**8.26**	10.15	11.06	11.65	10.30	9.23	9.04	8.97	8.5%
5. Serpentine River at 100 Avenue	611.2	**10.76**	12.60	13.40	14.19	12.71	11.82	11.59	11.51	7.0%
6. Hjorth Creek just above confluence with Serpentine River	108.2	**1.06**	1.21	1.28	1.37	1.23	1.16	1.13	1.13	6.2%
7. Serpentine River at 96	1233.0	**19.50**	22.30	23.94	25.85	22.44	20.70	20.13	20.01	2.6%
8. Bothwell Creek just above confluence with Serpentine River	168.6	**2.70**	2.94	3.11	3.29	2.97	2.79	2.73	2.71	0.4%
9. E Creek near confluence with Serpentine River	156.2	**1.57**	1.83	2.04	2.28	1.81	1.60	**1.50**	**1.50**	-4.9%
10. Austin Brook just above confluence with Serpentine River	27.5	**0.36**	0.41	0.47	0.53	0.41	**0.36**	**0.34**	**0.34**	-6.9%
11. Serpentine River at 92	1750.0	**18.31**	19.69	20.89	22.05	19.34	**18.30**	**17.81**	**17.74**	-3.1%
12. Swanson Brook just above confluence with Serpentine River	313.9	**4.87**	6.45	6.72	6.88	6.40	5.31	**4.75**	**4.38**	-9.9%
13. Serpentine River at 85A	2192.6	**21.21**	22.80	23.83	24.90	22.18	**21.02**	**20.44**	**20.36**	-4.0%
14. Lakiotis Creek at pump station to Serpentine River	406.2	**3.42**	4.03	4.64	5.21	**2.86**	**2.58**	**2.06**	**2.06**	-39.8%
15. Serpentine River below Lakiotis Creek	26185.6	**24.78**	26.94	28.50	29.91	24.86	**23.15**	**22.60**	**22.52**	-9.1%

KEY:

Main Serpentine River locations

Bold, black: Existing conditions results

Bold, blue: Scenarios yielding results less than or equal to Existing Conditions

%Diff: Percent change from Existing Conditions to Scenario 4

NOTES:

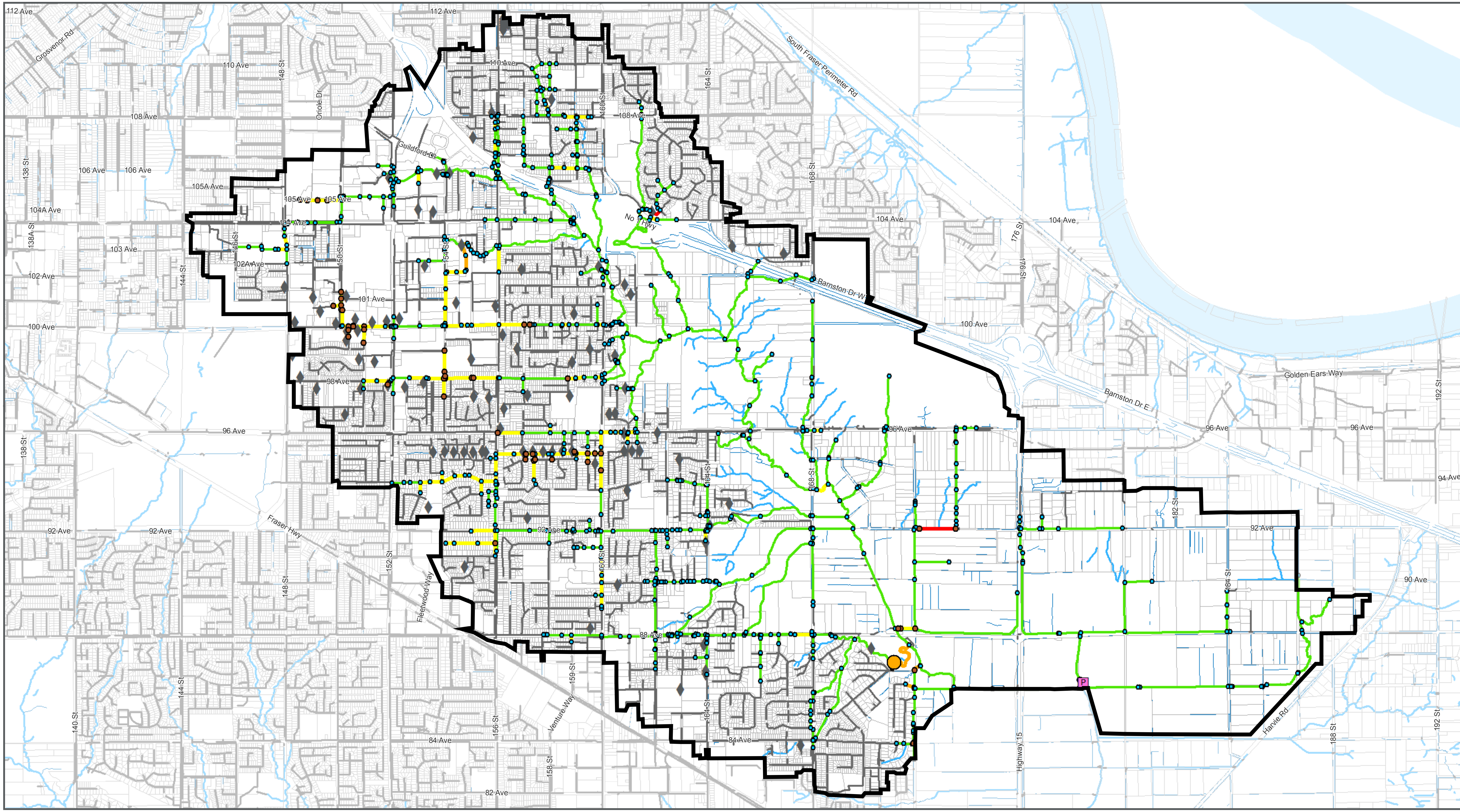
1. Except for the two regional ponds, none of the 104 existing detention ponds are included in the models; this applies to existing conditions as well as all scenarios.

2. Scenario descriptions:

Scenario:	*Existing*	*Future Unmanaged*	*Future Unmanaged + 10% Rainfall Increase*	*Future Unmanaged + 20% Rainfall Increase*	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*
Land Use Condition:	Existing	Future	Future	Future	Future	Future	Future	Future
Rainfall:	Per current standards	Per current standards	Rainfall depths increased by 10%	Rainfall depths increased by 20%	Per current standards	Per current standards	Per current standards	Per current standards
Roof Leader Disconnect for New Residential Areas:	*	No	No	No	Yes	Yes	Yes	Yes
Amended Soils Depth (mm):	n/a	n/a	n/a	n/a	300 (Anniedale only)	300 (all new development, incl infill)	400 (all new development, incl infill)	400 (all new development, incl infill)
Volume for Capture and Retention of 50% of Mean Annual Rainfall (MAR):	n/a	n/a	n/a	n/a	350 m3/imp ha (Anniedale only)	350 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale plus all areas >10% imp cover increase)

* Disconnected roof leaders assumed for all existing residential development, as per City standard (see text).

3. See Appendix E for fuller discussion of modeling.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

- Study Area Boundary
- Cadastral
- Watercourse
- Ditch
- Existing Storm Main
- Existing Pump Station

Model Nodes

- Flooding (<5 m^3)
- Flooding (5 m^3 - 10 m^3)
- Flooding(>10 m^3)
- Surcharging (No Flooding)

Model Conduits

- Surcharging (<6 hrs)
- Surcharging (6 hrs - 24 hrs)
- Surcharging (>24 hrs)
- Modelled Conduit or Watercourse

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Figure 4.11 - Future "Full LID" Scenario System Performance - 5 Yr Event

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As discussed previously, the modeling does not account for the effects of the numerous small detention ponds within the watershed which activate at the 5-year frequency event. Based on the results of the current modeling, it is possible that the presence of these ponds could largely mitigate the residual increases in peak flows shown here for the full LID scenario. The additional effort to upgrade the model to include these ponds and test this hypothesis would be quite small compared to capital costs of upgrading ponds and trunk sewers based solely on the current results. That said, there are several storm sewers which can be highlighted as most likely to require upgrade to alleviate anticipated pipe or manhole surcharging and/or flooding in the future. These are trunk sewers in areas with few or no existing detention ponds and thus not likely to need reassessment with an updated model that included all existing detention ponds. Maintaining full servicing capacity in these areas could be accomplished by pipe upgrades, addition of detention storage, installation of diversions or a combination of these:

- 88 Avenue, from 158 Street to 168 Street (#1[8]);
- 90 Avenue, from 162 Street to 164 Street (#2);
- 92 Avenue, from 156 Street to 164 Street, plus the lateral trunk along 160 Street from 189 Street (#3);
- 94 Avenue, from 152 Street to 156 Street (#4);
- Intersection of 103 Avenue & 146 Street to intersection of 105A Avenue & 152 Street (#5);
- 156 Street from 108 Avenue to Guildford Brook(#6); and
- The entire area from 110 Avenue to Highway 1, between 157 Street and 159 Street (#7).

These are in addition to the current set of existing system upgrades included in Surrey's "10 Year Servicing Plan (2014-2023)", none of which were included in the ISMP model. Lacking a basis in the current modeling, it is assumed that these still require implementation:

- Culvert upgrade, 102 Avenue / 162A Street (#6311[9]);
- Pipe upgrade, Partridge from Canary to Pheasant Drive (#6348);
- Pipe upgrade, 106A Avenue: 145 Street to 144 Street (#6415);
- Storm sewer upgrade, 148 Street: Halsted Place to 104 Avenue (#11639);
- Storm sewer upgrade, 96 Avenue: 148 Street to 149 Street (#11643);
- Storm sewer upgrade, 96 Avenue: 152 Street to 157 Street (#11644);
- Storm sewer upgrade, 160 Street to 162 Street: 93A Avenue to 96 Avenue (#11646);
- Pipe upgrade, 148 Street, north of 103 Avenue (#6266); and
- Detention pond, 160 Street / 106 Avenue (#6270).

The Servicing Plan also includes continued work on upgrading the Serpentine River dyking system (#11722), extending between the Sea Dam to 88 Avenue. This work has not been included in this ISMP.

In addition, the Servicing Plan includes specific infrastructure recommended in the Anniedale/Tynehead NCP servicing plan (see **Appendix G** for full list); the works cover storm sewers, ditch improvements and five water quality ponds.

[8] ISMP project ID number.

[9] "10 Year Servicing Plan" project ID number.

Review of the aerial photography (see **Figure 1.1**) shows that, though not fully densified, most of the catchments along these routes have little open space, which could limit detention storage possibilities. For purposes of estimating ISMP costs, pipe upgrades were assumed in all cases at this time.

Other than trunk servicing infrastructure previously identified in the Anniedale/Tynehead NCP servicing plan, no new trunk sewers were identified in the watershed. That is, though some inadequate capacities may become evident in the future, it appears that a complete storm trunk system already exists for the Upper Serpentine.

To round out this discussion, the results of modeling the 100-year frequency storm event are shown in **Table 4.3**. These peak discharge results are larger in magnitude than the 5-year event results (**Table 4.2**), but show roughly similar patterns of mitigation through the application of LID. As shown in **Figure 4.12**, the result is a storm sewer system with more surcharge but roughly similar flooding (at manholes) as compared to existing conditions (**Figure 4.4**). At this time we are unaware of specific, significant flooding issues in the system from very large storm events (like the 100-year), thus we assume that system modifications for these extreme events is not necessary at this time.

URBAN systems

Table 4.3: Comparison of Peak Discharges for 100-Year Return Storm Event

Location	Watershed Area (ha)	Peak Discharge (100yr 12hr) (m^3/s)								
		Existing	Future Unmanaged	Future Unmanaged + 10% Rainfall Increase	Future Unmanaged + 20% Rainfall Increase	Scenario 1	Scenario 2	Scenario 3	Scenario 4	%Diff
1. Serpentine Creek (east branch) above confluence with Serpentine River	71.0	**2.10**	2.34	2.41	2.51	2.35	2.31	2.26	2.20	4.5%
2. Guildford Creek just above confluence with Serpentine River	294.1	**8.01**	9.18	9.86	10.64	9.24	9.18	9.12	9.08	13.3%
3. Serpentine Creek (west branch) above confluence with Guildford Creek	146.9	**2.55**	2.83	2.97	3.16	2.83	2.73	2.68	2.66	4.2%
4. Serpentine River below two Serpentine Creeks and Guildford Creek combine	522.7	**62.7**	73.8	80.2	92.3	74.6	68.8	66.3	65.6	4.6%
5. Serpentine River at 100 Avenue	611.2	**14.8**	16.1	16.9	17.7	16.1	15.5	15.2	15.1	2.4%
6. Hjorth Creek just above confluence with Serpentine River	108.2	**1.49**	1.58	1.70	1.81	1.59	1.55	1.53	1.53	2.8%
7. Serpentine River at 96	1233.0	**27.6**	29.8	31.3	32.9	29.8	28.6	28.1	28.0	1.2%
8. Bothwell Creek just above confluence with Serpentine River	168.6	**3.52**	3.78	4.07	4.36	3.80	3.64	3.58	3.57	1.4%
9. E Creek near confluence with Serpentine River	156.2	**2.64**	2.99	3.32	3.71	2.97	2.76	2.68	2.66	0.8%
10. Austin Brook just above confluence with Serpentine River	27.5	**0.64**	0.71	0.80	0.90	0.71	0.66	**0.64**	**0.64**	-0.8%
11. Serpentine River at 92	1750.0	**23.8**	24.7	26.0	27.4	24.6	24.0	**23.6**	**23.6**	-1.0%
12. Swanson Brook just above confluence with Serpentine River	313.9	**7.01**	7.17	7.32	7.42	7.27	7.25	7.21	7.21	2.8%
13. Serpentine River at 85A	2192.6	**26.7**	27.6	28.8	29.9	27.3	**26.7**	**26.3**	**26.2**	-1.8%
14. Lakiotis Creek at pump station to Serpentine River	406.2	**5.76**	6.37	6.85	7.40	**5.59**	**5.40**	**4.97**	**4.97**	-13.7%
15. Serpentine River below Lakiotis Creek	26185.6	**32.1**	33.6	35.4	37.1	32.6	**31.8**	**31.1**	**31.1**	-3.3%

KEY:

Main Serpentine River locations

Bold, black: Existing conditions results

Bold, blue: Scenarios yielding results less than or equal to Existing Conditions

%Diff: Percent change from Existing Conditions to Scenario 4

NOTES:

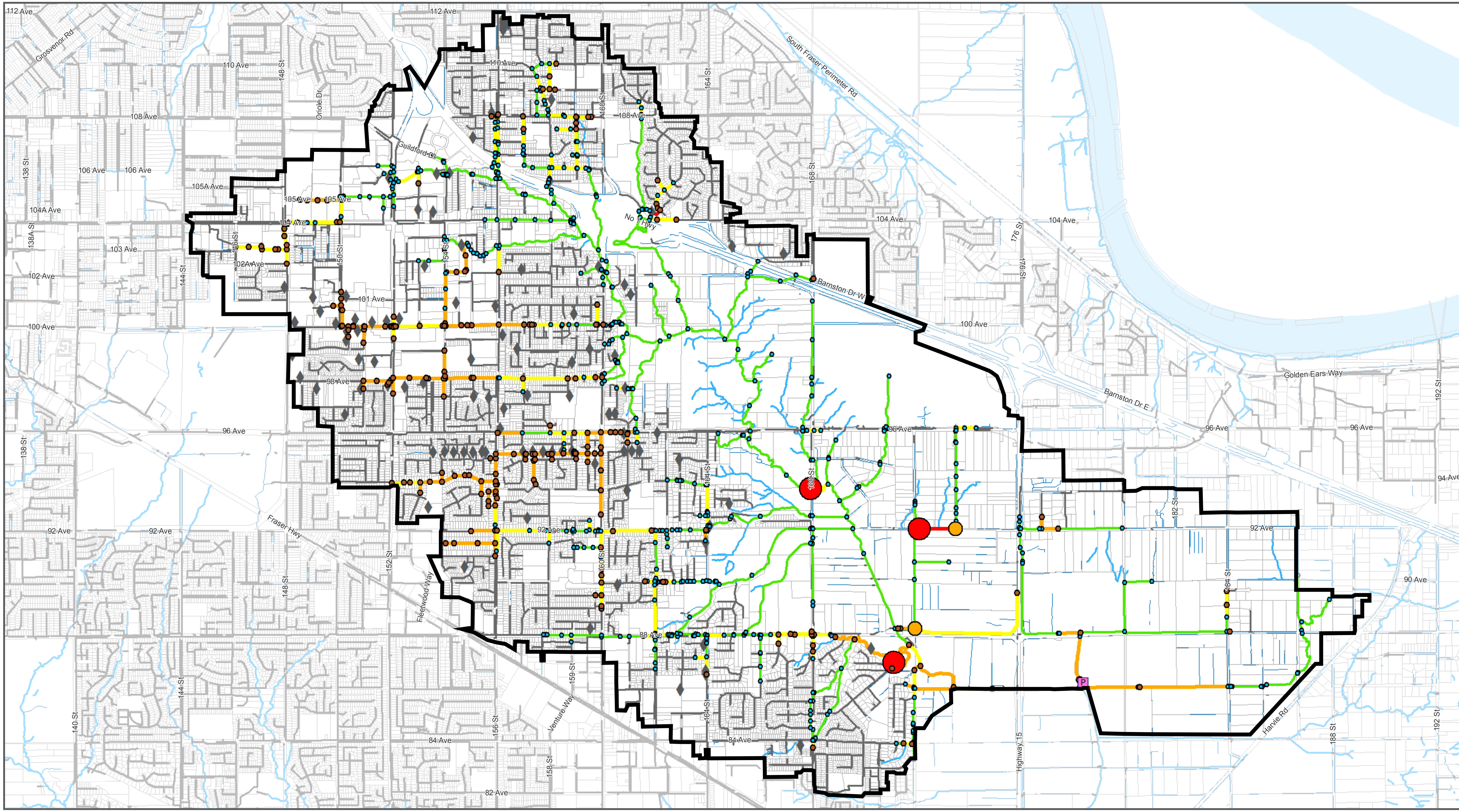
1. Except for the two regional ponds, none of the 104 existing detention ponds are included in the models; this applies to existing conditions as well as all scenarios.

2. Scenario descriptions:

Scenario:	*Existing*	*Future Unmanaged*	*Future Unmanaged + 10% Rainfall Increase*	*Future Unmanaged + 20% Rainfall Increase*	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*
Land Use Condition:	Existing	Future	Future	Future	Future	Future	Future	Future
Rainfall:	Per current standards	Per current standards	Rainfall depths increased by 10%	Rainfall depths increased by 20%	Per current standards	Per current standards	Per current standards	Per current standards
Roof Leader Disconnect for New Residential Areas:	*	No	No	No	Yes	Yes	Yes	Yes
Amended Soils Depth (mm):	n/a	n/a	n/a	n/a	300 (Anniedale only)	300 (all new development, incl infill)	400 (all new development, incl infill)	400 (all new development, incl infill)
Volume for Capture and Retention of 50% of Mean Annual Rainfall (MAR):	n/a	n/a	n/a	n/a	350 m3/imp ha (Anniedale only)	350 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale plus all areas >10% imp cover increase)

* Disconnected roof leaders assumed for all existing residential development, as per City standard (see text).

3. See Appendix E for fuller discussion of modeling.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 4 / 2

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Aerial provided by the City of Surrey, Jan. 2014
Town centre & NCP boundaries delineated by Urban Systems, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014

Legend

Study Area Boundary
Cadastral
Watercourse
Ditch
Existing Storm Main
Existing Pump Station
Detention Pond

Model Nodes

Flooding (<5 m³)
Flooding (5 m³ - 10 m³)
Flooding(>10 m³)
Surcharging (No Flooding)

Model Conduits

Surcharging (<6 hrs)
Surcharging (6 hrs - 24 hrs)
Surcharging (>24 hrs)
Modelled Conduit or Watercourse

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Figure 4.12 - Future "Full LID" Scenario System Performance - 100 Yr Event

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More modeling results are presented in **Appendix E**.

In summary, the modeling shows the clear value in robust application of LID BMPs within the watershed to mitigate the negative effects of increased impervious surfaces from new, infill and redevelopment. It does not answer questions about specific LID systems or facilities. For example, it is intuitive that having roof leaders (from single family residential lots) discharge to lawns instead of storm sewers is a good thing; however, this is not so evident in the current high level modeling results (minimum LID commitment Scenario 1). There may of course be other reasons for continuing the practice of requiring disconnected roof leaders, for example, the educational value of managing rainwater on site and mimicking natural hydrologic processes whenever possible.

4.1.5 PROPOSED MANAGEMENT APPROACH

4.1.5.1 Discussion

Over the past 15 years or so, stormwater management has moved increasingly towards the incorporation of "green infrastructure" solutions as a companion to the more traditional "grey infrastructure" methods used across North America. Certainly this is the case in British Columbia and, more to the point, in the City of Surrey. The integrated plans adopted by the City over this period have consistently supported such an approach to stormwater management. Similarly, Surrey's NCPs have also begun to incorporate green infrastructure, or low impact development (LID), into their servicing plans. The analysis completed for this ISMP has shown the value of using LID towards supporting stream and aquatic habitat health; as well, internal stakeholder discussions at the three project workshops showed strong support for LID. With that in mind, the following basic approach to stormwater management in the Upper Serpentine watershed is proposed:

- In addition to satisfying current City drainage servicing requirements (including roof leader discharge to lawns not to storm sewers on single family residential lots), require the use of adaptive site planning, source controls and green infrastructure for all new development, infill development and re-development. To assist with this effort, adopt minimum acceptable controls:
    - For single family and small multi-unit (8 units or less) residential properties: Place 400 mm of amended growing medium ("topsoil") for all pervious surfaces; and
    - For all other multi-unit residential, commercial, industrial and institutional development: Place 400 mm of amended growing medium ("topsoil") for all pervious surfaces and retain 400 m^3 of rainwater per hectare of impervious surface.
- Encourage the opportunistic use of adaptive site management and source control green infrastructure to retrofit existing private developments and properties and, more specifically, to retrofit roads, lanes and other City-owned property or rights of way.
- Over the long-term, upgrade existing grey infrastructure (storm sewers; detention ponds) to accommodate future growth as necessary to provide the City's full 5-year frequency level of drainage service.
- Over the long-term, reconfigure existing detention ponds to provide water quality treatment for rain events smaller than the 5-year frequency event.
- Enforce the existing requirement that single family residences discharge roof leaders to lawns, not storm sewers.
- Over the long-term, seek to revise zoning requirements to strictly limit effective impervious area.

Appendix H provides a succinct summary of the specific recommended requirements for development in the Upper Serpentine watershed for use with developers.

4.1.5.2 Recommendations – Infrastructure

At this time, the ISMP has identified a limited number of potential infrastructure improvements in order to maintain storm sewer capacity in the future. **Figure 4.13** and **Table 4.4** provide details on these sewers, all of which lie within Zone 1A. Approximately 11 kilometres of pipe have been identified at this time.

Because the current system model does not include the existing detention ponds of the watershed, it is not known at this time whether or how many of these ponds are providing the required level of service for detention (for control of storms greater than or equal to the 5-year frequency storm). Regardless, the large number of existing City-owned detention ponds located throughout Zone 1A represents an opportunity to enhance water quality as well as peak runoff attenuation. Some discussion arose during the workshops concerning decommissioning “non-functional” ponds and selling the land (with the proceeds made retained for other stormwater management controls). It would seem important to determine first which ponds provide the necessary system hydraulic control then investigate the possibility for reconfiguring for proper detention as well as for water quality treatment. Water quality treatment capacity will require that the ponds activate for rain events smaller than the 5-year frequency storm. Some consideration might also be given for detention (i.e. peak reduction) for rain events smaller than the 5-year event. For purposes of estimating ISMP costs, it is assumed that half of the 64[10] existing, City-owned detention facilities can be reconfigured, with the others assumed to be in working order already.

The City’s current “Ten Year Servicing (2014-2023)” includes nine projects to upgrade existing systems (eight sewer reaches; one detention pond)[11]. These improvements should be retained and implemented. All but one are designated for long-term implementation (7-10 year horizon). These projects are also shown on **Figure 4.13**.

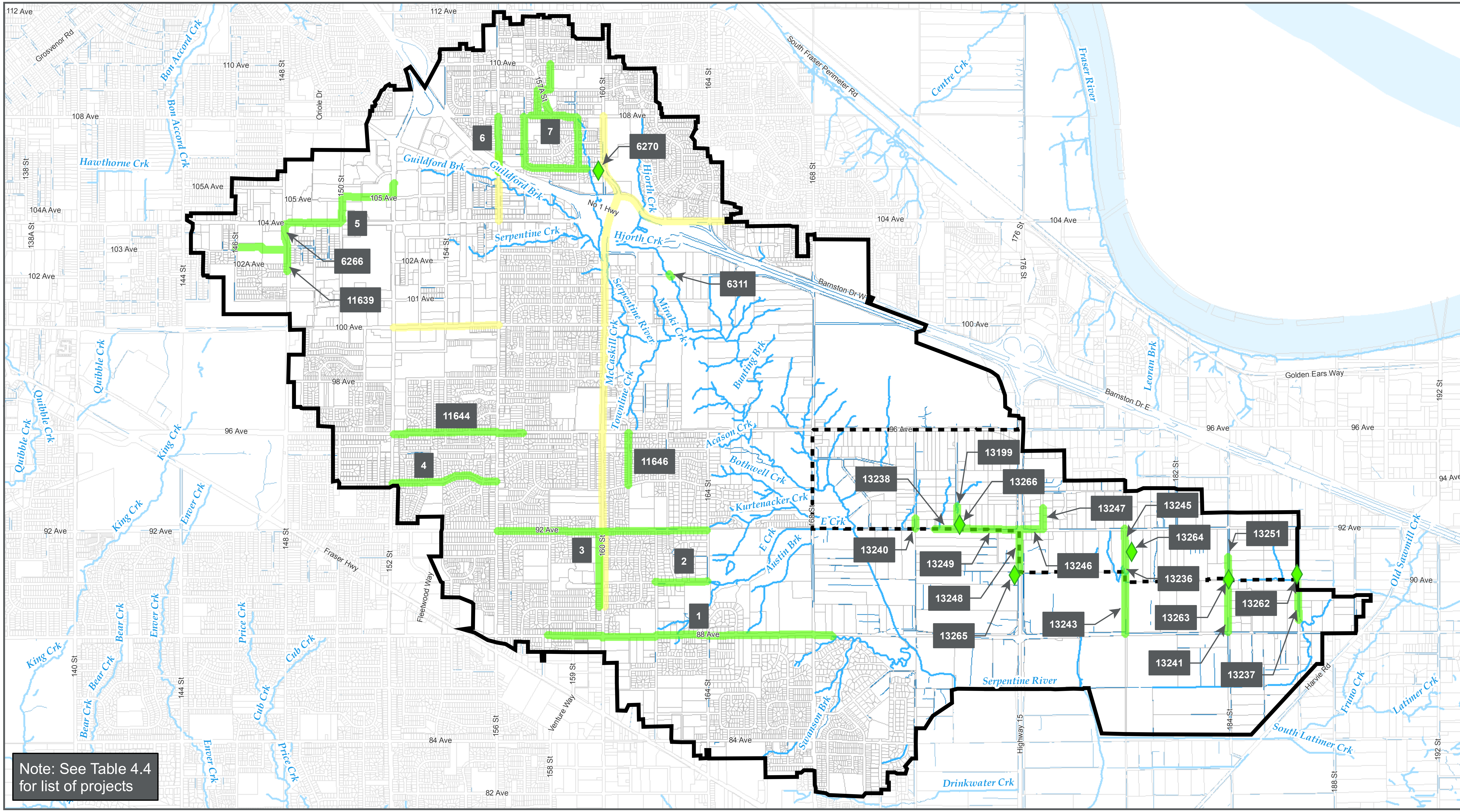
The Anniedale / Tynehead NCP servicing plan also has specific recommendations for infrastructure that are supported by this ISMP and should be implemented. The recommendations include trunk storm sewers, lowland ditch capacity improvements and five water quality ponds. A full description of the NCP recommendations is listed in **Appendix G**.

The City’s “Ten Year Servicing Plan” includes seven arterial widening (ultimate and interim) projects and two non-arterial road improvement projects. With one exception these are designated medium to long term initiatives (4-6 years and 7-10 years, respectively). As these reach detailed design, LID should be incorporated wherever possible. This might include use of absorbent landscaping or linear rain gardens in medians and boulevards, installation of perforated storm sewers, and use of permeable asphalt pavement in areas outside of high volume traffic (e.g. for sidewalks, ped/bike pathways and parking areas).

Not included in the current transportation Servicing Plan are the smaller opportunities for incorporation of green infrastructure by retrofit, including those which could accompany local street traffic calming efforts (e.g. curb bulges; intersection circles) and other minor road improvements.

[10] Does not include the two regional ponds (Guildford; Fraserglen).

[11] The Servicing Plan also includes continued improvements to the dyking system of the Serpentine, from 88 Avenue downstream to the Sea Dam. These improvements are not included in this discussion.



URBAN systems

Project #: 1072.0211.01
Author: SF
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Status: Final
Revision: A
Date: 2015 / 5 / 20

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:

Town centre, NCP boundaries provided by the City of Surrey, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014
Monitoring station locations from Flow Works website, Mar. 2014

Legend

- Study Area Boundary
- Anniedale / Tynehead NCP Boundary
- Cadastral
- Watercourse
- Ditch
- Recommended Sewer or Ditch Improvement
- LID Opportunity In 10 Year Plan Road Improvements
- Recommended Detention or Water Quality Pond

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Upper Serpentine Integrated Stormwater Management Plan
Figure 4.13 - Recommended Infrastructure Improvements

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Table 4.4 Summary of Recommended Infrastructure Improvements

ID #	Improvement Type	Location	Source
6311	Culvert Upgrades	102 Ave / 162A St	10-Yr Plan
6348	Pipe Upgrade	Partridge from Canary to Pheasant Dr	10-Yr Plan
11639	Storm Sewer Upgrade	148 St: Halsted Pl - 104 Ave	10-Yr Plan
11643	Storm Sewer Upgrade	096 Ave: 148 St - 14979	10-Yr Plan
11644	Storm Sewer Upgrade	096 Ave: 152 St - 157 St	10-Yr Plan
11646	Storm Sewer Upgrade	160 St to 162 St: 93A Ave to 96 Ave	10-Yr Plan
6266	Pipe Upgrade	148 St: North of 103 Ave	10-Yr Plan
6270	Detention Pond	160 St / 106 Ave	10-Yr Plan
13199	Storm Sewer	173A St: 92-93 Ave	A/T 10- Yr Plan
13236	Storm Sewer	180 St: 91-90 Ave	A/T 10- Yr Plan
13237	Ditch Improvement	187 St: 89-90 Ave	A/T 10- Yr Plan
13238	Ditch Improvement	092 Ave: 173-173A St	A/T 10- Yr Plan
13293	Ditch Improvement	Harvie Rd: 91-90 Ave	A/T 10- Yr Plan
13240	Storm Sewer	172 St: 93-92 Ave	A/T 10- Yr Plan
13241	Ditch Improvement	184 St: 90-88 Ave	A/T 10- Yr Plan
13243	Ditch Improvement	180 St: 90-88 Ave	A/T 10- Yr Plan
13245	Storm Sewer	180 St: 91-92 Ave	A/T 10- Yr Plan
13246	Storm Sewer	092 Ave: 176-177 St	A/T 10- Yr Plan
13247	Storm Sewer	177 St: 93-92 Ave	A/T 10- Yr Plan
13248	Storm Sewer	176 St: 90A-92 Ave	A/T 10- Yr Plan
13249	Storm Sewer	092 Ave: 173A-176 St	A/T 10- Yr Plan
13251	Storm Sewer	184 St. 91A-90 Ave	A/T 10- Yr Plan
13262	Water Quality Pond	090 Ave/187 St	A/T 10- Yr Plan
13263	Water Quality Pond	814 St/90 Ave	A/T 10- Yr Plan
13264	Water Quality Pond	180 St/91 Ave	A/T 10- Yr Plan
13265	Water Quality Pond	90A Ave/Hwy 15	A/T 10- Yr Plan
13266	Water Quality Pond	173A St/92 Ave	A/T 10- Yr Plan
1	Storm Sewer Upgrade	88 Ave from 158 St to 168 St	ISMP
2	Storm Sewer Upgrade	90 Ave from 162 St to 164 St	ISMP
3	Storm Sewer Upgrade	92 Ave from 156 St to 164 St, plus lateral trunk along 160 St from 89 Ave	ISMP
4	Storm Sewer Upgrade	94 Ave from 152 St to 156 St	ISMP
5	Storm Sewer Upgrade	Intersection of 103 Ave and 146 St to intersection of 105A Ave and 152 St	ISMP
6	Storm Sewer Upgrade	156 St from 108 Ave to Guilford Brook	ISMP
7	Storm Sewer Upgrade	Entire area north of Hwy 1 to 110 Ave, between 157 St and 159 St	ISMP
8	Detention Pond Reconfigurations (32)	Various	ISMP
	NOTE: Improvements to Serpentine River dyking along the Serpentine downstream of 88 St have not been included in this list.		
	NOTE: #6266 and #11639 may overlap with #5.		

4.1.5.3 Recommendations – In-Stream

A number of opportunities were identified that would benefit overall terrestrial or aquatic habitat value in the watershed, either through direct enhancement of existing habitat, construction of new habitat, or by addressing those mitigating factors currently having negative impacts on habitat. These opportunities should be considered preliminary at this time as further study is required to determine feasibility, establish overall habitat benefit, and allow us to conduct the required cost/benefit analyses. While some of these opportunities would likely have a significant overall benefit, it may be that space limitations, property acquisition costs, existing land use and other conflicts could render some of them impractical.

The identified opportunities will primarily benefit either the aquatic or terrestrial habitat, although some may have benefits for both. These opportunities include:

Aquatic Habitat

- Improved runoff control;
- Fish access improvement;
- Instream enhancement;
- Riparian infill and enhancement (links to upland terrestrial habitat);
- Bank stabilization;
- Flow diversion;
- Removal of anthropogenic debris; and
- Fencing to prevent livestock access.

Terrestrial Habitat

- Increased tree canopy;
- Increased number of street trees;
- Improved wildlife crossings and corridors;
- Increased upland plant diversity;
- Removal of invasive species;
- Work with farmers to preserve habitat and support biodiversity; and
- Formal protection of intact forested blocks.

These opportunities are discussed in more detail in **Appendix C**. Cost estimates are also included.

4.1.5.4 Costs

The costs for proposed system upgrades and other infrastructure recommendations listed in **Section 4.1.5.2** is $47.2 million (see summary in **Table 4.5**, with details provided in **Appendix F**); this includes newly identified improvements recommended in this ISMP along with those already identified in the City's 10-year servicing plan and those included in the Anniedale/Tynehead 10-year servicing plan. Unfortunately, none of these ISMP supported improvements lie along or within transportation corridors currently awaiting improvements (as per the 10-year servicing plan). This means that costs for these stormwater system upgrades cannot be piggybacked with road improvements as a cost reducing factor.

Depending on the extent of work to be completed, the costs for potential in-stream improvements varies from $1.6 to $3.1 million, with associated annual maintenance costs of $30,000. See **Appendix C** for details.

Table 4.5 Summary of Capital Costs for Recommended Infrastructure Improvements

Category	Estimated Capital Cost ($)
Storm Sewer & Pond Upgrades	$30,021,000
10 Year Servicing Plan Capital Improvements[12]	$3,985,000
Anniedale/Tynehead NCP Servicing Plan	$13,227,000
Total	**$47,233,000**

[12] Excludes dyke work along the Serpentine River (Servicing Plan ID #11722); only a small (but unspecified) portion of this work is within the watershed.

4.1.5.5 Recommendations – Additional Studies

The hydrologic modeling completed during preparation of this ISMP has primarily focused on high level assessment of stormwater management alternatives. This modeling has confirmed the value of adopting and applying green infrastructure and low impact development on a watershed-wide scale. The specific infrastructure recommendations could be clarified and refined by improving the model in several specific ways. First, at a minimum, we recommend that the existing detention ponds (both City-owned and as many privately-owned facilities as possible) be incorporated into the model and that storm sewer system coverage be expanded to include all pipes greater than or equal to 300 mm diameter. The updated model should then be run for existing conditions and for future "full scale LID" (Scenario 4) conditions[13]. The recommendations for storm sewer upgrades should be reviewed in light of the new results.

Second, we recommend that a systematic review of the potential for converting or enhancing the existing detention ponds to provide water quality treatment be undertaken. See previous discussion in Section 4.1.5.2.

4.1.6 Implementation Plan

A significant part of Workshop #3 focused on finding a solid set of actions and initiatives that can be implemented and will likely yield positive results. It was recognized that not all of the possibilities embodied in the goals listed in **Section 3.4** can be addressed immediately or simultaneously. What was clear is that a major step moving forward is to have firm acceptance of a green infrastructure (LID) approach as discussed during developing of the ISMP and assessed in this ISMP report; in order to give staff authority and responsibility for realizing this approach, support of the City Council is critical. Thus a first, crucial step of implementing the ISMP will be to seek that support. This will give staff in all departments the mandate necessary to expend effort in pursuing the use of green infrastructure and implementation of other aspects of this ISMP. Further it will show that the City is leading by example.

At the same time, it is also recognized that staff from a number of departments will be making both long-term and daily decisions that can make it possible to achieve the admirable goals set forth for the watershed. Thus a second, crucial part of ISMP implementation will be establishment of an inter-departmental coordinating group to champion the ISMP and to oversee attainment of ISMP goals within the context of all the services provided by the City. While the Utilities/Drainage & Environment Section can facilitate this group, other departments that should be represented at the table include Parks, Recreation & Culture, and Planning & Development, along with other key Engineering Department services such as Transportation Planning, Design & Construction, Development Services, Inspection Services, and Operations (Roads & Drainage Section; Fleet & Garage).

4.1.7 Responsibilities

[13] For comparison with results illustrated currently in ISMP Figures 4.2 through 4.4 (existing conditions) and Figures 4.9, 4.11 and 4.12 (Scenario 4 conditions).

Each of several key departments at the City will have responsibilities critical to the success of this ISMP with the Drainage & Environment Section of the Engineering Department providing direction and support. The primary responsibility for leadership and support to other departments will fall on the Drainage and Environment Section of the Engineering Department, while other departments will continue to provide leadership at key points which fall within their areas of responsibility and authority, for example, in the private development process, in City facilities design and during City operations.

Other key players will include:

- Developers (and their professional consultants);
- Businesses (and business associations);
- Local special interest groups, specifically Tynehead Hatchery; and
- Residents.

4.1.8 *Funding Mechanisms*

At present there are three primary mechanisms for funding improvements and initiatives recommended by this ISMP. Based on the workshop discussions, these are likely to remain primary into the future:

- Drainage Parcel Tax – The City levies an annual drainage user charge on property owners in the City. The rate varies by property user class, as determined by BC Assessment, with the classes currently grouped into three categories, as shown in **Table 4.6**. Since 2012, the rates have risen for residential/recreational, non-residential and farm properties by 21%, 35% and 84%, respectively. For purposes of this ISMP, it is assumed that similar (or greater) rates of increase will hold into the future.

Table 4.6: Annual Revenue from Surrey's Drainage Parcel Tax

User Class	Number of Parcels within Watershed	Annual Rate ($/parcel)*	Annual Revenue ($)
Classes 1 & 8 (Residential; Recreational)	8,746	$201.00	$1,757,946
Classes 2-6 (Non-residential)	828	$224.00	$185,472
Class 9 (Farm)	166	$201.00	$33,366
Totals	**9,740**		**$1,976,784**

* "2014 Annual User Charge Rate" as published at the City's website

- Development Cost Charge – Regional facilities (trunk storm sewers; detention facilities; water quality treatment facilities) necessary to service new, or growth, development are funded wholly or in part[14] from development cost charges (DCC). The City currently collects approximately $3,500 per single family residential home DCCs within the Upper Serpentine watershed. This

[14] At times, new storm facilities may both correct existing servicing issues (capacity; condition) as well as service new development, in which case general revenue or other funds must cover the upgrade costs while DCCs cover the new development servicing.

figure includes the DCCs recently adopted for the Anniedale/Tynehead area, where total growth-related storm servicing costs are estimated to be $26,637,000[15].

- General Revenue – Raised via property taxes, these funds must cover all other capital improvements as well as on-going operation and maintenance costs.

With the assumption that inclusion of existing detention ponds in the model will show that the current trunk system is adequate at this time to service existing development, all of the potential work cited in **Section 4.1.5.4** would be required to service growth and thus can be funded through DCCs.

[15] Note: This figure includes all growth-related infrastructure improvements in Anniedale/Tynehead, including those outside the Upper Serpentine watershed.

5 KEEPING THE WATERSHED HEALTHY

5.1 Discussion

Watersheds are complex entities; even with application of all recommendations based on the best analysis, the systems will respond in unusual ways to land use changes, urban growth and uncontrollable environmental variables, including climate. In addition, land use changes will occur over a long period of time, decades. And the actions and initiatives recommended here will be implemented over a long time period as well. Tracking the impact of actions taken under this ISMP will be essential to a long-term adaptive management process.

Adaptive management can be defined as a "planned and systematic process for continuously improving environmental management practices by learning about their outcomes" (CEAA, 2009). It is important to recognize that adaptive management is much more than simply monitoring activities and occasionally changing them. True adaptive management involves exploring alternative means to achieve management objectives, predicting the outcomes of alternatives based on available information, choosing and implementing an alternative, monitoring to assess impacts of the chosen alternative and using this monitoring data to update knowledge and adjust actions accordingly (DOI, 2009).

5.2 Monitoring

Metro Vancouver has recently released guidelines (2014) that describe recommended monitoring and adaptive management practices for member municipalities within the regional district. Surrey has committed to following the adaptive management framework approach described by Metro Vancouver and has established three locations within the watershed for water quality sampling (shown on **Figure 5.1**):

- Guildford Brook (at 108 Avenue);
- Townline Creek (at 96 Avenue); and
- E Creek (west of 168 Street and north of 88 Avenue).

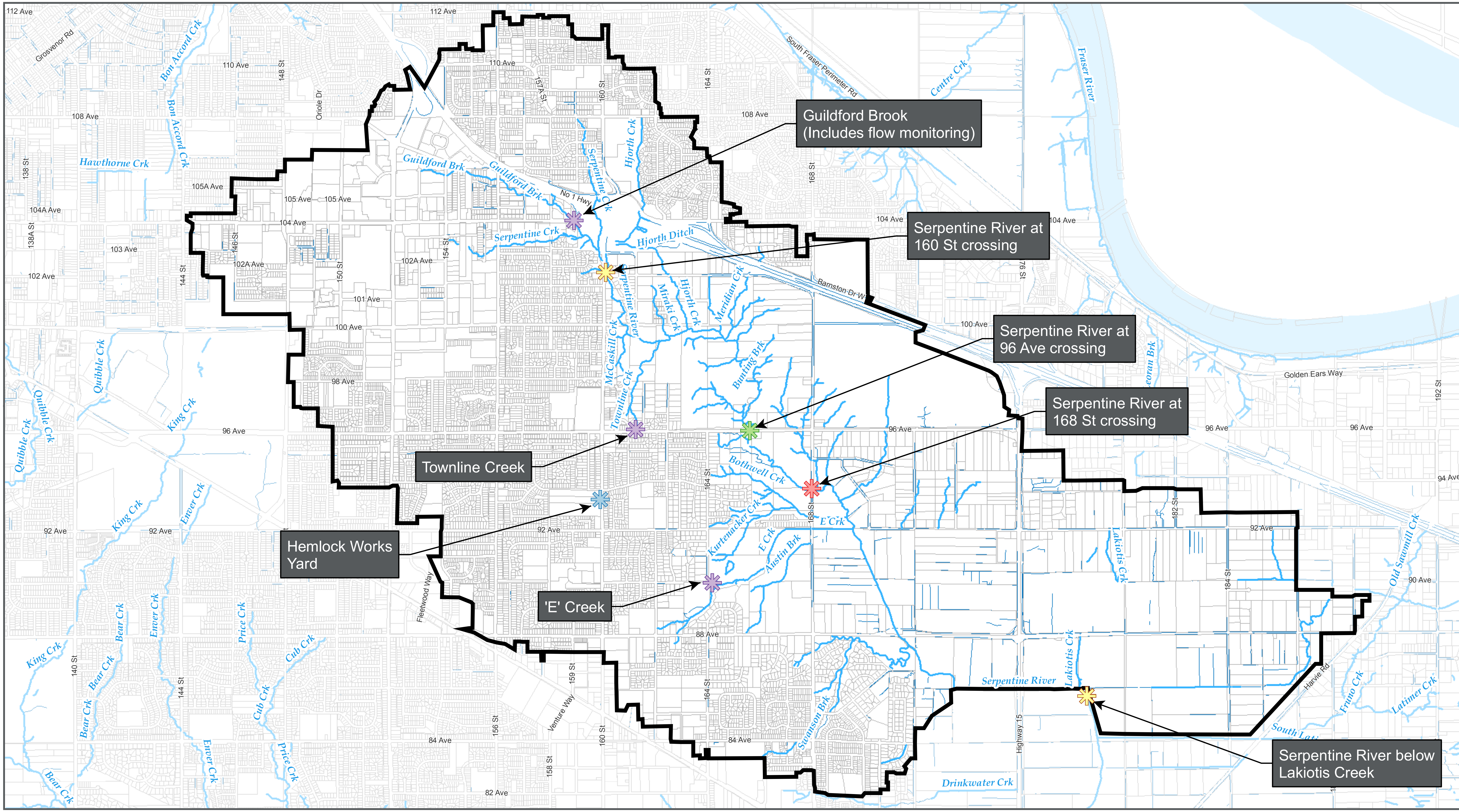
These locations will be sampled on a five year rotation with other adaptive management framework (AMF) stations throughout the City, beginning in three years. The current suite of parameters includes:

- Basic field measurement parameters (conductivity, dissolved oxygen, pH, temperature, turbidity);
- Nutrients (nitrate, nitrite, nitrate + nitrite);
- Bacteria (E. coli, fecal coliforms); and
- Total metals (low level: iron, cadmium, copper, lead and zinc).

In addition, the City will continue to collect flow data (i.e. water level, which can be used to estimate discharge) in the Serpentine River from a station located at 168 Street and precipitation data from a rain gauge along 160 Street, south of 96 Avenue. Further, as part of its participation in the multi-partner Boundary Bay Assessment and Monitoring Program (BBAMP), the City has sampled water quality on the Serpentine River at 96 Avenue, not far upstream of the existing water level monitoring station; the monitoring covered a full range of physical, chemical and biological parameters[16]. All of these monitoring stations are also shown on **Figure 5.1**.

The ISMP endorses these monitoring efforts and suggests consideration of two additional monitoring stations intended to provide a high level perspective on conditions within the Upper Serpentine watershed over time. These two additional stations bracket the existing BBAMP site, thus providing an additional site on a “high gradient” reach of the river plus a new downstream station on a “low gradient” reach. Water quality parameters could be monitored as per the current BBAMP protocol, with consideration given to assessing benthic invertebrates at the two high gradient stations and providing flow monitoring at the two newly suggested sites. These two suggested monitoring sites are shown on **Figure 5.1**.

[16] All parameters listed for Surrey’s AMF sites, plus salinity, phytoplankton, total suspended and dissolved solids, hardness, chloride, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, Enterococci and dissolved metals.



URBAN systems

Project #: 1072.0211.01
Author: SF
Checked: JR
Status: Final
Revision: A
Date: 2015 / 5 / 13

0 400 800 1,200 1,600 m

Scale: 1:27,500

N

Coordinate System:
NAD 1983 UTM Zone 10N

Data Sources:
Town centre, NCP boundaries provided by the City of Surrey, Mar. 2014
Study area delineated by Urban Systems, Feb. 2014
Monitoring station locations from Flow Works website, Mar. 2014

Legend
- Study Area Boundary
- Cadastral
- Watercourse
- Ditch
- Existing AMF WQ Site
- Existing BBAMP WQ Site
- Future Rain Guage Site
- Existing Water Level Site
- Suggested New Monitoring Station (Flow; WQ)

CITY OF SURREY
the future lives here.

Upper Serpentine
Integrated Stormwater Management Plan
Figure 5.1 -
Locations For Watershed Monitoring

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APPENDIX A

LIST OF REFERENCES

References

Aquafor Beech Limited (2001). "Upper Serpentine River Channel Stabilization – Restoration Project" Prepared for Urban Systems Ltd.

Associated Engineering. (1998). *Upper Serpentine Pump Station Project 4898-714 Functional Plan*. Prepared for City Surrey, British Columbia, Canada

Associated Engineering. (1999). "Upper Serpentine Ditch Upgrade Record Drawings". Prepared for City of Surrey, British Columbia, Canada.

Associated Engineering. (2000). "Drinkwater Creek Storm Diversion Record Drawings". Prepared for City of Surrey, British Columbia, Canada.

Blackman, D.C. and Simpson T.L. (1985). *The Serpentine River Watershed Salmonid Resource Studies 1984-85.* Prepared for Tynehead Zoological Park, Surrey, British Columbia.

Canadian Environmental Assessment Agency (CEAA). (2009). *Adaptive Management Measures under the Canadian Environmental Assessment Act (Operational Policy Statement)*.

City of Surrey. (2011). *2011 – 2015 Financial Plan.*

City of Surrey (2012). *Anniedale-Tynehead Neighbourhood Concept Plan (NCP)*.

City of Surrey (2012). *Amendment 1: Anniedale – Tynehead NCP, 2012-2021 Ten Year Servicing Plan*.

City of Surrey (2013). *Climate Adaption Strategy*.

City of Surrey (2013). *Plan Surrey, 2013 Official Community Plan (DRAFT), "*Bylaw No. 18020".

City of Surrey (2014). *Ten Year Servicing Plan (2014-2023).*

City of Surrey and Phillips Farevaag Smallenberg. (2011). *Surrey City Centre: Green Network Study*.

City of Surrey, "COSMOS" (online). Available: http://www.surrey.ca/city-services/665.aspx.

Dayton and Knight Ltd. (1990). *"1988 – 1989 Serpentine River Pumping Update and Design Study.* Prepared for City of Surrey.

Delcan. (1993). *Upper Serpentine River Drainage Study Conceptual Review – Final Report.* Prepared for City of Surrey.

Delcan. (2011). *Cloverdale McLellan Integrated Stormwater Management Plan*. Prepared for City of Surrey.

Diamond Head Consulting. (2014). *Biodiversity Conservation Strategy*. Prepared for City of Surrey.

Dillon Consulting Engineers, Planners, Environmental Scientists, "GIS Catchment Zone information".

Dillon Consulting Engineers, Planners, Environmental Scientists. (1995). *Greenway Wetland Project – D51/97 Preliminary Design Report*. Prepared for City of Surrey.

Dillon Consulting Engineers, Planners, Environmental Scientists. (1995). *Stormwater Management Review Feasibility and Functional Plans Upper Serpentine Area #6"*. Prepared for City of Surrey.

Dillon Consulting Engineers, Planners, Environmental Scientists. (2001). *Upper Serpentine River Area 1-4 Feasibility /Functional Study*. Prepared for City of Surrey.

Hatfield Consultants Partnership. (2013). *City of Surrey Stormwater Monitoring Program Annual Report 2012.* Prepared for City of Surrey.

HB Lanarc and Raincoast. (2011). *City of Surrey Ecosystem Management Study*. Prepared for City of Surrey.

IDG Group / Duncan and Associates Engineering Inc. (1996). *Upper Serpentine, Fleetwood and Greenway Basin Master Drainage Plan Volume 1 – Report*. Prepared for City of Surrey.

IDG Group / Duncan and Associates Engineering Inc. (1996). *Upper Serpentine, Fleetwood and Greenway Basin Master Drainage Plan Volume 2 – Tables and Figures*. Prepared for City of Surrey.

Kerr Wood Leidal. (2011). *Little Campbell River Integrated Stormwater Scoping Study – Volume 1*. Prepared for City of Surrey.

Kerr Wood Leidal. (2011). *Little Campbell River Integrated Stormwater Scoping Study – Volume 2: Repot* Figures. Prepared for City of Surrey.

Kiewit Flatiron. (2011). *Drainage and Utilities Plans for Segments E1 and E2*. Prepared for City of Surrey.

KPA Engineering Ltd. (Date unknown). "Floodplain Mapping of the Serpentine and Nicomekl Rivers", Maps 09, 10 and 11.

MetroVancouver. (2014). *Monitoring and Adaptive Management Framework for Stormwater*.

New East Consulting Services Ltd. (2005). *Campbell Heights City Land Servicing Study*. Prepared for City of Surrey.

New East Consulting Services Ltd. (2005.) *Latimer Lake: Stormwater Control Plan Conceptual Overview*. Prepared for City of Surrey.

New East Consulting Services Ltd.(2005). *Campbell Heights City Land Servicing Study – ADDENDUM.* Prepared for City of Surrey.

North West Hydraulics (NHC). (2012). *Serpentine, Nicomekl & Campbell Rivers, Climate Change Floodplain Review*.

Piteau Associates. (2004). *Groundwater Development at Fleetwood Site, 16555 Fraser Highway, Surrey.*

Piteau Associates. (2005). *Exploratory Drilling, Fleetwood Boster Station, Surrey.*

Raincoast Applied Ecology. (2012). *2011 City of Surrey Benthic Invertebrate Sampling Program: Methods and Results.* Prepared for City of Surrey.

Reid Crowther. (1996). *Greenway Feasibility – Functional Plan.* Prepared for City of Surrey.

Rhithron Associates, Inc. (2011). *Analysis of Biological Samples: Technical Summary of Methods and Quality Assurance Procedures*.

Rhithron Associates, Inc. (2012). *Analysis of Biological Samples: Technical Summary of Methods and Quality Assurance Procedures*.

Stantec Consulting Ltd. (2000) *Upper Serpentine Detention Ponds (Hydro Ponds) Drainage Package D62/*99. Prepared for City of Surrey.

Stantec Consulting Ltd. (2000). *Preliminary Design Report Upper Serpentine Detention Pond Upgrades Drainage Package D62/99*. Prepared for City of Surrey.

U.S. Department of the Interior (DOI), Adaptive Management Working Group. (2009). *Adaptive Management: The U.S. Department of the Interior Technical Guide*.

UMA. (1999). *Verification of the Functional Plan for the Upper Serpentine Pumpstation*. Prepared for City of Surrey.

UMA. (2002). *Verification of the Central and Lower Serpentine River Dyke Design*. Prepared for City of Surrey.

Urban Systems Ltd. (1998) *Upper Serpentine River Dyke Tie-in Functional Plan*. Prepared for City of Surrey.

Urban Systems Ltd. (2003). *Surrey Ravine Stability Assessment (2002)*. Prepared for City of Surrey.

Visser, Richard. (1991). *Upper Serpentine Drainage Basin Water Quality Study*. Prepared for City of Surrey.

WEB Engineering Ltd. (2009). *Project 4804-801, 2009 Ravine Stability Assessment*. Prepared for City of Surrey.

WEB Engineering Ltd. (2011). *2011 Ravine Stability Assessment*. Prepared for City of Surrey.

APPENDIX B

COMMUNICATIONS AND ENGAGEMENT

Appendix B - Communication and Engagement

Communicating and engaging with both internal and external stakeholders are important steps in developing an ISMP that can be implemented and reflects the community's values and knowledge of the watershed.

In the early stages of the project, a Communication and Engagement Strategy was developed to identify:

- stakeholders/audiences,
- the goals and objectives for communicating with and engaging each stakeholder group
- key issues
- a plan of actions to achieve the goals and objectives

The Communication and Engagement Strategy was implemented by both the City and Urban Systems. This Appendix includes the outputs and deliverables from implementation of the Communication and Engagement Strategy.

Communication and engagement, especially internal engagement with staff members from other departments, provided invaluable contributions to the development of the ISMP which will improve opportunities for future implementation success.

The following items are provided in this appendix:

- Communication and Engagement Strategy
- City of Surrey Website - ISMP Content
- ISMP Poster
- Workshop 1: Pre Workshop Survey
- Workshop 1 Summary Notes
- Workshop 2 Summary Notes
- Workshop 3 Summary Notes

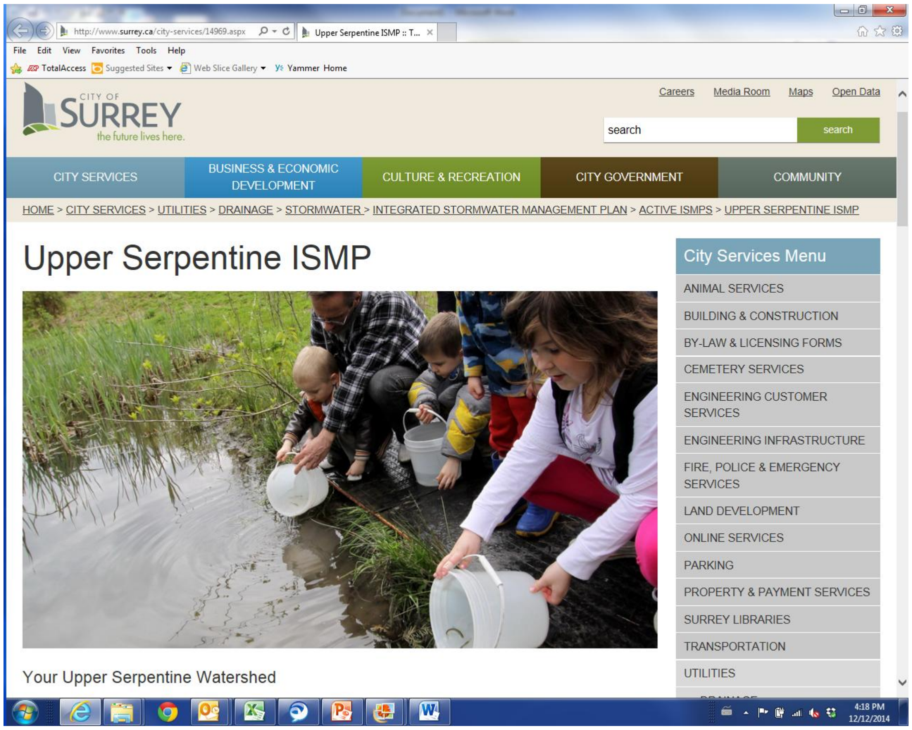


Photo: Upper Serpentine ISMP project description and invitation for information on City of Surrey website.

City of Surrey Upper Serpentine Integrated Stormwater Management Plan (ISMP) | Communications and Engagement Strategy

Introduction

The City of Surrey (City) is undertaking an Integrated StorTo be informwater Management Plan (ISMP) for the Upper Serpentine Watershed. The final ISMP will guide the City in maintaining and/or enhancing the overall health of the watershed while supporting future growth and development.

In response to the City's commitments under Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRMP), the City is striving to complete ISMPs for all of its watersheds by the end of 2014. The Upper Serpentine ISMP will add to the City's eight completed ISMP's and multiple ISMP's in progress.

This Communications and Engagement Strategy will guide the ISMP project team in supporting the overall success of the project. The strategy will identify stakeholders, define key messages, and outline timelines for all communication and engagement initiatives. As a living document, the Communications and Engagement Strategy will be updated to reflect any changing needs that may occur over the course of the project. We will ensure language used to communicate the ISMP project and process to external stakeholders reflects the tone and standards of the City of Surrey. All communication material will be reviewed by the City's internal communications department before going "live" to an external audience.

Key Audiences

Internal Stakeholders

City ISMP Team

- Engineering
- Planning and Development
- Parks, Recreation & Culture
- Sustainability Office
- Finance and Technology
- Marketing and Communications

External Stakeholders

Advisory Committees

- Development Advisory Committee (DAC)
- Agriculture and Food Security Advisory Committee (AFSAC)
    - Councillor Linda Hepner (Chair)

    - Carla Stewart (Committee Member and ISMP Project Team Member)

- Environmental Sustainability Advisory Committee (ESAC)
    - Councillor Bruce Hayne (Chair)

- Parks, Recreation and Sport Tourism Committee (PRSTC)
    - Councillor Linda Hepner (Chair)
    - Councillor Tom Gill (City Council Rep)

Agencies/Government Organizations

- Fisheries and Oceans Canada (DFO)
- Ministry of Environment
- Metro Vancouver
- TransLink
- Ministry of Transportation and Infrastructure (MoTI)
- Environment Canada

Special Interest Groups

- Tynehead Hatchery (Serpentine Enhancement Society)
    - Glenn Wright (Hatchery Volunteer)
      g.wright@asi-ltd.ca
      contact@tyneheadhatchery.ca

- Ivanhoe Cambridge
    - Peggy Howard (General Manager)
      peggy.howard@ivanhoecambridge.com

    - Petra Barker (Public and Community Relations Manager): petra.barker@ivanhoecambridge.com

Surrey Residents

- General Public

- Guildford Community Partners Society
    - Pam Wong (Secretary/Treasurer)
      (604) 588-6715
      gpcgs@vcn.bc.ca

- Tynehead Community Centre Association
    - info@tyneheadhall.ca

- Fleetwood Community Association
    - contact@fcasurrey.ca

Communication and Engagement Goals and Objectives

External Stakeholders

Goals

- To create awareness for the Upper Serpentine Integrated Stormwater Management Plan
- To provide opportunities to engage and provide input to the Upper Serpentine Integrated Stormwater Management Plan

Objectives

- To provide information to the general public and external stakeholders so that they feel well-informed, with the majority of engaged persons reporting they received the information they needed to contribute meaningfully to the project

Internal Stakeholders

Goals

- To provide City staff on the ISMP project team with the necessary resources and opportunities to work collaboratively towards an implementable and supported ISMP for the Upper Serpentine Watershed.

Objectives

Of the City staff who are participating in the ISMP project team, 90% will report having:

- A good understanding of what an ISMP is and why the City is undertaking ISMPs (beyond the regulatory requirements)
- A good understanding of how an ISMP relates to their individual day-to-day work
- A good understanding of current watershed conditions for the Upper Serpentine Watershed and the preferred strategy to maintain and/or enhance watershed conditions in the future
- The opportunity to provide their perspectives and opinions throughout the development of the Upper Serpentine ISMP

Key Messages

1. In late 2013, the City of Surrey began the process of preparing an Integrated Stormwater Management Plan (ISMP) for the Upper Serpentine watershed, in order to protect the overall health of the watershed now and into the future.

   An Integrated Stormwater Management Plan (ISMP) is a comprehensive plan that examines the interrelationships between drainage servicing, land use planning, and environmental protection. Its purpose is to outline an approach to support and promote the growth of a community in a way that maintains, or ideally enhances, the overall health of a watershed. By applying an integrated approach, an ISMP can be used to link watershed and stream health to land use and policy decisions. Further, as a policy level document, an ISMP can be a powerful tool that supports a community's path towards achieving its vision for the future.

2. The Upper Serpentine ISMP study area lies between 144th Street and 188th Street and 82nd Avenue to 112th Avenue, covering approximately 2,616 hectares. The study area includes both urban and suburban land uses, including one of Surrey's commercial hubs (Guilford Town Centre) and an important regional park (Tynehead Park).

   Over the long-term the area will see redevelopment in both the suburban and urban areas as the City's overall population continues to grow. Future growth and development is planned for the Anniedale-Tynehead area, as outlined in the Anniedale-Tynehead Neighbourhood Concept Plan (NCP). An area plan for Guildford Town Centre was also recently initiated by the City; it is anticipated that future growth and densification will be promoted in this area. With this anticipated growth and development, it is important for the City to have a plan in place to proactively protect the overall health of the Upper Serpentine Watershed.

3. The City is actively looking to enhance their knowledge and understanding of current conditions in the Upper Serpentine Watershed from those who live, work and interact with the area. If you have relevant information about this area, the City would like to hear from you! Please contact David Hislop, P.Eng., Project Supervisor at the City of Surrey at DOHislop@surrey.ca.

Audience Issues Analysis

Throughout the ISMP process, the project team will have the opportunity to communicate and hear from a variety of audiences, both internal and external. By identifying the concerns and aspirations of these key audiences, the project team's communication initiatives can be tailored to meet their needs and proactively consider these concerns and aspirations throughout the process.

Key Audience		Mandate	Concerns/Aspiration Regarding the Upper Serpentine Watershed		Potential Impact on the ISMP
City ISMP Team	Engineering	To ensure the efficient and effective delivery of high quality services including water, sewer, drainage, garbage collection, transportation systems, realty services, and maintenance of City buildings for both existing residents and for new growth, in a timely, responsible and effective manner	**Concerns**	Existing development impacts on peak flow and water quality; Narrow riparian corridors, some under private ownership; fish and wildlife accessibility and movement; retention of high value habitat	H
			Aspirations	Maximize opportunities through development / redevelopment; Establish sound rationale for adequate setbacks on creek corridors	
	Planning and Development	To advise City Council on the orderly development of the City by preparing land use plans, bylaws and policies; and managing the application approval process consistent with the approved plans, bylaws and policies	**Concerns**	Incomplete mapping of the floodplain areas; Development pressures (short and long term); Effectively addressing peak flows and water quality through development	H
			Aspirations	Utilizing surface oriented BMPs (e.g., rain gardens) for beautification and drainage; Refine existing / future Land Use Plans as needed to better support stormwater management objectives; Maximize opportunities through development /redevelopment	
	Sustainability Office	Facilitate and support sustainability initiatives and implementing the Climate Adaptation Strategy	**Concerns**	Understanding, anticipating, and planning for changes to precipitation patterns and the impacts of sea level rise	H
			Aspirations		
	Finance and	To provide financial expertise, information	**Concerns**		M

Key Audience		Mandate	Concerns/Aspiration Regarding the Upper Serpentine Watershed		Potential Impact on the ISMP
	Technology	systems (IT), advice and guidance to support City operations	Aspirations	Understand ISMP recommendations; assist in identifying sources of funding to implement the ISMP	
	Marketing and Communications	To ensure a positive civic image and identity	Concerns		M
			Aspirations	Partnership opportunities with stewardship groups	
	Parks, Recreation and Culture	To ensure the efficient and effective delivery of high quality services that includes parks, recreation, arts, heritage and marketing services in a timely, responsible and effective manner	Concerns	Private ownership of riparian corridors in some areas; stewardship of the primary tributaries west of Tynehead Park	H
			Aspirations	Improved / continued integration of parks and stormwater management / drainage features	
	Transportation	To provide a balanced transport system that gives sustainable choices in the way we travel to, from and within Surrey and which integrates with other policy areas associated with the environment, health and safety, economic well-being and land development	Concerns		M
			Aspirations	Understand ISMP recommendations and how transportation can influence stormwater management issues; improved integration of roads and stormwater management features	
Advisory Committees	Development Advisory Committee	To focus on creating a positive and constructive climate for change in the community that will be mutually beneficial for City and Development Industry	Concerns		
			Aspirations		
	Environmental Sustainability Advisory Committee	To receive and comment on issues related to the natural and built environment and to support the work of Council by advising them on environmental issues.	Concerns		
			Aspirations		
	Parks, Recreation and Sport Tourism Committee	To enhance City parks and recreation facilities and services for the enjoyment and well-being of current and future residents.	Concerns		
			Aspirations		

Key Audience		Mandate	Concerns/Aspiration Regarding the Upper Serpentine Watershed		Potential Impact on the ISMP
Agencies and Government Bodies	Agriculture and Food Security Advisory Committee	To make recommendations on all aspects of the agricultural community, including land use and economic development matters and to review and comment from the agricultural viability perspective on issues, plans and specific development applications referred by staff or Council. (read full mandate)	**Concerns**		
			Aspirations		
	Fisheries and Oceans Canada (DFO)	To work collaboratively towards advancing sustainable aquatic ecosystems and supporting safe and secure Canadian waters while fostering economic prosperity across maritime sectors and fisheries.	**Concerns**		
			Aspirations		
	Ministry of Environment	To protect human health and safety, and maintain and restore the diversity of native species, ecosystems and habitats.	**Concerns**		
			Aspirations		
	Metro Vancouver	Services and Solutions for a Livable Region	**Concerns**		
			Aspirations		
	TransLink	To create a transportation system for a sustainable region.	**Concerns**		
			Aspirations		
	Ministry of Transportation and Infrastructure	To be a world leader in moving people and goods safely, efficiently and sustainably, and to support a globally competitive economy and a high quality of life.	**Concerns**		
			Aspirations		
	Environment Canada	To preserve and enhance the quality of the natural environment, including water, air, soil, flora and fauna and conserve and protect Canada's water resources. (read full mandate)	**Concerns**		
			Aspirations		

Key Audience		Mandate	Concerns/Aspiration Regarding the Upper Serpentine Watershed		Potential Impact on the ISMP
Special Interest Groups	Tynehead Hatchery	The Serpentine Enhancement Society is committed to replenishing and restocking all locally endangered fish species.	**Concerns**		
			Aspirations		
	Ivanhoe Cambridge	Ivanhoe Cambridge is a world-class real estate company that leverages its high-level expertise in all aspects of real estate including investment, development, asset management, leasing and operations, to deliver an optimal return for its investors.	**Concerns**		
			Aspirations		
Surrey Residents	Guildford Community Partners Society		**Concerns**		
			Aspirations		
	Tynehead Community Centre Association		**Concerns**		
			Aspirations		
	Fleetwood Community Association	The FCA is committed to making positive change in the community and the City of Surrey by ensuring that the public plays an active role in the consultation and decision-making processes that shape our community now . . . and in the future, encouraging consultation with stakeholders to find practical, sustainable solutions to local and city-wide issues including infrastructure, transportation and social planning strategies, and working with residents, businesses , developers and all levels of government to balance growth with policies and enforceable bylaws to preserve eco-systems & green space	**Concerns**		
			Aspirations		

Online Strategy

The City currently uses a variety of social and online channels. These resources will aid the ISMP project team in creating awareness for the project and promoting opportunities for input. The use of the City's website will also provide interested community members a platform to stay informed through the process. For this process, updates on the City's ISMP page, the City's Facebook page, the City Speaks platform, and the City's Twitter account will drive the online presence for the Upper Serpentine ISMP.

The City's existing ISMP page within the City of Surrey's website will be the primary resource for information on the project. Traditionally, interest from the community at large to participate in the ISMP process has been low. However it will be important to have information available to those who are interested. This page will have information on the project, process, opportunities for engagement, and key milestones, among others.

The use of the City's current social media channels, primarily Facebook, Twitter, and the City Speaks platform, will aid in creating awareness and directing interested community members to the ISMP webpage.

The consultant team will provide content for the City website only. City staff will vet the content through the appropriate channels internally at the City and then post online. City staff will also be responsible for posting updates to social media channels at their discretion.

Tools and Techniques

There are a number of tools available to inform and engage the public and key stakeholders throughout the process. The following table will be added to and refined throughout the ISMP process

Phase 1: November to March					
Tool/ Technique	**Description/Purpose**	**Audience**	**Roles and Responsibilities**	**Timing**	**Complete**
Project Webpage	Central location for all project-related information. Connects interested community members to information about the project and process, provides contact information for the project, links to surveys and relevant documents as applicable, informs the community of project milestones	All	Content development: Urban Systems Content review and posting: City of Surrey	February - Ongoing	
Social Media Presence	Regular posting to the City's social media channels promoting new content to the webpage	All	City of Surrey	February - Ongoing	
Surrey ISMP Team Survey	A pre-workshop survey to gain preliminary information from the Surrey ISMP project team on the understanding of the project, study area, and significance of their involvement.	ISMP Team	Urban Systems	January	✓
Workshop No. 1 – Working Together	This workshop will include a tour of the study area, a discussion on existing watershed conditions, and a facilitated decision-making process to identify key issues to address in the ISMP	ISMP Team	Urban Systems	February	✓

Content Update – Project Page	Post a project update to the project page highlighting the results of phase 1 and next steps.	All	Content development: Urban Systems Content review and posting: City of Surrey	March	
Phase 2: March to May					
Tool/ Technique	**Description/Purpose**	**Audience**	**Roles and Responsibilities**	**Timing**	**Complete**
One-page digital poster	Solicit background information from key external stakeholders through a one-page digital poster distributed via email and on the project website. Inquire how targeted groups would like to be involved and informed as the project continues.	Agencies & Government Organizations Special Interest Groups Community Associations	Content development: Urban Systems Content review and distribution: City of Surrey	Late February	
Workshop No. 2 – Vision and Objectives	Through this workshop the vision and related objectives for the Upper Serpentine Watershed will be defined.	ISMP Team	Urban Systems	Early April	
Content Update – Project Page	Post a project update to the project page highlighting the vision and objectives for the ISMP, any new information learned through phase 2, and next steps.	All	Content development: Urban Systems Content review and posting: City of Surrey	Mid May	

Phase 3: May to July					
Tool/ Technique	**Description/Purpose**	**Audience**	**Roles and Responsibilities**	**Timing**	**Complete**
Workshop No. 3 – Setting Priorities	This workshop will help determine preferred approaches and priority actions for the City to take to maintain and/or enhance the overall health of the watershed.	ISMP Team	Urban Systems	Early June	
Content Update – Project Page	Post a project update to the project page highlighting the priorities set for the Upper Serpentine watershed, any new information learned through phase 3, and next steps.	All	Content development: Urban Systems Content review and posting: City of Surrey	Early July	
Phase 4: July to September					
Tool/ Technique	**Description/Purpose**	**Audience**	**Roles and Responsibilities**	**Timing**	**Complete**
Content Update – Project Page	Post a project update to the project page highlighting status and progress of plan, and link to the final ISMP report.	All	Content development: Urban Systems Content review and posting: City of Surrey	August/ September	
Surrey ISMP Team Feedback Form	A comment form will be distributed to City staff involved in the Upper Serpentine ISMP to ensure the internal objectives set out in this plan have been reached and explore opportunities for improvement. This survey will serve as a measurement tool, evaluating the internal objectives set out in this plan.	ISMP Team	Urban Systems	September	

Upper Serpentine Integrated Stormwater Management Plan (ISMP) Project Website

Site Features

1. About Page
2. ISMP Team
3. About the Upper Serpentine Watershed
4. Getting Involved

Overview: About Page

Title: Upper Serpentine Integrated Stormwater Management Plan

Overview (includes a map of the study area)

In late 2013, the City of Surrey began preparing an Integrated Stormwater Management Plan (ISMP) for the Upper Serpentine Watershed in order to protect the health of the watershed. The Upper Serpentine ISMP study area lies between 144th Street and 188th Street, and 82nd Avenue to 112th Avenue, covering approximately 2,616 hectares. The study area includes both urban and suburban land uses, including one of Surrey's commercial hubs (Guilford Town Centre) and an important regional park (Tynehead Park).

The Serpentine River originates near 160th Street and 104th Avenue and flows from the Northwest to the Southeast towards 176th Street and 88th Avenue. From there the river turns southwest and flows through the Surrey lowlands before discharging into Mud Bay. The upper reaches are generally contained within natural banks, whereas the lowland reaches (south of 92nd Avenue) are contained by a dike system. There are a number of major tributaries to the Upper Serpentine River (within the study area) including Hjorth Creek, Acason Creek, Bothwell Creek, E Creek, Austin Brook, Swanson Brook, and Lakiotis Creek.

Over the long-term, the area is expected to see redevelopment in both the suburban and urban areas. With this anticipated growth and development, it is important for the City to have a plan in place to proactively protect the health of the Upper Serpentine Watershed.

What is an Integrated Stormwater Management Plan?

An ISMP is a comprehensive plan that examines the interrelationships between drainage servicing, land use planning, and environmental protection. Its purpose is to outline an approach to support and promote the growth of a community in a way that maintains, or ideally enhances, the health of a watershed. By applying an integrated approach, an ISMP can be used to link watershed and stream health to land use and policy decisions. Further, as a policy level document, an ISMP can be a powerful tool that can help a community achieve its vision.

What is stormwater management?

When rain or snow comes in contact with the ground or other surfaces, it can evaporate, seep into the ground, be absorbed by vegetation like trees and shrubs, or run overland into storm sewers, ditches, lakes, and streams. The portion of water that runs overland is called stormwater runoff.

It is important to manage stormwater runoff in order to mitigate pollution as well as peak and low flows in receiving water bodies, and ensure water safely cycles back into the natural environment. When stormwater isn't managed property, it can result in flooding, property damage, erosion and pollution in streams and creeks, and negative impacts on habitat and fish.

How does the ISMP process work?

For the Upper Serpentine ISMP, the City of Surrey is taking a collaborative approach by engaging a broad group of City staff. The City also wants to hear from interested residents, businesses and other stakeholders. This approach will allow multiple viewpoints and perspectives to be considered throughout the development of the ISMP. After all, the more we know, the more we can do to protect this area as the community grows.

The process will unfold in four Stages over a 10 month period.

Stage 1: What Do We Have?

This stage will include gaining a better understanding of existing conditions within the watershed and identifying issues and opportunities.

Stage 2: What Do We Want?

In this stage we will develop a vision and related objectives for the watershed.

Stage 3: How Do We Put It Into Action?

Developing an implementable plan is key to the success of this initiative. In the third stage, we will create an action plan for meeting the vision and objectives established earlier in the process.

Stage 4: How Do We Stay on Target?

This stage will result in a monitoring and assessment plan to ensure objectives are reached in the short and long-term.

Overview: ISMP Team

Title: City ISMP Team

ISMP Team Overview

The ISMP Team for the Upper Serpentine Watershed is made up of a diverse group of City staff from various departments including: Engineering; Planning and Development; Parks, Culture and Recreation; Technology and Finance; and the Sustainability Office. City Staff are being supported by an external consulting team consisting of Urban Systems (engineering, planning and landscape architecture), Dillon Consulting (environmental) and Thurber Engineering (geotechnical) on this project. Over the course of the project, the ISMP Team will participate in three workshops in order to collaboratively make important decisions that will guide and shape the final ISMP for the Upper Serpentine Watershed.

Stage 1: Workshop #1 Outcomes - What Do We Have?

On February 4th, 2014 the ISMP team met for the first of three workshops. The inaugural workshop included discussions about what an ISMP is intended to do and why ISMPs are important to the City of Surrey. Team members highlighted various challenges and opportunities for the study area from their own unique perspectives. The group also toured the watershed, where they visited distinct areas that highlighted some of the positive work being done in the watershed as well as opportunities for improvements.

At the completion of the workshop, the ISMP Team determined four key themes to focus on in this ISMP. These themes will help guide the direction of the ISMP for the Upper Serpentine Watershed.

1. Develop solid, scientific-based rationale for riparian (i.e., land situated adjacent to rivers, streams or other water features) setbacks based on a comprehensive suite of considerations.
2. Consider a range of “grey” to “green” drainage infrastructure requirements to address future development.
3. Consider climate change implications when assessing various scenarios.
4. Provide recommendations for improvements to the City’s drainage parcel tax that better reflects development usage of drainage systems.

Overview: About the Upper Serpentine Watershed

Title: Your Upper Serpentine Watershed

The Upper Serpentine Watershed is a distinct area that many families, individuals, businesses, and wildlife call home. It is an area with both urban and suburban features for residents to live, work and play. Areas north and west of the river are generally urbanized with single family and multi-family residential, commercial, institutional, parks, and light industrial being the dominant land uses; areas east of the river are suburban with mainly agricultural uses. For the City of Surrey, finding a balance between development and conservation is both an opportunity and a challenge.

More information to come!

Overview: Getting Involved

Title: We’d like your input!

The City is actively looking to enhance their knowledge and understanding of current conditions in the Upper Serpentine Watershed from those who live, work and interact with the area. If you have relevant information about this area, the City would like to hear from you! Please contact David Hislop, P.Eng., Project Supervisor at the City of Surrey at DOHislop@surrey.ca **by Friday March 28, 2014.**

As the project moves forward, we will be updating and adding content to this website. If you have any questions or comments on the information presented here, please contact David Hislop, P.Eng., Project Supervisor at the City of Surrey at DOHislop@surrey.ca.

UPPER SERPENTINE INTEGRATED STORMWATER MANAGEMENT PLAN

About The Project

The City of Surrey is preparing an Integrated Stormwater Management Plan (ISMP) for the Upper Serpentine Watershed in order to protect the health of the watershed. An ISMP is a comprehensive plan that examines the interrelationships between drainage servicing, land use planning, and environmental protection.

The Upper Serpentine ISMP study area lies between 144th Street and 188th Street, and 82nd Avenue to 112th Avenue. The area includes both urban and suburban land uses, including one of Surrey's commercial hubs (Guilford Town Centre) and an important regional park (Tynehead Park).

Getting Involved

The City is actively looking to enhance their knowledge and understanding of current conditions in the Watershed from those who live, work, and interact with the area. If you have relevant information about this area, the City would like to hear from you! **Please contact David Hislop, P.Eng., Project Supervisor at the City of Surrey at DOHislop@surrey.ca by Monday March 31, 2014.**

CITY OF SURREY
the future lives here.

1. What is your name?	2. What is your title?	3. What department do you work in?	4. What is your role / main responsibilities?	5. What is your level of understanding of Integrated Stormwater Management Plans (ISMP)?	6. What is your level of knowledge of the Upper Serpentine Watershed?	7. From your perspective / experience, what is the biggest challenge(s) in this watershed?	8. From your perspective / experience, what is the biggest opportunity(ies) in this watershed?	9. Why do you think you've been asked to contribute to the Upper Serpentine ISMP study?	10. What additional information do you feel you need to meaningfully contribute to this study?	11. How might this ISMP better support you in your role at the City?	12. Do you have any additional thoughts or comments to add at this time?
Andrea Smeenk	Finance Manager, Engineering	Finance/Engineering	To manage and report on the Finance activities for the Citywide Engineering department	Medium	Low	Heavily urbanized in upper reaches, agricultural impacts in lower river, subject to fish kills, strong community interest in rehabilitation	Strong community interest in the area, the Hatchery	To identify sources of funding, have shown an interest in this area by attending the 2012 salmon run with my two young sons		To better understand the technical aspects of the Engineering Dept. is a huge benefit to my role	Not at this stage
Carrie Baron	Drainage & Environment Manager	Engineering	drainage & environmental planning, 10 year capital plan, flooding response & prevention, environmental compliance	High	High	retrofitting in the existing developed community - trying to bring back flows to more historic levels	redevelopment opportunities to put in new facilities/technologies and make improvements for water quality	assist with overall city management of stormwater and environmental systems	not sure yet	help set watershed direction, land development requirements, 10 year plan and asset renewal opportunities	not yet
Steve Whitton	Manager of Trees and Landscape	Planning and Development	Manager of the Tree Bylaw	Low	Low			My Section reviews all landscape plans for all development permits. Plus the Tree Bylaw.			No.
Patrick Klassen	Parks & Recreation Planner	Parks, Recreation & Culture	Lead planning processes of major City park & greenway systems.	Medium	Medium	Public ownership & stewardship of the primairy tributaries west of Tynehead Park, including Guildford Brk and Serpentine Creek.	While public ownership remains a challenge, there are key properties that remain public, which offer excellent opportunities for stormwater management.	It is the goal of the City to retain all riparian areas within the public realm, as parkland. Parks also has an interest in stormwater management within this watershed.	Background on the full extent of the watershed. General goals of the ISMP for this watershed.	Hopefully it will support the public retention of improtant tributaries.	None
Dave Orsetti	Engineer Assistant	Planning and Development, Building Division	Drainage review, lot grading and geotechnical report review.	Medium	Medium	Maintaining base flows and mitigating increase peak flows to maintain water quality, slow erosion, limit increase of lowland flooding.	Still lots of developable land in the watershed, giving opportunity to implement a strategy.	No idea.	Maps showing boundaries and proposed land uses.	No idea.	Not really.
Ted Uhrich	Parks Planning, Research and Design Manager	Parks	Manage the planning and design of parkland throughout Surrey	High	Medium	Old development covered watercourses or left minimal setbacks on remaining watercourses.	A new land use plan for Guildford Town Centre	Parkland can be managed to mitigate impacts to the Upper Serpentine	Watershed boundaries	Support decision making for parkland acquisition and design in the watershed	No
Carla Stewart	Senior Policy Planner	Community Planning - Planning and Development Department	OCP preparation, secondary plan preparation, Planning rep on AFSAC, planning rep on CEEP and City's Adapation Plan, general planning projects needing planning prescent	Medium	Medium						
Maggie Baynham	Sustainability Coordinator	City Manager's - Sustainability Office	Facilitating/supporting sustainability initiatives, leading development and implementation of Climate Adaptation Strategy	Low	Low	A growing challenge will be understanding, anticipating and planning for changes to precipitation patterns and the impacts of sea level rise downstream		Because of my involvement in the Climate Adaptation Strategy		As the first ISMP to be undertaken since the completion of the Adaptation Strategy (which identified the incorporation of climate change into ISMPs as an action: FL-2.3), it will be an important opportunity to determine how climate change can be integrated into ISMPs and land use decisions more broadly. It will likely be used as a model in future efforts.	No
Leita Martin	Associate Planner	Planning & Development	Development planning, project management	Low	Low	Incomplete mapping of the floodplain areas.	Opportunities for habitat restoration and corridor connections.	I have worked on development applications in the area.		Making better-informed decisions related to development.	Not at this time.
Richard Bull	Development Project Coordinator	Engineering Land Development	Assign work, over see conformance to City Design Criteria Standards and recommend changes to standards,	Medium	Medium						
Jeff Pang	Transportation Engineering Assistant	Transportation Engineering	Land Development Applicatons	Low	Low						
Richard Bull	Development Project Coordinator	Engineering Land Development	coordinate development work load, enforce city design criteria and policy, oversee development projects managed by the land development project managers, and recommend changes to city criteria and policy when required	Medium	Medium	continuded growth in the upland areas without providing reduction of flows to the lowland areas	the provision of sustainable drainage as part of the growth in the highland areas	a good understanding of the enforcement problems associated with adopting new drainage concepts as they will apply to new land development projects.		clear guidelines and objectives of the drainage department go a long way to helping with the coninuted growth of the city	not at this time
Doug Merry	Parks Planning Analyst	Parks Planning	Subdivsion referals, neighbourhood concept planning, park and environmental planning	Medium	Medium						
Nathan Gregory	Project Biologist and Associate	Natural Environment Management, Dillon	Environmental assistance	High	High	Mitigating the effects of urban development in the Guildford area	Enhancing and protecting the mainstem Serpentine and various tributaries	environmental support	benthic data	n/a	none
Stephen Godwin	Environmental Coordinator	Engineering	Oversee all environmental regulations and Best Management Practices that affect our Capital works projects. As well I oversee the Operations and Maintenance ditch cleangin program. I oversee the Nuisance mosquito program. I review development applications and provide short-term and long-term strategic environmental planning advice.	High	High	The riparian areas are too narrow to allow the watercourse to naturally meander so the City has been forced to do lots of erosion control. There is little gravel recruitments due to the armouring of the creek and the high velocities scour what gravel there is out. We are currently doing a pilot gravel seeding program to introduce gravel in to the headwater areas of the creek.	With new development we may be able to obtain better riparian setbacks to allow the creek dynamics to naturalize. Storm water retrofits may also be able to normalize flow regimes and base flows.	I can provide information on the biology and environmental aspects of this watershed	The Tynehead hatchery people have insights into the needs of the salmon in this system. The City of Surrey may have some benthic invertebrate monitoring information for this watershed	This will dovetail with other environmental initiatives in the City including the EMS and BCS	no
Markus Kischnick	Community Planner	Planning and Development	Preparing Neighbourhood Concept Plans (NCPs) and Preparing new planning policies.	Medium	Low	Development Pressures adjacent to Serpentine, Floodplain Issues, Land Use Conflicts, Sea Level Rise. (Ex. Anniedale-Tynehead NCP, Future South Port Kells NCP).	Land Use Plan in the Area not yet Approved, or those that have been have ability to be modified in Case of Issues, at time of redevelopment throught Rezoining. ALR Lands, have limits on Development.	Familiarity and involvement with Anniedale-Tynehead NCP, and Agricultural Planning Support	Future land use presures on the Watershed, and Policy Consideration for management including, zoning, development permit guidelines and Agricutlutural Policy.	Provide tangable direction for land use planning and agrictulural plans in the City.	Not at this time.
Preet Heer	Senior Planner	Community Planning	Neighbourhood and Town Centre Plans	Medium	Low	development of more urban areas and using different criteria that SF development	Using rain gardens and other infiltration options that work to beautify the street as well as provide drainage	I work on neighbourhood plans that may cover the watershed area			no
Carla Stewart	Senior Policy Planner	Community Planning Division - Planning and Development Department	Project planner for long-range planning; prepare policy documents.	Medium	Low	How to properly address runoff and stormwater drainage from urban development.	New development opportunities are plentiful - can take advantage of new policies sooner rather than later.	Working on Guildford Town Centre Plan	Specifics about existing drainage patterns; specifics about downstream issues as a result of current development forms	In writing the policy for the TC plan, I'll be able to incorporate specific policy for development that addresses this issue.	Nope.
Doug Merry	Parks Planning Analyst	Parks Planning, Research & Design	Represent parks in neighbourhood planning/subdivision/development applications; park acquisition; park development projects	Medium	Medium	Highly urbanized	Headwaters of the Serpentine, opportunities to do it better in Tynehead/Anniedale	To identify opportunities in parks and future parks to improve the health of the area and watershed.		It will inform park acquisition, park design and development	.

Upper Serpentine Integrated Stormwater Management Plan (ISMP)

Workshop # 1 – Working Together (February 4, 2014; City Municipal Hall)

Workshop Notes

1. Introductions

Attendees

Name	Department
David Hislop	Engineering (Utilities – Sewer, Water & Drainage)
Carrie Baron	Engineering (Utilities – Sewer, Water & Drainage)
Jeannie Lee	Engineering (Utilities – Sewer, Water & Drainage)
Jeff Pang	Engineering (Roads & Traffic Operations)
Harvinder Bains	Engineering (Land Development)
Liana Ayach	Engineering (Environment)
Carla Stewart	Planning and Development (Policy & Long Range Planning)
Markus Kischnick	Planning and Development (Policy & Long Range Planning)
Randall Epp	Planning and Development
Dave Orsetti	Planning and Development
Leita Martin	Planning and Development (Development Application Processing)
Mary Beth Rondeau	Planning and Development
Doug Merry	Parks, Recreation and Culture (Planning, Research & Design)
Andrea Smeenk	Finance & Technology (Financial Reporting)
Maggie Baynham	City Manager's Office (Sustainability Office)
Samantha Ward	Urban Systems
Sara Stevens	Urban Systems
Kelsea Bloxam	Urban Systems
Shannon Foster	Urban Systems
Nathan Gregory	Dillon Consulting

Why am I here?

- Have new / pending projects in the Study Area (e.g., Guildford Town Centre Plan) and there is an opportunity to incorporate ISMP goals and recommendations in other projects
- Was involved in past projects in the watershed (e.g., Anniedale-Tynehead NCP, past drainage plans)
- To provide perspectives from my department
- To provide my knowledge, experience of Upper Serpentine watershed and/or ISMPs
- To offer a diverse approach to the workshop
- To learn something new
- To learn drainage criteria
- Teamwork

Why do I think others are here?

- *Transportation*: drainage is an integral part of roads, design with environment and drainage in mind; plan better road network

- *Planning*: tie in OCP update, development permit guidelines for flood plains, hazard guidelines; gain better understanding of drainage issues to assist in processing development applications; provide insight from a different perspective; to better integrate planning with stormwater management
- *Parks*: to offer a diverse approach to the workshop; riparian areas are often included in dedicated parks / open space; drainage issues in parks space
- *Engineering*: drainage for on-site development, provide technical / historical knowledge of watershed

What decisions need to be made today?

1. Who is involved in an ISMP
2. What are the top themes for this ISMP to focus on

2. What is an ISMP?

Questions to group:

1. What do you think an ISMP is?
    - Both high level and detailed
    - Includes environment and habitat, land use, physical development
    - Watershed based – managing stormwater; pipes plus other considerations
    - Short and long term time horizons
    - Financial component
2. What do you think it is intended to do?
    - Guides 10 year capital plan
    - Guides park design and planning
    - Proactive
    - Reflect community acceptance – implementation
    - Useful tool
3. Who does it influence / impact?
    - Developers
    - Community
    - Business
    - Streamkeepers
    - Farmers
    - Wildlife / fish / vegetation

3. Watershed Overview

Parks

<u>Opportunities</u>

- Bear sighting in Tynehead Park, possibly migrating from north along Hjorth and Cattle Creek corridors
- Bobcat siting near 160th and Hwy 1 (north side)
- Cougar siting between Fraser River and CN tracks; potential to migrate along Cattle Creek to Tynehead Park?

- Integrate with BCS study
- Anniedale-Tynehead NCP is adopted but there's still opportunity for ISMP to influence area as development horizon is long term

Constraints

- Little opportunities for park space in Guildford Town Centre area

Planning

Opportunities

- High density with rapid transit along Fraser Hwy between 152 street and 164 street; also along 152 Street between Fraser Hwy and 104 Ave; also along 104 Ave between 140 street and 152 Street; higher densities within 800 metres of rapid transit corridors
- Higher density in area bounded by 150 St, 100 Ave, 154 St and Guildford Dr
- New shopping centre on northeast corner of 104 Ave and 156 Street
- Buffer zone between Anniedale NCP and ALR lands
- Possible increase in density near Hwy 1 and 176 St (Hwy 15) for industrial / mixed use employment

Constraints

- Missed opportunity during Guildford Town Centre mall redevelopment
- Don't want to compete with City Centre – desire to develop and densify that area first

Transportation

Opportunities

- Future rapid transit corridors – Fraser Hwy, 152 Street, 104 Avenue
- 160 Street road widening between 96 Ave and 104 St (to 4 lanes)
- Intersection improvements planning for 168 St and 96 Ave

Financial

Opportunities

- Drainage parcel tax (could develop as a more detailed stormwater utility and relate the charge to impervious area)

Constraints

- Current parcel tax structure charges same amount to all types of development regardless of stormwater runoff contribution (i.e., Guildford Town Centre pays the same amount as a condo)

Environment

Opportunities

- Gas ROW between 95 Ave and 95A Ave, runs from 148 Street (Green Timbers Park) to 184 St – possible migration enhancements?

- Partnership with Fraser Heights Secondary School (160 St / 108 Ave) for improvements to Hjorth Creek (see Feb 6th email from Liana Ayach)

Constraints

- Fish access barriers – Hjorth at 102 (Urban and Dillon currently designing a culvert upgrade here to address); Hjorth at 104th; Serpentine at 156 St and at outlet to Guildford Pond
- Gravel recruitment program may need to be ramped up – hatchery staff said creek eroded down to hard pan near 160 St

Drainage

Opportunities

- Poor drainage in older area bounded by 146 St, 104 Ave, 150 St and 101 Ave – opportunity to retrofit?
- Previous pond issues (2 ponds) in greenbelt, north of 96B Ave between 154 and 156 St; these have been fixed
- “ugly pond” on 157A Street just north of 108 Ave
- Sediment trap at 88 Avenue
- Detention needed in upper reaches near 156 St and 105A Ave

Constraints

- Encroachment on creek held within private ownership on Serpentine Creek between 155 St and 156 Street, immediately south of 103A Ave (downstream of existing pond)
- Contamination issues at following locations: SE corner of 150 St / 104 Ave; SW corner of 152St / 104 Ave; NW corner of 152 St / 105 Ave; NW and NE corners of 96 Ave and 168 St
- Beaver issues at pond at 104 Ave and Fraserglen Drive (just north of Hwy 1)
- Erosion issues on Hjorth Creek at 102 Ave (fixed as part of culvert replacement - TBC)
- Pipe capacity constraints for future development at area north of 96 Ave between 160A and 162A St
- Flooding issues along 173A Street between 92 and 96 Ave during January storm event (25 year return period)
- Serpentine is not diked north of 92 Ave
- Past drainage issues on 164 St between 84 and 87 Ave (resolved?)

4. Key Items to Address

Highlighted text below indicates the key issues to address in the ISMP based on ranking from City staff

Public Education

- Provide public education / information opportunities; focus on water quality / stormwater pollution reduction

Process

- Plan for long term horizon (provide comprehensive rationale for what could be done over time)

Implementation

- Integration with other City policies (e.g., development permit guidelines for hazardous areas, floodplain development bylaw)
- Specific recommendations for development applications
- Need more stringent construction guidelines for ESC and WQ
- Need to establish plans for annual O&M costs

Finances

- Parcel tax for storm not reflective of actual stormwater contribution from various land use types

Environment

- Consider impacts on salmon and hatchery (silt buildup in low / med storm events covers spawning gravel)
- Emphasis on protecting and enhancing Tynehead Park and hatchery
- Improve / create access for fish from 156 St to the Guildford Pond; take advantage of habitat provided by pond
- Replace culverts / install weirs for backfill at select sites to improve fish access
- Continue with gravel recruitment implementation ; potentially ramp up to provide required volume (little natural gravel in creek upstream of Tynehead Park)
- Explore possibilities of creating terrestrial habitat corridors to link Tynehead to large contiguous area of habitat north of Hwy 1
- Integrate Biodiversity Conservation Strategy (BCS) and Ecosystem Management Study (EMS) into ISMP
- Better defined riparian areas that are based on more factors than RAR; link to drainage needs not just fish value (why else are setbacks needed)

Planning

- Develop a “theme” for the GTC area that reflects natural environment and importance of good stormwater quality / quantity control to protect the Upper Serpentine
- Opportunity to revisit Anniedale NCP if needed to bring in line with ISMP policy since the development timeframe is longer (e.g., limit future impervious area)
- Acquire property where / if required, particularly in urbanized areas so riparian buffers can be established (include detention within these areas if possible)
- BMPs for new development; encourage above ground vs. underground solutions (e.g., swales)
- Encourage underground parking instead of surface parking to limit impervious surfaces
- Provide range of grey to green infrastructure solutions for GTC area (e.g., detention required in GTC area to protect habitat quality particularly downstream of 160th St)

Drainage

- Optimize existing stormwater features as part of redevelopment
- Consider climate change (specific reference to increasing intensity and frequency of heavy rain events)
- Groundwater recharge for base flows in summer
- Treat urban runoff to maintain quality
- Mitigate peak flows
- Potential sources of water quality / quantity sinks: auto mall, 156 St underpass , Hwy 1 widening

Transportation

- Opportunity to daylight road crossings (from culvert to bridge)

Parks and Green Space

- Incorporate stormwater management with active and passive park space / public space (including trails, buffers)
- Plant more trees everywhere; focus on species with wide canopies
- Better integrate Tynehead park with surrounding park space
- Make detention areas that also serve as amenity areas

5. Potential Barriers to Success

- Political climate
- Property / land value
- Long term operation and maintenance requirements
- Solid rationale for flow targets
- Surface oriented BMPs in public ROW – City needs to lead by example

6. Decisions:

1. Who is involved in an ISMP:
    - Generally agreed the right people are in the room
    - Transit, developer perspectives missing
    - Potential future workshop with DAC or UDI to gain better understanding of developer perspectives
    - Invite City staff dealing with transit to next workshop (David to debrief Workshop #1 results in advance with this folks)

2. What are the top themes for this ISMP to focus on:
    - Develop solid, scientific rationale for riparian setbacks based on other considerations beyond just fish (per RAR)
    - Provide a range of grey to green infrastructure requirements to address future development in Guildford Town Centre area and use as input to planning process
    - Consider climate change implications when assessing various servicing scenarios
    - Provide recommendations for improvements to City's drainage parcel tax that better reflect development usage of drainage systems (including creeks)

Upper Serpentine Integrated Stormwater Management Plan (ISMP)

Workshop # 2 – Vision and Objectives (May 26, 2014; City Municipal Hall)

Workshop Notes

Attendees

Name	Department
David Hislop	Engineering (Utilities – Sewer, Water & Drainage)
Carrie Baron	Engineering (Utilities – Sewer, Water & Drainage)
Jeannie Lee	Engineering (Utilities – Sewer, Water & Drainage)
Stephen Godwin	Engineering (Environment)
Liana Ayach	Engineering (Environment)
Harvinder Bains	Engineering (Land Development)
Rick Bull	Engineering (Land Development)
Carla Stewart	Planning and Development (Policy & Long Range Planning)
Markus Kischnick	Planning and Development (Policy & Long Range Planning)
Randall Epp	Planning and Development
Dave Orsetti	Planning and Development
Leita Martin	Planning and Development (Development Application Processing)
Mary Beth Rondeau	Planning and Development
Chris Atkins	Planning and Development
Doug Merry	Parks, Recreation and Culture (Planning, Research & Design)
Steve Whitton	Parks, Recreation and Culture (Trees and Landscape)
Erin Desautels	City Manager's Office (Sustainability Office)
Kent Waugh	Marketing and Communications
Samantha Ward	Urban Systems
Jody Rechenmacher	Urban Systems
Jeff Rice	Urban Systems
Nathan Gregory	Dillon Consulting

Visual Explorer Desk Results

Past / Current State of the Watershed

- Competing interests
- Benign impact (possibly)
- Clinical approach
- Engineering focused
- Scorched earth
- Leaving nothing for the future
- Reckless
- Sterile
- Consistency / repetition
- Thoughtless

- Lacks nourishment
- Singular (one size fits all)
- Impacted habitat but it’s trying to re-establish under different conditions
- Agriculture, mitigation of impact, old, update and change
- People trying to achieve goal of what watershed should be
- Agricultural base, developed, separates us from other local governments
- All about water; channelized agricultural, paved areas, no thought given to bigger picture
- Balance between developed and undeveloped areas (short term and long term; monetary vs non-monetary)
- Near tipping point
- Fragile

<u>Ideal Future of the Watershed</u>

- Look at big picture
- Solution for all (connectivity)
- Natural structure
- Natural space for things other than humans
- Incorporate environment into decisions first
- Nurturing
- Nourishing
- Caring for the future
- Future can be wild, unpredictable
- Be in sync with unpredictability
- Cooperation
- Controlled chaos
- Diverse healthy ecosystem
- Aim high but be cautious
- Appreciation of community; working together / cooperation
- Community is happy; embrace problems; need all aspects, do it for the community
- Bugs, bunnies and fish
- Teamwork
- Functionality
- Aesthetics
- Natural systems
- Political motivation (local / provincial)
- Money
- “take” only what we need
- Balance with future nature needs
- Resilient to change vs. sustaining today’s status quo

What is the Potential of this ISMP to enhance the environment in this area? (Desired Outcomes)

Zone 1A

- This zone / area has highest density (potential) in upper watershed; potential to use this density to benefit environment
- ISMP can help development proactively implement measures to improve downstream conditions (permeability, effective detention measures)
- Headwaters; setting conditions for success downstream
- Mitigation for past damages / conditions
- Opportunity for interim measures to address slow pace of redevelopment (incremental change leads to improvements)
- Redevelopment allows opportunity to "try new things"
- Use ISMP to reduce imperviousness of Zone; what actions can we take to ensure unavoidable redevelopment improves permeability
- Identify areas most suitable for infiltration; get specific
- Identify incentives to achieve goals
- Use ISMP to enhance / expand terrestrial and aquatic habitat / corridors; holistic approach, beyond stormwater
- Leverage resources / funds to achieve multiple objectives; (e.g., use capital funding priorities to achieve more than one goal); triple bottom line
- Ensure diverse parties / stakeholders at the table
- Increase awareness regarding the lifespan of these systems
- Understand long term costs
- Design management systems that are more cost-effective long term (natural systems)
- Educate individuals on their own (small –scale impacts)

Zone 1B

- Currently the greenest NCP; follow this during development (consistency); ISMP should align / strengthen this
- Effective riparian zone
- Create and enforce a strong riparian area bylaw
- Biodiversity Conservation Strategy; stand by core values of NCP
- Bring water quality to the forefront; enforce a water quality standard
- Be aware of downstream users
- Adaptive management framework; regional approach; monitor 1B more closely as development progresses
- Minimize private property paving
- Biggest goal for this area is to maintain current situation
- Front load green infrastructure costs

Zone 2

- Attenuate current erosive flows; more effective detention or other measures in zone 1A
- Vertical densification (zone 1A)
- Wetland creation in park
- Public education re human / development effects on water quality and quantity; connection between private property (lot) and watercourse
- Financial incentives to protect / retain habitat on private property
- Partnership with Metro Vancouver
- Maintain current function of park without increasing impervious area and infrastructure
- Enhance habitat; self-sustaining fish / salmon population; make the hatchery redundant (goal)
- Go into the schools to educate the next generation
- Political will to keep drainage in a state such that the environment thrives
- Detention areas also environmental features
- Instream enhancement (gravel, barriers, instream complexity)

Zone 3

- Purchase agricultural land to retain / preserve forested areas
- Upland detention / stormwater management to maintain summer baseflows / irrigation
- Increase awareness of optimal agricultural use (crops, irrigation, fertilizer, etc.)
- Serpentine River flow augmentation with Fraser River connection (Golder study)
- Reforestation (protection) of riparian areas (river, ditches, etc.)
- Encourage increase in ALR land for agricultural / floodplain properties

Should the ISMP strive to maintain or enhance current watershed conditions?

- Aim to enhance (we have to)
- Focus on where there are opportunities
- Learn more
- Results based (water quality)
- Benchmarks exist
- Tie in other long term planning actions
- Implementation timeline – 30 years
- Use interim measures on an area-by-area basis

Opportunities / Themes

- Anniedale area a “blank slate”
- Riparian area bylaw upcoming
- Education
    - what could we do?
    - Residents / council as champions
    - Bigger role for communication

- "transportation school" model – invite naysayers to workshop for education and awareness
  - Understanding language
  - Ongoing, sustained campaign
- Share data from monitoring
- Generate will and commitment
- Opportunities mainly outside of Zone 2
- Whole system – changes in uplands impact lowlands
- Success defined as a whole (connect zones)
- Partnerships – initiate – info transfer over time
- Protect what is there, don't get complacent
- Ways of building awareness beyond project (internal and beyond)
- Maintenance and follow up included in City budget
- Zone 1B
  - Water quality – dovetail with NCP
  - Green infrastructure front ended (like traditional infrastructure is now)
  - Monitoring and adaptive management
- Zone 1A
  - Mitigation of past mistakes
  - Interim measures given long-term redevelopment timeline
  - Small scale outreach / education programs
- Zone 2
  - Partnerships (e.g., Metro Van)
  - Financial incentives for private works
  - Goal to make fish hatchery redundant
- Zone 3
  - Land use change here – from forest to crop production
  - Land purchasing to preserve forested areas
- All – riparian areas bylaw, environmental and hazard Area DPs

Vision statements

- Balance, resilient, benefit, flexible, adaptable / adaptive, realistic
- Accommodate redevelopment? Reconcile it with other values?
- Use redevelopment (opportunity to create balance, resiliency); symbiotic relationship
- Adapt (re)development to benefit environment
- Use communication
- Awareness, engage stakeholders
- Enhance environmental ecosystems and community benefits
- Connections; integrate uplands / lowlands, existing / future
- Innovation

- Nature matters
- Money matters

"The City of Surrey will use (re)development to create opportunities to enhance suppleness and bounciness (re: the ductile nature of…) in order to benefit our natural environment and stormwater drainage in a wild and unpredictable future"

" A healthy and diverse watershed stewarded and supported by an engaged community"

"to create a resilient / realistic / adaptive plan to maximize awareness and engagement of stakeholders to enhance environmental and community benefits"

" the City will provide a viable community for all living things"

WORKSHOP SUMMARY

URBAN systems

Subject:	Upper Serpentine ISMP – Workshop #3
Meeting Date:	November 19, 2014
Report Date:	November 25, 2014
Meeting Location:	City Hall 2E Meeting Room 30.08
Time:	9:00am – 12:00pm
File:	1072.0211.01

Participants

David Hislop, Engineering (Utilities – Sewer, Water & Drainage)
Jeannie Lee, Engineering (Utilities – Sewer, Water & Drainage)
Jeff Pang, Engineering (Roads & Traffic Operations)
Harvinder Bains, Engineering (Land Development)
Richard Bull, Land Development
Steve Whitton, Trees / Landscape Manager
Samantha Ward, Engineering
Markus Kischnick, Planning and Development (Policy & Long Range Planning)
Leita Martin, Planning and Development (Development Application Processing)
Doug Merry Parks, Recreation and Culture (Planning, Research & Design)
Andrea Smeenk, Finance & Technology (Financial Reporting)
Erin Desautels, City Manager's Office (Sustainability Office)
Christopher Atkins, Planning and Development
Glen Shkurhan, Urban Systems
Jeff Rice, Urban Systems
Jody Rechenmacher, Urban Systems
Nathan Gregory, Dillon Consulting

Workshop Objectives

- Communicate results of watershed modelling (current and future conditions)
- Prioritize goals and actions to achieve goals
- Identify preliminary implementation plan for prioritized actions

Summary of Key Outcomes from Workshop #3 and Next Steps

1. More aggressive BMP recommendations (amount of topsoil and stormwater contained onsite) will be evaluated in the watershed model and included in the ISMP report
2. There is a current opportunity for the City to lead by example through incorporating the ISMP recommendations into the roads 10 year capital plan. This can be done now.
3. A Task Force will be assembled to oversee next steps of ISMP implementation. Task Force representation includes:
    a. Drainage
    b. Planning
    c. Land Development
    d. Buildings
4. The Task Force will develop a one page summary of the ISMP and plan for how to communicate the summary and recommendations of the ISMP to relevant internal departments and to council
    - Enforcement is the key issue; the Task Force should consider a recommendation to council that includes funding for enforcement

Workshop Agenda & Overview

This is a summary of the workshop proceedings. Further details and results from each section are included below.

ITEM

1. **Opening and workshop overview**
   David Hislop and Jody Rechenmacher opened the workshop. Opening included a review of ISMP project process, outcome of workshop #2, the vision for the ISMP and the draft goals.

2. **Presentation of analytical results - existing and future conditions in the watershed**
   Jeff Rice presented an overview of the watershed modelling results. The key message was that *"Extensive urban development in the Upper Serpentine Watershed has placed great stress on the Serpentine River and its tributaries, though they retain the potential to be environmental treasures for Surrey. Into the future, further stream degradation could occur if development occurs unrestrained. But actions initiated now, as a part of this integrated stormwater management plan, can chart a path that will make the Serpentine River the treasure it deserves to be."*

3. **Reviewing and Ranking Options and Opportunities**
   In small groups, participants reviewed a list of draft goals and potential actions to achieve these goals. Groups identified which goals should be high priority to focus on.

4. **Planning for Implementation of Actions**
   Each small group discussed what would be needed to achieve the high priority goals.

5. **Implementation of the ISMP**
   The full group discussed next steps.

6. **Close**

A Vision for the Upper Serpentine Integrated Stormwater Management Plan

In 30 years, the Upper Serpentine Watershed will be the Lower Mainland's leading example of how to capitalize on growth to significantly improve a watershed's health. Biodiversity, fish and aquatic communities, and other ecological resources are self-sustaining due to the high integrity and interconnectivity of riparian habitat, creeks, parks, landscape buffers and natural areas that connect to the broader ecological network, supported by enhanced water quality in the creeks.

Protection of the Upper Serpentine and the natural environment are the community's central themes, and are the basis of all land use planning in the watershed. Development is supported by innovative, green and cost effective servicing approaches that promote naturalized systems, reduce stresses on receiving systems, have the flexibility to adapt to changing climate conditions, and align with the aesthetic ideals expressed by the community.

This successful model of community growth and environmental protection has been achieved as a result of the City's leadership, supported by the strong stewardship ethic of an engaged community, strategic partnerships and alliances with various groups and levels of government.

Presentation of Analytical Results

Preliminary results indicate that basic (minimum) stormwater management requirements to maintain servicing and watercourse conditions are:

- Capture and retain 50% of mean annual rainfall (35mm in 24 hours)
- Apply to all new development (incl in-fill & redevelopment sites):
  - 300mm amended growing media ("topsoil") or absorbent landscaping
  - Disconnected roof leaders in SF residential areas (continue with current practice)
  - Capture and retain 350 m^3 rainwater per hectare impervious area in commercial/industrial/MF residential areas
- Specific BMPs up to developers

ISMP Goals

The following overall goals were proposed for the ISMP based on results from Workshop #2:

1. Improve watershed health, in the both the short and long term.
2. Incorporate best management practices, specifically green infrastructure, into future development plans.
3. Incorporate green infrastructure into available open areas in utility and transportation corridors (ROW).
4. Build resiliency into stormwater infrastructure to address future fluctuations in local climatic conditions (climate change).

5. Enhance aquatic habitat within the watershed's many watercourses, including enhancing aquatic species access to that habitat.
6. Conserve existing high quality riparian areas, while improving and expanding other riparian areas.
7. Foster public support of watershed protection and enhancement.
8. Support a "watershed-focused ethos" within and among City staff.

The goals identified by groups at Workshop #3 to be a high priority (biggest impact in achieving the vision for relative level of effort) are:

Goal 1: Improve watershed health, in the short and long term. The emphasis of this goal is on the short term; making improvements at a faster rate than waiting for development to occur.
Goal 2: Incorporate minimum best management practices, specifically green infrastructure, into future development plans. (Note: A strong desire was expressed to push to *exceed* the minimum requirements, for example, with a "400 and 400" option – 400 mm of absorbent landscaping and 400 m3 of storage per impervious hectare of development)
Goal 3: Incorporate green infrastructure into available open areas in utility and transportation corridors.
Goal 6: Conserve existing high quality riparian areas, while improving and expanding other riparian areas.

Implementation of Goals

Participants at Workshop #3 discussed and identified some key actions which will support achieving the goals. These are outlined below.

Goal 1
Key Actions – Roof leader disconnection
- estimated 2% reduction in flows to creeks
- What are the intermediate steps?
  - Education, information provided with utility bills
  - 5 year program of education and phasing
  - Lead up to bylaw enforcement
- Opportunity to work with others internally who are providing information to residents
- Drainage and Environment to work with Planning to implement
- Program is low cost relative to other programs
- The stormwater bylaw already provides regulatory framework
- Need to identify where properties can be disconnected; not all can be disconnected due to insufficient land area available
- Building Department need to be proactive with inspections
- Can measure success by measuring the percentage of reduction in connected roof leaders

Goal 2
Key Action – Zoning bylaw changes for impervious surface (single family dwellings)

- Review zoning bylaw (impervious surface)
- Require enforcement and monitoring
- Need inspection resources – what are best practices in inspection of impervious area?
- Need the political will to implement
- Partnerships with Development Advisory Committee, Builders Groups, residents

- Estimated up to four new staff needed for enforcement

Goal 3
Key Action – Implement BMPs in all transportation corridors

- 17% of the watershed is road ROWs, significant opportunity
- Street sweeping and vacuuming to remove pollutants
- Increase maintenance of catch basins
- Include a standard cross section of a green road in engineering design manual
- Land already belongs to the City, represents an opportunity
- Partnerships needed between Parks and Engineering (the operations and planning sides)
- Operations is more critical than capital for this initiative
- Partnerships with Translink and the Tynehead Hatchery
- Leverage boulevard planting beautification grants
- Leverage adopt a street programs
- Focus education on fronting properties
- Education (internal and external) on gravel boulevard parking

Goal 6
Key Action – Enhance riparian areas along Upper Serpentine watercourses
What is the potential?

- Create linkages with other habitat
- Improve local habitat
- Increase biodiversity
- Increased benefits for flood control and water quality

2. Intermediate steps and timelines.

- Identify high priority creeks and determine setbacks
- Confirm that the NCP conforms
- Determine cost and level of effort required for implementation of corrective measures
- Develop policy to increase setback over the minimum standard above the Riparian Areas Regulation (RAR). There was some discussion after we presented where apparently this bylaw is set to come in as it is going to council soon.
- Education (both council and the public)

3. What resources are required?

- People and skills
  - City Departments (Environmental, Engineering, Planning [as they relate to NCPs], Parks [land acquisition])
  - Consultants
- Money
  - Development Cost Charges (DCCs) for parks and drainage
  - Tax credit under DCCs
  - Acquire under NCP

- Land - likely a lot required. Riparian setback can be up to 30 m under the RAR but the City wants more for wildlife corridors (up to 100 m in the Biodiversity Conservation Strategy).
- Information - bylaws, pamphlets, existing habitat conditions, signage, outreach and education, City website
- Other - donated land

4. Partnerships and alliances

- Internal
    - There is generally good internal discussion already occurring.
    - School District
- Businesses
    - Developers - there was a comment they should be instructed as to what to do and helped achieve the goals.
    - Guildford Business Association
    - Guildford Town Centre
    - Engage business through Green Awards Program
- External special interest groups
    - Tynehead Hatchery (they also engage with DFO). Perhaps get them to engage other streamkeepers.
    - There's is someone named, we think, Deb Jackson, who is an engaged individual. The woman sitting at my table this morning said she would look into it.
    - Metro Vancouver
    - Fraser Heights Ratepayers Association. Not certain this is the name. Engage Rick to determine for sure.
    - Fraser Heights School
    - Public outreach
- Other
    - There may be provincial or federal funding available for habitat restoration programs.

5. Relevant regulatory frameworks

- Riparian Areas Regulation (Surrey standard is greater). As mentioned, a new bylaw will apparently being going before council soon and is expected to pass.
- Bylaw improvements and amendments
- Design criteria improvements
- Supplementary design drawings standards; new BMP standards
- Revamp the Building Division's mandate to assist with monitoring of implementation of BMPs. Related to this is to keep in mind that in some cases lots are too small for disconnected roof leaders so something else would have to be done.
- DCC bylaw credit
- Development Permit Areas

6. Existing process or programs

- SHaRP
- Confirm if the pre-SHaRP tree planting activities conducted by the City are still ongoing.

7. Determination of success

- Wider corridors
- Improved water quality*
- More fish and wildlife*
- Less erosion*
- Stable gravel*
- Presence of more rare species
- Complex habitat

* These items could also be achieved through means other than riparian improvements.

8. Who is responsible?

- Everyone but the City leads and should be seen to be leading.

Please contact Workshop Facilitator, Jody Rechenmacher, at Urban Systems with corrections, revisions or clarifications to these notes (jrechenmacher@urbansystems.ca).

APPENDIX C

ENVIRONMENTAL CONDITIONS REPORT

DILLON CONSULTING

Upper Serpentine Watershed Integrated Stormwater Management Plan

Existing Conditions Report

December 2014 – 14-8893

Table of Contents

Figures

Tables

1.0 INTRODUCTION AND BACKGROUND

This report provides a summary of existing habitat conditions supported within the Upper Serpentine River watershed (the Project Area) completed as part of the Upper Serpentine Integrated Stormwater Management Plan (ISMP). To determine the existing conditions, Dillon Consulting Limited (Dillon) completed a desktop review of existing background information and supplemented it with a field investigation to fill gaps identified during the literature review. The information obtained to determine the existing habitat conditions focused on the following components within the Project Area:

- Watercourse habitat value and classification;
- Fish presence potential and barriers to access;
- Riparian extent and condition;
- Benthic invertebrate composition;
- Wildlife corridors, hubs, and patches along with an inventory of possible species;
- Terrestrial habitat values of treed and wooded areas;
- Potential presence of rare species and ecosystems;
- Invasive species presence;
- Sensitive environmental areas;
- Biodiversity; and
- Potential water quality issues.

Please note that benthic invertebrate collection and water quality sampling were not components of the field program. As such, our commentary is limited to a discussion of the limited background information available.

This summary of existing habitat conditions supported within the watershed can be utilized as a baseline for comparisons to environmental conditions and ecological health as development proceeds or stormwater management practices are implemented. It also serves to identify areas of environmental sensitivity and importance in order to act as a tool to help direct future development in such a way as to sustain critical aquatic and terrestrial habitat.

The information obtained through the assessment of existing conditions has also been used to make a qualitative determination of overall watershed health, and may be used as a tool to identify enhancement opportunities and potential (for both aquatic and terrestrial species) as well as to outline future studies which can be implemented to track the overall efficacy of stormwater management implemented as part of the Upper Serpentine ISMP project.

The Upper Serpentine watershed supports a wide variety of aquatic and terrestrial habitats within its boundaries. The Project Area demonstrates high density development in the Guildford area where habitat values are quite limited, to the intact second growth forest of Tynehead Park where large mammals are known to be present at some times of the year. Large residential lots and agricultural properties are also characteristic of the Project Area. Aquatic habitat ranges from the spawning reaches of the Serpentine River and its tributaries to the impacted stream reaches in Guildford to linear agricultural ditches in the lowlands.

The study area for the Upper Serpentine ISMP was divided into three zones:

- Zone 1: Developed Uplands. This zone is divided into two sub-areas: 1A (Guildford) and 1B (Anniedale). Zone 1A consists of high and medium density residential areas located generally to the west of Tynehead Park and 164th Street. It also includes the area north of Highway 1 which is largely residential and consists mainly of single-family homes as well as commercial development along and near 152nd Street. Zone 1B consists of the area generally east of 168th Street between 92nd and 96th Avenues. This area is considered low-density, but the existing Neighbourhood Concept Plan calls for extensive development of this area in the future.

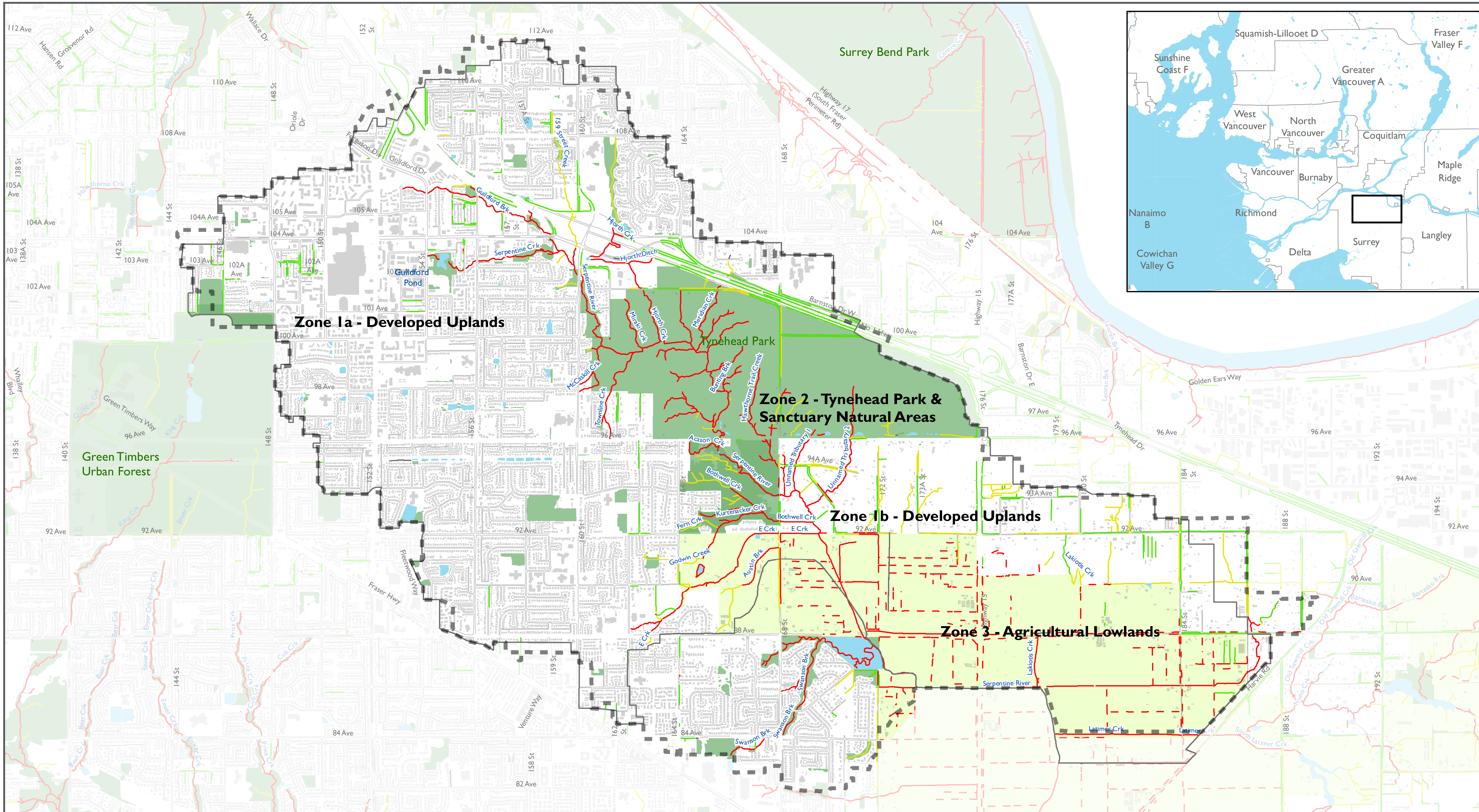
- Zone 2: Tynehead Park & Sanctuary Natural Areas. The Tynehead Park & Sanctuary Natural Area is generally located north of 96th Avenue between Highway 1 and 160th Street. A portion of it extends south of 96th Avenue to the west of 168th Street. It is characterized by generally intact second growth forest and relatively undisturbed contiguous habitat. It is the most significant hub for wildlife in the area. The eastern portion of this zone may be open to undetermined development at Metro Vancouver's discretion.
- Zone 3: Agricultural Lowlands. The Agricultural Lowlands are located in the southeast portion of the Project Area and are generally bound by 164th Street to the west and 92nd Avenue to the north.

The Project Area is shown in Figure 1. The Project Area includes watercourses that provide a variety of different habitats, which are classified using the City of Surrey's watercourse classification system. Definitions for the four classification types are provided below.

- Class A (red-coded): Year-round salmonid presence or potential with access enhancement;
- Class A(O) (red-dashed): Overwintering salmonid habitat or potential with access enhancement. Water quality barriers generally restrict summer presence of salmonids;
- Class B (yellow-coded): No salmonid presence but a significant food/nutrient contribution to downstream reaches; and
- Class C (green-coded): No salmonid presence and an insignificant food/nutrient contribution to downstream reaches.

Class A watercourses provide habitat for salmonids at a variety of life stages. Spawning habitats are areas where there is sufficient gravel and clean flow to allow salmon and trout to lay eggs. Rearing habitat is generally lacking in sufficient gravel and/or has lower flow such that salmonids may reside there but cannot lay eggs. Migratory habitat is utilized by salmonids to pass to areas of better habitat in upstream reaches of a channel. Access for salmonids to upstream areas of some Class A channels can be restricted due to gradient or anthropogenic barriers. Class A(O) watercourses typically provide only rearing and migratory habitat for salmonids and are generally restricted to low-gradient linear ditches with limited complexity. Class A(O) watercourses are characteristic of agricultural areas. Class B channels are typically inaccessible to fish but have sufficient flow and riparian (streamside) vegetation cover to provide and convey food and nutrients to fish-occupied reaches. Class C channels generally lack the flow and/or riparian cover that provide food and nutrients.

The entire Project Area is located within the Coastal Western Hemlock (CWH) biogeoclimatic zone. The CWH is characterized by mild and wet winters with generally sunny and dry summers. Western hemlock is the dominant tree species in undisturbed areas and climax vegetation communities.



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Author: ECH
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0 250 500 750 1,000 m
Scale: 1:28,936
N

Coordinate System:
UTM Zone 10N Nad83

Data Sources:
City of Surrey Open Data, ESRI Base Layers, Dillon Consulting Limited, Urban System

Legend

Watercourse Classification
- A
- A(O)
- B
- C
- Upper Serpentine Watershed
- Watershed Zones
- Waterbodies
- Parks and Natural Areas
- Agricultural Land Reserve
- Building Footprints

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Upper Serpentine Integrated Stormwater Management Plan

Figure 1 - Study Area and Watercourse Classification

2.0 METHODOLOGY

2.1 Background Review

Background information on the Upper Serpentine watershed was provided to Dillon by Urban Systems Limited and the City of Surrey. Existing online information was also assessed during the background review. Dillon also utilized information gathered from site assessments and instream maintenance completed within the watershed for other projects during 2012 and 2013. Background information was reviewed and data on each watercourse and each segment of the Upper Serpentine main channel was compiled. Gaps in information for each watercourse were identified and these areas were targeted during site assessments. Large contiguous blocks of intact vegetation were also targeted for assessment.

Water quality data was available from several of the background materials provided, as well as from the Tynehead Hatchery. Water quality data from the Tynehead Hatchery was compared to BC Water Quality and Canadian Council of the Ministers of the Environment standards for the protection of aquatic life, and was analysed for high-level temporal trends.

Benthic invertebrate data in the background information was very limited.

A full list of references is found in Section 5.0.

2.2 Site Assessments

Site assessments were completed by Dillon staff for all named watercourses and surrounding terrestrial areas on January 23 and 24, 2014. Swanson Brook was later added to the Project Area. It was assessed on May 20, 2014. The following data was collected during the site assessments:

- Stream characteristics (wet and bankfull width and depth, grade, substrate composition, habitat suitability and instream complexity);
- Riparian corridor characteristics (riparian width and health, vegetation species, extent of riparian cover and overhanging vegetation, invasive species);
- Terrestrial habitat composition (structure and composition, invasive presence);
- Wildlife potential (species observed, habitat potential, corridors and connectivity);
- Water Quality (visual observations only); and
- Areas for improvement (erosion sites, fish barriers).

3.0 RESULTS

As referenced, the Upper Serpentine watershed can be divided into three zones based on land use: the Developed Uplands (subdivided into Zones 1A and 1B), Tynehead Park and surrounding natural areas (Zone 2), and the Agricultural Lowlands (Zone 3) as indicated in Figure 1. Each section of the watershed is discussed separately in the following sections.

3.1 Developed Uplands

The Developed Uplands areas consist of high and medium density residential areas in the Guildford area, located generally to the west of Tynehead Park and 164th Street (Zone 1A) and low density areas east of 168th Street between 92nd and 96th Avenues (Zone 1B). It also includes the area north of Highway 1 which is largely residential and consists mainly of single-family homes. A commercial area exists along 152nd Street and north of 100th Avenue. Storm sewers convey runoff into the several Class A and B watercourses and several Class C swales in Zone 1A. Drainage in Zone 1B consists of numerous Class B and C swales (instead of storm sewers), and two Class A watercourses.

3.1.1 Zone 1A

Aquatic habitat within this portion of the Developed Uplands is provided by the following named watercourses: Guildford Brook, Serpentine Creek, 159th Street Creek, Hjorth Creek and Swanson Brook. Two of these watercourses have significant areas identified as Class B (159th Street Creek, Hjorth Creek), while the rest are Class A. Storm sewers and Class C swales convey runoff from developed areas into the series of the watercourses in this portion of the watershed. A large detention facility, Guildford Pond, is located south of 103A Avenue and east of 154th Street.

Terrestrial habitat in this area is limited to small patches of forest (*e.g.*, northeast of 160th Street and 92nd Avenue), manicured urban parks and landscaped residential properties. The streams in this area have forested riparian zones that act as corridors for wildlife. Wildlife crossings underneath Highway 1 exist along both 159th Street Creek and Hjorth Creek, and may allow wildlife to travel between Surrey Bend Park along the Fraser River to the north, and Tynehead Park and the surrounding natural areas to the south (Zone 2, discussed in Section 3.2 below).

3.1.1.1 Aquatic Habitat

Guildford Brook and Serpentine Creek are similar Class A watercourses located northwest of Tynehead Park. They are each located within natural stream corridors in deep ravines with steep banks in a medium-density residential area. Both streams follow a fairly linear path, with small bends (not meanders), run and riffle morphology with some small pool areas. Some sloughing of the banks has occurred at a few areas along Serpentine Creek.

Historic fish observations in Guildford Brook include spawning Coho salmon and cutthroat trout (from 158th Street east to the Serpentine River; Dillon Consulting 2001). Other historic observations include Chinook, sockeye, rainbow trout (BC MoE 2014b), Coho fry, juvenile cutthroat and rainbow trout, adult cutthroat trout and coastrange sculpin in both watercourses (Dillon Consulting, 2001; BC MoE 2014b). Please note that Chinook and sockeye salmon observations are historic only, and it is likely that these species are no longer present in Guildford Brook. Both watercourses are largely suitable for salmonid rearing, with few potential sites for spawning (Dillon Consulting 2001). Substrate in both channels consists mainly of sand, gravel, cobbles and boulders but the channel bottoms are scoured in some areas, leaving only hardpan clay substrate (Donahue 2012). The Upper Serpentine Gravel Recruitment study, completed by Dillon in 2012, identified that severe erosive forces were at work in both watercourses and that they contained inadequate gravel (0.2 m depth required at a minimum) for spawning of identified salmonid species (trout and Coho) in some locations. Erosive flows are largely the result of limited detention in developed areas upstream of these watercourses. Based on the findings of the Upper Serpentine Gravel Recruitment Study, 2m^3 of gravel was deposited at each of four locations along Guildford Brook between August 19 and 23, 2013 as follows:

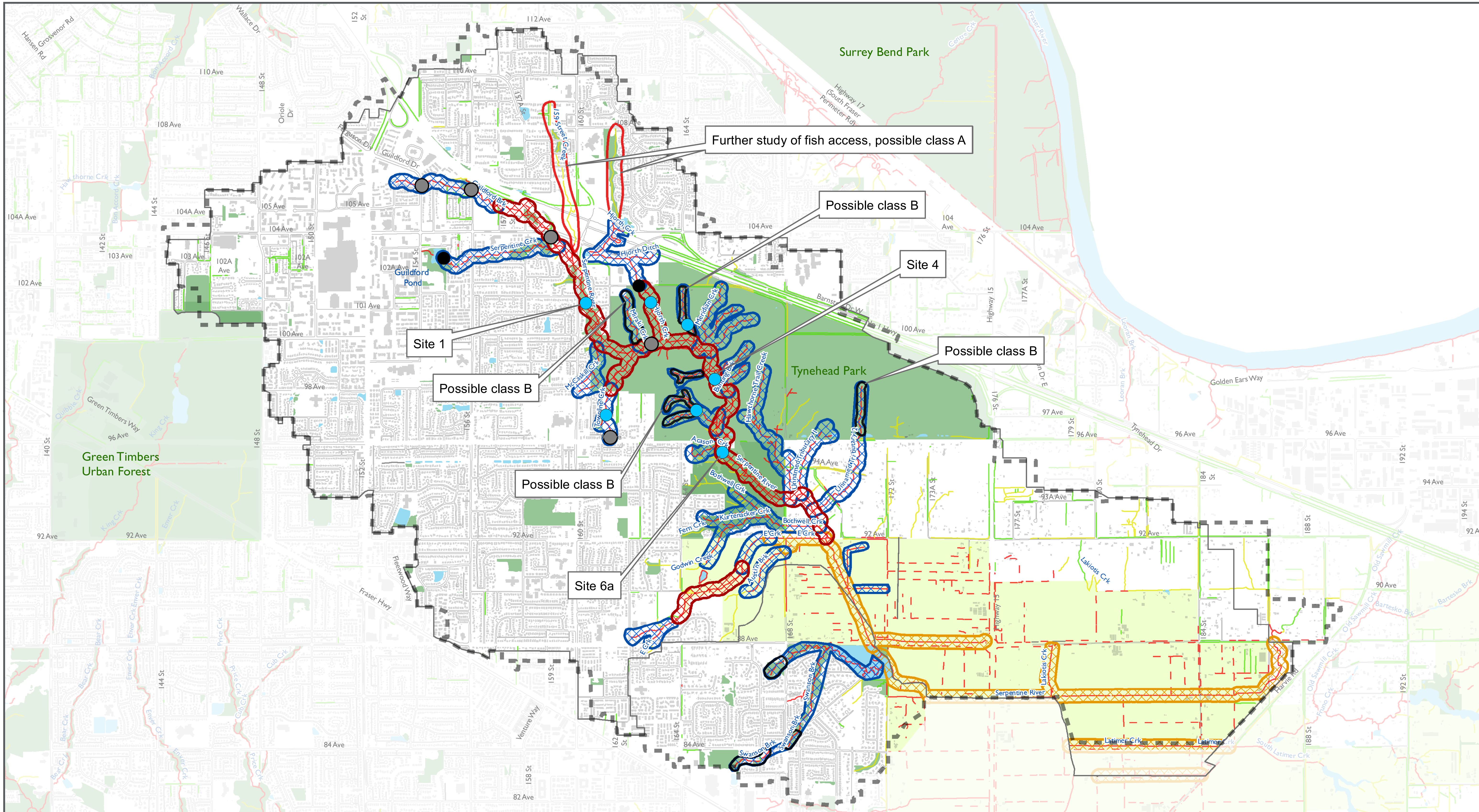
- At two locations on the north side of Guildford Brook at Guildford Drive and 154A Street;
- On Guildford Brook west of 156th Street, just south of Highway 1; and
- On the west side of Guildford Brook at 104th Avenue and 158B Street (Donahue 2012).

These locations are indicated on Figure 2. Some additional placement at two of these locations was conducted in 2014. An assessment of the results of the placement has not yet been completed.

A potential fish barrier exists at the upstream end of Serpentine Creek at the culvert under 156th Street, where debris accumulation has presented a barrier to fish in the past (Dillon Consulting 2001).

There were no visual indicators of poor water quality in either watercourse during the site assessments.

Guildford Pond is a constructed stormwater detention pond, built in 2000, at the upstream end of Serpentine Creek, located within a park in a medium density residential area. It was designed to have an operating depth of 1.5m, with wetland areas at the inlets and outlet (Stantec 2000). The pond is designed to provide some initial first flush treatment opportunities for runoff from the upstream commercial district (Stantec 2000). The substrate in the pond consists largely of silt, clay and organics. A weir approximately 0.4 m in height is present at the outlet of the pond that likely acts as a barrier to fish passage except during very high flows. However, it should be noted that the main purpose of the pond is for detention and not fish habitat. There have been no known fish observations within the pond since its construction but the BC MoE Habitat Wizard indicates historic observations of cutthroat trout and Coho salmon in Serpentine Creek west of 156th Street (in what is presently Guildford Pond – no date given; BC MoE 2014b). It should be noted that a culvert in this vicinity may pose a barrier to fish migrating upstream (west) of 156th Street. The pond has the potential to provide habitat for rearing of various species if made accessible but is unlikely to have potential as a salmon spawning area due to the silty substrate and limited flow. Water temperatures in the pond are likely high during the summer months due to the lack of vegetative cover. There is some reed canary grass, rushes and cattail within the pond. The riparian area is generally healthy but does not provide much shade or cover.



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0 250 500 750 1,000 m
Scale: 1:28,000
N

Coordinate System:
UTM Zone 10N Nad83

Data Sources:
City of Surrey Open Data, ESRI Base Layers, Dillon Consulting Limited, Urban System

Gravel Deployment
Fish Barriers
Historic Benthic Sampling (1985[4])

Habitat Utilization Potential for Salmonids
Migratory Only
Rearing Only
Spawning and Rearing

Possible Watercourse Reclassification
Possible Class B (Further Study)
Possible Class A (Further Study)
Upper Serpentine Watershed

Watercourse Classification
A
A(O)
B
C

Waterbodies
Parks and Natural Areas
Agricultural Land Reserve

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Upper Serpentine
Integrated Stormwater Management Plan
Figure 2 -
Fish Habitat Suitability

G:\GIS\148893 Upper Serpentine ISMP\Figure 2 - Fish Habitat Suitability.mxd Last updated by 42ECH on Friday, December 19, 2014 at 10:14:54 AM

Guildford Brook and Serpentine Creek converge and form the Serpentine River at the approximate159A Street and 103A Avenue rights-of-way. The character of this section of the river is similar to the tributaries upstream. The river is within a natural stream corridor with steep banks, small bends (not meanders) and run/riffle/pool morphology (Web Engineering 2011). The substrate in this area consists of sand, gravel and cobbles. A stormwater structure drains the Highway 1 area to the north and discharges to the river at the confluence, which often leads to rapid increases in stream flow during storm events (Web Engineering 2011). There are several sites near 160th Street where trees have collapsed or large debris in the stream have altered the flow and caused erosion of the banks. Historic fish observations in this area include spawning Coho and chum salmon and cutthroat trout, adult sockeye and Chinook salmon, Coho fry, juvenile rainbow trout, and coastrange sculpin (Backman and Simonson 1985; Dillon Consulting 2001; BC MoE 2014b). Please note that sockeye salmon observations are historic only, and it is likely that sockeye are no longer present in the Serpentine River.

Hjorth and 159th Street Creeks originate north of Highway 1 and flow south where they join the Serpentine River in Tynehead Park. Both stream corridors are natural but narrow and heavily impacted by the surrounding development and follow relatively sinuous paths through flat, wide floodplains. Both streams are classified as Class B north (upstream) of Highway 1 and Class A south of it. Recent upgrades to the culverts under Highway 1 may allow a future upgrade to Class A habitat (see Figure 2); however further study is warranted to confirm this. Hjorth Creek and the 159th Street Creek are similar in character north of Highway 1 where the stream channels are exposed and open and their courses have been modified as part of the Highway 1 improvements. Both watercourses have sand, cobble and gravel substrate, and run/riffle/pool morphology. Historic fish presence in Hjorth Creek includes juvenile Coho salmon as well as chum salmon. Coho salmon and cutthroat and rainbow trout have been observed historically in the 159th Street Creek (Dillon Consulting 2001; BC MoE 2014b). Within Tynehead Park (Zone 2), Hjorth Creek provides good rearing habitat for salmonids, and may provide spawning habitat in some areas (Dillon Consulting 2001). This section of the stream has overhanging riparian vegetation and water quality was clear based on visual observations at the time of assessment. It should be noted that a fish ladder was installed at 102nd Avenue in the summer of 2014 to facilitate access at least to Highway 1.

Swanson Brook is a small watercourse with Class A and Class B sections that flows northeast from 168th Street and 84th Avenue, and then meanders along the south side of 88th Avenue before discharging to the Serpentine River near a sediment sump just south of 88th Avenue. Substrate consists mainly of silt with a small amount of gravel. Some downstream areas are suitable for rearing of salmonids, but flow and depth are likely limiting in upstream areas, as the stream becomes intermittent and is likely ephemeral in these areas. Historic fish observations include Coho salmon (1995), cutthroat (1995) and rainbow trout (2000), sculpin, threespine stickleback, western brook lamprey, redside shiner and carp (BC MoE 2014b). It is likely that the channel only supports salmonids during the wetter periods of the year, and is more suitable for coarse fish in accessible areas year-round. The stream has forested riparian zones with a mixture of native and invasive species. There were no visual indications of poor water quality where flow was present in downstream areas during site assessments. Upstream areas contained little flow and iron precipitate was observed in the channel at several locations. Garbage was observed in the stream and riparian areas near 168th Street south of 87th Avenue, and may be partially blocking culverts at some locations. The invert of the channel where it outlets to the Serpentine River is significantly higher than the river during certain times of the year and may be an obstacle to fish access.

3.1.1.2 Terrestrial Habitat

Terrestrial habitat in Zone 1A is limited to small patches of forested areas (*e.g.*, northeast of 160th Street and 92nd Avenue), riparian corridors, manicured urban parks in the western portion of the zone, and landscaped residential properties. Given the level of development, terrestrial habitat value has been severely compromised and wildlife utilization is expected to be limited to urban generalist species. Wildlife corridors are limited to the riparian zones of named creeks as well as a BC Hydro right-of-way paralleling 96th Avenue to the south. The streams northwest of Tynehead Park (159th Street Creek, Hjorth Creek, Guildford Brook, and Serpentine Creek), that all convey flow to the Serpentine River, are forested and act as corridors for wildlife. The streams in this area provide travel corridors for wildlife to nearby natural areas (discussed in more detail in Section 3.6.3). Several birds were observed along the watercourses during site assessments, and discussions with local residents indicated that many birds and generalist wildlife species are often found around Guildford Pond (species observed and habitat potential outlined in Section 3.6.1).

Vegetation in Zone 1A is predominantly found within landscaped properties and parks. Native species are generally restricted to riparian corridors and parkland. Table 1 below outlines riparian species (native and invasive) observed during site assessments at each watercourse. The list of native riparian species and invasive species is not exhaustive and is limited to observations made during the site assessments. Further assessment is required to determine the full extent of native and invasive species presence along each watercourse.

TABLE 1: RIPARIAN PLANT SPECIES OBSERVED DURING SITE ASSESSMENTS IN ZONE 1A

Watercourse	Native Riparian Species Present	Invasive Riparian Species Present
Serpentine Creek	Bigleaf maple, red alder, western hemlock, western redcedar, salmonberry, vine maple, sword fern, rushes, cattail	Himalayan Blackberry, lamium, English ivy at top-of-bank areas
Guildford Pond	Western redcedar, Sitka spruce, western hemlock, red alder, bigleaf maple, western flowering dogwood, snowberry, baldhip rose, hardhack, sword fern	Lamium, English holly, Himalayan blackberry, English ivy
Guildford Brook	Western redcedar, bigleaf maple, red alder, salmonberry, sword fern	English ivy at top-of-bank areas near 104th Avenue, reed canary grass and Himalayan blackberry near Guildford Pond
Hjorth Creek	Red alder, bigleaf maple, black cottonwood, and red elderberry north of Highway 1. Red alder, western hemlock, western redcedar, bigleaf maple, salmonberry and sword fern in Tynehead Park (transitioning to Zone 2).	Himalayan blackberry north of Highway 1
159th Street Creek	Red alder, bigleaf maple, black cottonwood, and red elderberry north of Highway 1. Red alder, western hemlock, western redcedar, bigleaf maple, salmonberry and sword fern in Tynehead Park (transitioning to Zone 2).	Himalayan blackberry, English ivy north of Highway 1
Swanson Brook	Western redcedar, bigleaf maple, red alder, beaked hazelnut, Pacific willow, red elderberry, salmonberry, skunk cabbage, cattail, ferns, buttercup, Indian plum and grasses.	Policeman's helmet, Himalayan blackberry

3.1.2 Zone 1B

This section of the Developed Uplands consists primarily of low-density housing in the Anniedale area, generally east of 168th Street, and south of 96th Avenue to the Agricultural Lowlands. The Anniedale Tynehead Neighbourhood Concept Plan calls for extensive development of the area in the future. Aquatic habitat consists mainly of Class B and C channels that eventually flow into Class A and A(O) channels in Zone 3, and the downstream ends of two unnamed tributaries that originate in the eastern section of Tynehead Park (discussed in Section 3.2.1.3). Terrestrial habitat in this area consists of patches of forest within low-density residential and agricultural areas as well as landscaped properties. These areas provide some connectivity to the eastern portion of Tynehead Park to the north.

3.1.2.1 Aquatic Habitat

There are two unnamed Class A tributaries that originate in Tynehead Park west of 168th Street (referred to as Unnamed Tributary 1 and Unnamed Tributary 2) that flow south through Zone 1B to the Serpentine River. Both watercourses are narrow, with silt and clay substrate. Both channels are covered with thick instream reed canary grass and Himalayan blackberry north of 96th Avenue. Unnamed Tributary 1 is culverted under 96th Avenue approximately 250 m east of 168th Street, and is culverted under 94A Avenue, before discharging to the Serpentine River west of Bothwell Drive. Unnamed Tributary 2 is culverted under 96th Avenue approximately 230 m west of 172nd Street and under Bothwell Drive before discharging to the Serpentine River. South of 96th Avenue, Unnamed Tributary 2 flows through a wider, more natural stream corridor than Unnamed Tributary 1 and has instream gravel and clear flow. This section of Unnamed Tributary 2 provides better rearing habitat for salmonids than areas north of 96th Avenue. The corridor surrounding Unnamed Tributary 1 south of 96th Avenue is more disturbed, the stream channel is small and shallow and it is culverted under a residential property on the north side of 94A Avenue. Fish access to both tributaries is likely limited north of 96th Avenue due to insufficient depth. Fish habitat in Unnamed Tributary 2 is generally better than that in Unnamed Tributary 1. Historic fish presence in Unnamed Tributary 2 is limited to observations of threespine stickleback (BC MoE 2014b), and no historic data on fish presence was available for Unnamed Tributary 1. South of 96th Avenue, stream habitat is likely suitable for rearing salmonids in both watercourses. Both watercourses are connected to Class B, C and (in the case of Unnamed Tributary 2) Class A watercourses south of 96th Avenue.

Other aquatic habitat in Zone 1B consists primarily of Class B and C roadside watercourses that eventually drain into the Class A and A(O) watercourses in the Agricultural Lowlands in Zone 3 to the south. These watercourses do not provide rearing or spawning habitat for fish, but the Class B channels do provide food and nutrients to downstream reaches. Some of these channels have very steep grades near 92nd Avenue where the uplands near 176th Street and Highway 1 slope down to the flat, Agricultural Lowlands to the south. Substrate in these channels consists mainly of silt and clay, and many channels are ephemeral and/or intermittent.

3.1.2.2 Terrestrial Habitat

Terrestrial habitat in this area consists of patches of forest within low-density residential areas (*e.g.*, north of 92nd Avenue, between Bothwell Drive and 176th Street, and west of 180th Street to the north of 92nd Avenue). These areas provide some habitat for wildlife and connectivity to forested areas north of Highway 1, to Tynehead Park, and to wildlife corridors leading south of the Project Area.

The width of riparian areas is varied, and vegetation along some channels consists entirely of reed canary grass, while those channels adjacent to forested areas contain more native trees and shrubs.

Table 2 below outlines riparian species (native and invasive) observed during site assessments at each watercourse. The list of native riparian species and invasive species is not exhaustive and is limited to observations made during the site assessments. Further assessment is required to determine the full extent of native and invasive species presence along each watercourse.

TABLE 2: RIPARIAN PLANT SPECIES OBSERVED DURING SITE ASSESSMENTS IN ZONE 1B

Watercourse	Native Riparian Species Present	Invasive Riparian Species Present
Unnamed Tributary 1	Western redcedar, red alder, bigleaf maple, salmonberry, reed canary grass	English holly, Himalayan blackberry
Unnamed Tributary 2	Western hemlock, western redcedar, bigleaf maple, red alder, black cottonwood, reed canary grass, buttercup	Himalayan blackberry

3.2 Tynehead Park and Surrounding Natural Areas

Tynehead Park (Zone 2) is located generally north of 96th Avenue between Highway 1 and 160th Street. The natural area also extends south of the park, south of 96th Avenue and west of 168th Street. This natural area is large and is characterized by generally intact second growth forests and relatively undisturbed contiguous terrestrial habitat. It is the most significant hub for wildlife in the area. Watercourses in the area include the Serpentine River and numerous other Class A watercourses. The channels are generally found on their original alignments and display high complexity with a varied substrate, instream woody debris, and sections of pool, riffle, and run habitat. Impacts are greater on the watercourses east of 168th Street and south of 96th Avenue. Some Class A channels may warrant further investigation to confirm fish access to all reaches and, as such, whether the Class A designation is accurate for the entire length.

3.2.1 Aquatic Habitat

3.2.1.1 Main Channel

The Serpentine River follows a sinuous path through Tynehead Park within a narrow, flat floodplain area 80 to 100 m wide, bounded by steep banks of 5 to 7 meters in height. These slopes abut the river in some areas. Sloughing of the banks and erosion has occurred in several areas within the park (ID Group 1996). A large area of erosion was noted in 2011 on the channel between Hjorth and Meridian Creeks, where the stream had shifted, causing undercutting which compromised numerous trees (Web Engineering 2011). Erosion of the banks and several compromised trees were also observed along the river near 160th Street (Web Engineering 2011). The banks of the river show evidence of sloughing likely due to higher water levels during storm events.

Substrate in this section of the river consists of sand, silt, gravel and cobbles. The habitat in this area is suitable for both spawning and rearing of salmonids. Historic fish presence includes rainbow and cutthroat trout, Coho, sockeye, chum and Chinook salmon, brassy minnow and sculpin (general, coastrange and prickly; Backman and Simpson 1985; BC MoE 2014b), although it is likely that sockeye are no longer present. Tynehead Park was found to have the highest species density of Coho fry in the whole Upper Serpentine watershed by a study completed in the mid-1980s (Backman and Simonson 1985). Adult salmonid carcasses were observed during the site assessment and spawning salmonids were observed throughout the channel by Dillon staff on December 2, 2013. To enhance the spawning habitat downstream within the park, 2m^3 of gravel was deposited along the south side of the Serpentine River between August 19 and 23, 2013 just upstream of where Miraki Creek enters the river. The location of gravel deployment was chosen based on the findings of the Upper Serpentine Gravel Recruitment Study (Donahue 2012).

Between the south end of Tynehead Park and 92nd Avenue, the river meanders through a natural, flat, park area, with extensive, natural riparian zones, and has a lower grade and lower banks than within Tynehead Park. A natural gas right-of-way crosses the river just south of 96th Avenue. The banks here have been reinforced with small riprap and erosion protection cloth. The substrate in this section of the channel consists of silt, sand, gravel and cobbles and there are some gravel bars along the sides of the channel. There are run/riffle/pool sequences and the channel provides good spawning and rearing habitat for salmonids. Historic fish presence includes spawning Coho, sockeye and Chinook salmon and rainbow trout and sculpin (Backman and Simonson 1985; BC MoE 2014b).

3.2.1.2 Tynehead Park West of 168th Street

McCaskill Creek and Young Brook (also called Townline Creek) are similar in character and flow north through the western portion of Tynehead Park to the Serpentine River. They both have run/riffle/pool sequences and silt, sand, gravel, cobble and boulder substrate. The gradient of both streams is steep in some areas, especially towards the upstream reaches, and this may act as a barrier to fish. There are several sites along McCaskill Creek where minor erosion was observed in 2011 (Web Engineering 2011). Historic fish presence includes Coho salmon, cutthroat and rainbow trout (Dillon Consulting 2001). Spawned-out chum salmon carcasses were also observed in McCaskill Creek during the site assessment. Both streams provide good rearing habitat for salmonids and likely provide spawning habitat in a few areas. Overhanging vegetation along both channels is dense and provides good cover for adult salmonids and rearing fry. Based on the findings of the Upper Serpentine gravel recruitment study, 2m^3 of gravel was deposited on the east side of Townline Creek at 96th Avenue and 161A Street between August 19 and 23, 2013 to enhance the available spawning.

Meridian Creek follows a relatively sinuous path through a flat, wide floodplain and flows south into the Serpentine River. Meridian Creek has a sand, cobble and gravel substrate, and run/riffle/pool morphology. It provides good rearing habitat for salmonids, but access for spawning fish may be limited (Dillon Consulting 2001). No historic data on fish presence could be obtained. Meridian Creek has abundant overhanging riparian vegetation and water quality was clear based on visual observations at the time of assessment.

The portion of Hjorth Creek (fully discussed in Section 3.1.1.1) within Tynehead Park is similar in character to Meridian Creek, and provides good rearing habitat for salmonids, with potential for spawning habitat in some areas (Dillon Consulting 2001). Overhanging riparian vegetation is abundant and water quality was clear based on visual observations at the time of assessment.

Miraki Creek and Bunting Brook are both narrow, ephemeral watercourses that each follow a sinuous path within a small, flat floodplain with minimal banks. Fish access to the channels is limited and likely restricted to areas immediately upstream of the Serpentine River. Further investigation is warranted to determine if a change to a Class B designation is appropriate in the upstream reaches of both watercourses. These areas would provide rearing habitat for salmonids should they be accessible. There is no known historic data on fish presence (Dillon Consulting 2001). The substrate in these channels consists mainly of silt, clay, and organics, with sand and small gravel becoming dominant at the downstream end.

Four similar, unnamed channels flow south from the northwest part of Tynehead Park to the Serpentine River. Fish access in these channels is likely limited to the areas near the river, as they are all intermittent in the upstream reaches. Substrate is similar among these watercourses and generally consists of sand and gravel at the downstream end, and silt, clay and organics further upstream. A steep gradient and large drops of 0.5 to 1.0 m in some areas likely pose as barriers to the upstream migration of fish. No historic fish presence data was available for any of these watercourses. Access for adult salmonids is likely very limited. Further investigation is warranted to determine fish access to these channels and whether the upstream reaches warrant downgrading to Class B.

Hawthorne Trail Creek is the furthest east Class A tributary to the Serpentine River within Tynehead Park. It flows south just west of 168th Street, before flowing underneath 96th Avenue and discharging to the Serpentine River near the 93B Avenue Alignment. It is narrow and follows a sinuous path through a flat floodplain and has silt and clay substrate with some sand. A branched Class A/B swale that is similar in character enters Hawthorne Trail Creek just south of 96th Avenue. The water was noticeably silty in both watercourses during the site assessments. South of 96th Avenue, the channel becomes more poorly defined and dominated by instream reed canary grass. No historic fish data was available for these channels. Fish access to upstream areas of Hawthorne Trail Creek and its tributary may be limited where the watercourses become intermittent.

3.2.1.3 Tynehead Park East of 168th Street

Two unnamed Class A tributaries originate in Tynehead Park east of 168th Street and flow south to the Serpentine River, discharging near the 94th Avenue alignment (discussed fully in Section 3.1.2.1). Two Class B watercourses originate northeast of the intersection of 168th Street and 96th Avenue, join just west of 168th Street and then flow south into Hawthorne Trail Creek (described in Section 3.2.1.2). Between the confluence and the point of discharge to Hawthorne Trail Creek, this watercourse is designated as Class A, and therefore provides habitat for salmonids. Substrate in this section of the watercourse is largely silty with some cobbles, sand and gravel. Upstream of the confluence, substrate is largely silt and the channels contain some instream reed canary grass.

3.2.1.4 City Park South of 96th Avenue

Acason Creek is a short tributary that flows east through a flat park area on the south side of 96th Avenue. It has sand and silt substrate and some instream reed canary grass. There is no historic fish presence data, but the creek likely provides habitat for rearing salmonids.

Fern and Godwin Creeks originate near 164th Street and 92nd Avenue, and join to form Kurtenacker Creek, which flows into Bothwell Creek just west of 168th Street. The upstream reaches of these watercourses are forested and follow natural, sinuous paths. Bothwell Creek is straightened west of 168th Street and enters the Serpentine River near the 169th Street alignment. The downstream portion of Bothwell Creek generally consists of a poorly-defined, grassy stream channel within a flat, grassy floodplain. The surrounding land use in the downstream area is agricultural, and the adjacent properties are cropped or fallow. Substrate in upstream areas consists of silt, sand, gravel and cobbles, whereas substrate in lowland areas is dominated by silt, clay and organics. Bothwell Creek is connected to Class C roadside ditches along both sides of 168th Street. Historic fish presence in Bothwell Creek includes cutthroat trout, Coho salmon, sculpin (general), lamprey (general) and threespine stickleback near the confluence with the Serpentine River (BC MoE 2014b). There was no data available on historic fish presence in its tributaries, but the upstream areas likely provide rearing habitat for salmonids, while areas closer to the Serpentine River serve as migratory corridors to upstream areas. There is typically a significant amount of large, vegetative debris in Bothwell Creek (Web Engineering 2011). Sloughing has occurred in several areas along Bothwell Creek near 168th Street and on the roadside ditches in the area.

3.2.2 Terrestrial Habitat

Tynehead Park is the largest natural area in the Upper Serpentine watershed and represents the most significant hub for wildlife in the Project Area. It is largely undisturbed and provides a variety of habitats (stream, riparian, upland wooded areas) for numerous species (outlined in detail in Section 3.6.1) The park provides good habitat for birds and many species were observed during the site assessments.

Riparian vegetation in Tynehead Park contained little to no invasive vegetation at the time of assessment. Vegetation in upland areas within the park was more characteristic of disturbed areas, with invasive species such Himalayan blackberry, English ivy, and English holly present. An area west of the river immediately north of 96th Avenue consisted of Sitka spruce trees spaced at regular intervals with little to no understory vegetation.

The health of the riparian zones within the western portion of the park was observed to be excellent. Riparian vegetation observed at the time of assessment included a mixed deciduous/coniferous canopy with a diverse understory of native shrub and herbaceous species. Riparian vegetation included, but was not limited to, bigleaf maple, red alder, black cottonwood, western redcedar, western hemlock, Douglas-fir, sword fern, deer fern, salmonberry, red-osier dogwood, dull Oregon grape, red huckleberry and reed canary grass.

Riparian vegetation adjacent to watercourses in the portion of Tynehead Park east of 168th Street showed impacts from development and more abundant invasive species. Many watercourses were overgrown with Himalayan blackberry and reed canary grass. Other riparian vegetation in this area included red alder, bigleaf maple, western redcedar, black cottonwood, paper birch, salmonberry and sword fern.

Riparian vegetation in the City park south of Tynehead Park west of 168th Street showed some evidence of disturbance and typically included bigleaf maple, western hemlock, Sitka spruce, red alder, Pacific flowering dogwood, salmonberry, sword fern, buttercup, red-osier dogwood, baldhip rose, hardhack, comfrey, reed canary grass, sword fern and some Himalayan blackberry. A FortisBC gas right-of-way exists just south of 96th Avenue and vegetation along this corridor consists mainly of manicured grass. Many wildlife corridors (stream and river corridors and utility rights-of-way) connect Tynehead Park to the surrounding natural areas (discussed in Section 3.6.3).

3.3 Agricultural Lowlands

The Agricultural Lowlands (Zone 3) are located in the southeast portion of the Project Area and are generally bound by 164th Street to the west and 92nd Avenue to the north. Aquatic habitat in the Agricultural Lowlands is provided by the Serpentine River, two named Class A watercourses, and a series of linear Class A(O) ditches. Aquatic habitat is largely limited to migratory or rearing reaches with only some small sections of potential spawning habitat present. The channels tend to be lower gradient with substrates dominated by silts and organics other than in the upstream reaches. Watercourses are often channelized and have been reconstructed along linear alignments such that instream complexity is reduced. Riparian vegetation has often been cleared to at or near the top-of-bank such that there is limited shade. As a result, water quality is reduced, particularly in the Class A(O) channels, further limiting the value of the habitat to salmonid species.

Terrestrial habitat in the Agricultural Lowlands is largely limited to patches of grassland and forest. Most of the area is developed for agricultural or low density residential use, and the terrestrial habitat in the area is fragmented. The Serpentine River acts as a corridor for wildlife moving south from the large hub at Tynehead Park.

3.3.1 Aquatic Habitat

3.3.1.1 Serpentine Main Channel

The Serpentine River becomes more characteristic of lowland watercourses in agricultural areas south of 92nd Avenue, is straightened south of the 91st Avenue right-of-way and is bounded by dikes south of the 90th Avenue right-of-way. The riparian zones are much narrower and provide little cover of the channel, there is less instream complexity than in upstream areas and the substrate consists largely of silt and clay. The river at this location serves more as a migratory corridor for salmonids moving to and from upstream spawning and rearing areas. The water temperature and sediment load are higher, with dissolved oxygen lower than upstream areas (Van der Eerden 1996). Numerous linear Class A(O) channels convey flow from agricultural areas to the Serpentine River.

The river from 88th Avenue south is prone to flooding and the surrounding land is flat and lies only slightly above sea level (Van der Eerden 1996). There is a constructed sump designed to collect sediment from upstream areas on the south side of 88th Avenue. Historically, there have been Coho salmon killed due to low dissolved oxygen levels in the water early in the run (in late October and early November; Backman and Simonson 1985). Tide gates may serve as barriers to fish migrating to tributaries in this section of the river (Backman and Simonson 1985). Piscivorous fish such red-sided shiners, sticklebacks and cottids (sculpin) typically utilize this section of the river, making it unsuitable for juvenile salmonids (Backman and Simonson 1985). Historic fish observations include these three fish species, as well as Coho salmon, cutthroat and rainbow trout and lamprey (general and western brook), as well as invasive sunfish and carp downstream of 88th Avenue (BC MoE 2014b). Single observations of pink and sockeye salmon, Dolly Varden and sturgeon (general) were made in 1985 in the river at the outlet of Latimer Creek (BC MoE 2014b) although, as previously referenced, sockeye are likely no longer present. Fish observations in August 2013 in the sump just south of 88th Avenue by Dillon staff included threespine stickleback and lamprey.

3.3.1.2 Tributaries

West of the Serpentine River

E Creek originates in Zone 1A, near 162nd Street and 88th Avenue and enters the Serpentine River west of the intersection of 92nd Avenue and Bothwell Drive. Upstream areas of E Creek have steep banks, are forested and the channel follows a natural, sinuous path. The stream is straightened as it flows through the low density residential/agricultural lowlands near the confluence with the Serpentine River. The lowland area consists of a poorly-defined, grassy stream channel within a flat, grassy floodplain. The riparian zone is thin and almost non-existent along E Creek on both sides of 168th Street (Dillon Consulting 1996). The properties in this area are fallow or used for growing crops. Some instream reed canary grass is present in E Creek near 168th Street. Substrate in upstream areas consists of silt, sand, gravel and cobbles, whereas substrate in lowland areas is dominated by silt, clay and organics. E Creek is connected to Class A, B and C roadside ditches along both sides of 168th Street. The roadside ditches in this area have narrow or non-existent riparian zones, and substrate consists largely of silt. Historic fish presence in E Creek consists of spawning Coho salmon, cutthroat trout, threespine stickleback, western brook lamprey and other salmonids (Backman and Simonson 1985; Van der Eerden 1996; BC MoE 2014b). The stream provides rearing habitat for salmonids in the upstream reaches and the downstream areas serving as migratory corridors from the Serpentine River.

A weir is located at the downstream end of the culvert on E Creek underneath 88th Avenue and may present a barrier to fish. There is typically a large amount of vegetative debris in E Creek, which has periodically blocked flow at some locations (Web Engineering 2011). There are multiple sites where minor erosion has occurred within the channel and the creek is experiencing altered erosive flows leading to a change in morphology (Donahue 2012). The streambed of E Creek at the 90th Avenue alignment is eroded at the intersection with a Class B tributary due to the height of the culvert outlet above the channel at this location (Dillon Consulting 1996; Van der Eerden 1996). Additionally, development upstream of E Creek and the Class B tributary have accelerated erosion processes within the watercourses (Dillon Consulting 1996). Sedimentation from erosive processes could limit the ability of E Creek to support the spawning and rearing of salmonids.

Austin Brook is a small, grassy Class A/B watercourse that flows north from 88th Avenue towards 168th Street, where it flows along the east side of 168th Street before discharging to E Creek at the 92nd Avenue right-of-way. The upstream areas have narrow, forested riparian zones. The riparian zone is grassy and almost non-existent near 168th Street. Substrates are largely silt, clay and organics and the stream likely only provides minor rearing habitat for salmonids. The stream may be intermittent or ephemeral in the upstream reaches during drier periods. Large debris blockages have existed in the past in the upstream areas of the channel (Web Engineering 2011) and may pose as barriers to the upstream migration of fish. Historic fish presence includes Coho salmon and rainbow trout (BC MoE 2014b) but the channel likely only supports salmonids during the wetter periods of the year, and is more suitable for coarse fish in accessible areas year-round.

There are several linear Class A(O) watercourses between 168th Street and the Serpentine River to the east. These watercourses all bear typical flat, lowland A(O) channel characteristics with silty substrates, narrow riparian zones, low flow and often poor water quality. Surrounding land use is agricultural.

East of the Serpentine River

Lakiotis Creek and Latimer Creek are the dominant Class A watercourses in Zone 3 east of the Serpentine River. Both are linear and flow through flat, agricultural watersheds. Lakiotis Creek is branched with one section conveying flow from Class A(O) watercourses at 88th Avenue south to the Serpentine River, and the other branch flowing west to the Serpentine River along the 86th Avenue right-of-way east of 176th Street. The headwaters of both Latimer Creek and the eastern branch of Lakiotis Creek are fed by several Class B and C swales. Several Class A(O) watercourses discharge into the downstream portions of the creeks. Lakiotis Creek discharges to the Serpentine River through the Upper Serpentine Pump Station on the 86th Avenue alignment. Latimer Creek is bordered by narrow, vegetated dikes on each side. The substrate consists of silt and organics in both watercourses and they typically carry moderate sediment loads and are naturally dark due to dissolved plant tannins. Instream reed canary grass is present in some portions of both watercourses. Instream habitat is more suitable for coarse fish and migrating salmonids. Historic fish observations in Latimer Creek include Coho salmon, rainbow and cutthroat trout and lamprey (BC MoE 2014b). No historic fish data was available for Lakiotis Creek.

Numerous linear and roadside Class A and A(O) watercourses drain the agricultural areas east of the Serpentine River, north of 86th Avenue. These watercourses are typical of those in flat, lowland, agricultural areas, and have silty substrates, narrow riparian zones and low flow. Class A(O) watercourses provide habitat for coarse fish and rearing habitat for salmonids during higher flow periods from fall to spring. Most have instream reed canary grass and low instream complexity.

3.3.2 Terrestrial Habitat

Terrestrial habitat in the Agricultural Lowlands is largely limited to patches of grassland and forest, as well as narrow riparian zones. Most of the area is developed for agricultural or residential use, and the terrestrial habitat in the area is fragmented. There is limited habitat for larger wildlife and species presence is expected to consist largely of a variety of bird species, some amphibian and reptiles, and mammalian urban generalists adapted to disturbed habitats. Agricultural row crops and turf grass (areas of manicured grass) are expected to have a particularly low biodiversity compared to the other habitat types in the watershed. The primary terrestrial habitat is the riparian zone of the Serpentine River which acts as a corridor for wildlife moving to and from the large hub at Tynehead Park. Wildlife observations during the site assessments were limited to a few bird species and beaver sign.

The headwaters of many of the streams in the area are forested, with riparian areas that are wider, which provides good cover for the channels. Species typically consisted of western redcedar, western hemlock, red alder, bigleaf maple, black cottonwood, salmonberry and sword fern. Riparian areas along the Serpentine River and tributaries in lowland agricultural areas are narrow or non-existent, providing minimal channel cover. Vegetation typically consists of Himalayan blackberry, hardhack and reed canary grass, with red alder, baldhip rose and red-osier dogwood found in some areas. Riparian vegetation along linear Class A and A(O) channels typically consists of Himalayan blackberry, hardhack and reed canary grass with intermittent deciduous trees characteristic of disturbed areas (red alder, black cottonwood).

3.4 Benthic Invertebrates

Data on benthic invertebrate populations in the watershed was limited to historic data from one study completed in 1984 (Backman and Simonson 1985). These benthic invertebrate results should be treated with caution because of their age and changes in methods of collection and analysis. Benthic invertebrates were sampled at three locations on the Serpentine River (shown in Figure 2) at one high- (Site 1), one medium- (Site 4) and one low-gradient site (Site 6a), and at four locations on tributaries to the Upper Serpentine River within Zone 2 (Tynehead Park on Townline Creek, Hjorth Creek, Meridian Creek and an unnamed tributary west of the Serpentine River in the southern portion of the park). Samples on the Upper Serpentine River were collected once per week between July and August, 1984 and samples were collected on the tributaries once, on August 23, 1984. Water temperatures during sampling were between 12.5 and 16.5 C and water flows were constant, with no appreciable rainfalls during the collection period. Benthic invertebrates in this study were grouped in terms of their tolerance to compromised water quality: tolerant, moderately tolerant and sensitive to pollution. The relative proportion of the species in each of these categories was used as an indicator of the water quality at that location (Backman and Simonson 1985).

Results showed that the medium-gradient site (Site 4 located north of 96th Avenue) had the highest number of aquatic invertebrates (913 per m^2 on average) and the most varied types of invertebrates (8 total) while the low-gradient site had the lowest average number of invertebrates (153 per m^2) and different types of invertebrates (4 total). There were 203 invertebrates per m^2 at the high gradient site. The total number of invertebrates was much higher on the tributaries than in the main channel of the river. The site on the unnamed tributary had the greatest total number of invertebrates (approximately 4,400 per m^2), followed by Hjorth Creek (3,500 per m^2), Meridian Creek (1,700 per m^2) and Townline Creek (350 per m^2). The average number of different types of invertebrates was also higher on the tributaries than in the Serpentine River, and was highest at Meridian Creek (14 types), followed by the unnamed tributary (13), Hjorth Creek (10) and Townline Creek (7). The high- and low-gradient sites on the Serpentine River (Sites 1 and 6a, respectively) had more than 50% moderately tolerant benthic organisms (of genera *Dipteria*, *Hydracarina*, *Coleoptera*, *Isopoda* and *Amphipoda*), suggesting moderately reduced water quality but not severe pollution. The same results were found on the unnamed tributary, with moderately tolerant species making up an even higher proportion (>75%) at the site on Townline Creek (dominant organisms were of genera *Oligochaeta* and *Mollusca*). Runoff from developed areas to the west may have impacted water quality, and therefore the genera of invertebrates present at the high-gradient site (Site 1). Chemical spills and fish kills have been recorded in this area historically (Backman and Simonson 1985) and may have influenced benthic distribution and abundance.

Overall, species abundance and diversity was higher on the tributaries in Tynehead Park than in the Serpentine River. Abundance and diversity on the river was highest at the medium-gradient site (north of 96th Avenue), with species diversity on the tributaries highest on Meridian Creek and the unnamed tributary (Backman and Simonson 1985).

3.5 Water Quality

Water quality data from the following resources was used in this study:

- Raw water quality data from the Tynehead Hatchery from 2009-2013 (Evergreen 2013);

- The Serpentine River Watershed Salmonid Resource Studies (data from 1984-5; Backman and Simonson 1985);
- The Upper Serpentine River Drainage Basin Water Quality Study (1989-1991; Visser 1991); and
- Status of Water Quality Objectives Attainment in the Little Campbell River, Serpentine River, Nicomekl River, 1971-2009 (Bull and Freyman 2013).

All water quality results should be treated with caution, as methods of analysis have changed and quality control measures varied at the time of sampling. Additional notes about each source of water quality data include the following.

The Upper Serpentine River Drainage Basin Water Quality Study examined water quality at several locations within the Upper Serpentine River watershed during June and July 1991. Water quality was examined at locations northwest of Tynehead Park (Guildford Brook, Serpentine Creek, 159th Street Creek, Hjorth Creek and the Serpentine River upstream of the park). Conductivity was higher in all watercourses when sampling occurred during a storm event (470-2,100 µs/cm. Conductivity during non-storm sampling events at all sampling sites ranged from 94 to 320 µs/cm and was slightly higher on average in the tributaries than in the Serpentine River main channel. The pH at all sample sites averaged approximately 8.0 during the sampling period. The report also cited water quality data from 1988 and 1989 from a series of reports prepared by the BC MoE, but only one sampling location (the mouth of Latimer Creek) is within the study area, and no sampling dates were specified in the data, so the data was not reviewed in this report.

Water temperatures were available for several sites in the Upper Serpentine watershed from April 1984 to February 1985 as outlined in the Serpentine River Salmonid Resource Studies document. Monitoring sites were located on the Serpentine River immediately downstream of 160th Street, the confluence with Hjorth Creek, immediately downstream of 96th Avenue, immediately upstream of 88th Avenue and Hjorth Creek downstream of 102nd Avenue. Summer water temperatures (June to August) were generally between 10 and 15 C at all sites, and winter temperatures (December to February) were between 1 and 5 C. Dissolved oxygen (DO) and pH data are also available for Hjorth Creek and the Serpentine River upstream of 88th Avenue. Both DO and pH were more variable further downstream (south) on the Serpentine River (at 88th Avenue; pH values ranged between 6.1 and 7.6; DO ranged between 7.0 and 13.0 mg/L) than they were in Tynehead Park (at Hjorth Creek; pH values were between 7.0 and 7.7; DO was between 9.0 and 12.0 mg/L).

Only one sample site from the Status of Water Quality Objectives report is within the Project Area (Latimer Creek at Harvie Road). Historic data from 1972 to 2002 were analysed for this report, and sampling was performed in 2009. Results of sampling from 2009 and historic water quality results were compared to Canadian Council of the Ministers of the Environment (CCME) criteria for long-term and instantaneous maximum water quality. Historic water quality results from Latimer Creek indicated that long-term CCME water quality objectives were generally not met for faecal coliforms (standards for aquatic life) and *Escherichia coli* (*E. coli* - standards for irrigation and livestock) but that standards for instantaneous maxima were met in most cases. Faecal coliforms ranged from 50 to 1,100 CFU/100 mL in the summer and 60-490 in the fall, and *E. coli* ranged from 40 – 1,100 CFU/100 mL in the summer and 45-480 in the fall.

Water quality data from the Tynehead Hatchery was obtained from 2009 to 2013. Sampling was conducted on the Serpentine River adjacent to the hatchery, just north of 96th Avenue.

Sampling was generally conducted five times in a 30-day period twice annually, in the summer and late fall. Raw data is discussed below.

DO was 10.7 mg/L on average, with a minimum of 7.4 mg/L and maximum of 12.8 mg/L. DO was below the acute and 30-day average standards for buried alevin life stages on many sampling dates, but was generally high and above guidelines for other life stages. These results indicate that the river has adequate DO to support a variety of fish populations, but some areas may be unsuitable for spawning due to inadequate DO levels during certain periods. Conductivity was generally low, with an average value of 165 µS/cm during the study period. The pH consistently met guidelines for aquatic life, with an average pH of 7.75 throughout the study period. The overall average water temperature at the site was 11.9 C, with a range of 2.14 to 18 C. The average warm weather water temperature was 15 C, with a range of 12 to 18 C. The average cold weather water temperature was 8.6 C, with a range of 2.1 to 11.8 C. Turbidity was 5.33 Nephelometric Turbidity Units (NTU) on average throughout the study period. Higher turbidity ($\geq$ 15 NTU) observed on several occasions may have been due to storm events. Total suspended solids also exceeded regulatory criteria (CCME and BC Water Quality) on two of the same dates.

Total phosphorus values were generally in the range considered eutrophic by CCME standards ($>$0.035 mg/L), with values on some sampling dates considered hyper-eutrophic ($>$0.1 mg/L). CCME defines eutrophic as having an over-supply of organic matter, and does not imply that a eutrophic state is necessarily bad, but does represent the potential to cause harmful alterations of ecosystems. Eutrophication and nutrient over-enrichment can cause algal blooms that result in hypoxic or anoxic conditions and the creation of substances which are toxic to aquatic organisms (CCME 2007).

Ammonia was generally low, with only two exceedances of CCME standards. Total organic carbon was low (2.78 mg/L on average throughout the study period with a range between 1.0 and 5.21 mg/L). Comparison to regulatory criteria was not possible due to the lack of appropriate background data.

E. coli exceeded BC Water Quality regulatory criteria (for agriculture – crops eaten raw which is the most stringent criteria) on most the dates sampled, as did faecal coliforms (standards for irrigation). *E. coli* ranged from 52 to 4,100 CFU/100mL and faecal coliforms ranged from 29 to 1,700 CFU/100mL. *Enterococcus* spp. exceeded regulatory criteria (irrigation – crops eaten raw) on all sampling dates. No applicable standards exist for these microbes for the protection of aquatic life, except for standards for shellfish harvesting, which are not applicable for the Project Area.

Copper, iron, selenium, thallium, uranium and zinc exceeded regulatory criteria on several sampling dates. Lead and cadmium exceeded guidelines on one date. Levels of all other parameters met regulatory criteria and were generally low. Generally, water quality was suitable for a variety of aquatic life at this location, with only periodic and likely event-driven exceedances of water quality criteria.

Water quality in the Upper Serpentine watershed based on visual observations made during site assessments was very good in the Tynehead Park area, good in the developed uplands and moderate in the Agricultural Lowlands. Silty substrate in watercourses was associated with a noticeable sediment load. Some tributaries to the Serpentine River (Bothwell Creek, E Creek and Austin Brook) contained a small sediment load where they crossed 168th Street.

Agricultural lowland ditches were largely tea-coloured due to dissolved organic material. No unusual odours were noted in any watercourses during the site assessments.

Anecdotal evidence from representatives at the Tynehead Hatchery indicates that the Serpentine River 'runs murky' during high rain/high flow events, although no data is available to indicate turbidity or levels of total suspended solids (personal communication with staff from the Tynehead Hatchery). Based on data collected on the Serpentine River at 96th Avenue (adjacent to the Tynehead Hatchery), average turbidity from 2009 to 2013 for this location was 5.33 NTU. However, this data should be used with caution, as sampling was not conducted at regular intervals.

In summary, available water quality data was insufficient to fully understand water quality at all points in the watershed. However, the following inferences can be drawn:

- The two major potential non-point sources of water pollution include the developed upland areas in the western portion of the watershed and agricultural properties in the lowland areas;
- Higher conductivity at sites in Zone 1A and higher turbidity in Zone 2 (1989-1991) during storm events (Visser 1991) may be indicative of erosive forces due to high flows during storm events, and/or contribution via storm sewers of runoff from developed areas;
- Exceedances of guidelines for faecal coliforms and *E. coli* were observed in Latimer Creek, a tributary in Zone 3, but also in the Serpentine River Zone 2, indicating that the natural background levels of these bacteria may exceed regulatory criteria in the Serpentine River;
- The Serpentine River at the downstream end of Zone 2 has adequate DO to support a variety of fish populations, but some areas may be unsuitable for spawning due to inadequate DO levels during certain periods; and
- Total phosphorus was generally eutrophic or hyper-eutrophic at the Tynehead Hatchery, indicating a potential for an oversupply of organic matter and the potential for harmful algal blooms, even upstream of agricultural areas in the watershed.

Further investigation of water quality at all points in the watershed is necessary to better understand potential point sources of contamination.

3.6 Wildlife and Corridors

3.6.1 Wildlife Observed and Species Potential

The potential for biodiversity varies throughout the Upper Serpentine watershed. Tynehead Park and the surrounding areas consist mainly of young forests, with some sections of old forest and unmanaged herb, grass and shrub land (Diamond Head 2014). Small pockets of manicured grass exist in surrounding residential parks and urban trees are present in low-density residential areas (Diamond Head 2014). Young mixed, coniferous and deciduous forests (like those found in Tynehead Park) are expected to have a high diversity and number of mammal, amphibian, and bird species. Unmanaged shrub, herb and grass areas are expected to have a lower biodiversity and number of species. Agricultural row crops and areas of manicured grass are expected to have a particularly low biodiversity compared to the other habitat types in the watershed.

Riparian areas support high levels of biodiversity and, as a result, are of particular importance in Zones 1 and 3 given the general lack of significant areas of natural vegetation. The riparian setbacks recommended in the City's Biodiversity Conservation Strategy are: 30 m around large

Class A and A(O) watercourses; 15 m around Class B watercourses and wetlands, and 5 m around Class C watercourses (Diamond Head 2014). Larger habitat patches and those that are in close proximity generally support greater biodiversity.

A number of wildlife observations were made during the watercourse assessments. As was expected, a greater number of species were observed in Tynehead Park (Zone 2) than other areas. Wildlife observations during assessments are presented in the Table 3 below.

TABLE 3: WILDLIFE OBSERVATIONS DURING SITE ASSESSMENTS

Area	Species Observed
Tynehead Park	• Pileated Woodpecker • Spotted Towhee • Black-capped Chickadee • Chestnut-backed Chickadee • Golden-Crowned Kinglet • Pine Siskin • Cedar Waxwing • Red squirrel • Anecdotal observations by Tynehead Hatchery staff: black bear, black-tailed deer, beaver, coyote, raccoon, mink, river otter and various raptor species
Serpentine River from 96th Avenue to 88th Avenue	• Mallards • Evidence of beaver activity (dam remnants, chews)
Guildford Pond	• Observed by residents: Bald Eagle, Sandhill Crane, Redwing Blackbird, beaver, coyote, possum, Mallards
Serpentine Creek	• Northern Flicker
Guildford Brook	• Black-capped Chickadees
E Creek, Bothwell Creek	• Black-capped Chickadees

Additionally, observations were made on habitat potential and are presented in the Table 4 below.

TABLE 4: WILDLIFE POTENTIAL OBSERVED DURING SITE ASSESSMENTS

Area	Wildlife Habitat Potential Observed During Assessments
Tynehead Park	• Suitable banks along Serpentine River for burrowing animals • Wildlife trees and stumps abundant (cavity and nest habitat for birds, bats) • Fallen trees, snags logs (amphibians, reptiles) • Wet, seasonally flooded areas in upstream areas of some tributaries to the Serpentine River (amphibians) • Open, grassy areas (grazing for ungulates) • Salmonberry and other berries (grazing for bears) • Constructed osprey nest in east portion of park • Intermittent/ephemeral channels may provide habitat for amphibians

Area	Wildlife Habitat Potential Observed During Assessments
Serpentine River from 96th Avenue to 88th Avenue	• Riparian areas for beaver (evidence of activity – chews and dam remnants) • Open water for waterfowl • Banks (burrowing animals)
Guildford Pond	• Open water for waterfowl
Serpentine Creek	• Stumps, wildlife trees
Guildford Brook	• Stumps, wildlife trees
E Creek, Bothwell Creek	• Stumps, wildlife trees • Large logs (amphibians) • Woody debris on banks of streams

There are many identified species of mammal, amphibians, reptiles and birds which have the potential to exist in the Upper Serpentine watershed (Diamond Head 2014). This list is not exhaustive and species present will depend on habitat availability in each area. These species are presented in Table 5 to Table 7 below.

TABLE 5: MAMMAL SPECIES POTENTIAL BY LAND USE TYPE (REPRODUCED FROM SURREY'S BIODIVERSITY CONSERVATION STRATEGY – DIAMOND HEAD 2014)

Mammal	Agricultural	Suburban North
Black-tailed deer	x	x
Bat species	x	x
Coyote	x	x
Creeping vole	x	x
Douglas squirrel	x	x
Ermine		x
Mink	x	x
Mouse/shrew/vole sp.	x	x
Muskrat	x	x
Pacific water shrew	x	x
River otter	x	x
Shrew mole	x	
Striped skunk	x	
Townsend's vole	x	x
Trowbridge's shrew	x	x

TABLE 6: AMPHIBIAN AND REPTILE SPECIES POTENTIAL BY LAND USE TYPE (REPRODUCED FROM SURREY'S BIODIVERSITY CONSERVATION STRATEGY – DIAMOND HEAD 2014)

Amphibian/Reptile	Agricultural	Suburban North
Northern red-legged frog	x	x
Common garter snake	x	x
Long-toed salamander	x	x
Northwestern salamander	x	
Pacific tree frog	x	x
Western toad	x	

TABLE 7: BIRD SPECIES POTENTIAL BY LAND USE TYPE (REPRODUCED FROM SURREY'S BIODIVERSITY CONSERVATION STRATEGY – DIAMOND HEAD 2014)

Bird	Agricultural	Suburban North
Bald Eagle	x	x
Band-tailed Pigeon	x	
Barn Owl	x	
Barn Swallow	x	x
Belted Kingfisher	x	x
Common Goldeneye	x	x
Common Yellowthroat	x	
Cooper's Hawk		x
Downy Woodpecker	x	x
Great Blue Heron	x	x
Great Horned Owl	x	x
Green Heron	x	
Hooded Merganser	x	x
House Finch		x
Lincoln's Sparrow	x	
Northern Flicker		x
Northern Harrier	x	
Pacific Wren		x
Pacific-slope Flycatcher	x	x
Peregrine Falcon	x	
Pileated Woodpecker	x	

Bird	Agricultural	Suburban North
Red-breasted Sapsucker		x
Red-eyed Vireo		x
Red-tailed Hawk	x	x
Savannah Sparrow	x	
Shorebirds (various)	x	x
Short-eared Owl	x	
Song Sparrow	x	x
Spotted Towhee	x	x
Swainson's Thrush	x	x
Trumpeter Swan	x	
Vaux's Swift		x
Warbling Vireo	x	x
Western Meadowlark	x	
Willow Flycatcher	x	x
Yellow Warbler	x	x

3.6.2 Species at Risk and Rare Element Species

A search of the Conservation Data Centre (CDC) information for the area returned no known occurrences of rare species , but there are many species listed in the general area which have the potential to occur within the Upper Serpentine watershed: snowshoe hare, Townsend's big-eared bat, Keen's myotis, Pacific water shrew, Olympic shrew, Trowbridge's shrew, painted turtle, western toad, northern red-legged frog, Salish sucker, bull trout, western thorn, Pacific sideband, threaded vertigo, broadwhorl tightcoil, scarletback taildropper, evening fieldslug, black gloss, beaverpond baskettail, autumn meadowhawk, Audouin's night-stalking tiger beetle, and Pacific vertigo (MoE 2012).

3.6.3 Corridors, Patches and Hubs

Wildlife hubs are defined by Surrey's Biodiversity Conservation Strategy as large, intact core habitat areas larger than 10 ha in size that provide habitat for a diversity of species (Diamond Head 2014). They act as source areas for wildlife dispersal, provide interior habitat and refuge areas, support species with larger home ranges and may contain regionally important habitat. Sites are smaller habitat patches (<10 ha) that provide habitat for fewer species, those more tolerant of human disturbance and with smaller home ranges and may also contain locally rare of sensitive habitats.

Tynehead Park and the City park immediately to the south form the largest natural area in the Upper Serpentine watershed and represent a large hub for wildlife (Diamond Head 2014). It is largely undisturbed and provides a variety of habitats (stream, riparian, upland wooded areas) for numerous species. Other large hubs nearby include Surrey Bend Park to the north, and Green Timbers Urban forest to the west (Diamond Head 2014). Sites in the watershed include several urban park areas in Zone 1A, numerous small patches of forest southeast of Tynehead Park in Zone 1B and Zone 3. Connectivity between sites in Zone 1B is good, while that between the urban parks in Zone 1A and patches of forest in Zone 3 is generally poor.

Wildlife corridors are linear habitat areas that allow the movement of species between hubs and sites. They promote re-colonization and allow species to maintain genetic diversity among their populations. Large corridors are ideal because they are better suited to species that are less tolerant of human disturbance and they support a greater diversity of species (Diamond Head 2014). Two definitions of wildlife corridors as taken from the Diamond Head report were utilized in this report:

- Regional: 50-100 m wide; provides movement for a wide range of species, including those less tolerant of human disturbance; limited recreation opportunities; connect large habitat areas; and
- Local: narrower (10-50 m); provides movement for species more tolerant of human disturbance, connect smaller sites (*e.g*. hydro rights-of-way, greenways through developed areas).

Several regional and local corridors exist within the watershed. These are outlined below and shown in Figure 3.

Regional corridors within and adjacent to the Project Area (from Phillips Farevaag Smallenberg 2013):

1. Hjorth Creek from the north end of Tynehead Park to Highway 1;
2. Unnamed Tributary 2 from the eastern portion of Tynehead Park south to the Serpentine River;
3. Serpentine River from 168th Street to the confluence with E Creek;
4. 92nd Avenue right-of-way from E Creek to 176th Street, south along 176th Street to the 89th Avenue right-of-way, then east along this right-of-way to Lakiotis Creek;
5. Lakiotis Creek from the 89th Avenue right-of-way south to the Serpentine River;
6. Serpentine River downstream of Lakiotis Creek, south of 86th Avenue;
7. Leoran Brook from 94th Avenue to Highway 1 to the north, then north to the Fraser River; and
8. Latimer Creek at the southern portion of the watershed.

Local corridors within and adjacent to the Project Area:

9. Hjorth Creek north of Highway 1 may provide some connectivity to small natural areas and parks (sites) between Highway 1 and Surrey Bend Park to the north (outside of the watershed; Phillips Farevaag Smallenberg 2013);
10. The Serpentine River acts as a local corridor from the confluence with E Creek until the confluence with Lakiotis Creek near the 86th Avenue right-of-way (Diamond Head 2014);

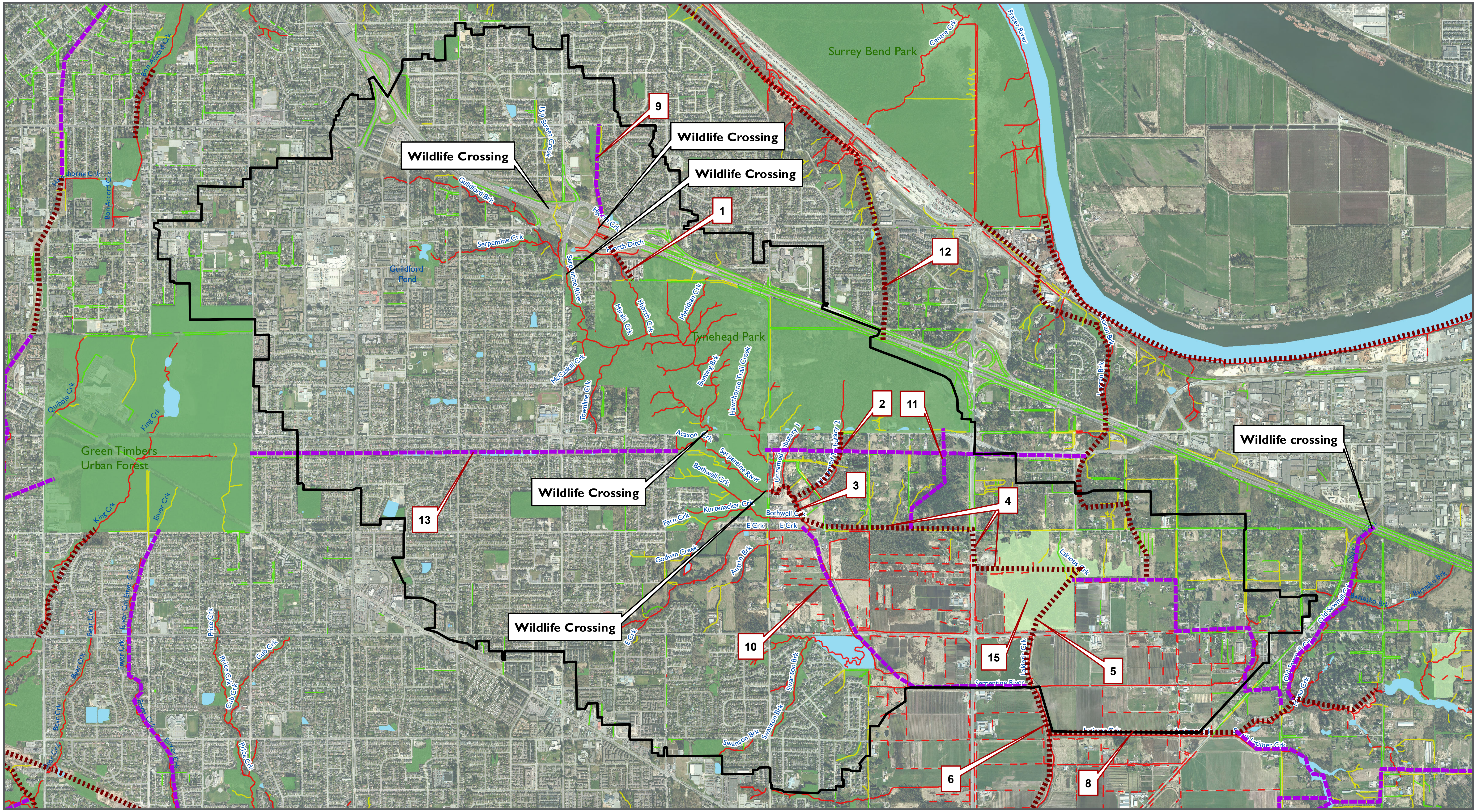
11. A park west of 176th Street and south of 96th Avenue connects the eastern portion of Tynehead Park to a Regional corridor along the 94th Avenue right-of-way to the south (Phillips Farevaag Smallenberg 2013);

12. Connectivity exists between the east portion of Tynehead Park and a small natural area east of 172nd Street north of Highway 1, which connects to Surrey Bend Park to the north. There is no wildlife crossing under Highway 1 at this location; and

13. The FortisBC right-of-way south of 96th Avenue provides connectivity with Green Timbers Urban Forest to the west, along the western boundary of the watershed. There are several regional and local corridors connecting Green Timbers Urban forest to many surrounding natural areas (eventually to Mud Bay via Bear Creek Park and other natural corridors to the south, and eventually to the Fraser River via several corridors and parks north of Green Timbers Urban Forest; Phillips Farevaag Smallenberg 2013). The FortisBC right-of-way also provides connectivity to a Regional Corridor along Leoran Brook to the west, near the eastern boundary of the watershed, and the local corridor through the park west of 176th Street (Phillips Farevaag Smallenberg 2013).

Wildlife crossings underneath major roadways allow connectivity between hubs along Local and Regional corridors. Important wildlife crossings in the Upper Serpentine watershed include:

- The clear-span bridge over the Serpentine River at 96th Avenue. This bridge provides adequate space for large wildlife to migrate between the south end of Tynehead Park and the natural areas immediately to the south;
- Underneath Highway 1 along both 159th Street Creek and Hjorth Creek. These may allow wildlife to travel between Surrey Bend Park along the Fraser River to the north and Tynehead Park and the surrounding natural areas;
- A large culvert (180 cm in diameter) exists where the Serpentine River is culverted under 160th Street, west of Tynehead Park, and provides connectivity to natural areas on Guildford Brook, Serpentine Creek and Guildford Pond (City of Surrey 2014);
- Twinned culverts (each 105 cm in diameter) convey the Serpentine River underneath 168th Street south of Tynehead Park and allow for connectivity to the Regional corridor along the river south of the 94th Avenue right-of-way (City of Surrey 2014); and
- Wildlife crossings just outside the study area also exist near 200th Street where Old Sawmill Creek crosses Highway 1 (outside of the watershed; Samantha Ward 2014).



DILLON CONSULTING	
Project #:	14-8893
Author:	ECH
Checked:	NG/ML
Status:	Draft
Revision:	A
Date:	2014 / 12 / 19

0 250 500 750 1,000 m

Scale: 1:28,000

N

Coordinate System:

UTM Zone 10N Nad83

Data Sources:

City of Surrey Open Data, ESRI Base Layers, Dillon Consulting Limited, Urban System

Wildlife Corridors

- Regional
- Local
- 1 Corridor Number

Watercourse Classification

- A
- A(O)
- B
- C

Upper Serpentine Watershed

Parks and Natural Areas

Waterbodies

High Priority Unprotected Habitat Areas

CITY OF SURREY the future lives here.

Upper Serpentine Integrated Stormwater Management Plan

Figure 3 - Terrestrial Habitat

4.0 SUMMARY AND CONCLUSION

The Project Area exhibits a wide range of habitat for both the aquatic and terrestrial components. Highly complex and valued habitat is exhibited by the Serpentine River in Tynehead Park where spawning and rearing for salmonids is possible. Tynehead Park also has numerous tributaries that could support salmonids or at least have a significant food/nutrient contribution to fish-occupied reaches. At the other end of the scale are a series of low value Class A(O) ditches with poor water quality that are generally suited to coarse fish species and have limited salmonid potential. Overlaying this is the impact experienced due to urban development. This is most exhibited by Guildford Brook and Serpentine Creek west of 160th Street where spawning gravels have largely been removed from the system due to erosive flow. This high flow can also have significantly detrimental effects on water quality.

On the terrestrial side, Tynehead Park is a significant and valued hub for wildlife species including large mammals not normally associated with an urban setting such as black bear and black-tailed deer. Other terrestrial habitat includes the impacted Agricultural Lowlands where biodiversity is quite low as well as the highly urbanized Zone 1A where terrestrial habitat value is very low. Overlaying this is a series of Regional and Local wildlife corridors which allow for movement of species between intact terrestrial hubs and sites throughout Surrey.

In general, there is significant potential in the Project Area if protection and enhancement is implemented to benefit terrestrial and aquatic resources.

5.0 REFERENCES

Backman, D. C. and Simonson, T. L. (1985). The Serpentine River Watershed Salmonid Resource Studies, Tynehead Zoological Park, 1984-1985.

BC Ministry of Environment. (2014) Water Quality Guidelines (Criteria) Reports – Approved and Working Guidelines. Accessed from http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html

BC Ministry of Environment. (2014b). Habitat Wizard – All Fish Points. Accessed from http://maps.gov.bc.ca/ess/sv/habwiz/

Bull, J. and Freyman, L. (2013). Status of Water Quality Objectives Attainment in the Little Campbell River, Serpentine River and Nicomekl River, 1971-2009. Surrey, BC: BC Ministry of Environment.

Canadian Council of Ministers of the Environment. (2014). Canadian Environmental Quality Guidelines Summary Table. Accessed from http://st-ts.ccme.ca/en/index.html

Canadian Council of Ministers of the Environment. (2007). Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Accessed from file:///C:/Users/42mpl/Downloads/Phosphorus%20(en)%20(1).pdf

City of Surrey (2014). City of Surrey's Online Mapping System (COSMOS). Retrieved fromhttp://cosmos.surrey.ca/external

Diamond Head Consulting Ltd. (2014). Biodiversity Conservation Strategy, City of Surrey. Vancouver, BC: Diamond Head Consulting Ltd.

Dillon Consulting Ltd (1996). Stormwater Management Review Feasibility and Functional Plans, Upper Serpentine Area #6. Richmond, BC: Dillon Consulting Ltd.

Dillon Consulting Limited (2001). Upper Serpentine River Area 1-4 Feasibility/Functional Study – Draft Report. Richmond, BC: Dillon Consulting Limited.

Dillon Consulting Limited (2013). SHaRP 2013 Salmon Habitat Restoration Program. Site Reference G3 – Gravel Deposition. Richmond, BC: Dillon Consulting Limited

Dillon Consulting Limited (2014). SHaRP 2014 Salmon Habitat Restoration Program. Site Reference REV-15. Richmond, BC: Dillon Consulting Limited

Donahue, P. (2012). Upper Serpentine River Salmon Spawning Gravel Restoration Pilot Project. Richmond, BC: Dillon Consulting Limited.

Evergreen. (2013). Water Quality Monitoring Data from the Tynehead Hatchery, Surrey – 2009 to 2013. Vancouver, BC.

I.D. Group/Duncan & Associates Engineering Inc. (1996). Upper Serpentine, Fleetwood and Greenway Basin Master Drainage Plan, City of Surrey. Volume 1 – Report. Surrey, BC: I.D. Group/Duncan and Associates Engineering Inc.

I.D. Group/Duncan & Associates Engineering Inc. (1996b). Upper Serpentine, Fleetwood and Greenway Basin Master Drainage Plan, City of Surrey. Volume 2 – Tables and Figures. Surrey, BC: I.D. Group/Duncan and Associates Engineering Inc.

Ministry of Environment (2012). BC Ecosystems Explorer. Victoria, BC: Ministry of Environment. Accessed on 11, 2014 from: http://a100.gov.bc.ca/pub/eswp/jsp/results.jsp?pager.offset=20

Personal Communication with Samantha Ward from Urban Systems Limited, March 12, 2014. List of Wildlife crossings of Highway 1, Surrey, BC.

Phillips Farevaag Smallenberg (2013). Surrey City Centre Green Network Study. Vancouver, BC: Phillips Farevaag Smallenberg.

Russell, S. H. (1993). Upper Serpentine River Drainage Study, Conceptual Review and Final Report. New Westminster, BC: Delcan Corporation.

Stantec Consulting Ltd. (2000). Upper Serpentine Detention Ponds (Hydro Ponds), Drainage Package D62/99. Vancouver, BC: Stantec Consulting Ltd.

Van der Eerden, J. (1996). Upper Serpentine Pump Station Project 4898-714 Functional Plan. Burnaby, BC: Associated Engineering

Visser, R. (1991). Upper Serpentine River Drainage Basin Water Quality Study. Surrey, BC: District of Surrey.

Web Engineering Ltd. (2011). City of Surrey 2011 Ravine Stability Assessment. Burnaby, BC: Web Engineering.

1.0 Enhancement Opportunities and Cost Estimates

A number of opportunities were identified that would benefit overall terrestrial or aquatic habitat value in the Study Area, either through direct enhancement of existing habitat, construction of new habitat, or by addressing those mitigating factors currently having negative impacts on habitat. These opportunities should be considered preliminary at this time as further study is required to determine feasibility, establish overall habitat benefit, and allow us to conduct the required cost/benefit analyses. While some of these opportunities would likely have a significant overall benefit, it may be that space limitations, property acquisition costs, existing land use and other conflicts could render some of them impractical.

The identified opportunities will primarily benefit either the aquatic or terrestrial habitat within the Study Area, although some may have benefits for both. These opportunities consist of the following.

Aquatic Habitat

- Improved runoff control;
- Fish access improvement;
- Instream enhancement;
- Riparian infill and enhancement (links to upland terrestrial habitat);
- Bank stabilization;
- Flow diversion;
- Removal of anthropogenic debris; and
- Fencing to prevent livestock access.

Terrestrial Habitat

- Increased tree canopy;
- Increased number of street trees;
- Improved wildlife crossings and corridors;
- Increased upland plant diversity;
- Removal of invasive species;
- Work with farmers to preserve habitat and support biodiversity; and
- Formal protection of intact forested blocks.

Discussion on these opportunities is provided below

1.1 Aquatic Habitat

1.1.1 Improved runoff control

In some sections of the Study Area, particularly Zone 1A, runoff control is quite limited. This has resulted in severe impacts to downstream aquatic habitat that has included scouring of spawning beds down to hardpan clay, bank erosion, decreased water quality, and severe impacts to spawning beds. Improved runoff control would significantly reduce these impacts and would also have a positive effect on some of the other aquatic enhancement opportunities. Runoff control would likely provide the greatest benefit to aquatic habitat of the opportunities listed here. However, it is anticipated that it would also be the most costly to implement and may not be feasible due to land use constraints. It is also possible that the timeline to achieve a noticeable benefit could be in the order of 10 or more years.

1.1.2 Fish access improvement

Fish access improvement has the benefit of opening up potentially large sections of channel that are currently inaccessible to fish. This would be of particular benefit where access is not compromised by natural features such as steep topography but due to anthropogenic barriers such as improperly installed culverts. These barriers can be removed through the installation of weirs or fish ladders, the reconstruction of poorly installed weirs, the installation of new infrastructure, or the construction of new channel habitat. Depending on the nature of the barrier and the extent of the channel to be opened up, both the cost and the benefit can be moderate to high. Implementation could be achieved in the short-term for some locations but may take considerably longer at other locations.

1.1.3 – Instream Enhancement

Instream enhancement is designed to add complexity to a channel in order to improve its ability to support fish. Enhancement can include the installation of weirs, large woody debris (typically logs) and boulder clusters for cover and improved rearing habitat. The initiation of a gravel recruitment program can supplement or even create spawning habitat. Depending on the extent of the enhancement, the benefits can be moderate to high and not difficult to implement. Implementation could take as little as one year to complete. Costs could be quite low for some opportunities, gravel recruitment for example, but are more likely to be moderate for weir, large woody debris and boulder cluster installations.

1.1.4 Riparian infill and enhancement

Riparian vegetation provides numerous benefits to aquatic habitat including shading, bank stabilization, a source of litter fall and insect drift, and attenuation of flow and pollutants. These benefits could be improved by increasing the width of riparian corridors through planting of native vegetation where it is currently lacking. The removal of invasive species and its replacement with native vegetation could also be achieved. The benefits can be quite extensive if conducted over a large area, but obviously this would be accompanied by increasing costs. Although initiation could be realized in as little as a year, the benefit could be considerably more difficult to achieve as installed vegetation would take time to mature, invasive species can be exceeding difficult to eradicate, and property access may be constrained.

It should be noted that riparian infill and enhancement would also improve terrestrial wildlife access.

1.1.5 Bank Stabilization

The primary benefit of bank stabilization for aquatic habitat is the removal of a source of sediment that can be conveyed to spawning beds downstream. Severe sedimentation can occur as a result of a catastrophic failure of the bank with the resulting smothering of spawning gravel as a result. An additional benefit is the retention and protection of riparian vegetation at erosion sites. It should be noted that some natural erosion is required to renew spawning gravel at downstream locations. Erosion protection can be implemented in the short-term and would have both a localized benefit as well as a benefit to downstream water quality.

1.1.6 Flow diversion

Flow diversion consists of the realignment of the storm sewer system to supplement flow within channels that have fish habitat value but which may have intermittent or ephemeral flow. Increased flow can create conditions that allow for longer term fish presence; however, the expense would be significant and difficult to implement. A detailed engineering study would be required to ensure the benefits of diversion are warranted or possible.

1.1.7 Removal of anthropogenic debris

Several of the watercourses in the Study Area were observed to have high levels of garbage in the channel. Removal would improve the aesthetics of the channel and remove potentially harmful substances that could leach into the water column. Implementation would be immediate and could be done at a low cost. For example, students from the SHaRP program could be utilized.

1.1.8 Fencing for livestock

Livestock that are able to access channels can have a significant effect on fish habitat. Impacts include destabilized banks, loss of instream complexity, loss of vegetation, and degraded water quality. Fencing would address these concerns. Implementation would result in an immediate benefit at a moderate cost.

1.2 Terrestrial Habitat

1.2.1 Increased tree canopy

An increased tree canopy would have obvious benefits to terrestrial habitat through an increase in overall area. It would also serve to attenuate rainfall, promote the recharge of ground water, and reduce the overall “flashiness” of watercourses in the Study Area through increased rainfall interception. Depending on the level of effort, costs could be moderate to high with increasing benefits realized with increasing canopy cover. Implementation could prove challenging where land may not be available or property owner “buy-in” is lacking. In addition, the benefits would not be realized for at least 5 to 10 years as the trees mature.

1.2.2 Increased number of street trees

Increased the number of street trees in the more developed sections of the Study Area, particularly Zone 1A, would create microhabitats which could be utilized by human-tolerant bird species for nesting and foraging. It would also contribute to the increased tree canopy as outlined in Section 1.2.1, above. Similar to increased tree canopy, implementation could prove challenging and longer term benefits would not likely be realized for at least 5 to 10 years.

1.2.3 Improved wildlife crossings and corridors

Alteration of the landscape for development purposes can result in a fragmentation of habitat. Wildlife that is restricted to movement on the ground (most mammals, reptiles and amphibians for example) can be reluctant to cross roads and, as a result, populations can sometimes not be sustained within the remaining habitat fragments. Improved corridors can remove or at least reduce this fragmentation effect. This can be accomplished either through allowing wildlife to bypass the road network (via a tunnel for example) or through a reduced road width at a crossing location. The corridors can also be enhanced through additional terrestrial planting to encourage wildlife presence. This would also have the added benefit of increasing the tree canopy. The infrastructure needed to achieve this enhancement opportunity, while having a significant benefit, would be expensive and difficult to implement.

1.2.4 Increased upland plant diversity

Increased plant diversity can be achieved through the installation of additional native species. For example, a planted Sitka spruce monoculture was observed in one section of Tynehead Park. Selective pruning and replacement with appropriate alternate species could be undertaken to improve overall habitat value. Implementation would not be difficult and the cost would be moderate. Benefits would be localized and likely take upwards of 5 years for an improvement to be observed.

1.2.5 Removal of invasive species

Invasive species can have a significant impact on biodiversity. They can out-compete native species and alter habitat such that native wildlife species diversity is reduced. The removal of invasive species and its replacement with native vegetation address this issue. However, the eradication of invasive species can be a difficult, labour-intensive, and long-term process. In addition, benefits may take at least 5 years to be realized.

1.2.6 Work with farmers to preserve habitat and support biodiversity

Farmers often have forested patches or wetlands on their properties. The retention of these features would obviously have significant habitat benefits. The City could enter into mutually beneficial agreements to protect these features. Such agreements could include tax benefits, for example. The ease of implementation and the potential cost would be largely dependent on the individual farmer. However, if successful, benefits could be realized immediately.

1.2.7 Formal protection of intact forested blocks

Some land owners have intact forest blocks on their properties. The retention of these blocks would have an obvious benefit to terrestrial habitat as well as increase rainfall interception for the benefit of storm water impact mitigation. The purchase of these properties to create parks for example, would provide this benefit. Costs would likely be quite high and the designations of park space difficult to implement.

1.3 Cost Estimates

The following table outlines the various enhancement opportunities by zone for both the aquatic and terrestrial habitat. High level cost estimates have been developed for both design and construction as well as annual operations and maintenance. The cost of property acquisition for the construction of, for example, detention features or park land is not included in the estimates.

Zone	Location	Opportunity	Cost		Comments
			Design & Construction	Operations & Maintenance	
Aquatic					
Zone 1A	Serpentine Creek, Guildford Brook	Improved runoff control	$250,000 to $1,000,000	$2,000	Will address concerns with erosive flow in the channels. Property acquisition required, likely as a requirement for a stormwater detention pond(s) in the headwater areas.
Zone 1A	Guildford Pond	Fish access improvement	$15,000 to $30,000	<$1,000	Remove or improve weir at pond outlet; installation of fish ladder may be considered.
Zone 1A	Guildford Pond	Instream enhancement	$1,000 per log or boulder cluster; ($20,000 minimum)	<$1,000	Including installation of large woody debris (logs) cabled onto the banks or large rocks and/or the installation of boulder clusters. Suggest minimum of 10 each to add complexity to the pond.
Zone 1A	Hjorth Creek, 159th Street Creek north of Highway 1	Fish access improvement	$150,000	<$1,000	Confirm if recent Highway 1 works achieved fish access prior to initiating design. Retrofit of pipe may be required if access is not possible.
Zone 1A	Hjorth Creek, 159th Street Creek north of Highway 1	Instream enhancement	$1,000 per log or boulder cluster, $1,500 per weir ($10,000 minimum per channel)	<$1,000	Assumes access is possible. Including installation of weirs, large woody debris (logs) cabled onto the banks or large rocks and/or the installation of boulder clusters. Suggest minimum of 10 per channel to add complexity to the channel. Look for partnership opportunities with Fraser Heights Secondary School.
Zone 1A	Hjorth Creek, 159th Street Creek north of Highway 1	Riparian infill and enhancement	$50/m^2	Varies based on extent	Cost includes topsoil, seeding and installation of one native plant; annual maintenance would vary depending on extent of planting. Look for partnership opportunities with Fraser Heights Secondary School.
Zone 1A	Serpentine River at confluence of Guildford Brook and Serpentine Creek (160th Street)	Improved runoff control	$250,000 to $1,000,000	$2,000	Will address concerns with erosive flow in the channels. Property acquisition required, likely as a requirement for a stormwater detention pond(s) in the headwater areas.
Zone 1A	Serpentine River at confluence of Guildford Brook and Serpentine Creek (160th Street)	Bank stabilization	$15,000 to $20,000	<$1,000	Includes the installation of native vegetation at completion of construction.
Zone 1A	Swanson Brook	Flow diversion	$100,000	<$1,000	An engineering study would be required to determine feasibility and overall benefit.
Zone 1A	Swanson Brook	Removal of anthropogenic debris	$2,500	None	Opportunity for SHaRP program involvement.
Zone 1A	Swanson Brook	Fish access improvement	$25,000	<$1,000	Possible installation of fish ladder or improvement of weir structures. Investigate benefit or creating access during summer months when flow in both the Serpentine River and Swanson Brook would be low.
Zone 1B	Unnamed Tributary 1 and 2	Instream enhancement	$1,000 per log or boulder cluster; $1,500 per weir ($10,000 minimum per channel)	<$1,000	Including installation of weirs, large woody debris (logs) cabled onto the banks or large rocks and/or the installation of boulder clusters. Suggest minimum of 10 per channel to add complexity to the channels.

Zone	Location	Opportunity	Cost		Comments
			Design & Construction	Operations & Maintenance	
Zone 2	Miraki Creek, Bunting Brook, four unnamed swales in northwest Tynehead Park, Hawthorne Trail Creek and tributaries	Fish access improvement	$1,500/weir	<$1,000	Access improvements would consist of the installation of a series of weirs. Number of weirs needed would require a detailed site assessment including the investigation of existing fish access and habitat value.
	Bothwell Creek near 168th Street	Instream enhancement	$1,000 per log or boulder cluster; $1,500 per weir ($50,000 minimum)	<$1,000	Assumes access is possible. Including installation of weirs, large woody debris (logs) cabled onto the banks or large rocks and/or the installation of boulder clusters. Suggest minimum of 5 to add complexity to the channel.
		Riparian infill and enhancement	$50/m^2	Varies based on extent	Cost includes topsoil, seeding and installation of one native plant; annual maintenance would vary depending on extent of planting. Riparian widening may require City acquiring a right-of-way along this section of stream at a higher additional cost.
		Fencing to prevent livestock access	$55/m	<$1,000	This would be contingent on a City right-of-way or property ownership agreement.
Zone 3	Serpentine River main channel south of 88th Avenue	Instream enhancement	$1,000 per log or boulder cluster ($20,000 minimum)	<$1,000	Including installation of large woody debris (logs) cabled onto the banks or large rocks and/or the installation of boulder clusters. Suggest minimum of 10 each to add complexity to the channel.
	E Creek and Austin Brook near 168th Street	Instream enhancement	$1,000 per log or boulder cluster; $1,500 per weir ($5,000 per channel minimum)	<$1,000	Including installation of weirs, large woody debris (logs) cabled onto the banks or large rocks and/or the installation of boulder clusters. Suggest minimum of 5 per channel to add complexity to the channel.
		Riparian infill and enhancement	$50/m^2	Varies based on extent	Cost includes topsoil, seeding and installation of one native plant; annual maintenance would vary depending on extent of planting. Riparian widening may require City acquiring a right-of-way along these sections of stream at a higher additional cost.
		Fencing to prevent livestock access	$55/m	<$1,000	This would be contingent on a City right-of-way or property ownership agreement.
	E Creek at 88th Avenue	Fish access improvement	$35,000	<$1,000	Assumes fish access to 88th Avenue.
	E Creek	Improved runoff control	$500,000	$2,000	Will address concerns with erosive flow in the channels. Property acquisition required, likely as a requirement for a stormwater detention pond(s) in the headwater areas.
	Latimer Creek, Lakiotis Creek, linear A(O) channels	Riparian infill and enhancement	$50/m^2	Varies based on extent	Cost includes topsoil, seeding and installation of one native plant; annual maintenance would vary depending on extent of planting. Riparian widening may require City acquiring a right-of-way along these streams at a higher additional cost. Should include agreements with farmers to restrict farming near channel tops-of-bank.

Zone	Location	Opportunity	Cost		Comments
			Design & Construction	Operations & Maintenance	
	Roadside ditches	Bank stabilization	$5,000-$10,000	<$1,000	Requires periodic assessment by Operations crews.
All	All watercourses	Instream enhancement	$2,500/year	none	This opportunity is specific to the City's gravel recruitment program. Follow up on results of the program and identify areas for future deployment; opportunity for SHaRP involvement.
		Riparian infill and enhancement	$50/m^2	Varies based on extent	Cost includes topsoil, seeding and installation of one native plant; annual maintenance would vary depending on extent of planting. Educate owners of adjacent properties about not planting invasive species in residential gardens that can spread to natural areas.
		Removal of anthropogenic debris	$2,500	None	Opportunity for SHaRP program involvement.
Terrestrial					
Zone 1	Throughout study area	Increased tree canopy Increased number of street trees	$50/m^2	Varies based on extent	Cost and benefit dependent on number of trees planted.
Zone 1a	Highway 1 at 172nd Street alignment	Improved wildlife crossing and corridor	$250,000+	<$1,000	Confirm existing condition of corridors leading to the 172nd Street alignment to determine if an improved crossing would be beneficial. A crossing wold likely take the form of a wildlife underpass.
Zone 2	Tynehead Park, west of Serpentine River, north of 96th Avenue	Increased upland plant diversity	$5,000	$1,000 for replacement stock after Year 1 only	This opportunity is specific to pruning the Sitka spruce monoculture. After replacement of dead stock one year after planting, no further maintenance required. Additional upland diversity could be achieved at a cost of $50/m^2.
	Tynehead Park east and west of 168th Street	Removal of invasive species	$50/m^2	Varies based on extent	Educate owners of adjacent properties about not planting invasives in residential gardens that can spread to natural areas; educate public about not disturbing riparian corridors following enhancement. Eradication can require several years' effort.
Zone 3	Whole area south of 92nd Avenue	Work with farmers to preserve habitat and support biodiversity	None	None	No construction required but negotiation would be required with property owners.
	Woodlot north of 88th Avenue and east of 176th street	Formal protection of intact forested blocks			No construction but property acquisition would be required.
All	Whole Area	Improved wildlife crossings and corridors	$50/m^2	Varies based on extent	Consisting of additional planting where possible in existing wildlife corridors.

APPENDIX D

GEOTECHNICAL ASSESSMENT

THURBER ENGINEERING LTD.

UPPER SERPENTINE INTERGRATED STORMWATER MANAGEMENT PLAN

GEOTECHNICAL ASSESSMENT

Report to

URBAN SYSTEMS LTD.

Thurber Engineering Ltd.
Vancouver, B.C

Andy Bowker, P.Eng, C.Geol. (UK)
Project Engineer

PROFESSIONAL
PROVINCE OF
A. G. BOWKER
39481
BRITISH
COLUMBIA
ENGINEER

Dec 10, 2014

December 10, 2014
File No: 17-610-183

David Hill, P.Eng.
Review Principal

THURBER

TABLE OF CONTENTS

THURBER

1. INTRODUCTION

As requested, Thurber Engineering Ltd. (Thurber) has completed a geotechnical assessment of the Upper Serpentine River watershed to support Urban Systems Ltd. (USL)'s development of an Integrated Storm Water Management Plan (ISMP) for the City of Surrey (City). The assessment was carried out in general accordance with our proposal dated September 3, 2014.

This report has been prepared for the exclusive use of USL and the City. Use of this report is subject to the attached Statement of Limitations and Conditions that are an integral part of this report. Any use that a third party makes of this report, or any reliance on decisions based on it are the responsibility of such third parties. Thurber accepts no responsibility for damages incurred by third parties as a result of decisions made or actions taken based on this report.

2. BACKGROUND AND SCOPE OF WORK

The Upper Serpentine ISMP study area is shown in Figure 1. The study area occupies around 2,600 hectares and is approximately bounded by 144 Street to the west and 188 Street to the east and by 85 to the south and 112 Avenues to the north. The ISMP focuses upon urban development in the upper reaches of the east channel of the Serpentine watershed in the high ground area. Only a minor portion at the southern edge of the study area is located in the Serpentine lowlands.

The scope of Thurber's works is to provide an overview level report describing:

- the surficial geology and drainage characteristics in the study area
- the current conditions at erosion site 25-3 previously identified by Web Engineering Ltd. (Web, 2011).

To complete these tasks Thurber carried out a review of in-house and publically available geotechnical information as well as geotechnical information provided by the City. Thurber also inspected erosion site 25-3 in December 2013 to document current conditions.

3. DESKTOP INFORMATION REVIEW

3.1 General

Topopgraphically, the northwest portion of the study area comprises an area of high ground where the Fraser Heights, Guildford, Johnson Heights and Fleetwood neighbourhoods are located. The study area to the south of about 92A Avenue comprises the most northerly portion of the Serpentine Lowlands.

In the high ground area, the Serpentine River has carved a northwest-southeast trending main channel valley with numerous dendritic tributary channels, most of which are individually named creeks. Upon reaching the lowland, the river is channelized within flood control dykes and flows southward, ultimately draining into Mud Bay. The ground surface in the highlands in the northwest of the study area reaches about El. 110 m, sloping down to the southeast to the lowlands at an elevation a few meters above sea level.

3.2 Ground and Groundwater Conditions

3.2.1 Published Geological Information

According to the Geological Survey of Canada 1:50,000 scale map sheet 1484A Surficial Geology for New Westminster, the study area uplands are predominantly underlain by Capilano Sediments (C_d) and pockets of Vashon Drift (VC) of Pleistocene Age, as shown in Figure 2. The Capilano Sediments comprise marine and glaciomarine stony (including till-like) deposits to stoneless silt loam to clay loam with minor sand and silt normally less than 3 m thick, but up to 30 m thick, thickening to the west. These C_d deposits are generally competent, stiff, fine grained soils. Vashon Drift is exposed in the uplands locally and on Upper Serpentine River System north and south valley sidewalls. At these locations, the Vashon Drift consists of till, glaciofluvial sands and gravel, glaciolacustrine laminated stony silt and ice contact deposits. Overlying the Capilano Sediments in the southeast lowlands are postglacial Salish Sediments (SA_b) of Quaternary Age comprising generally bog, swamp and shallow lake deposits and predominantly lowland peat up to 14 m thick.

3.2.2 Published Aquifer Classification information

As shown on the BC Ministry of Environment (BC MoE) online mapping, the entire upland portion of the study area has been classified by the BC MoE Water Protection and Sustainability Branch as the IIIC Newton Upland Aquifer. The qualifier "III" refers to a light development aquifer subclass, indicating demand is relatively low compared to productivity, and the qualifier "C" indicates a low vulnerability subclass. The portion of the study area occupied by the Salish Sediments, i.e. the lowlands, does not appear to have an aquifer classification.

3.2.3 Test Hole/Water Well Log Information

A review of 24 test hole and 11 water wells logs obtained from Thurber in house files and the City's records has been completed. The locations of the test holes and water wells are shown on Figures 1 and 2 and the logs are attached in Appendix 1. A summary of the test holes with relevant key information is given in Table 1.

The soil profiles reported on the test holes are generally consistent with the published geology and encountered predominantly shallow fills, topsoil or clay/silt caps over dense, till-like, silty sand soils in the uplands. In the southeast available test holes encountered around 2 to 6.5 m of peat over clay.

Groundwater was encountered in 16 of the reviewed test holes. Artesian flows were recorded in WTN-19770 (0.5 US gal/min), WTN-2924 (0.1 US gal/min) and WTN-54689 (0.33 US gal/min).

Standing water levels of less than 1 m depth were observed in test holes AH/CPT-04-01 (0.9 m) and WTN-20543 (0.6 m). The three aforementioned wells with artesian conditions and the two shallow water levels were in wells/test holes located generally at lower elevations and/or within the lowlands to the southeast.

Table 1 – Test Hole and Water Level Information

Test Hole/Well	Depth (m)	Water Level[1] (m)	Comment	Date	Engineer	Type
AH/CPT 04-04	9.1	0.9[P] 4/05/2004		04/05/2004	GAL	SSA/CPT
AH06-01				29/06/2006	GAL	SSA
AH06-12	3		Wet below 2.29m	29/06/2006	GAL	SSA
BH05-03	5.5		Piezo: dry 26/05/2005 and 20/09/2005	08/04/2005	GAL	MR
BK04-01	14.8			05/05/2004	GAL	Becker
BK04-77	26.4		Wet below 16.46m	10-11/05/2004	GAL	Becker
D&M AH1					D&M	HA
D&M AH2					D&M	HA
D&M AH3					D&M	HA
D&M AH4					D&M	HA
LVT TH1	7.6	2.7[P] 17/12/1999	Perched water at 0.6m during drilling	08/12/1999	LES	SSA
LVT TH2	4.6		Ponding at surface during drilling	08/12/1999	LES	SSA
LVT TH3	6.1	0.5	Seepage during drilling	08/12/1999	LES	SSA
TH12-01	9.1	1.7[P] 27/11/2012		23/11/2012	Thurber	SSA
TH12-02	6.1			23/11/2012	Thurber	SSA
TH12-03	9.1		wet below 3.7m	23/11/2012	Thurber	SSA
TH12-04	6.1			23/01/1900	Thurber	SSA
TH12-05	6.1	1.9	Piezo installed, no reading	23/01/1900	Thurber	SSA
TH-E1-08-451		6.8		19/11/2008&10/05/2009	Thurber	SSA/MR
TH-E1-08-452	7.9		Dry at construction	19/11/2008&12/03/2009	Thurber	SSA/MR
TP13-04	1.6		no seepage observed	30/01/2013	Thurber	Backhoe
TP13-05	2.2		no seepage observed	30/01/2013	Thurber	Backhoe
TP13-06	1.9		no seepage observed	30/01/2013	Thurber	Backhoe
WTN-100690	20.7	0.6		2004		
WTN-11037	4	4		1950		
WTN-11192	5.2	2.1		1950		
WTN-11296	4.3	3.7		1950		
WTN-11305	11.6	3		1950		

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Test Hole/Well	Depth (m)	Water Level[1] (m)	Comment	Date	Engineer	Type
WTN-19770[A]	100.6			1966		
WTN-20543	129.5	6.7		1967		
WTN-2848	21.6	20.1		1947		
WTN-2924[A]	27.4			1948		
WTN-54689[A]	115.8			1985		
WTN-78527	47.9	4.6		1993		

Notes: Golder Associates Limited (GAL), Dames and Moore (D&M), Levelton Engineering Solutions (LES), SSA=Solid Stem Auger, MR=Mud Rotary, CPT=Cone Penetrometer, [A]artesian flows, [1]water level depth during drilling (m) unless suffix [P] which indicates piezometer reading and date, the prefix WTN indicates a water well

In the uplands, groundwater levels were typically encountered at around 2 to 4 m depth, and up to about 7 m depth. It is noted that information listed on some water wells is over 50 years old, may record driller's observations and may not be wholly reliable.

4. EROSION SITE 25-3 OBSERVATIONS

Web (2011) identified a single high risk erosion site on the Upper Serpentine River. The Web ravine stability assessment data sheet for the site commented as follows:

2009 comment: Continuation of erosion with many trees undermined in this area. Significant changes from 2005 to 2007 to 2009.

2011 comment: Erosion prevalent. New trees look to have fallen in river recently.

A site reconnaissance was completed on December 16, 2013 by David Regehr, P.Eng. of Thurber. The purpose of the site visit was to observe the site/slope conditions and compare the current conditions to those shown on the 2011 Web data sheet for the site which is provided in Appendix 2. Photographs of the site were taken and exposed soil conditions were logged in the field. Photo 1 was taken for comparison with the first Web 2011 photograph.

Creek erosion on the right bank has resulted in sloughing and slope instability of the creek bank. A large tree has fallen across the creek, likely due to undermining of the creek bank. The tree is still alive and, based on observed new limb growth, it may have fallen a few years ago. The root ball of the tree is currently retaining sloughed material on the slope above (Photo 2). Upstream of the fallen tree, there is an approximately 3 to 4 m high, semi-vertical exposed soil slope. The soil profile exposed in the slope comprises grey, very dense, silty sand with some gravel, a trace of clay and occasional boulders i.e. Vashon Drift glacial till which is consistent with the published information. Recent ravelling and minor sloughing of this exposed soil slope has occurred, likely due to ongoing weathering process such as freeze/thaw and surface erosion. The lower portion of the slope is also likely subject to creek erosion during periods of high creek flows. There is grey/brown sand with some silt (possibly C_d deposits) exposed in the upper portion of the slope at the head scarp. No seepage from the slide scarp area was noted during the site visit.

Beyond the weathering and ravelling described above, there appeared to be little change in the overall slope conditions as compared to the 2011 data sheet photos. Vegetation is becoming more established in the slough material upslope of the tree root ball and in some areas of the head scarp. The overhanging roots/vegetation mat seen along the crest of the slope in the photos appears to be unchanged. The trees along the crest do not appear to be undermined or adversely affected by the slide scarp.

In our opinion, the risk assessment levels shown in the 2011 Data Sheet for the site are somewhat conservative. However, risk assessment levels for this earlier study are subjective and we assume somewhat comparative to all the sites that were reviewed for the larger study.

For continuity with the previous ravine surveys we provide the following comment:

2013 Comment: Erosion continues at creek level with some minor sloughing of the bank. There does not appear to be recent retrogression of the crest of slope. Some erosion of the toe of the slope upstream of a fallen tree.

5. DISCUSSION AND CONCLUSIONS

The western uplands within the study area are generally underlain by Capilano Sediments with localized pockets of Vashon Drift of Pleistocene Age. The predominant soils are generally fine grained as indicated by the both the available mapping and test hole and water well records. The lowland test holes and wells recorded peat deposits over clays, also in agreement with published information.

In our opinion the upland silts and sands are likely to offer low to moderate permeabilities. Barnes (2000) provides permeabilities in the range $1x10^{-5}$ to $1x10^{-6}$ ms^{-1} for silty fine sands to $1x10^{-8}$ ms^{-1} for silts.

In our opinion, relatively low permeability upland native soils are likely to offer moderate to low infiltration potential and elevated surface run-off potential. Natural drainages are likely to be semi-flashey and relatively quickly convey flows from upland to lowland areas.

Under periods of prolonged rainfall, the lowland, flat lying, surficial peat and organic silt soils overlying low permeability clays are likely to promote elevated groundwater levels. The lowlands will become saturated in response to prolonged periods of rainfall and offer minimal to no storage, resulting in surface water ponding.

If required, new ditches and irrigation channels in the lowlands are likely to encounter peat and organic silt soils and high groundwater conditions, particularly in winter. Further, any new dykes built to manage surface waters will require careful construction on soft, sensitive peat and organic soils and should be designed by a professional geotechnical engineer to manage the risk of foundation soil failure and/or slope failure within the dyke service life.

REFERENCES

Barnes G.E. (2000) Soil Mechanics Principals and Practice 2nd ed. MacMillan Press Limited.

BC Water Resources Atlas (http://webmaps.gov.bc.ca/imf5/imf.jsp?site=wrbc)

BC Ministry of Environment Water Protection and Sustainability Branch Aquifer Classification Mapping (http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/index.html)

Dames and Moore (1992) Stage 1 – Concept Studies Preliminary Geotechnical Report Upper Serpentine Drainage Study Surrey, B.C.

Levelton Engineering Solutions (1999) Geotechnical Assessment Report Proposed 103'A' Avenue Detention Pond 103'A' Avenue & 154th Street Surrey, BC

Web Engineering Limited (2011) City of Surrey 2011 Ravine Stability Assessment

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering or environmental consulting practices in this area. No other warranty, expressed or implied, is made.

2. COMPLETE REPORT

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

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

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document, subject to the limitations provided herein, are only valid to the extent that this Report expressly addresses proposed development, design objectives and purposes, and then only to the extent there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation or to consider such representations, information and instructions.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS WE MAY EXPRESSLY APPROVE. The contents of the Report remain our copyright property. The Client may not give, lend or, sell the Report, or otherwise make the Report, or any portion thereof, available to any person without our prior written permission. Any use which a third party makes of the Report, are the sole responsibility of such third parties. Unless expressly permitted by us, no person other than the Client is entitled to rely on this Report. We accept no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without our express written permission.

5. INTERPRETATION OF THE REPORT

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

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by us. We are entitled to rely on such representations, information and instructions and are not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

(see over …)

c) Design Services: The Report may form part of the design and construction documents for information purposes even though it may have been issued prior to the final design being completed. We should be retained to review the final design, project plans and documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the report recommendations and the final design detailed in the contract documents should be reported to us immediately so that we can address potential conflicts.

d) Construction Services: During construction we must be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RISK LIMITATION

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause an accidental release of those substances. In consideration of the provision of the services by us, which are for the Client's benefit, the Client agrees to hold harmless and to indemnify and defend us and our directors, officers, servants, agents, employees, workmen and contractors (hereinafter referred to as the "Company") from and against any and all claims, losses, damages, demands, disputes, liability and legal investigative costs of defence, whether for personal injury including death, or any other loss whatsoever, regardless of any action or omission on the part of the Company, that result from an accidental release of pollutants or hazardous substances occurring as a result of carrying out this Project. This indemnification shall extend to all Claims brought or threatened against the Company under any federal or provincial statute as a result of conducting work on this Project. In addition to the above indemnification, the Client further agrees not to bring any claims against the Company in connection with any of the aforementioned causes.

7. SERVICES OF SUBCONSULTANTS AND CONTRACTORS

The conduct of engineering and environmental studies frequently requires hiring the services of individuals and companies with special expertise and/or services which we do not provide. We may arrange the hiring of these services as a convenience to our Clients. As these services are for the Client's benefit, the Client agrees to hold the Company harmless and to indemnify and defend us from and against all claims arising through such hirings to the extent that the Client would incur had he hired those services directly. This includes responsibility for payment for services rendered and pursuit of damages for errors, omissions or negligence by those parties in carrying out their work. In particular, these conditions apply to the use of drilling, excavation and laboratory testing services.

8. CONTROL OF WORK AND JOBSITE SAFETY

We are responsible only for the activities of our employees on the jobsite. The presence of our personnel on the site shall not be construed in any way to relieve the Client or any contractors on site from their responsibilities for site safety. The Client acknowledges that he, his representatives, contractors or others retain control of the site and that we never occupy a position of control of the site. The Client undertakes to inform us of all hazardous conditions, or other relevant conditions of which the Client is aware. The Client also recognizes that our activities may uncover previously unknown hazardous conditions or materials and that such a discovery may result in the necessity to undertake emergency procedures to protect our employees as well as the public at large and the environment in general. These procedures may well involve additional costs outside of any budgets previously agreed to. The Client agrees to pay us for any expenses incurred as the result of such discoveries and to compensate us through payment of additional fees and expenses for time spent by us to deal with the consequences of such discoveries. The Client also acknowledges that in some cases the discovery of hazardous conditions and materials will require that certain regulatory bodies be informed and the Client agrees that notification to such bodies by us will not be a cause of action or dispute.

9. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on our interpretation of conditions revealed through limited investigation conducted within a defined scope of services. We cannot accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

FIGURES

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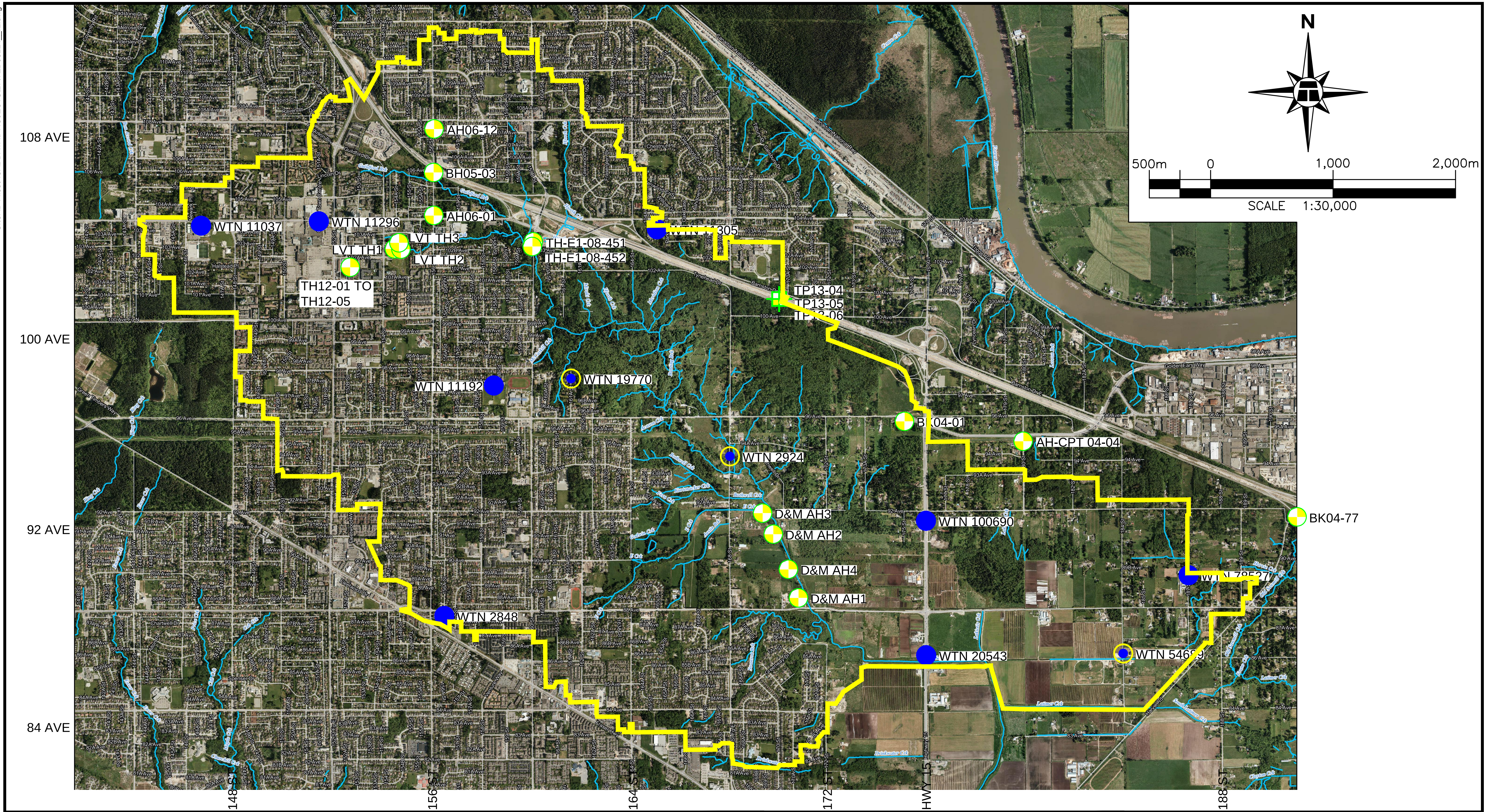

NOTES:
1. BASE MAP PROVIDED BY USL NOV. 1, 2013.
2. REFER TO REPORT TEXT FOR TEST HOLE DETAILS.

LEGEND:
- ARTESIAN WELL
- WELL
- TEST HOLE
- TEST PIT
- ISMP STUDY AREA
- OPEN CHANNEL

REV	DESCRIPTION	DATE	BY
1	REVISED ISMP STUDY AREA ISSUED WITH THURBER ENGINEERING DEC. 10, 2014 REPORT	DEC. 10, 2014	AGB
0	WITH THURBER ENGINEERING LIMITS, FEB. 3, 2014 REPORT	FEB. 3, 2014	NAK

REVISIONS

URBAN SYSTEMS LTD.

STUDY AREA

UPPER SERPENTINE INTEGRATED STORMWATER MANAGEMENT PLAN

SURREY, B.C.

THURBER ENGINEERING LTD.

ENGINEER:	CHECKED:	DRAWN:	
AGB	DWH	NAK	
DATE:	SCALE:	PROJECT No:	FIG:
FEB. 3, 2014	1:30,000	17-610-183	1

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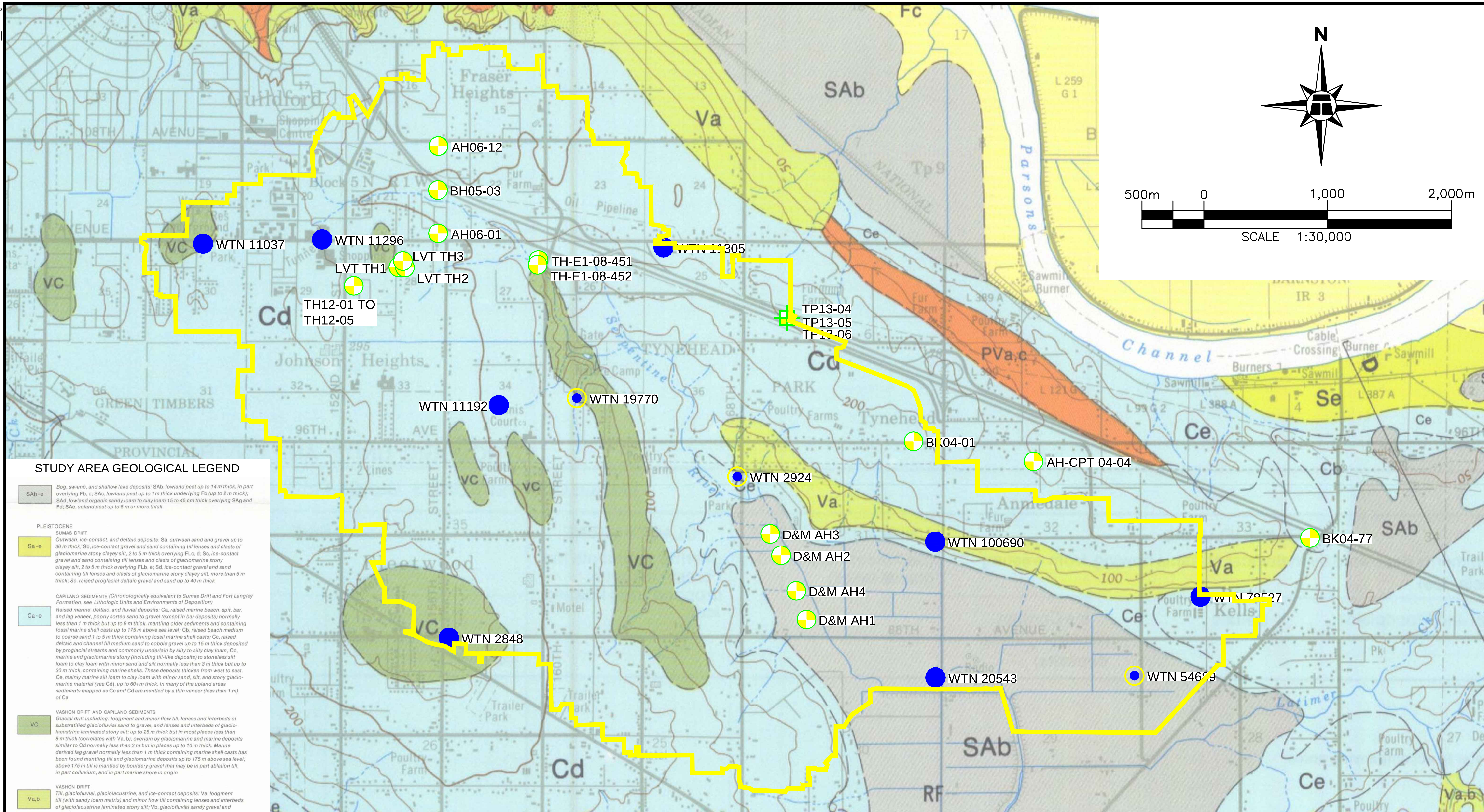


NOTES:

1. SURFICIAL GEOLOGY EXTRACT FROM GEOLOGICAL SURVEY OF CANADA 1:50,000 SCALE MAP SHEET 1484A SURFICIAL GEOLOGY NEW WESTMINSTER (1977).
2. REFER TO REPORT TEXT FOR TEST HOLE DETAILS.

LEGEND:

- ARTESIAN WELL
- WELL
- TEST HOLE
- TEST PIT
- ISMP STUDY AREA

REV	DESCRIPTION	DATE	BY
1	REVISED ISMP STUDY AREA ISSUED WITH THURBER ENGINEERING DEC. 10, 2014 REPORT	DEC.10, 2014	AGB
0	WITH THURBER ENGINEERING LIMITS, FEB. 3, 2014 REPORT	FEB. 3, 2014	NAK

REVISIONS

URBAN SYSTEMS LTD.

SURFICIAL GEOLOGY

UPPER SERPENTINE INTEGRATED STORMWATER MANAGEMENT PLAN

SURREY, B.C.

THURBER ENGINEERING LTD.

ENGINEER:	CHECKED:	DRAWN:	
AGB	DWH	NAK	
DATE: FEB. 3, 2014	SCALE: 1:30,000	PROJECT No: 17-610-183	FIG: 2

PHOTOGRAPHS

Photo 1 – Image for comparison with Web 2011 ravine study photograph (Dec 16, 2013)

Photo 2 – Large root ball with creek flowing under fallen tree. Glacial till exposed in a near vertical slope upstream of the root ball (Dec 16, 2013).

APPENDIX 1 – TEST HOLES AND WATER WELLS

RECORD OF AUGERHOLE: AH 04-4

PROJECT No.: 022-1138 (2260)

LOCATION: 180th St., South of 96th Ave.
N: 49242.6 E: 20344.6

BORING DATE: May 4, 2004

SHEET 1 OF 1

DATUM: Geodetic

BORING METHOD: Conetec M7 Marl - Truck Mounted Auger

SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m
Ground Surface	43.96			
Asphalt	43.86 / 0.10			
Compact to dense, moist to dry, brown SAND and GRAVEL, trace silt. (FILL)	43.50 / 0.46	1	AS	
Firm to stiff, wet, brown CLAYEY SILT to SILTY CLAY, trace sand.	41.52 / 2.44	2, 3	AS	
Stiff, wet, grey, SILTY CLAY to CLAY, trace sand.	40.61 / 3.35	4	AS	
Compact to dense, wet, grey, sandy SILT, trace clay.	36.34 / 7.62	5, 6	AS	
Dense, wet, grey, sandy SILT, trace to some sub-rounded gravel.	34.82 / 9.14	7	AS	
End of AUGERHOLE.				

DEPTH SCALE METRES: 0 – 10

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp —○W— Wl — 20 40 60 80

ADDITIONAL LAB. TESTING

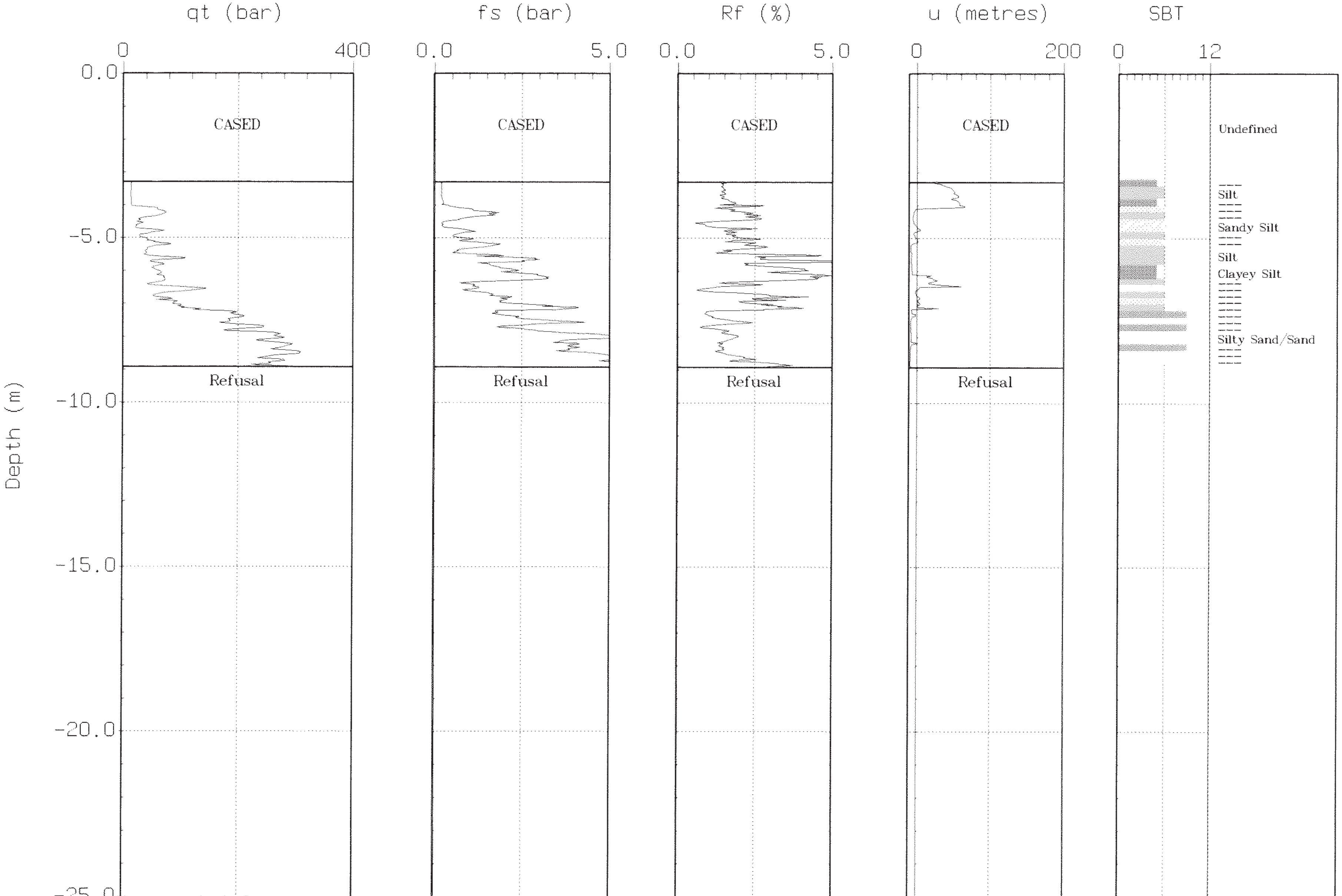
PIEZOMETER OR STANDPIPE INSTALLATION: May 4/04 ∇

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AH
CHECKED: TB/TK

ConeTec | Golder | Site: CPT04-04 | Cone: 20 Ton St 150
Location: 180 Street | Date: 05:04:04 14:32



Max. Depth: 8.93 (m)

Depth Inc.: 0.025 (m)

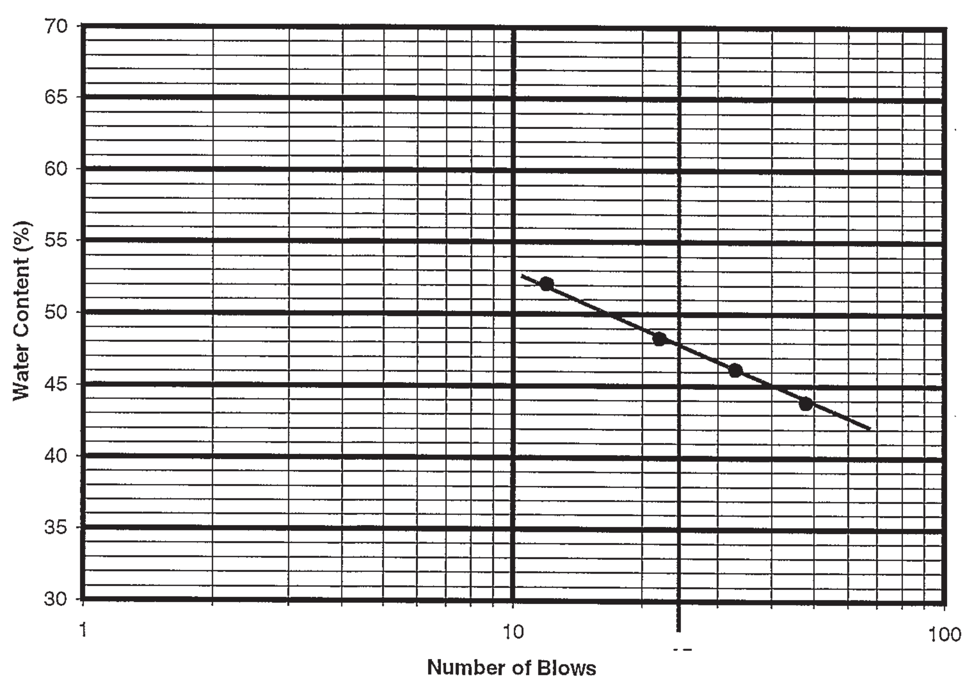
SBT: Soil Behavior Type (Robertson 1990)

Project # 022-1138-2260 Tech : TP

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER						
NUMBER OF BLOWS	33	22	12	48		
MASS WET SOIL + TARE	31.16	31.18	41.54	50.43		170.40
MASS DRY SOIL + TARE	25.64	25.24	35.41	43.72		127.30
MASS OF WATER	5.52	5.94	6.13	6.71		43.10
MASS OF CONTAINER	13.68	12.94	23.64	28.41		18.10
MASS OF DRY SOIL	11.96	12.30	11.77	15.31		109.2
WATER CONTENT W (%)	46.2	48.3	52.1	43.8		39.5

TYPE OF TEST	PL	PL	BOREHOLE NO.	AH04-04
CONTAINER NUMBER			SAMPLE	AS 4
MASS WET SOIL + TARE	31.23	30.68	DEPTH	2.44-2.74m
MASS DRY SOIL + TARE	30.54	30.19	LIQUID LIMIT (%)	47.7
MASS OF WATER	0.69	0.49	PLASTIC LIMIT (%)	24.1
MASS OF CONTAINER	27.72	28.13	PLASTICITY INDEX (%)	23.6
MASS OF DRY SOIL	2.82	2.06	W% Natural (%)	39.5
WATER CONTENT W (%)	24.5	23.8	LIQUIDITY INDEX	0.65



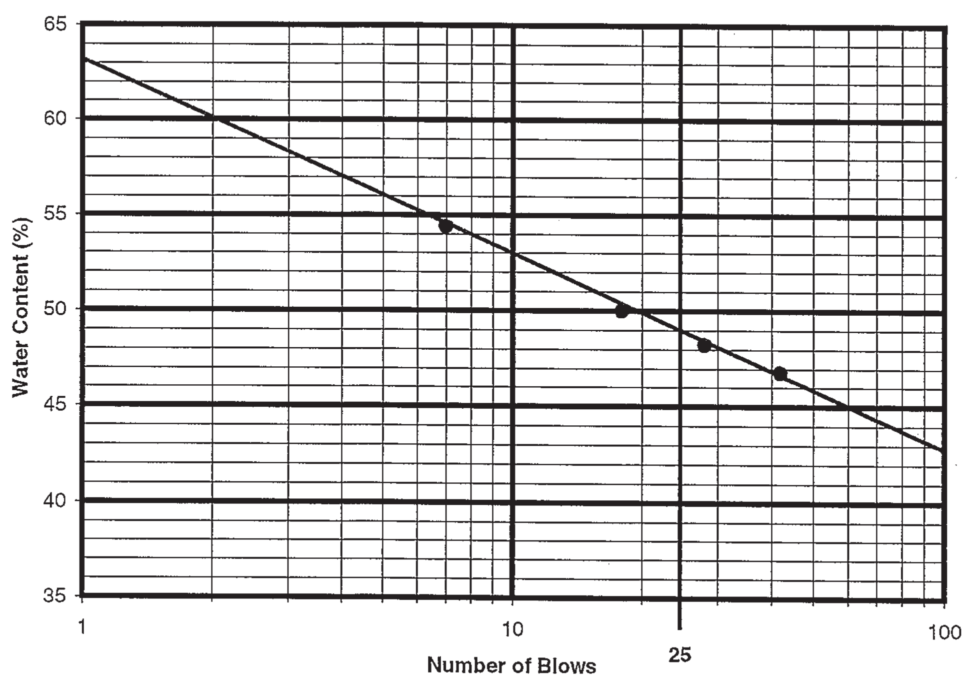
SAMPLE DESCRIPTION : CL

Project # 022-1138-2260 Tech : TM

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER	156	107	110	158		
NUMBER OF BLOWS	42	28	18	7		
MASS WET SOIL + TARE	8.49	8.57	10.71	10.05		177.90
MASS DRY SOIL + TARE	6.24	6.25	7.61	7.01		134.70
MASS OF WATER	2.25	2.32	3.10	3.04		43.20
MASS OF CONTAINER	1.43	1.44	1.41	1.42		13.90
MASS OF DRY SOIL	4.81	4.81	6.20	5.59		120.8
WATER CONTENT W (%)	46.8	48.2	50.0	54.4		35.8

TYPE OF TEST	PL	PL	BOREHOLE NO.	AH04-05
CONTAINER NUMBER	180	155	SAMPLE	TO 5
MASS WET SOIL + TARE	4.36	5.11	DEPTH	4.57-5.18m
MASS DRY SOIL + TARE	3.74	4.34	LIQUID LIMIT (%)	49.0
MASS OF WATER	0.62	0.77	PLASTIC LIMIT (%)	26.8
MASS OF CONTAINER	1.47	1.42	PLASTICITY INDEX (%)	22.2
MASS OF DRY SOIL	2.27	2.92	W% Natural (%)	35.8
WATER CONTENT W (%)	27.3	26.4	LIQUIDITY INDEX	0.40



SAMPLE DESCRIPTION : CL

PROJECT No.: 06-1411-053

RECORD OF AUGERHOLE: AH06-01

SHEET 1 OF 1

LOCATION: 156th Street South of Highway 1, Surrey.
N: 5448846.225 E: 515316.162

BORING DATE: June 29, 2006

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE - DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - O (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		Ground Surface		78.35							
0	Mud Bay Drilling Co. Ltd. / M5T - Track Mounted Auger (Solid Stem)	Asphalt Concrete.		78.23							
		Compact to dense, moist, dark grey, SAND and GRAVEL, trace silt. (FILL)		78.05	1	AS					
		Compact to dense, moist, red-brown, gravelly, sandy SILT, trace clay. (FILL)		77.89 / 0.46	2	AS			○		
		Stiff, moist, grey-brown, mottled, SILTY CLAY to SILT and CLAY, trace sand.			3	AS			○		
1					4	AS			○		
2					5	AS					
3				75.30 / 3.05							
		End of AUGERHOLE.									

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: G.B.
CHECKED: N.W.

PROJECT No.: 06-1411-053

RECORD OF AUGERHOLE: AH06-12

SHEET 1 OF 1

LOCATION: 156th Street North of Highway 1, Surrey.
N: 5449550.652 E: 515319.023

BORING DATE: June 29, 2006

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - O (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	Mud Bay Drilling Co. Ltd. MST-Track Mounted Auger (Solid Stem)	Ground Surface		82.19							
		Asphaltic concrete.		82.01 / 0.18							
		Compact to dense, moist, grey, SAND and GRAVEL. (FILL)			1	AS			○		
		Compact, moist, dark brown, SILT, some sand, with organics (rootlets).		81.58 / 0.61							
1		Very stiff, moist, grey-brown, mottled, SILTY CLAY to CLAY, trace gravel.			2	AS			○		
2		Dense to very dense, wet, grey, silty SAND, some gravel.		79.91 / 2.29	3	AS					
3		End of AUGERHOLE.		79.14 / 3.05							

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: G.B.
CHECKED: N.W.

PROJECT No.: 03-1411-095/5000/5000

RECORD OF BOREHOLE: BH05-03

LOCATION: 156th St. & Hwy.1
N: 5449196.4 E: 515319

BORING DATE: April 8, 2005

DATUM: Local

SAMPLER HAMMER, 64kg; DROP, 762mm

BORING METHOD: Foundex Track Mounted Mud Rotary (SIMCO 2800)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	Ground Surface	21.92 / 0.00						
0–2.13	Loose to compact, moist to wet, brown to grey SAND, some silt to silty SAND, containing organics: rootlets and charcoal. (Possible FILL)	19.78 / 2.13	1	50 DO	10	W ≈ 32	M	Dry piezometer May 26/05 Sept. 20/05; Cuttings
2.13–5.18	Soft, moist to wet, mottled grey to light brown, SILTY CLAY to CLAY, trace to some sand.	16.73 / 5.18	2	50 DO	3	Wp–W–Wl	H	
			3	50 DO	4	Wp–W–Wl (52)	H	Bentonite Seal
5.18–9.60	Very dense, moist, grey, gravelly SAND, some silt to SAND, some gravel, some silt, trace clay, containing cobbles and boulders.	12.31 / 9.60	4	50 DO	85	W ≈ 11	H	
			5	50 DO	111	W ≈ 10		
			6	50 DO	56			
9.60–10	Very dense, moist, grey, silty SAND, some gravel, trace clay, containing cobbles.							

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: A.H.
CHECKED: T.C.B.

PROJECT No.: 03-1411-095/5000/5000

RECORD OF BOREHOLE: BH05-03

LOCATION: 156th St. & Hwy.1
N: 5449196.4 E: 515319

BORING DATE: April 8, 2005

DATUM: Local

SAMPLER HAMMER, 64kg; DROP, 762mm

BORING METHOD: Foundex — Track Mounted Mud Rotary (SIMCO 2800)

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	Very dense, moist, grey, silty SAND, some gravel, trace clay, containing cobbles. *(continued)*	10.49 / 11.43	7	50 DO	76			Pea Gravel
11–12	Very dense, moist, brown, fine to medium SAND, some silt, trace to some gravel, containing cobbles.	9.11 / 12.80	8	50 DO	75	O	M	Slotted PVC Pipe
13–15	Very dense, moist to dry, grey to light brown SAND, trace to some silt to SILT, trace to some sand, trace to some gravel, containing cobbles.	6.07 / 15.85	9	50 DO	100			
			10	50 DO	>100	O		
16–17	Very dense, moist, grey SAND and GRAVEL, trace silt, containing cobbles and boulders.	4.54 / 17.37	11	50 DO	>100			
17–18	Very dense, moist, grey, fine to medium SAND.	3.96 / 17.95	12	50 DO	100	O		
18	End of BOREHOLE. (Achieved Target Depth)							

Chart headings: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - O (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —O W— Wl (10, 20, 30, 40)

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: A.H.
CHECKED: T.C.B.

PROJECT No.: 022-1138 (2260)

RECORD OF BOREHOLE: BK04-1

LOCATION: 96th Ave., West of 176th St.
N: 49399.9 E: 19375.9

BORING DATE: May 5, 2004

DATUM: Geodetic

BORING METHOD: Foundex Becker Hammer - HAV 180

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING
0	Ground Surface	57.26 / 0.00						
	Asphalt.	56.95 / 0.30						
	Compact, moist, brown SAND and GRAVEL, some silt, containing cobbles and small boulders. (FILL)	56.04 / 1.22	1					
1	Stiff to very stiff, moist, brown, mottled, SILTY CLAY to CLAY, trace gravel and sand.	52.69 / 4.57	2	51 DO	18			
			3	51 DO	18		Wp—W—Wl	
			4	51 DO	13			
5	Stiff to very stiff, moist, brown to grey, SILTY CLAY, trace sand and gravel. - changing to grey after 6.09m	49.94 / 7.32	5	51 DO	8		W	
			6	76 TO		rem V.; nat V. 208		
	Compact to dense, moist, grey, sandy SILT, some gravel, trace clay, containing cobbles.	49.03 / 8.23	7	CS				
	Dense to very dense, moist, grey, SILT and SAND, some gravel, trace clay, contains cobbles.		8	51 DO	44		W	M, H
10			9	51 DO	73			

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl — 20 40 60 80

PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: LW
CHECKED: TB/TK

PROJECT No.: 022-1138 (2260)

RECORD OF BOREHOLE: BK04-1

LOCATION: 96th Ave., West of 176th St.
N: 49399.9 E: 19375.9

BORING DATE: May 5, 2004

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT PERCENT (Wp, W, Wl)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10–13.41	Foundex, Becker Hammer - HAV 180	Dense to very dense, moist, grey, SILT and SAND, some gravel, trace clay, contains cobbles. *(continued)*	43.85 / 13.41	11	51 DO	>50				
				12	CS					
13.41–14.78		Dense to very dense, moist, grey, medium to fine SAND, trace silt.	42.48 / 14.78	13	CS					
				14	51 DO	88				
14.78		End of BOREHOLE.								

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: LW
CHECKED: TB/TK

BOREHOLE 022-1138.GPJ GLDR_CAN.GDT 16/9/04

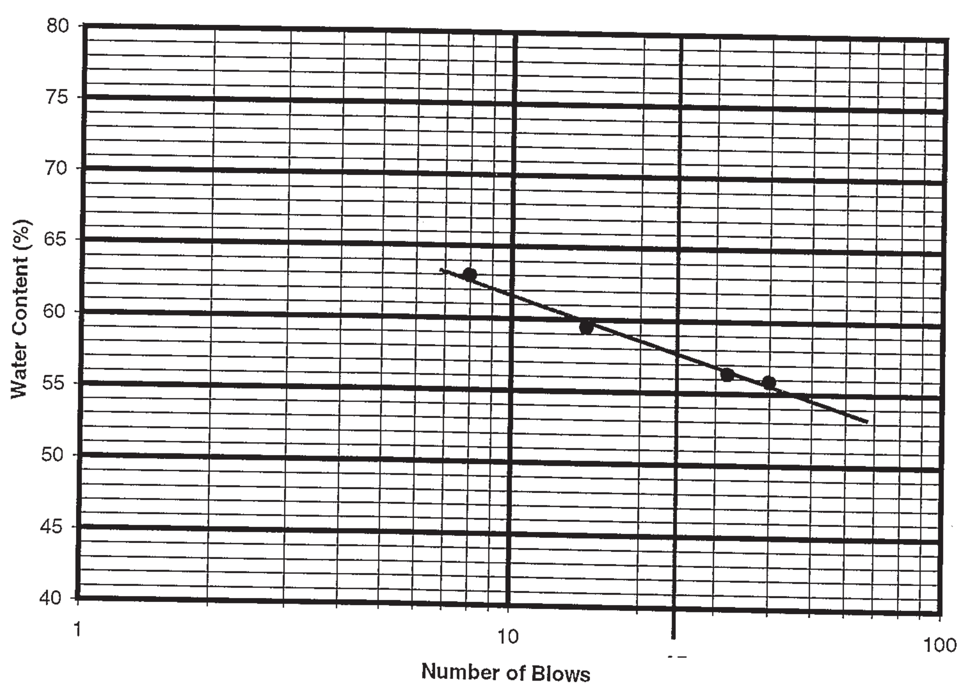
Project # 022-1138-2260

Tech : TP

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER						
NUMBER OF BLOWS	40	32	15	8		
MASS WET SOIL + TARE	48.12	41.15	48.49	45.04		92.80
MASS DRY SOIL + TARE	41.09	36.29	40.44	38.41		75.20
MASS OF WATER	7.03	4.86	8.05	6.63		17.60
MASS OF CONTAINER	28.50	27.66	26.90	27.88		18.40
MASS OF DRY SOIL	12.59	8.63	13.54	10.53		56.8
WATER CONTENT W (%)	55.8	56.3	59.5	63.0		31.0

TYPE OF TEST	PL	PL	BOREHOLE NO.	BK04-01
CONTAINER NUMBER			SAMPLE	DO 3
MASS WET SOIL + TARE	30.41	33.13	DEPTH	2.13-2.59m
MASS DRY SOIL + TARE	29.82	32.49	LIQUID LIMIT (%)	57.6
MASS OF WATER	0.59	0.64	PLASTIC LIMIT (%)	29.6
MASS OF CONTAINER	27.85	30.30	PLASTICITY INDEX (%)	28.0
MASS OF DRY SOIL	1.97	2.19	W% Natural (%)	31.0
WATER CONTENT W (%)	29.9	29.2	LIQUIDITY INDEX	0.05



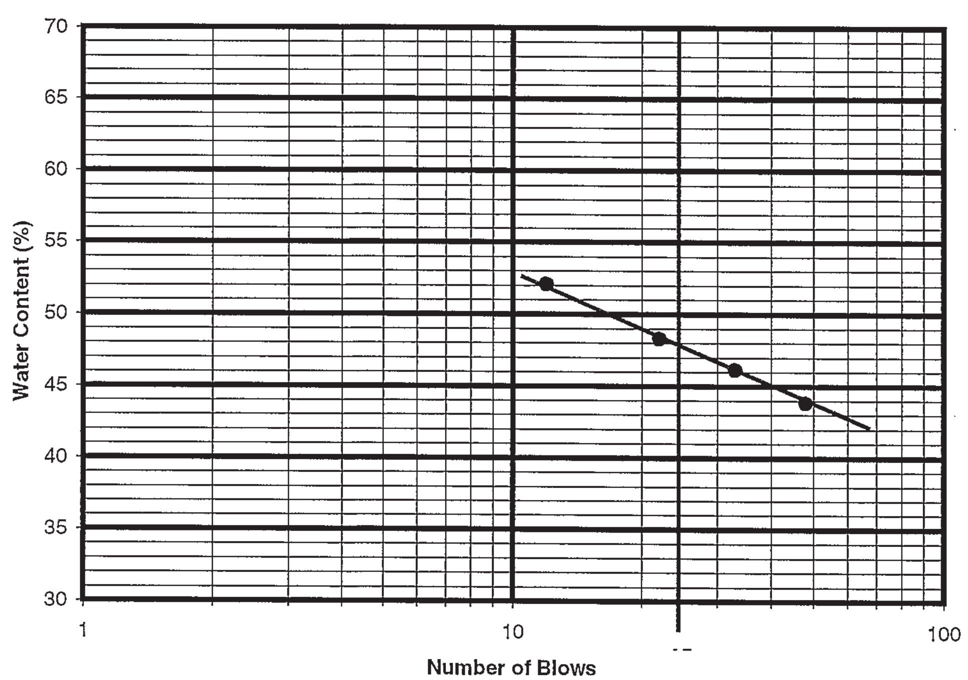
SAMPLE DESCRIPTION : CH

Project # 022-1138-2260 Tech : TP

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER						
NUMBER OF BLOWS	33	22	12	48		
MASS WET SOIL + TARE	31.16	31.18	41.54	50.43		170.40
MASS DRY SOIL + TARE	25.64	25.24	35.41	43.72		127.30
MASS OF WATER	5.52	5.94	6.13	6.71		43.10
MASS OF CONTAINER	13.68	12.94	23.64	28.41		18.10
MASS OF DRY SOIL	11.96	12.30	11.77	15.31		109.2
WATER CONTENT W (%)	46.2	48.3	52.1	43.8		39.5

TYPE OF TEST	PL	PL	BOREHOLE NO.	AH04-04
CONTAINER NUMBER			SAMPLE	AS 4
MASS WET SOIL + TARE	31.23	30.68	DEPTH	2.44-2.74m
MASS DRY SOIL + TARE	30.54	30.19	LIQUID LIMIT (%)	47.7
MASS OF WATER	0.69	0.49	PLASTIC LIMIT (%)	24.1
MASS OF CONTAINER	27.72	28.13	PLASTICITY INDEX (%)	23.6
MASS OF DRY SOIL	2.82	2.06	W% Natural (%)	39.5
WATER CONTENT W (%)	24.5	23.8	LIQUIDITY INDEX	0.65



SAMPLE DESCRIPTION : CL

PROJECT No.: 022-1138 (2260)

RECORD OF BOREHOLE: BK04-77

LOCATION: South of Highway No. 1
N: 48619.2 E: 22581.5

BORING DATE: May 10-11, 2004

DATUM: Geodetic

Boring method: Foundex Becker Hammer Hav - 180m 168mm OD Open Casing

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH / WATER CONTENT	ADDITIONAL LAB. TESTING
0	Ground Surface	22.20					
	Topsoil.	22.10 / 0.10	1	51 DO	17		
1	Loose to compact, moist, brown SAND and GRAVEL, some silt to silty; and grey CLAYEY SILT with cobbles. (FILL)		2	CS			M
2			3	51 DO	36		
3			4	51 DO	14		
4			5	CS			
		17.63 / 4.57	6	51 DO	11		
5	Firm to stiff, moist to wet, brown and grey mottled, SILTY CLAY, trace fine sand and peat (organics).		7	76 TO		W ≈ 42 %	
6						rem V ≈ 27 kPa; nat V 116 kPa	
		15.80 / 6.40					
7	Firm to sott, moist to wet, grey brown mottled, SILTY CLAY, trace fine sand and silty sand layers.		8				
8			9	76 TO			
		13.97 / 8.23					
9	Firm to stiff, moist, grey, SILTY CLAY to CLAY and SILT, trace fine sand. Fine sand lenses. - trace rounded gravel from 10.06m - 14.94m depth					rem V ≈ 20 kPa; nat V ≈ 68 kPa	
10							

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Column headings: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - O; 20 40 60 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT (Wp —O^W— Wl; 20 40 60 80); PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: LW
CHECKED: TB/TK

PROJECT No.: 022-1138 (2260)

RECORD OF BOREHOLE: BK04-77

LOCATION: South of Highway No. 1
N: 48619.2 E: 22581.5

BORING DATE: May 10-11, 2004

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
10 – 16.46	Foundex; Becker Hammer Hav - 180m 168mm OD Open Casing	Firm to stiff, moist, grey, SILTY CLAY to CLAY and SILT, trace fine sand. Fine sand lenses. - trace rounded gravel from 10.06m - 14.94m depth *(continued)*			10	76 TO		
					11	76 TO		M
					12	76 TO		
16.46 – 20		Firm to stiff, moist to wet, grey, silty CLAY, trace fine sand. - from 18.9m - 19.8m depth: trace gravel and sand (sub-rounded to sub-angular). - from 20.57m - 21.03m depth: sandy gravelly layers.		5.74 / 16.46	13	76 TO		
					14	76 TO		

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl — 20 40 60 80

PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: LW
CHECKED: TB/TK

PROJECT No.: 022-1138 (2260)

RECORD OF BOREHOLE: BK04-77

LOCATION: South of Highway No. 1
N: 48619.2 E: 22581.5

BORING DATE: May 10-11, 2004

DATUM: Geodetic

BORING METHOD: Foundex — Becker Hammer Hav - 180m 168mm OD Open Casing

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
20	Firm to stiff, moist to wet, grey, silty CLAY, trace fine sand. - from 20.57m - 21.03m depth: sandy gravelly layers.	1.17 / 21.03	14	76 TO		
21	Very dense, moist, grey GRAVEL and silty SAND mixture with cobbles.	-0.05 / 22.25	15	CS		
22–23	Dense to very dense, moist to wet, grey SAND and silty SAND layers, trace gravel with cobbles.	-1.88 / 24.08	16	51 DO	>100	M
24	Dense to very dense, moist, grey, sandy SILT and hard CLAYEY SILT layers.	-2.49 / 24.69				
25–26	Hard, moist, grey, SILT and CLAYEY SILT layers, some sandy silt layers.	-4.17 / 26.37	17	CS		
			18	51 DO	75	
	End of BOREHOLE.					

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

PIEZOMETER OR STANDPIPE INSTALLATION

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

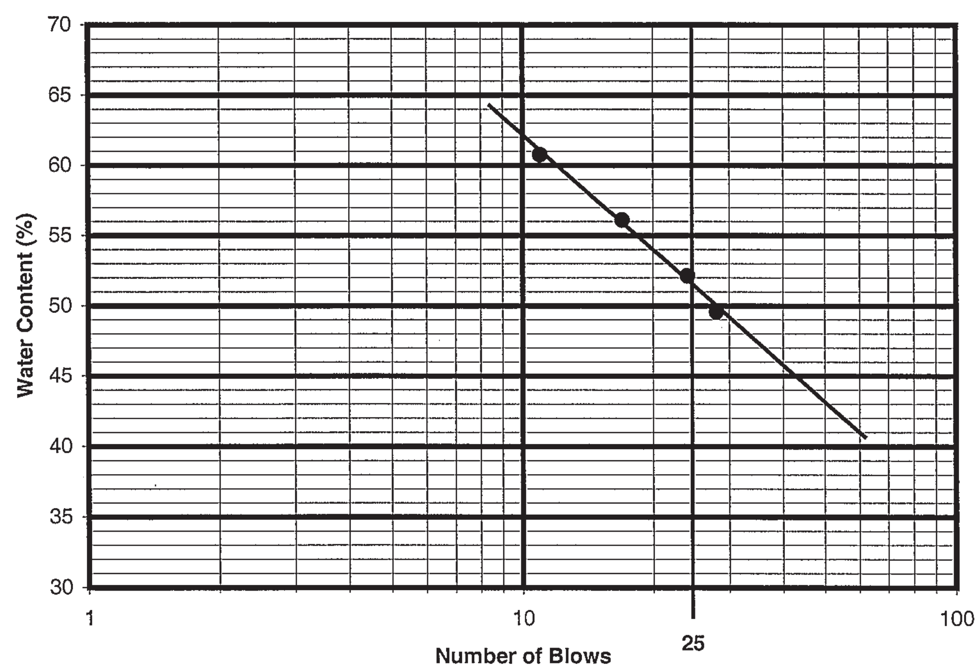
Summary of In Situ Vane Results				
Borehole	Depth (m)	Vane type	Undrained Shear Strength (kPa)	
			Peak	Remolded
AH04-59	5.49-5.589	Torque	34	7
AH04-59	10.06-10.16	Torque	109	17
AH04-59	12.13-12.43	Torque	94	19
AH04-59	19.20-19.30	Torque	131	15
AH04-62	9.75-9.87	Torque	79	11
AH04-62	14.33-14.44	Torque	109	32
BK04-77	6.25-6.40	Torque	116	27
BK04-77	8.69-8.84	Torque	67	19
BK04-77	11.06-11.28	Torque	64	18
BK04-77	13.50-13.72	Torque	68	64
BK04-77	15.94-16.15	Torque	61	17
BK04-77	18.38-18.59	Torque	71	20
BK04-77	20.82-21.03	Torque	89	68
BK04-78	6.25-6.40	Torque	53	21
BK04-78	8.08-8.23	Torque	53	27
BK04-78	10.52-10.67	Torque	48	27
BK04-78	13.11-13.26	Torque	40	13
BK04-78	15.39-15.54	Torque	53	19
BK04-78	18.44-18.59	Torque	56	19
BK04-78	20.88-21.03	Torque	53	13
BK04-78	23.93-24.08	Torque	80	35

Project # 022-1138-2260 Tech : JTG

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER	144	148	186	161		
NUMBER OF BLOWS	11	17	24	28		
MASS WET SOIL + TARE	14.41	17.44	11.86	16.41		371.80
MASS DRY SOIL + TARE	9.50	11.68	8.32	11.44		322.90
MASS OF WATER	4.91	5.76	3.54	4.97		48.90
MASS OF CONTAINER	1.42	1.41	1.53	1.41		212.40
MASS OF DRY SOIL	8.08	10.27	6.79	10.03		110.5
WATER CONTENT W (%)	60.8	56.1	52.1	49.6		44.3

TYPE OF TEST	PL	PL	BOREHOLE NO.	BK04-77
CONTAINER NUMBER	200	224	SAMPLE	TO 11
MASS WET SOIL + TARE	8.02	6.61	DEPTH	41-43
MASS DRY SOIL + TARE	6.82	5.66	LIQUID LIMIT (%)	51.5
MASS OF WATER	1.20	0.95	PLASTIC LIMIT (%)	22.4
MASS OF CONTAINER	1.47	1.43	PLASTICITY INDEX (%)	29.1
MASS OF DRY SOIL	5.35	4.23	W% Natural (%)	44.3
WATER CONTENT W (%)	22.4	22.5	LIQUIDITY INDEX	0.75



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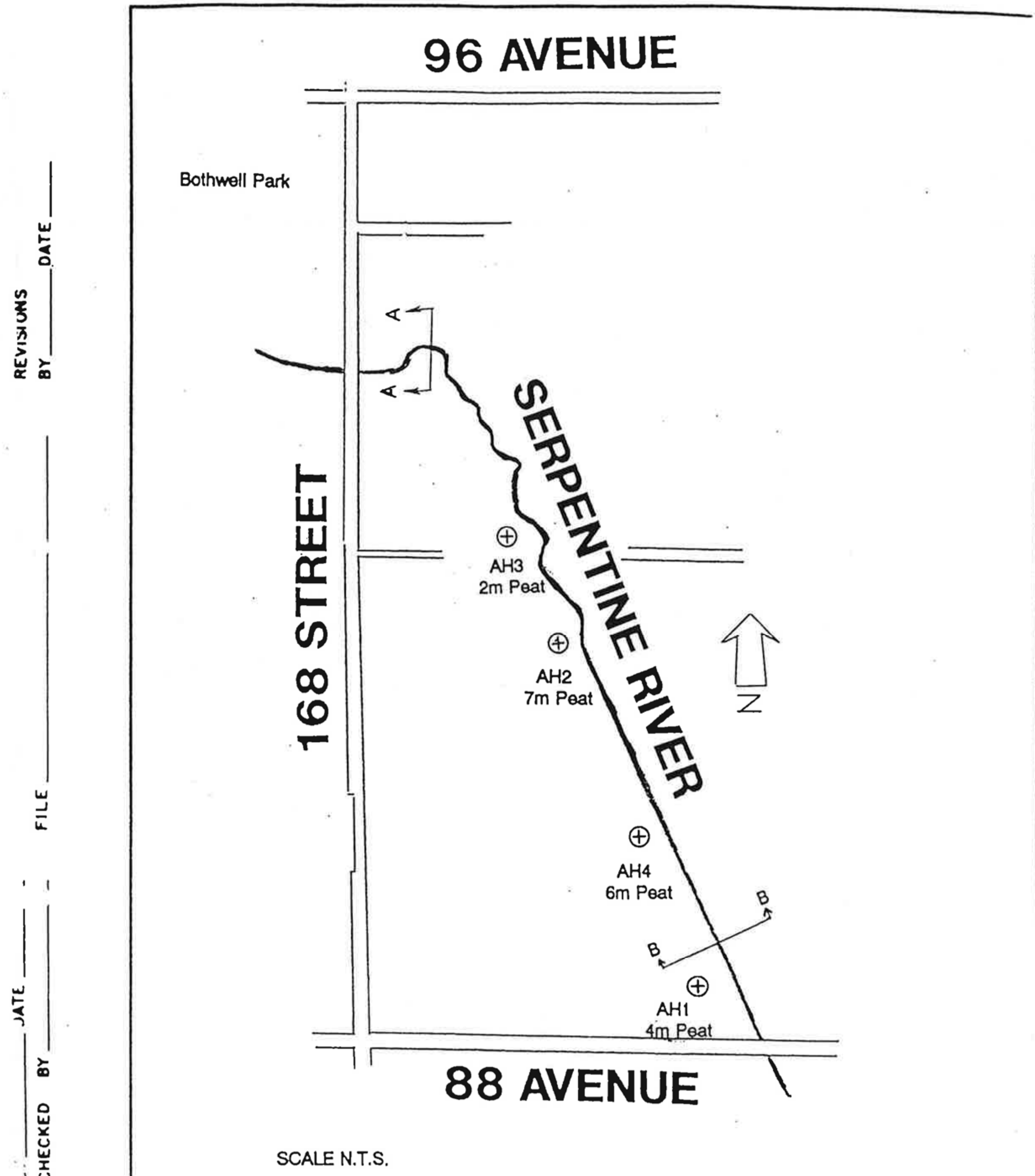


LEGEND

⊕AH Auger Hole Location

TEST HOLE LOCATION PLAN - SKETCH
SERPENTINE RIVER
SURREY, B.C.

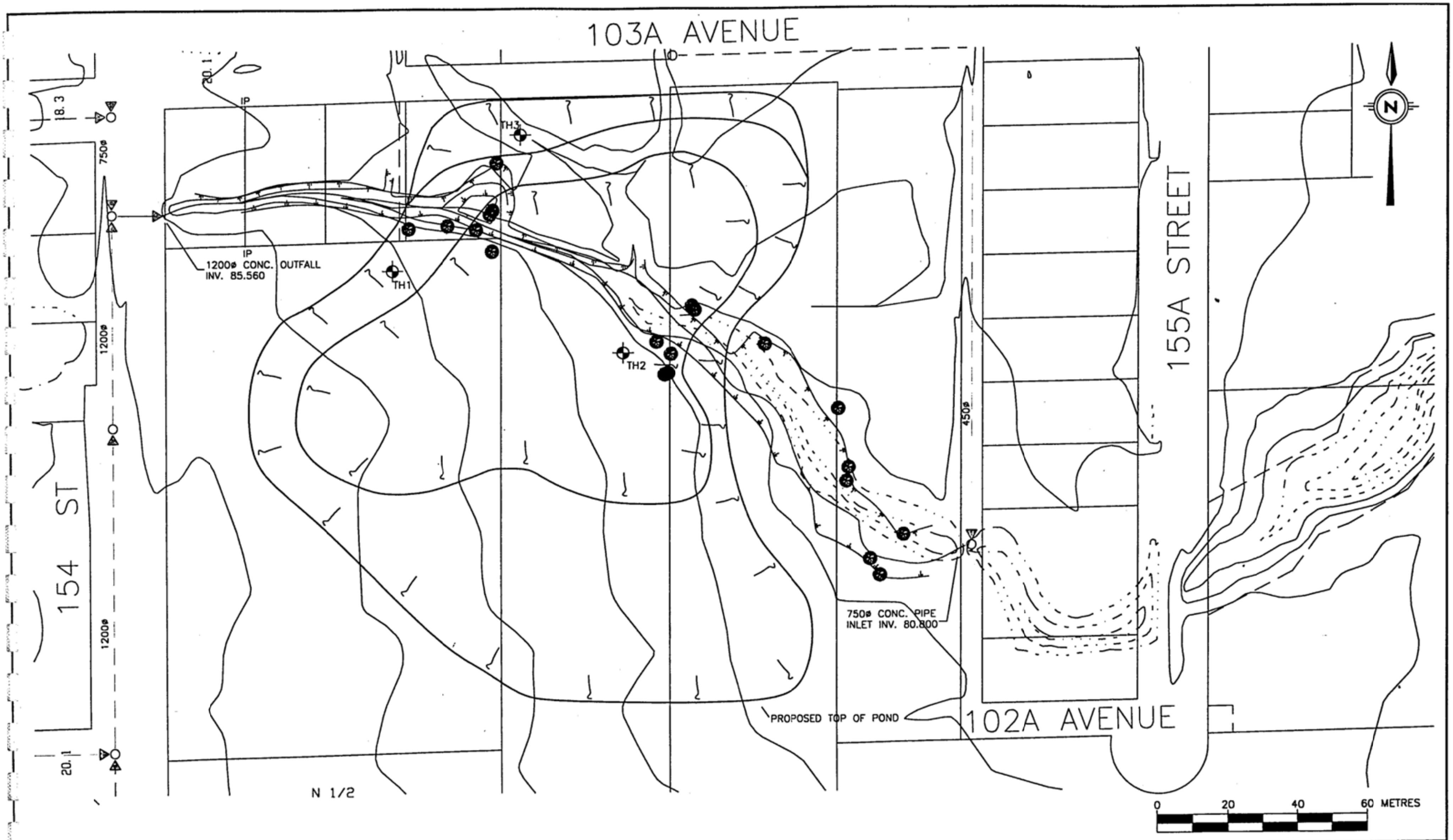
Dames & Moore

PLATE 2

TABLE 1

SUMMARY OF TEST HOLE LOGS

Test No.	Location	Soil Conditions
1	75 m north of 88 Ave.	0–0.35 m silty loam, fibrous 0.35–3.85 m brown, soft fibrous peat 3.85–4.0 m blue, stiff to firm clay
2	500 m north of 88 Ave.	0–0.35 m silty loam, fibrous 0.35–6.5 m light brown, trace of silt peat 6.5–6.75 m blue, stiff to firm clay
3	600 m north of 88 Ave.	0–2.05 m brown, soft, silty peat 2.05–2.15 m grey, compact medium sand trace of organics
4	200 m north of 88 Ave.	0–5.95 m brown, soft, amorphous peat 5.95–6.1 m grey, stiff to firm clay



LEGEND

APPROXIMATE LOCATION OF TEST HOLE

NOTE:
THIS DRAWING IS THE SOLE PROPERTY OF LEVELTON ENGINEERING AND CANNOT BE USED OR DUPLICATED IN ANY WAY WITHOUT EXPRESS WRITTEN PERMISSION

SEAL

LEVELTON
Engineering Solutions

CLIENT: STANTEC CONSULTING LTD.

PROJECT: 103 AVENUE DETENTION POND

TITLE: SITE PLAN SHOWING TEST HOLE LOCATIONS

SCALE	DESIGN	DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
1:1000		DEC 1/99	899-0178	FIGURE 1	
DRAWN SJD	REVIEWED PRE				

CANCEL PRINTS BEARING EARLIER LETTER

SOIL LOG

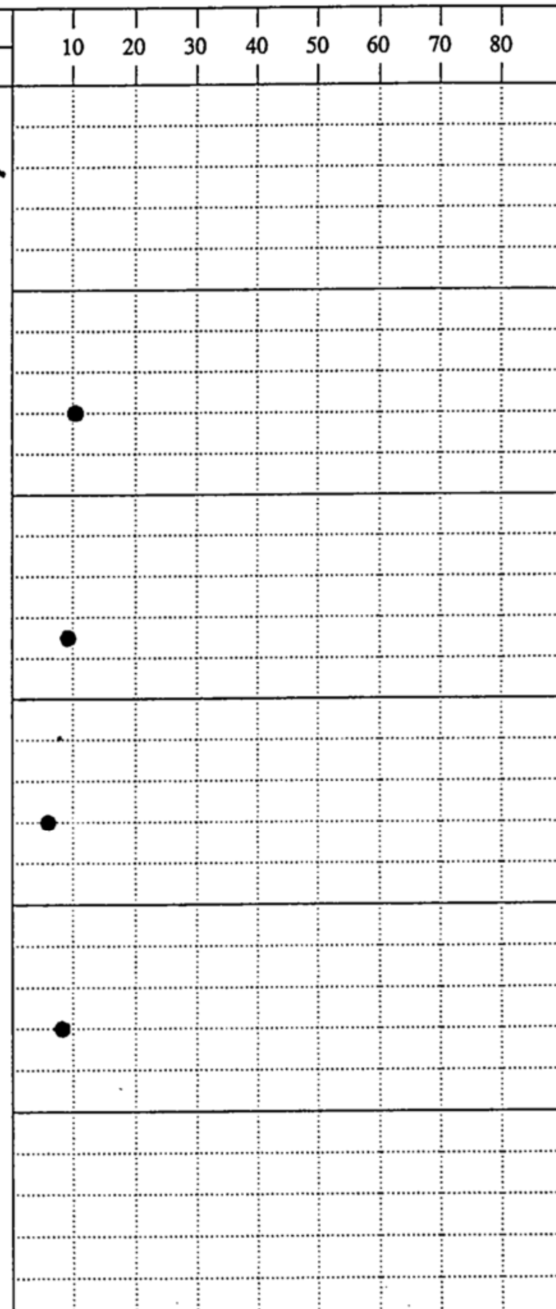
LOGGED BY: GC | COLLAR ELEV.: Surface | PIT/HOLE No: TH-1

C : Sample condition - GOOD / DISTURBED / NO RECOVERY
N : Number of blows
UU : Unconfined Compressive Strength
PP : Pocket Penetrometer
(TV) : Torvane

Type : Type of Sample
SPT : Split Spoon
S : Shelby tube
G : Grab
O : Other (specify)

● : Moisture Content (% of dry weight)
Plastic Limit
Liquid Limit
▼ : Ground Water Level

Depth Ft	DESCRIPTION	Symbol	Depth Ft	Well	Sample N	Sample Type
0	TOPSOIL					
	0.61m		2.0			
	Hard, brown, clayey SILT, trace sand - PP = 4.0 ton/sq.ft. at 2 ft.		3.0			
	0.91m					
5	Loose to dense, light brown, silty SAND(till-like), trace gravel					
10						
15	- some gravel below 14 ft.					
20						
25	7.62m		25.0			
30	End of drill hole Note : 1) Minor groundwater seepage encountered below 2 ft. below grade 2) Groundwater table measured on Dec.17,99 at 8.8ft. below grade (2.68m)					



LEVELTON Engineering Solutions

PROJECT: Detention Pond, 154 Street and 103A Avenue, Surrey, BC

CLIENT: Stantec Consulting Ltd.

JOB No: 899-0178

SHEET No: 1 OF 1

DATE: 8 DEC 99

SOIL LOG

LOGGED BY: GC   COLLAR ELEV.: Surface   PIT/HOLE No: TH-2

C : Sample condition - GOOD / DISTURBED / NO RECOVERY
N : Number of blows
UU : Unconfined Compressive Strength
PP : Pocket Penetrometer
(TV) : Torvane

Type : Type of Sample
SPT : Split Spoon
S : Shelby tube
G : Grab
O : Other (specify)

● : Moisture Content (% of dry weight)
Plastic Limit
Liquid Limit
▼ : Ground Water Level

Depth Ft	DESCRIPTION	Symbol	Depth Ft	Well	Sample N	Sample Type	10 20 30 40 50 60 70 80
0	TOPSOIL 0.3m	▼	1.0				
	Hard, brown, clayey SILT, trace sand - PP = 4.25 ton/sq.ft. at 2 ft. 0.91m		3.0				
5	Loose to dense, light brown, silty SAND(till-like), some gravel, moist						● (~10)
10							
15	4.56m		15.0				
	End of drill hole Note : 1) Water ponding encountered on the surface 2) Drill hole located near the stream						
20							
25							
30							

LEVELTON
Engineering Solutions

PROJECT: Detention Pond, 154 Street and 103A Avenue, Surrey, BC
CLIENT: Stantec Consulting Ltd.
JOB No: 899-0178
SHEET No: 1 OF 1
DATE: 8 DEC 99

SOIL LOG

LOGGED BY: **GC** COLLAR ELEV.: **Surface** PIT/HOLE No: **TH-3**

C : Sample condition - GOOD / DISTURBED / NO RECOVERY
N : Number of blows
UU : Unconfined Compressive Strength
PP : Pocket Penetrometer
(TV) : Torvane

Type : Type of Sample
SPT : Split Spoon
S : Shelby tube
G : Grab
O : Other (specify)

● : Moisture Content (% of dry weight)
Plastic Limit
Liquid Limit
▼ : Ground Water Level

Depth Ft	DESCRIPTION	Symbol	Depth Ft	Well	Sample N	Sample Type	10 20 30 40 50 60 70 80
0	TOPSOIL 0.46m	▼	1.5				
	Hard, brown, clayey SILT, trace sand - PP = 4.5 ton/sq.ft. at 3 ft. 1.68m						
5	Loose to dense, light brown to grey, silty SAND(till-like), trace to some gravel		5.0				
10							
15							
20	6.1m		20.0				
	End of drill hole Note : 1) Minor groundwater seepage encountered below 1.5 ft. below grade						
25							
30							

LEVELTON
Engineering Solutions

PROJECT: **Detention Pond, 154 Street and 103A Avenue, Surrey, BC**

CLIENT: **Stantec Consulting Ltd.**

JOB No: **899-0178**

SHEET No: **1 OF 1**

DATE: **8 DEC 99**

LOG OF TEST PIT

TEST PIT NO. **12-01**

THURBER

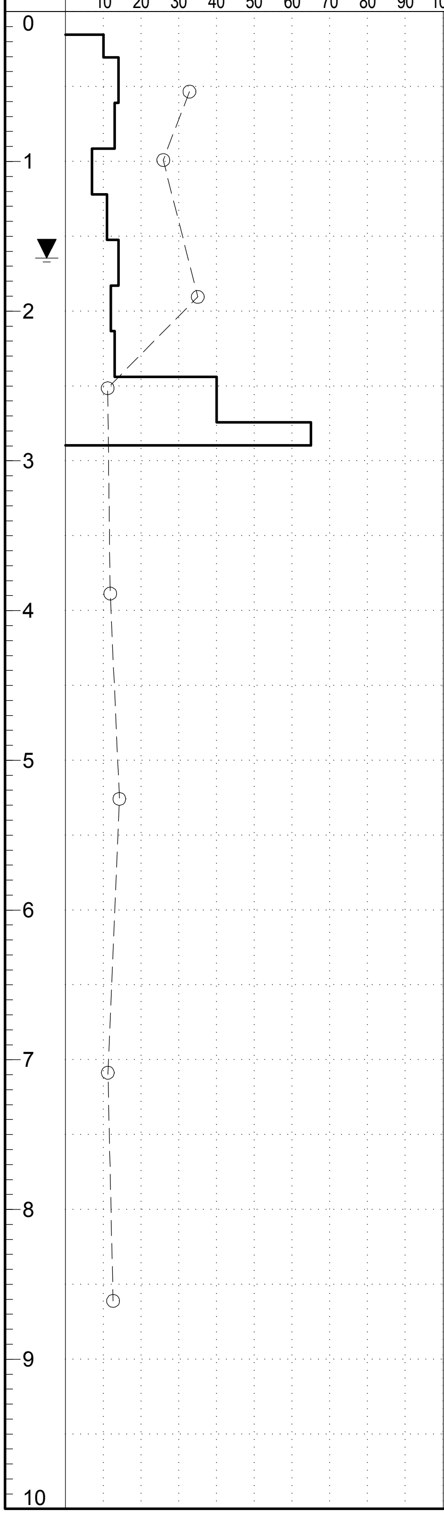
LOCATION: 102A Ave & 152A St, Surrey BC
N 5448424, E 514642

CLIENT: Guildford Real Estate Corporation
PROJECT: Proposed Guildford Business Centre

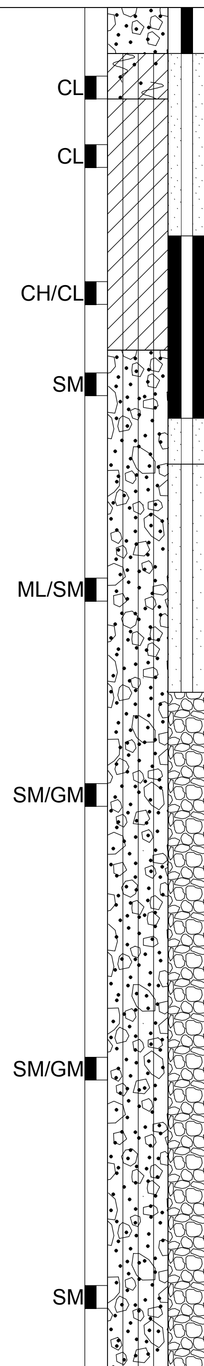
TOP OF HOLE ELEV:
METHOD: Truck/Solid Stem Auguer
DRILLING CO.: On-Track Drilling Inc.
INSPECTOR: CHS

DATE: November 23, 2012
FILE NO.: 19-6346-0

PENETRATION (blows/300 mm) | WATER CONTENT (%): ○ Disturbed, ● Undisturbed; Plastic Limit, Liquid Limit | WATER LEVEL | SAMPLES: Disturbed, Undisturbed, No Recovery | UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak, ◇ Residual, Remolded | GRAIN SIZE (%): ▲ Passing #200 sieve, △ Passing #4 sieve | SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading



Depth (m)	COMMENTS		SOILS DESCRIPTION
0			60 mm of asphalt over compact, grey, fine to medium SAND with some gravel (Fill).
			Firm, dark brown, sandy SILT & CLAY with trace to some organic silt, and with traces of gravel and roots (Possible Native Ground).
1			Soft to firm, light grey brown SILT & CLAY with trace to some sand, and traces of gravel and organics.
	Water level recorded on November 27, 2012.		
			Stiff to very stiff/dense to very dense, light grey brown SILT & SAND, with some gravel and trace clay (Till-like).
3	DCPT effective refusal.		
			Gravel content increasing with depth
			End of hole at required depth. Hole collapse at 4.6 m.



Sheet 1 of 1

LOG OF TEST PIT

TEST PIT NO. **12-02**

THURBER

LOCATION: 102A Ave & 152A St, Surrey BC
N 5448383, E 514627

TOP OF HOLE ELEV:

METHOD: Truck/Solid Stem Auguer

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: CHS

CLIENT: Guildford Real Estate Corporation

PROJECT: Proposed Guildford Business Centre

DATE: November 23, 2012

FILE NO.: 19-6346-0

DEPTH (m)

PENETRATION (blows/300 mm)

WATER CONTENT (%): ○ Disturbed ● Undisturbed; Plastic Limit, Liquid Limit

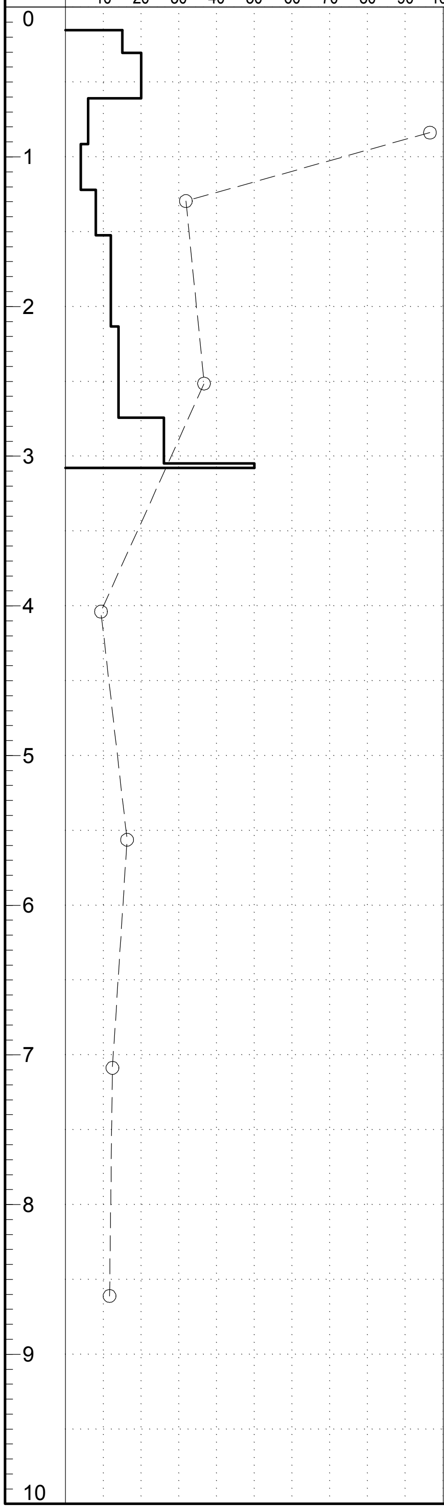
WATER LEVEL

SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery

UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ⬙ Remolded

GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve

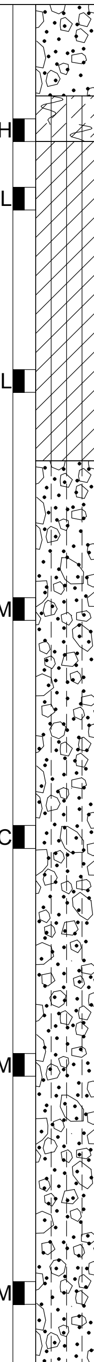
SOIL HEADSPACE READING (ppm): ✖ GASTECH reading ✖ PID reading



COMMENTS

DCPT effective refusal.

Samples: OH, CL, CH/CL, SM, SM/SC, SM, SM/GM



SOILS DESCRIPTION

60 mm of asphalt over compact, grey brown, fine to medium SAND with some gravel (Fill).

Soft, dark brown, organicy SILT with some clay and trace fine sand (Possible Native Ground).

Soft, light grey SILT & CLAY with trace to some sand and traces of gravel & organics. Green weathering at 3.0 m

Firm below 1.5 m

Dense to very dense, grey brown, silty & gravelly SAND with a trace of clay (Till-like).

Gravel content increasing with depth

End of hole at required depth. Hole collapse at 5.2 m.

LOG OF TEST PIT

TEST PIT NO. **12-03**

THURBER

LOCATION:	102A Ave & 152A St, Surrey BC N 5448439, E 514626	**CLIENT:**	Guildford Real Estate Corporation
		PROJECT:	Proposed Guildford Business Centre
TOP OF HOLE ELEV:			
METHOD:	Truck/Solid Stem Auguer	**DATE:**	November 23, 2012
DRILLING CO.:	On-Track Drilling Inc.	**FILE NO.:**	19-6346-0
INSPECTOR:	CHS		

DEPTH (m)

PENETRATION (blows/300 mm)

WATER CONTENT (%): ○ Disturbed ● Undisturbed; Plastic Limit — Liquid Limit

WATER LEVEL

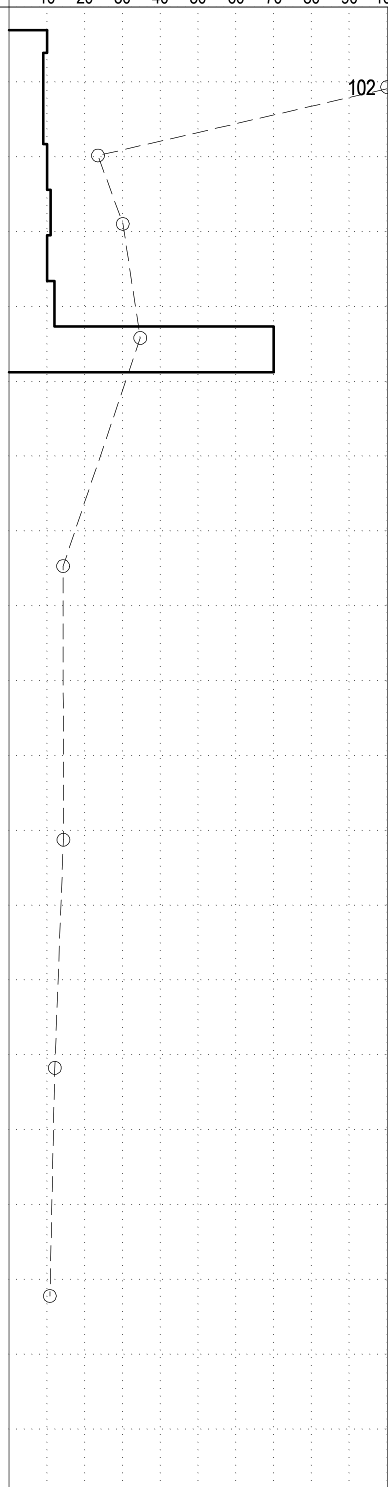
SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery

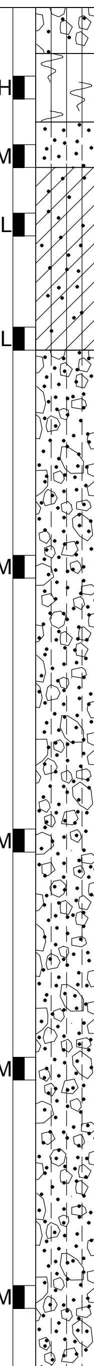
UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ⬙ Remolded

GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve

SOIL HEADSPACE READING (ppm): ✖ GASTECH reading ◌ PID reading

10 20 30 40 50 60 70 80 90 100





Depth (m)	Comments	Sample	Soils Description
0			60 mm of asphalt over compact, grey brown SILT with some sand & gravel (Probable Fill).
		OH	Soft to firm, dark brown, organicy SILT with trace sand (Possible Native Ground).
1		SM	Loose to compact, brown, silty SAND, with traces of gravel and organics.
		CL/ML	Soft to firm, light grey SILT & CLAY, with some sand and traces of gravel and organics.
2		CH/CL	
	DCPT effective refusal.		Dense to very dense, grey brown, silty, gravelly SAND with a trace of clay (Till-like).
3			
		SM	Green weathering at 3.7 m, soil wet below.
4			Occasional zones of soft silt & clay.
5			
		GC/GM	Gravel content increasing with depth
6			
7		GM/SM	
8		SM/GM	
9			End of hole at required depth. Hole collapse at 5.6 m.
10			

Sheet 1 of 1

LOG OF TEST PIT

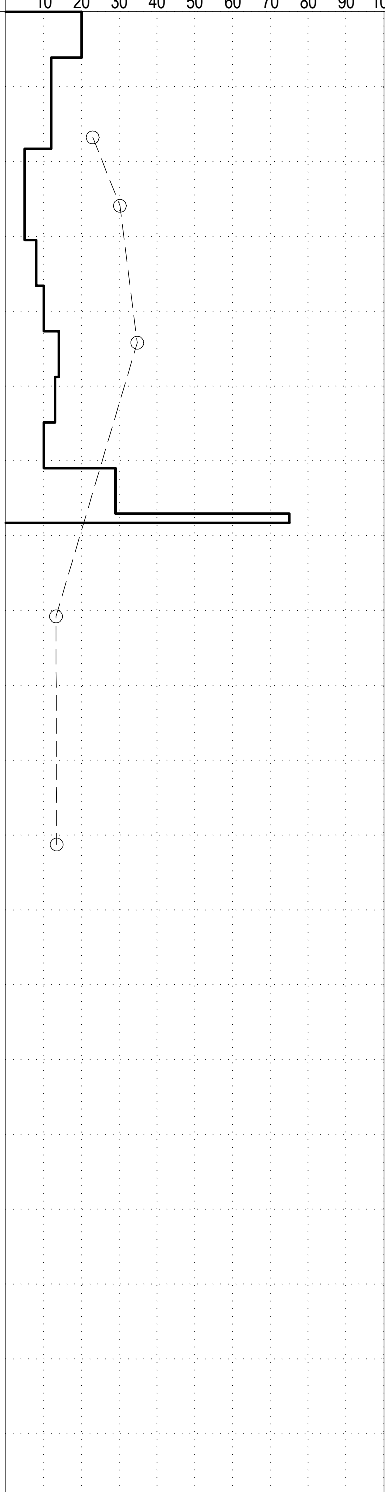
TEST PIT NO. **12-04**

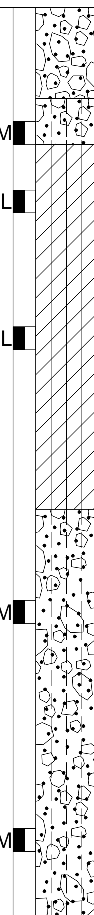
THURBER

LOCATION:	102A Ave & 152A St, Surrey BC N 5448380, E 514668	**CLIENT:**	Guildford Real Estate Corporation
		PROJECT:	Proposed Guildford Business Centre
TOP OF HOLE ELEV:			
METHOD:	Truck/Solid Stem Auguer	**DATE:**	November 23, 2012
DRILLING CO.:	On-Track Drilling Inc.	**FILE NO.:**	19-6346-0
INSPECTOR:	CHS		

PENETRATION (blows/300 mm) — WATER CONTENT (%): ○ Disturbed, ● Undisturbed; Plastic Limit, Liquid Limit — WATER LEVEL — SAMPLES: Disturbed, Undisturbed, No Recovery — UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak, ◇ Residual, Remolded — GRAIN SIZE (%): ▲ Passing #200 sieve, △ Passing #4 sieve — SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m) 0–10; scale 10 20 30 40 50 60 70 80 90 100





DEPTH (m)	COMMENTS	Sample	SOILS DESCRIPTION
0			Compact, brown SAND & GRAVEL with trace of silt (Fill).
		SM	Compact, brown, gravelly SAND with some silt & organic silt, and trace of fibrous organics (Possible Native Ground).
1		CL	Soft to firm, light grey brown, SILT & CLAY, with traces of gravel & sand.
2		CH/CL	
3	DCPT effective refusal.		Dense to very dense, grey, silty, gravelly SAND with a trace of clay (Till-lke).
4		SM	
			Gravel content increasing with depth
5		SM/GM	
6			End of hole at required depth. Hole collapse at 4.9 m.
7			
8			
9			
10			

Sheet 1 of 1

LOG OF TEST PIT

TEST PIT NO. **12-05**

THURBER

LOCATION: 102A Ave & 152A St, Surrey BC
N 5448444, E 514663

TOP OF HOLE ELEV:

METHOD: Truck/Solid Stem Auguer

DRILLING CO.: On-Track Drilling Inc.

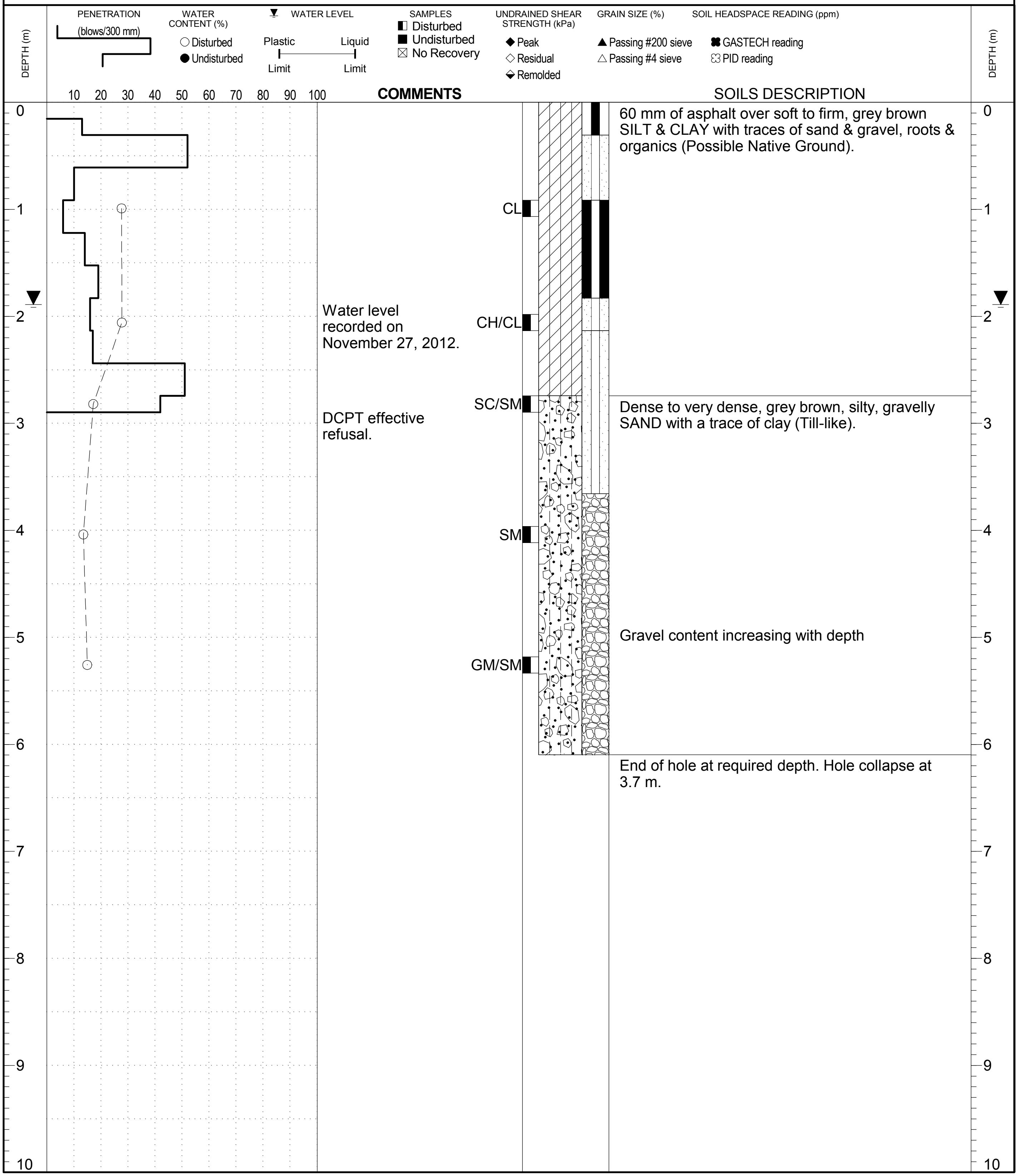
INSPECTOR: CHS

CLIENT: Guildford Real Estate Corporation

PROJECT: Proposed Guildford Business Centre

DATE: November 23, 2012

FILE NO.: 19-6346-0



Depth (m)	Comments	Soils Description
0		60 mm of asphalt over soft to firm, grey brown SILT & CLAY with traces of sand & gravel, roots & organics (Possible Native Ground).
2	Water level recorded on November 27, 2012.	
2.8	DCPT effective refusal.	Dense to very dense, grey brown, silty, gravelly SAND with a trace of clay (Till-like).
5		Gravel content increasing with depth
6.1		End of hole at required depth. Hole collapse at 3.7 m.

LOG OF TEST HOLE

TEST HOLE NO. **E1-08-451**

LOCATION: Wall W60997L / Structure 8395R
N 450808.888, E 66138.983

TOP OF HOLE ELEV: 55.9 m

METHOD: Solid Stem Auger / Mud Rotary

DRILLING CO.: On-Track / Mud Bay

INSPECTOR: PKE

THURBER

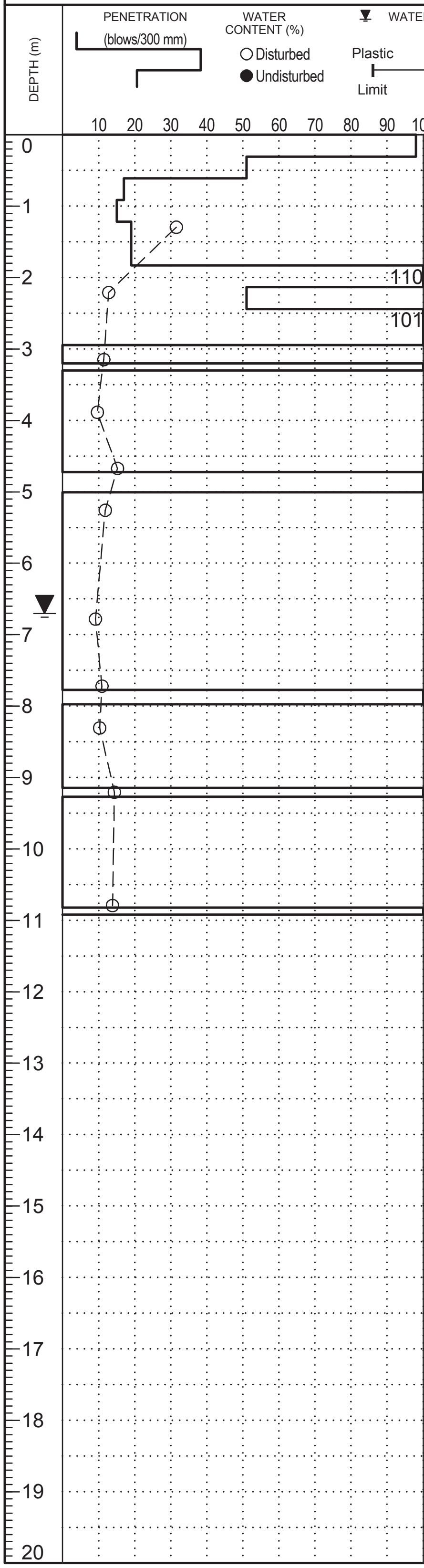
CLIENT: H5M

PROJECT: Port Mann / Highway 1
Segment E1

DATE: Nov. 19, 2008 & May 10, 2009

FILE NO.: 19-5187-15D

REVIEWED BY: SP



SAMPLES: Disturbed; Undisturbed; No Recovery
UNDRAINED SHEAR STRENGTH (kPa): Peak; Residual
GRAIN SIZE (%): Passing #200 sieve; Passing #4 sieve
SOIL HEADSPACE READING (ppm): GASTECH reading; PID reading

COMMENTS

- DCPT between 0.0 and 2.9 m depth.
- DCPT: 100 blows per 200 mm
- SPT: 50 blows per 100 mm
- SPT: 94 blows per 280 mm
- SPT: refusal on probable cobble or gravel (bouncing rods)
- SPT: 100 blows per 200 mm
- End of auger hole at 9.1 m due to refusal.
- 100 blows per 125 mm
- SPT: 50 blows per 100 mm

Sample classifications: CL/CH, SM, GM, SM, SM, SM, SM, GM, SM, GP-GM, GM

SOILS DESCRIPTION

- 150 mm of ASPHALT.
- Dense, brown, sandy GRAVEL with a trace of silt (Fill).
- Stiff to very stiff, brown CLAY and SILT with a trace of sand (Possible Fill).
- Dense to very dense, brown, silty, gravelly SAND (Till-like).
- Dense to very dense, brown, silty SAND with some gravel (Till-like).
- Very dense, brown SAND and GRAVEL with a trace to some silt. Some silty zones.
- End of mud rotary hole at required depth. Groundwater level was measured upon completion of auger hole.

ELEVATION (m): 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36

LOG OF TEST HOLE

TEST HOLE NO. **E1-08-452**

THURBER

LOCATION: Wall 1901-N
N 450770.297, E 66136.446

TOP OF HOLE ELEV: 53.6 m

METHOD: Solid Stem Auger / Mud Rotary

DRILLING CO.: On-Track Drilling Inc.

INSPECTOR: PKE

CLIENT: H5M

PROJECT: Port Mann / Highway 1
Segment E1

DATE: Nov. 19, 2008 & Mar. 12, 2009

FILE NO.: 19-5187-15D

REVIEWED BY: SP

Legend: PENETRATION (blows/300 mm); WATER CONTENT (%): ○ Disturbed, ● Undisturbed; Plastic Limit, Liquid Limit; WATER LEVEL; SAMPLES: Disturbed, Undisturbed, ☒ No Recovery; UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak, ◇ Residual; GRAIN SIZE (%): ▲ Passing #200 sieve, △ Passing #4 sieve; SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

DEPTH (m) | ELEVATION (m)

Scale: 10 20 30 40 50 60 70 80 90 100

Depth (m)	Penetration	Comments	Samples	Soils Description	Elevation (m)
0.0–0.15				150 mm of ASPHALT.	
0.15–0.7				Compact, brown, sandy GRAVEL with a trace of silt (Fill).	53
0.7–3.0	133, 105, 106	End of DCPT at 1.5 m depth	SM/GM, SM, SM	Dense to very dense, brown, silty SAND with some gravel.	52, 51
3.0–7.9	101	SPT: 50 blows per 125 mm (at ~3.2 m); SPT: 50 blows per 125 mm (at ~7.8 m)	SM, SM, SP-SM, SM, SM, SM, GP-GM	Very dense, brown SAND with some silt to silty and a trace to some gravel. - 100 mm thick lens of grey-brown sand	50, 49, 48, 47, 46
7.9				End of hole at required depth. No groundwater observed in auger hole.	45

Depth scale: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Elevation scale: 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39

Sheet 1 of 1

LOG OF TEST PIT

TEST PIT NO. **TP13-04**

THURBER

LOCATION: See Dwg. 17-123-782-2

TOP OF HOLE ELEV:

METHOD: Rubber Tire Backhoe

EXCAVATOR: Case 590

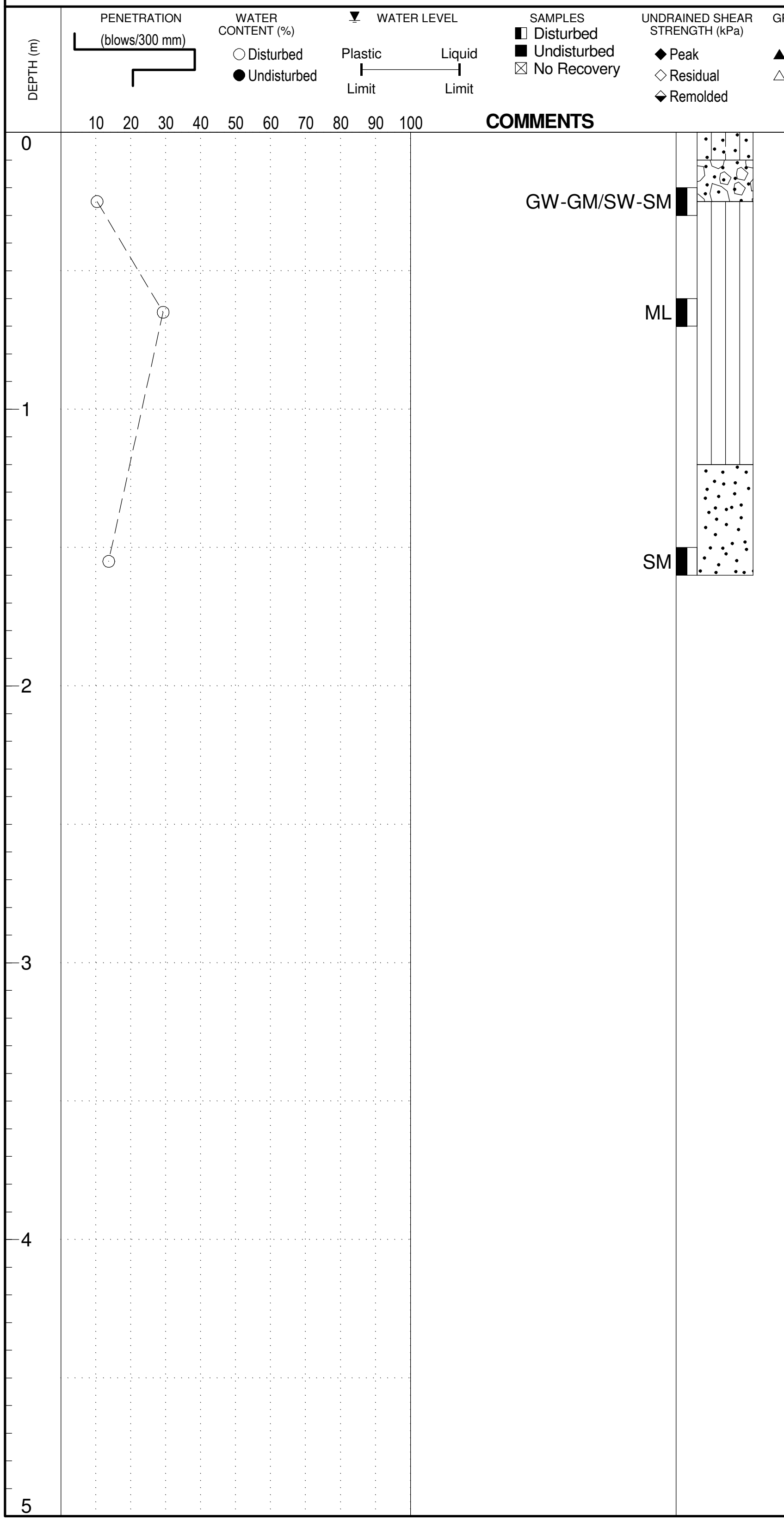
INSPECTOR: EPS

CLIENT: Associated Engineering

PROJECT: PMH1 Mobile Weigh Scales

DATE: January 30, 2013

FILE NO.: 17-123-782



Depth (m)	COMMENTS	SOILS DESCRIPTION
0		100 mm of dark brown, moist silty SAND with some fibrous organics (Topsoil).
	GW-GM/SW-SM	Compact to dense, grey, moist, GRAVEL and SAND with a trace of silt and fibrous organics (Fill).
	ML	Firm to stiff, grey, damp to moist, SILT with a trace of sand and clay.
	SM	Compact, brown, moist, medium to fine SAND with some gravel with a trace of silt.
		End of pit at required depth. No seepage or sloughing was observed.

Sheet 1 of 1

LOG OF TEST PIT

TEST PIT NO. **TP13-05**

THURBER

LOCATION:	See Dwg. 17-123-782-2	**CLIENT:**	Associated Engineering
		PROJECT:	PMH1 Mobile Weigh Scales
TOP OF HOLE ELEV:			
METHOD:	Rubber Tire Backhoe	**DATE:**	January 30, 2013
EXCAVATOR:	Case 590	**FILE NO.:**	17-123-782
INSPECTOR:	EPS		

DEPTH (m)

PENETRATION (blows/300 mm)

WATER CONTENT (%): ○ Disturbed ● Undisturbed

Plastic Limit — Liquid Limit

WATER LEVEL

SAMPLES: Disturbed; Undisturbed; No Recovery

UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ⬙ Remolded

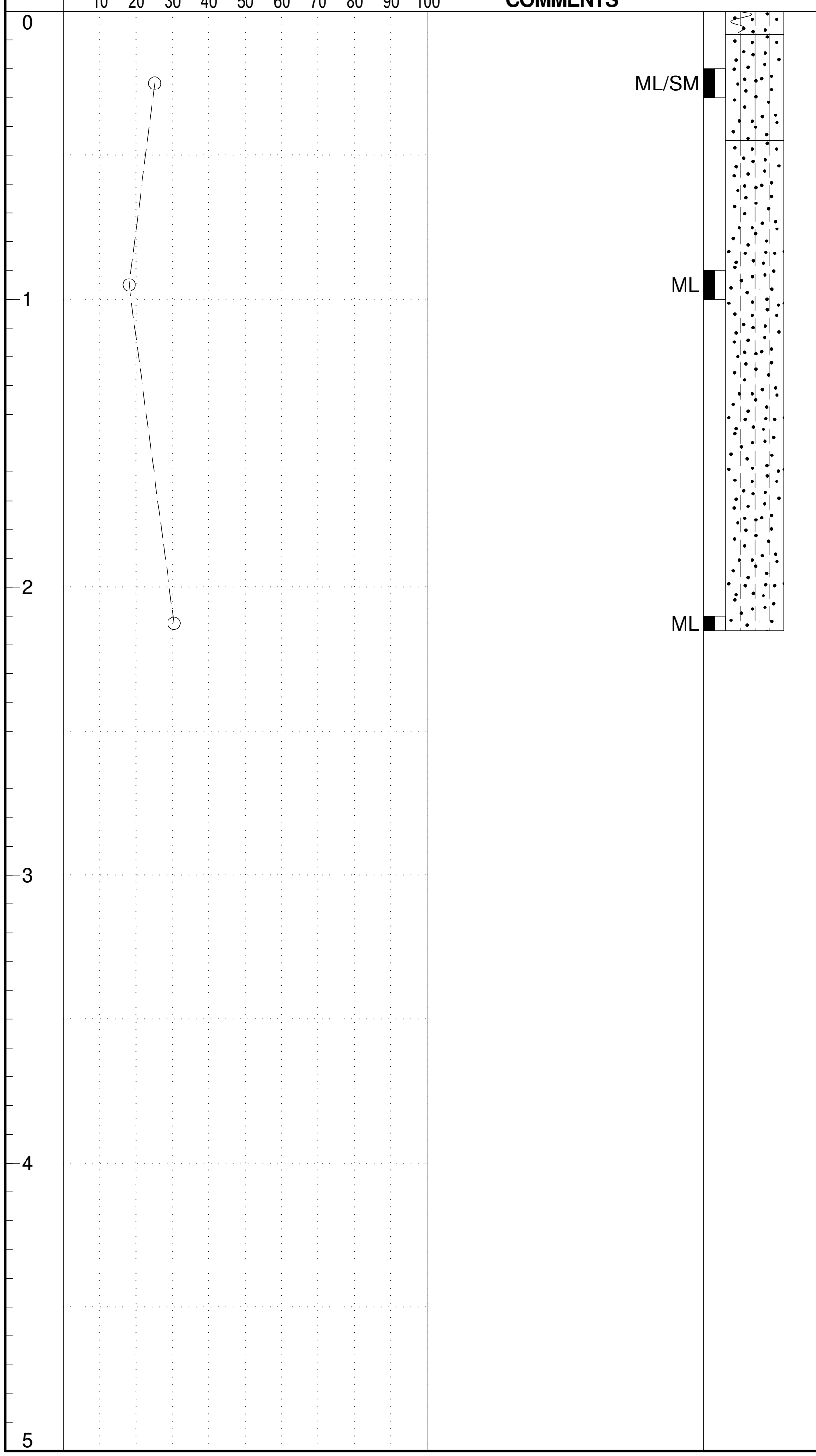
GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve

SOIL HEADSPACE READING (ppm): GASTECH reading; PID reading

10 20 30 40 50 60 70 80 90 100

COMMENTS

SOILS DESCRIPTION



Depth (m)	Soils Description
0	80 mm of loose, dark brown, moist, silty SAND with some fibrous organics (Topsoil).
	Stiff, brown and grey, damp to moist SILT and SAND with a trace of clay.
	Very stiff, brown and grey, moist SILT with some medium to fine sand and clay, with a trace of gravel.
	End of pit at required depth. No seepage or sloughing was observed.

DEPTH (m)

Sheet 1 of 1

LOG OF TEST PIT

TEST PIT NO. **TP13-06**

THURBER

LOCATION: See Dwg. 17-123-782-2

TOP OF HOLE ELEV:

METHOD: Rubber Tire Backhoe

EXCAVATOR: Case 590

INSPECTOR: EPS

CLIENT: Associated Engineering

PROJECT: PMH1 Mobile Weigh Scales

DATE: January 30, 2013

FILE NO.: 17-123-782

Legend: PENETRATION (blows/300 mm); WATER CONTENT (%) ○ Disturbed ● Undisturbed; Plastic Limit, Liquid Limit; WATER LEVEL; SAMPLES: Disturbed, Undisturbed, No Recovery; UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak, ◇ Residual, Remolded; GRAIN SIZE (%): ▲ Passing #200 sieve, △ Passing #4 sieve; SOIL HEADSPACE READING (ppm): GASTECH reading, PID reading

Scale: 10 20 30 40 50 60 70 80 90 100

DEPTH (m)	COMMENTS	Sample	SOILS DESCRIPTION
0 – 0.5		SM/GM	Compact to dense, greyish-brown, damp to moist SAND and GRAVEL with some silt (Fill).
0.5 – 1.1		SP	Compact, brown, damp, medium to fine, gravelly SAND with a trace of silt (Fill).
1.1 – 1.85	1:1 cut - sand fill next to native Silt		Very stiff, grey and brown, damp, SILT with some clay and sand.
1.85			End of pit at required depth. No seepage or sloughing was observed.

Depth scale (m): 0, 1, 2, 3, 4, 5

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 100690

Owner: DIRODI

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 56616 Lot: 9
Township: 8 Section: 31 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): Well:

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: Y
Well Depth: 68 feet
Elevation: feet (ASL)
Final Casing Stick Up: 19 inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2004-01-12 00:00:00

Driller: Clark Drilling Services Ltd.
Well Identification Plate Number: 101472
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 7 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method: Other
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 2 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material: Bentonite clay
Method:
Depth (ft):
Thickness (in):
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
61	68		20

Casing from	to feet	Diameter	Material
0	63	6	null

GENERAL REMARKS:
AQUIFER NOT COMPLETELY PENETRATED. SHOES WELDED. SCREENS JOHNSON SS. 7.16 C/W A 2.5' RISER PIPE. KPACK 6. PUMP TESTED 6 USGM ROM 35'. WELL

LITHOLOGY INFORMATION:
From 0 to 5 Ft. brown silty sand
From 5 to 50 Ft. SAND & GRAVEL. MAKING SOME WATER. brown
From 50 to 68 Ft. GOOD CLEAN WATER BEARING SAND & GRAVEL

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 11037

Owner: I GARDEN

Address: 104TH AVE.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 12 Section: 29 Range: 1
Indian Reserve: Meridian: Block: 5
Quarter:
Island:
BCGS Number (NAD 27): 092G016444 Well: 15

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 13 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 13 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 13 Ft. Hardpan

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 11192 Owner: L AASEN Address: 156TH ST. Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: Section: 34 Range: 1 Indian Reserve: Meridian: Block: 5 Quarter: Island: BCGS Number (NAD 27): 092G017331 Well: 25 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Dug Diameter: 0.0 inches Casing drive shoe: Well Depth: 17 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950-01-01 00:00:00 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 7 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Till

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 11296 Owner: R MONAGHAN Address: 104TH AVE. Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: 12 Section: 29 Range: 1 Indian Reserve: Meridian: Block: 5 Quarter: Island: BCGS Number (NAD 27): 092G016444 Well: 9 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Dug Diameter: 0.0 inches Casing drive shoe: Well Depth: 14 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950-01-01 00:00:00 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 12 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. No information

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 11305

Owner: R W HOWARD

Address: 104TH AVE.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: Section: 25 Range: 1
Indian Reserve: Meridian: Block: 5
Quarter:
Island:
BCGS Number (NAD 27): 092G017334 Well: 12

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 38 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 10 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
GOOD SUPPLY

LITHOLOGY INFORMATION:

From	0 to	3 Ft.	Clay
From	3 to	38 Ft.	Till

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 19770 Owner: SUNNY TRAILS CLUB Address: 9900 162A ST. Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: NW Island: BCGS Number (NAD 27): 092G017332 Well: 29 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 330 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: N File Info Flag: N Sieve Info Flag: N Screen Info Flag: N Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1966-01-01 00:00:00 Driller: Jim Clent Drilling Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: (Driller's Estimate) Development Method: Pump Test Info Flag: N Artesian Flow: .5 U.S. Gallons per Minute Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: N Field Chemistry Info Flag: Site Info (SEAM): N Water Utility: N Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: N Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
WATER FLOWING .5QUART PER MINUTE

LITHOLOGY INFORMATION:

From	0	to	26	Ft.	Dug hole
From	26	to	90	Ft.	Silt
From	90	to	205	Ft.	Silty clay with fine sand layers W.B.
From	205	to	330	Ft.	Silt and clay

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

```
Well Tag Number: 20543

Owner: MUN OF SURREY

Address: 8620 176TH ST.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot:  Plan:  Lot:
Township: 8 Section: 29 Range:
Indian Reserve:  Meridian:  Block:
Quarter: NW
Island:
BCGS Number (NAD 27): 092G017321 Well: 4

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Observation Well
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 8.0 inches
Casing drive shoe:
Well Depth: 425 feet
Elevation:    0  feet (ASL)
Final Casing Stick Up:  inches
Well Cap Type:
Bedrock Depth:  feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:
```

```
Construction Date: 1967-02-01 00:00:00

Driller: Western Water Wells
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield:    35 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 22 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:
```

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

```
GENERAL REMARKS:
 SEE NOTES BY J.C. FOWERAKER RE: PUMP TEST PROJECT FOLIO "TEST WELL, NORTH SURREY AUG. '66"

LITHOLOGY INFORMATION:
From     0 to    18 Ft.   Soft brown sand
From    18 to   200 Ft.   Clay - blue
From   200 to   205 Ft.   Clay, silt some gravel
From   205 to   210 Ft.   Silt, sand
From   210 to   212 Ft.   Silt, sand, gravel, a little water
From   212 to   230 Ft.   Silt, clay with some coarser zones,
From     0 to     0 Ft.   little water
From   230 to   238 Ft.   Silty coarse to med. gravel
From   238 to   242 Ft.   Coarse to med. gravel
From   242 to   245 Ft.   Fine, silty gravel
From   245 to   250 Ft.   Sand and gravel
From   250 to   260 Ft.   Med. sand, some gravel
From   260 to   273 Ft.   Very fine sand
From   273 to   300 Ft.   Sand with silt a little clay, water shut
From   273 to   300 Ft.   cont...off.
From   300 to   309 Ft.   Silty sand
From   309 to   330 Ft.   Sand with some clay
From   330 to   335 Ft.   Sand with clay
From   335 to   350 Ft.   Sandy clay with some pebbles
From   350 to   354 Ft.   Solme gravel with silt and sand
From   354 to   360 Ft.   Sand with some gravel - tight - till ?
From   360 to     0 Ft.   Reduced from 10" to 8" casing
From   360 to   370 Ft.   Sand with silt
From   370 to   379 Ft.   Sand and clay
From   379 to   385 Ft.   Hard blue clay
From   385 to   425 Ft.   Clay, sand, silt some small pebbles
```

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 2848

Owner: J BATEMAN

Address: 156TH ST.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 2 Section: 35 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): 092G017313 Well: 22

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 71 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1947-01-01 00:00:00

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 66 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	35	Ft.	Till
From	0	to	0	Ft.	Gravel
From	0	to	0	Ft.	Sand

BRITISH COLUMBIA

Report 1 - Detailed Well Record

```
Well Tag Number: 2924

Owner: W BOTHWELL

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot:  Plan: 2918 Lot: 4
Township: 2 Section: 36 Range:
Indian Reserve:  Meridian:  Block:
Quarter: NE
Island:
BCGS Number (NAD 27): 092G017314 Well: 23

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 3.0 inches
Casing drive shoe:
Well Depth: 90 feet
Elevation:    0  feet (ASL)
Final Casing Stick Up:  inches
Well Cap Type:
Bedrock Depth:  feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:
```

```
Construction Date: 1948-01-01 00:00:00

Driller: Surrey Well Drillers
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield:       (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:  .01 U.S. Gallons per Minute
Artesian Pressure (ft):
Static Level: 1 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM): N

Water Utility: N
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:
```

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

```
GENERAL REMARKS:
 WATER FLOWED IMMEDIATELY, CAN SHUT OFF. SUPPLY HAS INCREASED SLIGHTLY, WATER BROUGHT UP FINE SAND. ARTESIAN.

LITHOLOGY INFORMATION:
From     0 to     20 Ft.   Yellow clay
From    20 to     22 Ft.   Gravel
From    22 to     89 Ft.   Blue clay (pure clay
From    89 to     90 Ft.   Gravel and sand and water
```

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 54689 Owner: RALPH THERRES Address: 8577 184TH ST. Area: SURREY WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: 38258 Lot: 3 Township: 8 Section: 29 Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092G017322 Well: 4 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Y Well Depth: 380 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: N File Info Flag: N Sieve Info Flag: N Screen Info Flag: Y Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1985-04-22 00:00:00 Driller: Columbia Water Wells Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 5 (Driller's Estimate) Imperial Gallons per Minute Development Method: Pump Test Info Flag: N Artesian Flow: .33 Imperial Gallons per Minute Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: N Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size
370.52	380		25

Casing from	to feet	Diameter	Material	Drive Shoe
0	380	6	Steel	Y

GENERAL REMARKS:
OLD WELL - BUILT BEFORE MOVED IN WAS CORRODED, ETC. SO DRILLED NEW WELL - RAN LOW IN SUMMERS - DIDN'T KNOW DEPTH.

LITHOLOGY INFORMATION:

From	0	to	2	Ft.	Fill - top soil
From	2	to	9	Ft.	Brown peat
From	9	to	18	Ft.	Firm - blue-green clay
From	18	to	60	Ft.	Blue clay
From	60	to	220	Ft.	Grey clay
From	220	to	264	Ft.	Stoney grey clay
From	264	to	295	Ft.	Water bearing very fine sand with lenses
From	0	to	0	Ft.	of grey clay
From	295	to	304	Ft.	Very firm grey stoney clay
From	304	to	309	Ft.	Packed silty sand and gravel
From	309	to	324	Ft.	Gravelly till
From	324	to	372	Ft.	Layered grey stoney clay and till
From	372	to	377	Ft.	Water bearing sand and gravel - tight
From	0	to	0	Ft.	with lenses of grey clay
From	377	to	380	Ft.	Packed sand and gravel

- Return to Main
- Return to Search Options
- Return to Search Criteria

Report 1 - Detailed Well Record

Well Tag Number: 78527

Owner: LEE

Address: 8942 187 STREET

Area: SURREY

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 1070 Lot: 24
Township: 8 Section: 33 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G017324 Well: 63

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: 157 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: Y

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-09-24 00:00:00

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 15 (Driller's Estimate) U.S. Gallons per Minute
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 15 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
157	153		50
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
8942 187 ST SURREY BC

LITHOLOGY INFORMATION:

From	0 to	1 Ft.	SOIL
From	1 to	46 Ft.	SAND BROWN WET
From	56 to	69 Ft.	SILTY FINE SAND
From	69 to	123 Ft.	SILT
From	123 to	139 Ft.	CLAY GREY
From	139 to	157 Ft.	GRAVEL COARSE SOME BINDER

- Return to Main
- Return to Search Options
- Return to Search Criteria

APPENDIX 2 – WEB 2011 EROSION SITE 25-3 RAVINE STABILITY ASSESSMENT DATA SHEET

Ravine Stability Assessment Data Sheet 2011

Site ID # **25-3**

Watercourse: **Upper Serpentine River**

SURREY
CITY OF PARKS

Site Location: From Guildford Brook confluence to northern edge of Tynehead Park

Date Assessed: Mar.15, 2011

Coordinates: N 5448601 E 516044

Nearest Civic Address: 10264 – 159A Street

2009 Site ID 25-3

Description of Risk / Deficiency: Erosion

Characteristic of Risk	Risk Assessment (Low, Med, High)	Channel Dimensions	m	Channel Dimensions	m
Risk Probability (L1, M2, H3)	H	Left Bank Height:	2.0	Right Bank Height:	10
Risk Consequence (L1, M2, H3)	M	Left Bank Slope (H:V):	2 : 1	Right Bank Slope (H:V):	1 : 6
Cost to Mitigate (H1, M2, L3)	H	Low Flow Channel Width:	1.0		
Overall Risk Level High , Med , Low	High	Low Flow Channel Depth:	0.2		


2011 Assessment Photo


2009 Assessment Photo

2011 Comment: Erosion prevalent. New trees look to have fallen in river recently.

2009 Comment: Continuation of erosion with many trees undermined in this area. Significant changes from 2005 to 2007 to 2009.

APPENDIX E

HYDROLOGIC / HYDRAULIC ANALYSIS

APPENDIX E

PCSWMM Modeling

Parameters & Results

Contents

1. GENERAL MODELLING PARAMETERS (EXISTING CONDITIONS)

1.1 Subcatchments

Attribute	**Default Value or Method of Determination**
Area (ha)	Minimum area of upstream subcatchment is 20ha. Subsequent subcatchments as necessary to create model.
Outlet	Selected as most downstream junction adjacent to the subcatchment.
Width (m)	Generated using GIS process that determines average width and length of subcatchment polygon. This value was adjusted to 25% of the GIS calculated value during calibration step.
Slope (%)	Generated using GIS process that determines average slope of LIDAR surface of subcatchment polygon.
Imperv. (%)	Generated using GIS process that determines impervious surface from hi-res satellite imagery. This process associates colours with ground cover types.
N Imperv	0.012 for smooth concrete (PCSWMM Handbook - McCuen, R. et al. (1996), Hydrology, FHWA-SA-96-067, Federal Highway Administration, Washington, DC)
N Perv	0.2 for medium density grass (PCSWMM Handbook - McCuen, R. et al. (1996), Hydrology, FHWA-SA-96-067, Federal Highway Administration, Washington, DC)
Dstore Imperv (mm)	1.5 (as per model created for Anniedale)
Dstore Perv (mm)	1 (GVSDD recommendation)
Subarea Routing	Rural and single family areas routed to PERVIOUS. Industrial and multi-family areas routed to OUTLET. Assumed subcatchments with more than 45% site coverage are considered industrial or multi-family (original value 60% but adjusted during calibration).
Percent Routed (%)	100% for existing condition base model.
Infiltration: Horton	

Max. Infil. Rate (mm/hr)	5 (original value of 10 but reduced during calibration)
Min. Infil. Rate (mm/hr)	0.75 (original value of 1 but reduced during calibration)
Decay Constant 1/hr)	4 (from Anniedale model)
Drying Time (days)	7 (from Anniedale model)
Max. Volume (mm)	0 (from Anniedale model)

1.2 Junctions

Attribute	**Default Value or Method of Determination**
Invert Elev. (m)	From lowest connected pipe invert (PCSWMM routine)
Rim Elev. (m)	From provided GIS data (primary) or from LIDAR surface data (secondary).
Depth (m)	Calculated by subtracting invert elevation from rim elevation.
Ponded Area (m^2)	100 – this allows for buffering of stormwater in and out of the system
Inflows	
Baseline (m^3/s)	Baseline flow was applied to junctions that are subcatchment outlets only. Summer dry weather flow for the Upper Serpentine at 104th Ave was determined from stream flow records. The average dry weather was determined to be 0.017 m^3/s. This flow was divided by the total contributing area to this sample location (294.05 ha) to determine the base flow of 5.781×10^{-5} $m^3/s/ha$. Using this rate, the base flow from each subcatchment was calculated and applied to each subcatchment's respective outlet junction.

1.3 Conduits – Pipes & Culverts

Attribute	Default Value or Method of Determination
Length (m)	From PCSWMM Auto-Length routine during import.
Roughness	Concrete Pipe, PVC, PE = 0.013 CMP (culvert) = 0.024
Inlet Elev. (m)	From GIS data: UP_ELEV
Outlet Elev. (m)	From GIS data: DOWN_ELEV
Entry Loss Coeff.	0.5
Exit Loss Coeff	0
Cross-Section	CIRCULAR
Geom1 (m)	From GIS data: MAIN_SIZE

1.4 Conduits - Ditches

Attribute	Default Value or Method of Determination
Length (m)	From PCSWMM Auto-Length routine during import.
Roughness	Ditch with grass/brush = 0.065
Inlet Elev. (m)	From GIS data: UP_ELEV
Outlet Elev. (m)	From GIS data: DOWN_ELEV
Entry Loss Coeff.	0
Exit Loss Coeff	0 (connected pipe); 1 (end pipe or culvert)
Cross-Section	TRAPEZPOIDAL
Geom1 (m)	2 (2 m deep)
Geom1 (m)	1 (1m bottom width)
Geom3	3 (3:1 side slopes)
Geom4	3 (3:1 side slopes)

1.5 Conduits – Creeks & Rivers

Attribute	Default Value or Method of Determination
Length (m)	Calculated length from PCSWMM Auto-Length routine during import.
Roughness	Main channel with weeds and stones = 0.045
Inlet Elev. (m)	From GIS data: UP_ELEV
Outlet Elev. (m)	From GIS data: DOWN_ELEV
Entry Loss Coeff.	0
Exit Loss Coeff	0
Cross-Section	IRREGULAR
Transect	Transects taken from LIDAR surface at approximately 200m intervals along the creek.

1.6 Pump Station

The Upper Serpentine pump station, located east of where the river crosses under 176th St, was added to the model. The pump station is comprised of two major components: a floodbox and a pump station. The floodbox is comprised of a trio of 1500mm diameter aluminum CSP cuvlerts installed in parallel with slide gates at the inlet and flap gates at the outlets. The pump station is comprised of dual screw pumps with associated structural and electrical components.

The floodbox was modelled as per other culverts, confirming details with the pump station record drawings.

The screw pumps were added to the model as two separate PUMPS. The following image shows the pump curve used for the model. The pumping rate of 1m3/s was taken from the record drawings. Screw pumps pump at a constant rate while they are ON.

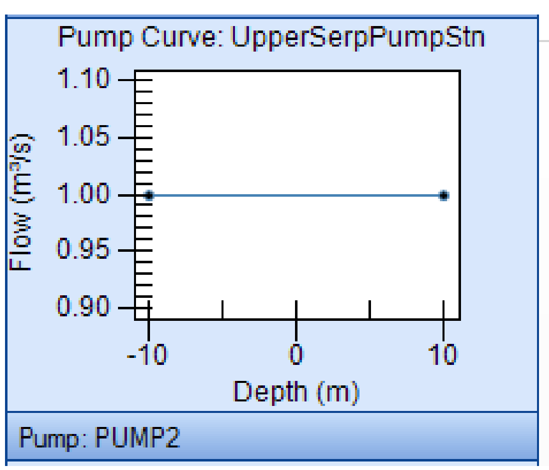


Figure 1: Upper Serpentine Pump Station - Screw Pump Curve

The following table lists the control information for the pumps as listed on the record drawings.

Pump ID	**Description**	**Startup Depth (m)**	**Shutoff Depth (m)**
PUMP1	Lead Pump	1.36	0.96
PUMP2	Lag Pump	1.66	1.46

1.7 Detention Ponds

Two detention ponds were modelled: Guilford Heights and Fraserglen. These were modelled using record drawings as reference.

Guilford Heights is comprised of a large storage pond with a 1m diameter outlet pipe which is connected to a control manhole. The storage was modelled with a TABULAR storage curve, which is shown in the following figure.

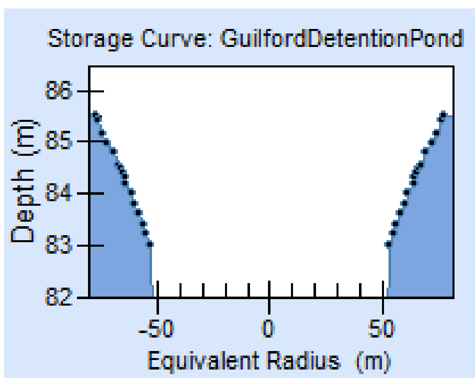
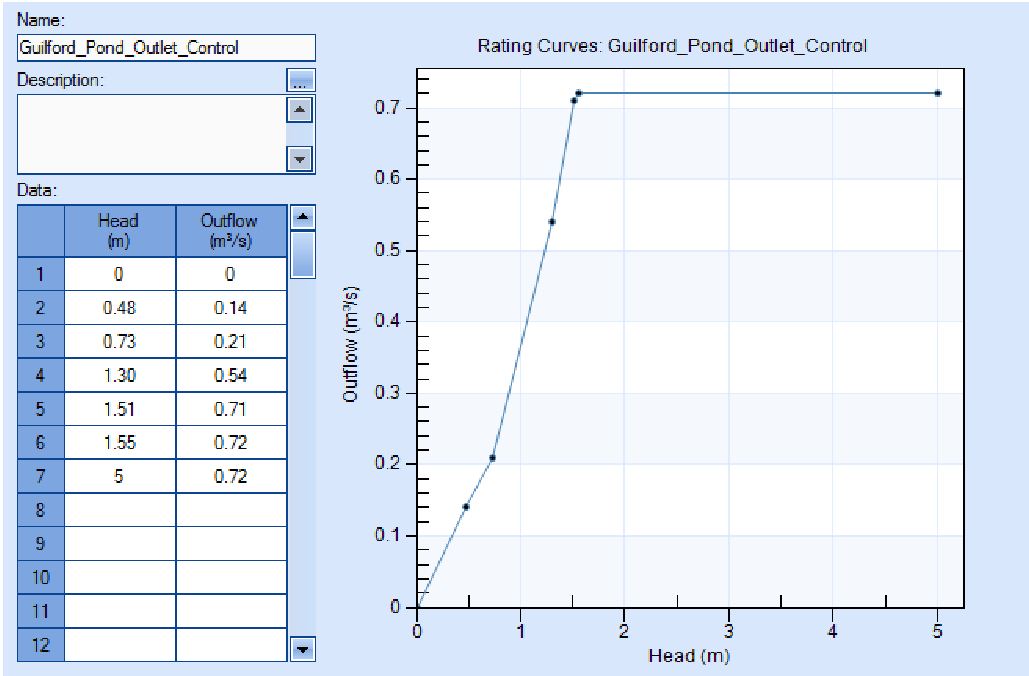


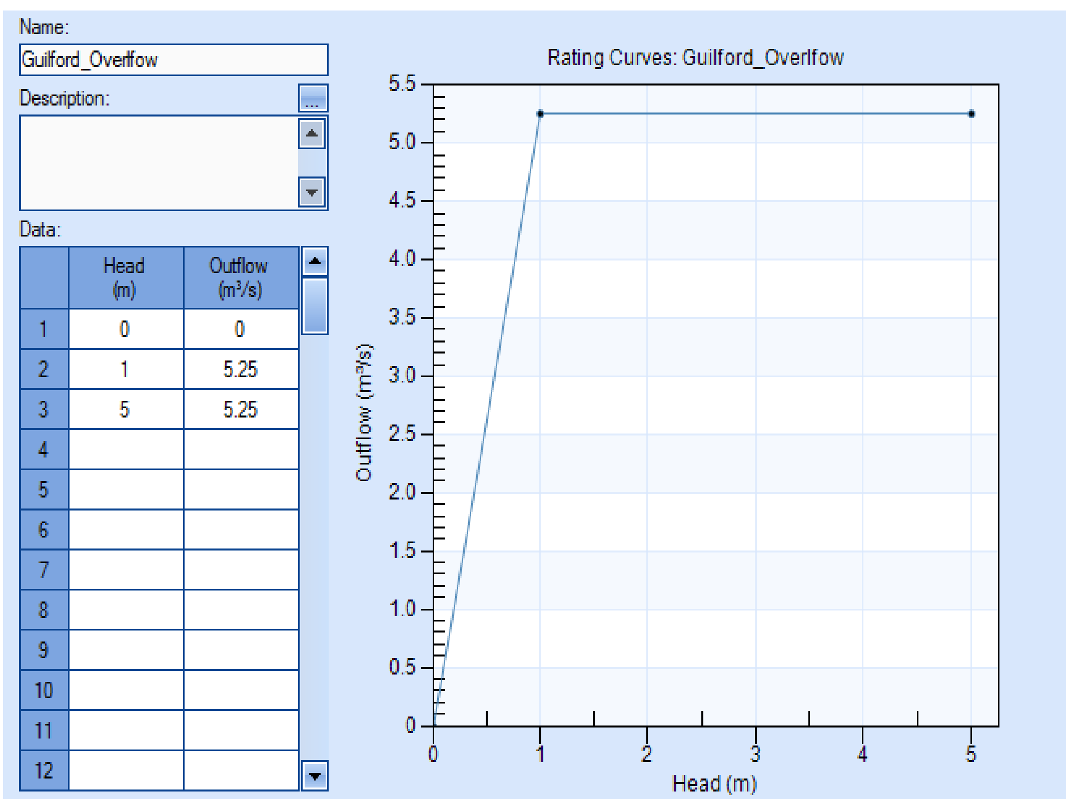
Figure 2: Guilford Heights Detention Pond Storage Curve

The control manhole was modelled with two outlets: a normal outlet and an overlflow outlet. The pond outlets are both controlled by TABULAR/DEPTH rating curves, which are shown in the following figures. In general, the normal outlet flow rate is set of 0.72 m^3/s. Should this flow rate be insufficient to maintain reasonable detention pond depth, the overflow activates to release flow at a rate of 5.25 m^3/s.



	Head (m)	Outflow (m³/s)
1	0	0
2	0.48	0.14
3	0.73	0.21
4	1.30	0.54
5	1.51	0.71
6	1.55	0.72
7	5	0.72
8		
9		
10		
11		
12		

Figure 3: Guilford Pond - Normal Outlet Control



	Head (m)	Outflow (m³/s)
1	0	0
2	1	5.25
3	5	5.25
4		
5		
6		
7		
8		
9		
10		
11		
12		

Figure 4: Guilford Pond - Overlow Outlet Control

Similarly, the Fraserglen Pond is comprised of a storage pond with two outlets: one controlled by orifice, and the other a larger diameter overflow. In this case, the overflow was modelled as a simple conduit while the normal outflow was modelled as an orifice. The following figures illustrate the storage and orifice parameters for Fraserglen Pond.

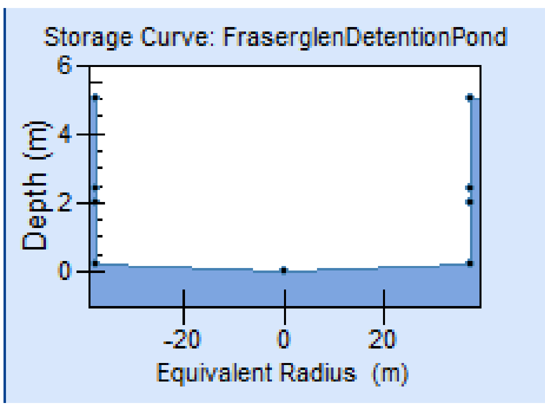


Figure 5: Fraserglen Detention Pond Curve

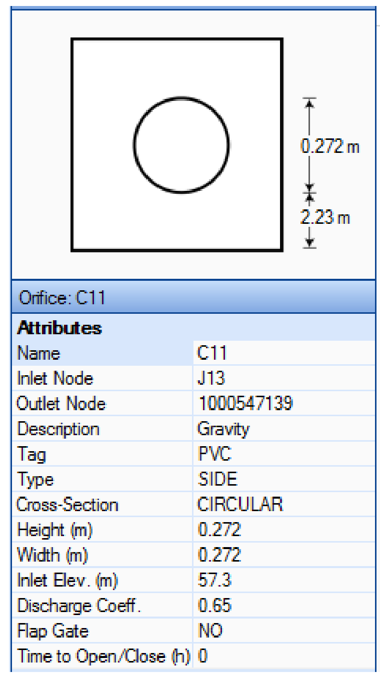
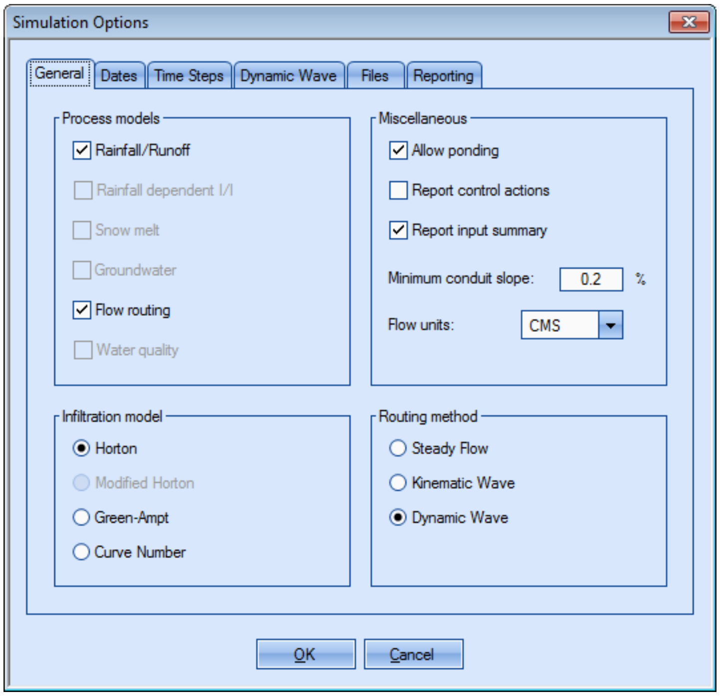


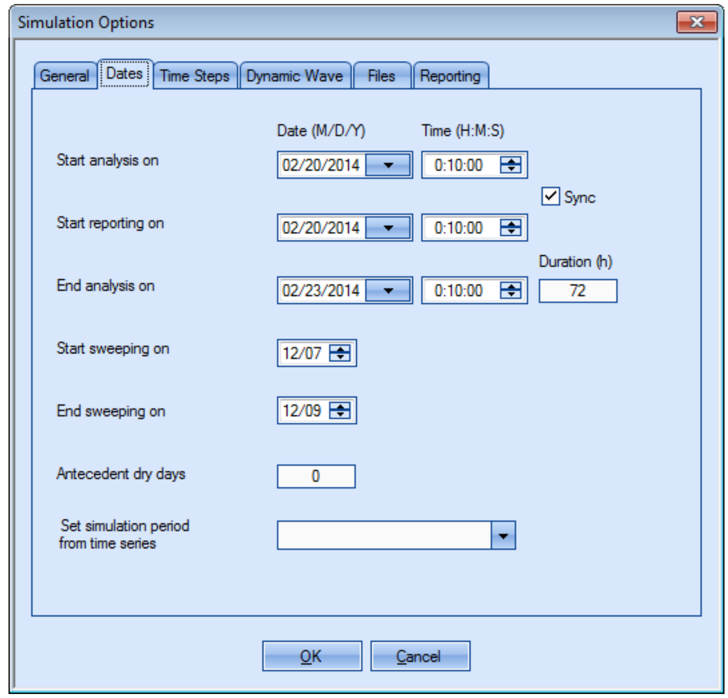
Figure 6: Fraserglen Pond Outlet Orifice

1.8 Outfall

There is one outfall in the model, OF1, which is modelled as a NORMAL type of outfall, meaning that the outfall stage is based on normal flow depth in the connecting conduit.

1.9 Simulation Options





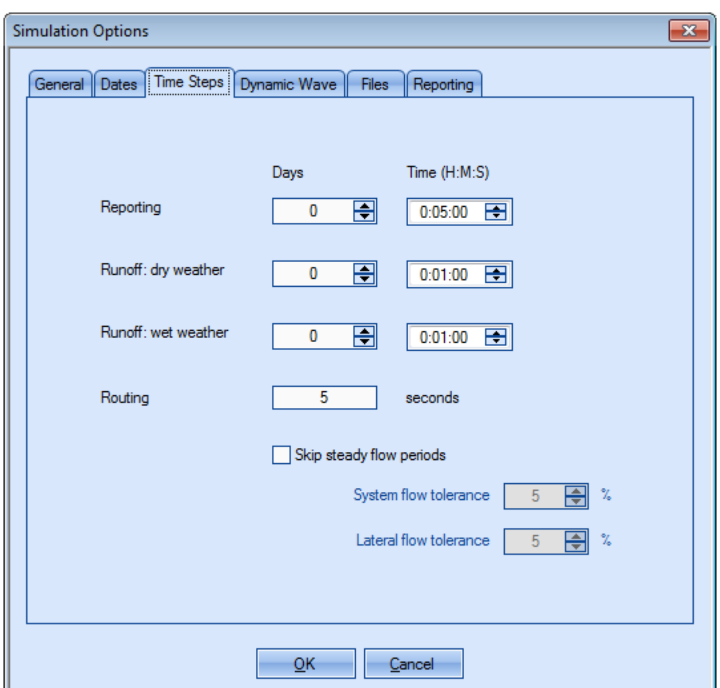
1.10 Rainfall

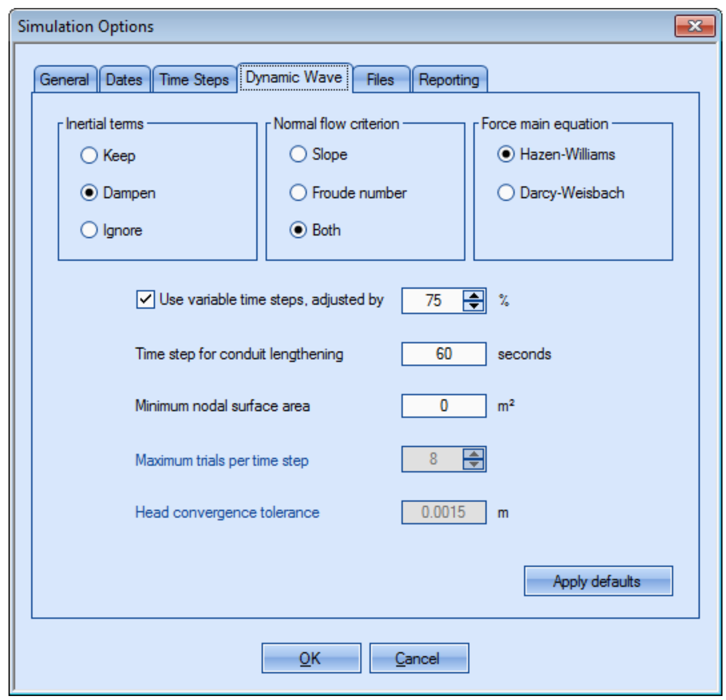
The Environment Canada IDF data used for the model was as follows:

SURREY KWANTLEN PARK BC 1107873

Latitude: 49 11'N Longitude: 122 52'W
Elevation/Altitude: 78 m

Years/Années : 1962 - 1999 # Years/Années : 37





Rainfall hyetographs were generated for each 2 year, 5 year, and 100 year storm intensities. The following table lists the hyetograph type for each storm duration.

Storm Duration	Hyetograph Type
1 hour	Modified AES Short Storm
2 hour	Modified AES Short Storm
6 hour	AES Long Storm
12 hour	SCS Type 1A
24 hour	SCS Type 1A

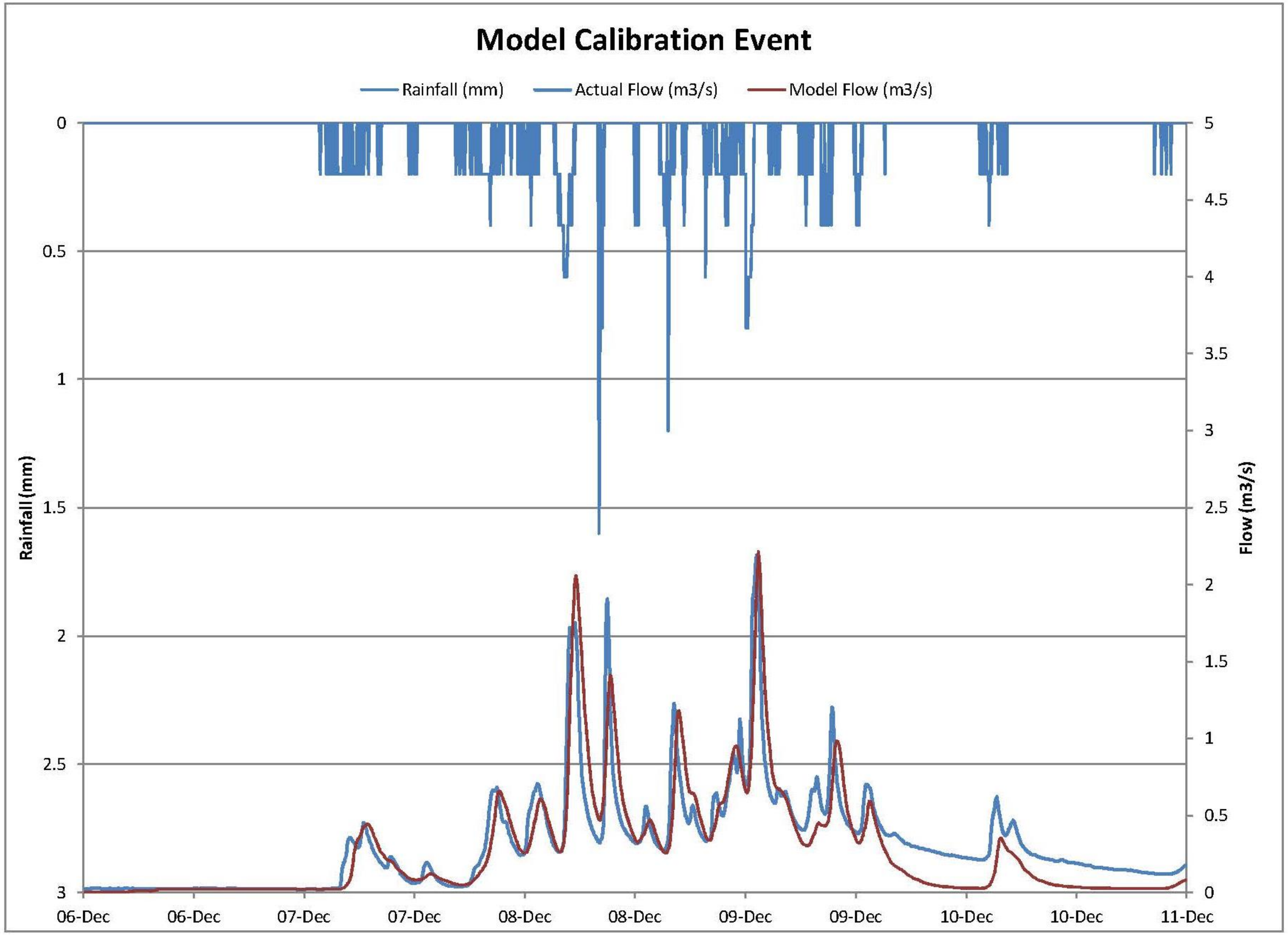
2. CALIBRATION

The model was calibrated against stream gauge data for the Serpentine River at 104 Ave. The model was initially calibrated against one typical winter storm (December 2010), and then the calibrated model was run against three months of winter data (Oct-Dec 2011) to confirm the results. The following table lists the parameters that were reviewed during the calibration exercise:

Parameter	Original Value	Adjusted Value	Notes
Subcatchment Width	1	0.25	Globally multiplied subcatchment widths to 25% of original value to lower the highest flow peaks.
Subarea Routing	60%	45%	Changed boundary between 'OUTLET' and 'PERVIOUS' subarea routing to lower threshold of site coverage.
Dstore Imperv (mm)	1.5	1.5	No significant effect of modification.
Dstore Perv (mm)	5	1	Raised early peaks and volumes but did not help recession limb.
Max Infil Rate (mm/hr)	10	5	
Min Infil Rate (mm/hr)	1	0.75	Increased volume under peaks; slowed recession.
Base Flow Rate (m^3/s/ha)	0.00005781	0.00007517	Increased base flow rate to match flow gauge.

See **Figure E-1** which shows the results of the calibration modeling.

Figure E-1: Model Calibration Event



3. BMPs

3.1 Disconnected Roof Leaders

The first type of BMP is disconnected roof leaders. In the model, this translates to Subarea Routing. In this case, disconnected roof leaders was only applied to single family developments, agricultural areas, and parkland. To accomplish application of this to the model, the percentage of each subcatchment that was comprised of single family, agricultural, or parkland was determined, and this percentage of the subcatchment was applied as the PERCENT ROUTED and the SUBAREA ROUTING was toggled to PERVIOUS for any applicable subcatchment.

3.2 Amended Topsoil

Amended topsoil was modelled via the DSTORE PERV subcatchment attribute. It was not practical to assume that topsoil would be placed on all impervious areas in existing developments; therefore, the land coverage was compared between existing and future land use to determine areas undergoing development. It was assumed that if the land was becoming, for example, 40% more impervious, that 40% of the site could be treated with topsoil. Since Anniedale will undergo full development, the entire amount of topsoil was applied to the Anniedale subcatchments.

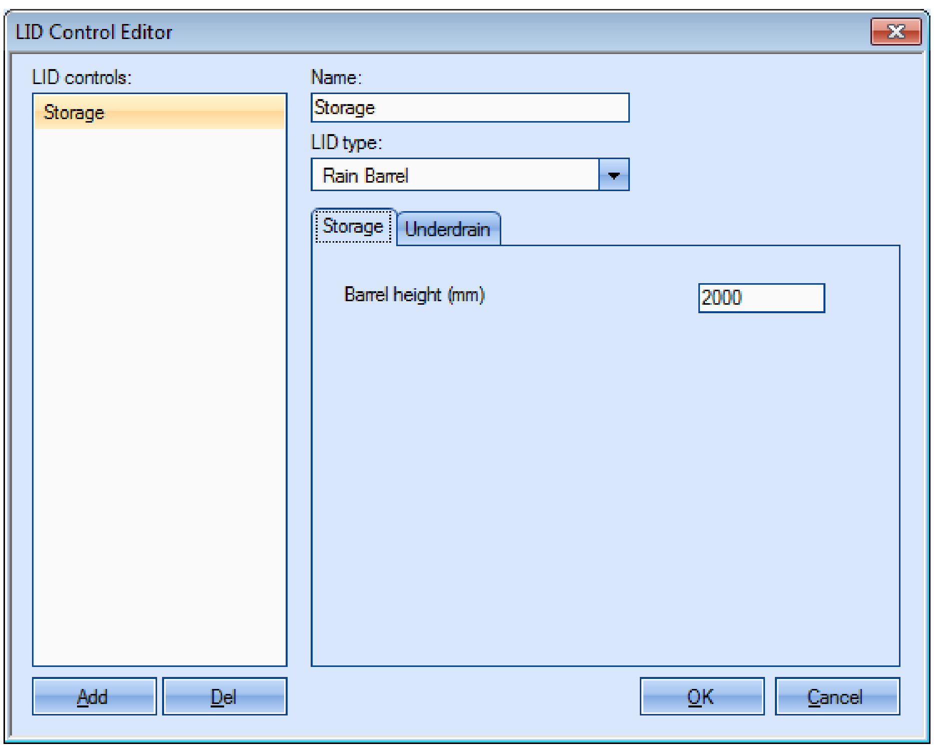
Two different thicknesses of topsoil were modelled for the various scenarios. To determine the corresponding DSTORE PERV value, porosity was assumed to be 30%, with a factor of safety of 1.5. The calculations are as follows:

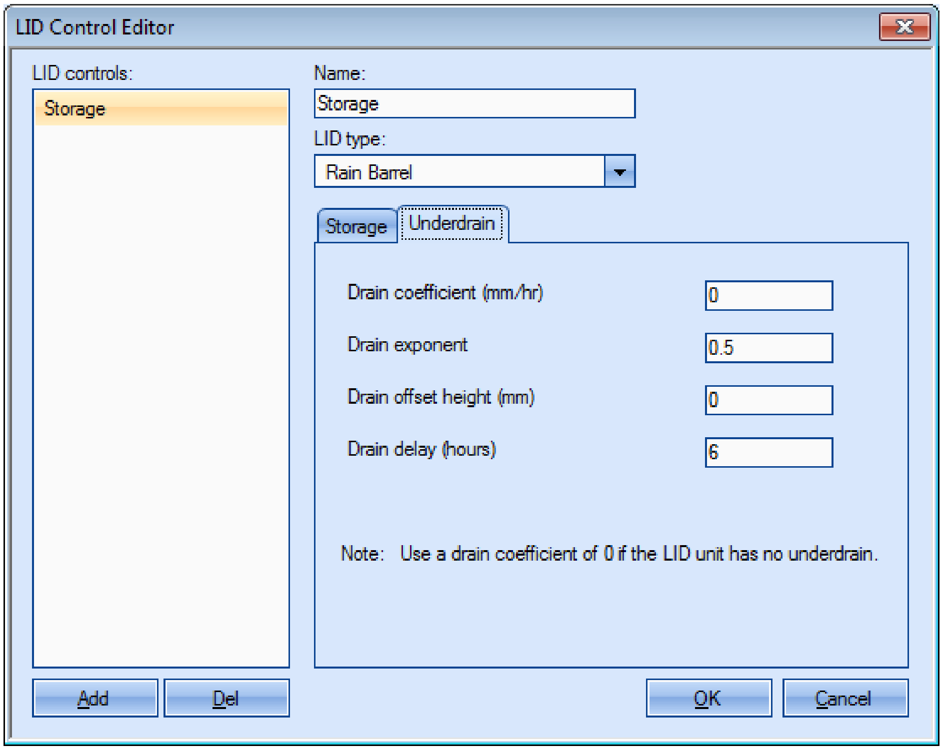
300mm topsoil x 30% porosity / 1.5 FS = 60mm Dstore Imperv

400mm topsoil x 30% porosity / 1.5 FS = 80mm Dstore Imperv

3.3 Stormwater Storage

Stormwater storage was modelled via the LID module in PCSWMM. To determine the storage volume, the storage rate was multiplied by the impervious site area. This storage volume was applied to each applicable subcatchment as a rainbarrel with a nominal height of 2.0m and no underdrain (never releases back into the system). The following figures describe the input parameters for the LID storages.




LID Control Editor
LID controls:
Storage
Name:
Storage
LID type:
Rain Barrel
Storage
Underdrain
Drain coefficient (mm/hr)
0
Drain exponent
0.5
Drain offset height (mm)
0
Drain delay (hours)
6
Note: Use a drain coefficient of 0 if the LID unit has no underdrain.
Add
Del
OK
Cancel

4. SCENARIOS

4.1 Future Condition

The future condition was created by applying subcatchment impervious values as per OCP for type of land use. The percent impervious for each subcatchment was calculated using a GIS routine. The following table summarizes the assumed percent impervious for each land use type.

Table 1: Land Use Type and Assumed Imperviousness

LAND USE TYPE	ASSUMED PERCENT IMPERVIOUS
OCP Areas:	
Agriculture	20%
City Centre	90%
Commercial	90%
Conservation	10%
Industrial	90%
Multiple Residential	80%
Suburban	55%
Town Centre	90%
Urban	65%
Anniedale-Tynehead Neighbourhood:	
Low Density Residential	65%
Medium Density Residential	80%
High Density Residential	80%
Suburban Cluster	55%
Riparian Area / Fish Buffer	10%
Commercial	90%
Institutional	80%
Industrial / Industrial Business Park	90%
Park / Trail / Landscape Buffer	20%
Fleetwood Town Centre:	
Single Family / Low Density Residential	65%
Medium Density Residential	80%
Commercial	90%
Industrial	90%
Institutional	80%
Park / Corridor	20%

4.1 Climate Change

Climate change was modelled by multiplying the time series of the design storms by 1.1 and 1.2 to analyze the effects of 10% and 20% increase in rainfall.

4.2 Scenario 1

Scenario 1 included the following BMPs:

- Disconnected roof leaders
- 300mm of amended soil *in Anniedale neighbourhood only*
- 350 m^3/ha impervious *in Anniedale neighbourhood only*

4.3 Scenario 2

Scenario 2 included the following BMPs:

- Disconnected roof leaders
- 300mm of amended soil in Anniedale neighbourhood *plus all other developing areas*
- 350 m^3/ha impervious in Anniedale neighbourhood only

4.4 Scenario 3

Scenario 3 included the following BMPs:

- Disconnected roof leaders
- *400mm* of amended soil in Anniedale neighbourhood plus all other developing areas
- *400 m^3/ha* impervious in Anniedale neighbourhood only

4.5 Scenario 4

Scenario 4 included the following BMPs:

- Disconnected roof leaders
- 400mm of amended soil in Anniedale neighbourhood plus all other developing areas
- 400 m^3/ha impervious in Anniedale neighbourhood *plus all other developing areas (greater than 10% increase in impervious area)*

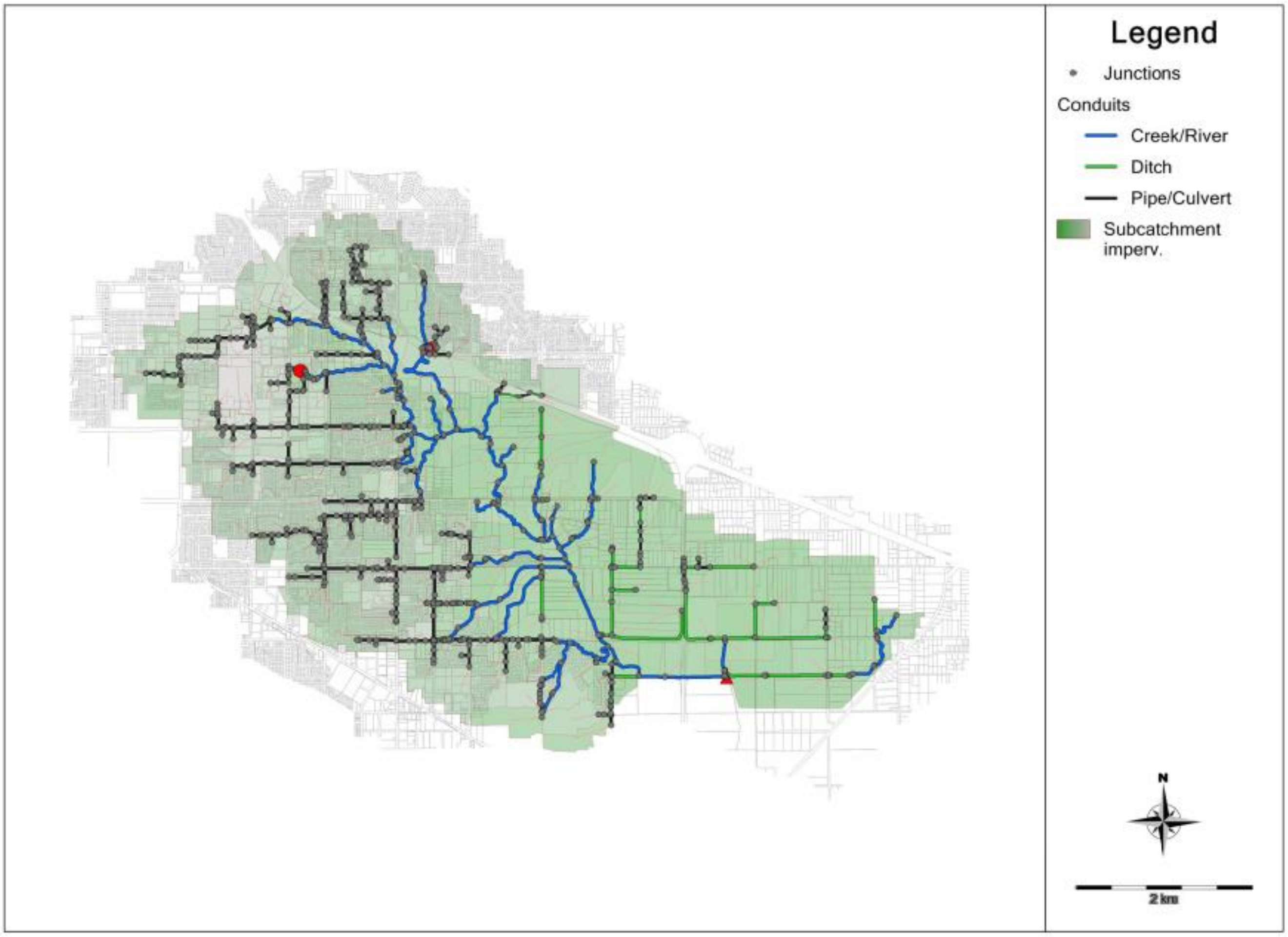
4.6 Summary

The following table summarizes the scenarios that were analyzed for the project:

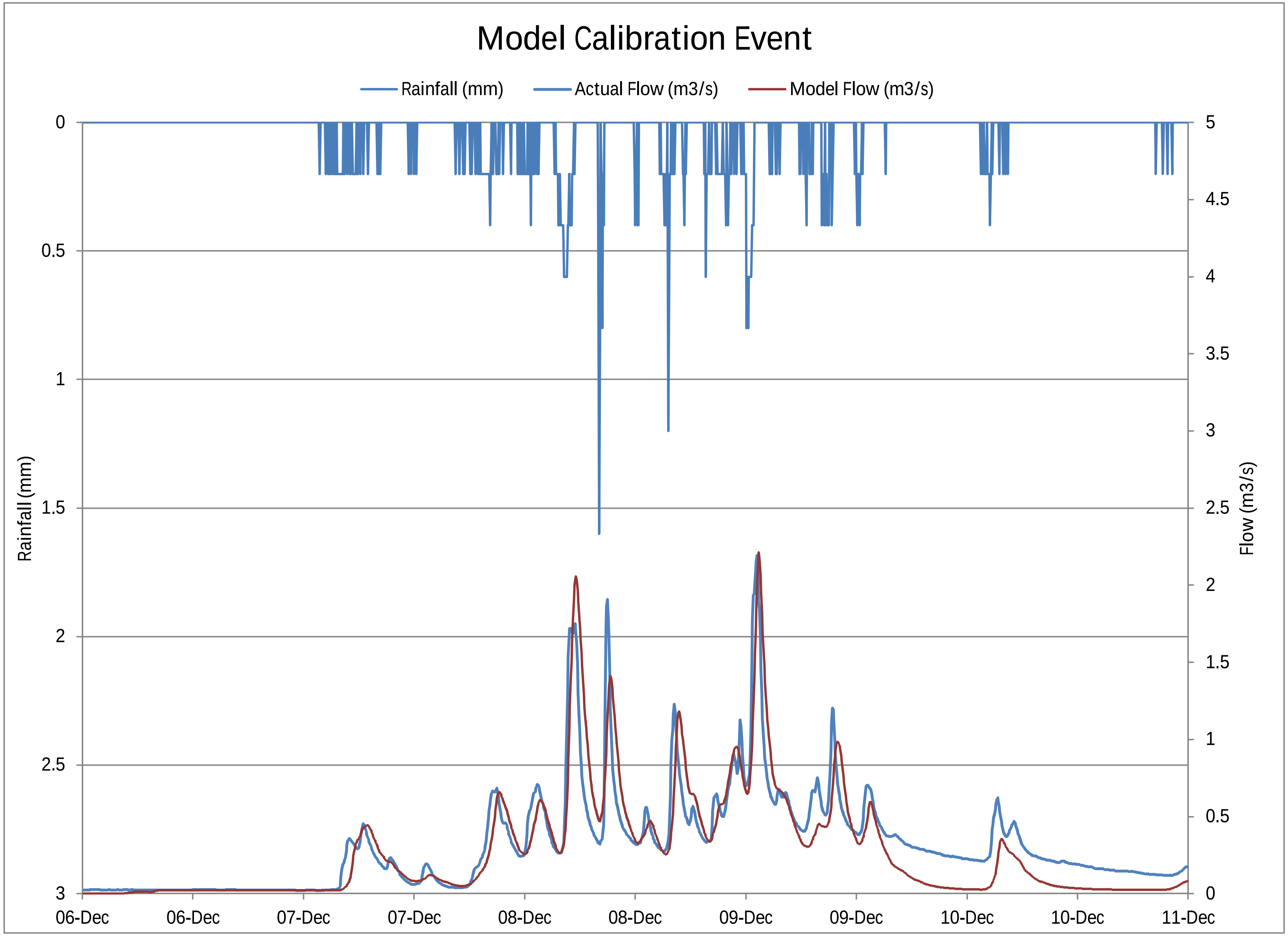
Scenario:	Existing	Future Unmanaged	Future with Climate Change #1	Future with Climate Change #2	Future Management Scenario #1	Future Management Scenario #2	Future Management Scenario #3	Future Management Scenario #4
Land Use Condition:	Existing	Future	Future	Future	Future	Future	Future	Future
Rainfall:	Per current standards	Per current standards	+10%	+20%	Per current standards	Per current standards	Per current standards	Per current standards
Roof Leader Disconnect:	Yes	No	No	No	Yes	Yes	Yes	Yes
Amended Soils Depth (mm):	n/a	n/a	n/a	n/a	300 (Anniedale only)	300 (all new development, incl infill)	400 (all new development, incl infill)	400 (all new development, incl infill)
50% MAR capture:	n/a	n/a	n/a	n/a	350 m3/imp ha (Anniedale only)	350 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale only)	400 m3/imp ha (Anniedale plus all areas >10% imp cover increase)

5. SAMPLE MODEL: EXISTING CONDITIONS - 5YR12HR

5.1 Map



[NOTE: Output on to be provided in digital format with final report]



Model Calibration Event
Rainfall (mm)
Actual Flow (m3/s)
Model Flow (m3/s)
Rainfall (mm)
Flow (m3/s)
0
0.5
1
1.5
2
2.5
3
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
06-Dec
06-Dec
07-Dec
07-Dec
08-Dec
08-Dec
09-Dec
09-Dec
10-Dec
10-Dec
11-Dec

APPENDIX F

COST ESTIMATES

Upper Serpentine ISMP

Estimated Construction Costs for Recommended Storm Sewer Upgrades & Pond Reconfigurations

Location of Recommended Storm Sewer Upgrade	**Total Pipe Length (m)**												**Totals**
Existing Pipe Size	250mm	300mm	375mm	450mm	525mm	600mm	675mm	750mm	900mm	1050mm	1200mm	1800mm	
Proposed Pipe Size	**300mm**	**375mm**	**450mm**	**525mm**	**600mm**	**675mm**	**750mm**	**900mm**	**1050mm**	**1200mm**	**1800mm**	**2000mm**	
Construction Cost (per metre)	$1,154	$1,368	$1,475	$1,582	$1,689	$1,796	$2,010	$2,224	$2,438	$2,866	$3,294	$4,117	
88 Ave from 158 St to 168 St						173	657	218	123	1012			2,183
	$ -	$ -	$ -	$ -	$ -	$ 310,708	$ 1,320,570	$ 484,832	$ 299,874	$ 2,900,392	$ -	$ -	$ 5,316,376
90 Ave from 162 St to 164 St		114	278										392
	$ -	$ 155,952	$ 410,050	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 566,002
92 Ave from 156 St to 164 St, plus lateral trunk along 160 St from 189 St						777	203	400	538	299			2,217
	$ -	$ -	$ -	$ -	$ -	$ 1,395,492	$ 408,030	$ 889,600	$ 1,311,644	$ 856,934	$ -	$ -	$ 4,861,700
94 Ave from 152 St to 156 St						222		167	433				822
	$ -	$ -	$ -	$ -	$ -	$ 398,712	$ -	$ 371,408	$ 1,055,654	$ -	$ -	$ -	$ 1,825,774
Intersection of 103 Ave and 146 St to intersection of 105A Ave and 152 St						416		70	610	679			1,775
	$ -	$ -	$ -	$ -	$ -	$ 747,136	$ -	$ 155,680	$ 1,487,180	$ 1,946,014	$ -	$ -	$ 4,336,010
156 St from 108 Ave to Guilford Brook						110	250					108	468
	$ -	$ -	$ -	$ -	$ -	$ 197,560	$ 502,500	$ -	$ -	$ -	$ -	$ 444,636	$ 1,144,696
Entire area north of Hwy 1 to 110 Ave, between 157 St and 159 St	340	300		862	201	599			432	458	274		3,466
	$ 392,360	$ 410,400	$ -	$ 1,363,684	$ 339,489	$ 1,075,804	$ -	$ -	$ 1,053,216	$ 1,312,628	$ 902,556	$ -	$ 6,850,137
												TOTAL LENGTH of Sewer Upgrades	**11,323**
												TOTAL COST of Sewer Upgrades	**$ 24,900,695**

Plus Cost to Reconfigure City-owned Ponds to provide WQ treatment	Assumes 1/2 of 64 off-line ponds* will be reconfigured @ $160,000 per pond; see main report Section 4.1.5.2	**TOTAL COST of Pond Upgrades**	**$ 5,120,000**
		GRAND TOTAL	**$ 30,020,695**

* There are 66 City-owned ponds identified in the watershed; the Fraserglen & Gildford Regional Ponds are on-line ponds.

Existing Capital Plan projects:

Proj ID	Name	Location	Priority*	Total	Growth	Non-Growth	Ext Funding
10-Yr Capital Improvement Drainage Projects							
	Ref: City of Surrey, "Ten Year Servicing Plan (2014-2023)".						
Program 1662 - Existing System Upgrades							
6311	Culvert Upgrades	102 Ave / 162A St	LT	$ 20,000		$ 20,000	
11639	Storm Sewer Upgrade	148 St: Halsted Pl - 104 Ave	LT	$ 840,422		$ 840,422	
11644	Storm Sewer Upgrade	096 Ave: 152 St - 157 St	LT	$ 998,455		$ 998,455	
11646	Storm Sewer Upgrade	160 St to 162 St: 93A Ave to 96 Ave	LT	$ 418,347		$ 418,347	
Program 1664 - Lowlands							
11722	Serpentine River Dyking	Serpentine River: Sea Dam to 088 St	ST	$ 3,466,711	$ 693,342	$ 2,773,369	
Program 1670 - Relief and Trunk Systems							
6266	Pipe Upgrade	148 St: North of 103 Ave	MT	$ 70,000	$ 70,000		
Program 1672 - Community Detention							
6270	Detention Pond	160 St / 106 Ave	LT	$ 1,638,000	$ 1,638,000		
Program 1679 - Erosion and Ravine Stabilization							
Total				**$ 7,451,935**	**$ 2,401,342**	**$ 5,050,593**	**$ -**
Total Excluding Dyke Work:				**$ 3,985,224**	**$ 1,708,000**	**$ 2,277,224**	**$ -**

10-Yr Anniedale/Tynehead NCP Capital Projects							
	Ref: City of Surrey, "Amendment 1: Anniedale-Tynehead NCP, 2012-2021 Ten Year Servicing Plan".						
Program 1676 - Drainage							
13199	Storm Sewer	173A St: 92-93 Ave	NCP driven	$ 249,000	$ 249,000		
13236	Storm Sewer	180 St: 91-90 Ave	NCP driven	$ 266,000	$ 266,000		
13237	Ditch Improvement	187 St: 89-90 Ave	NCP driven	$ 34,000	$ 34,000		
13238	Ditch Improvement	092 Ave: 173-173A St	NCP driven	$ 27,000	$ 27,000		
13293	Ditch Improvement	Harvie Rd: 91-90 Ave	NCP driven	$ 14,000	$ 14,000		
13240	Storm Sewer	172 St: 93-92 Ave	NCP driven	$ 220,000	$ 220,000		
13241	Ditch Improvement	184 St: 90-88 Ave	NCP driven	$ 54,000	$ 54,000		
13243	Ditch Improvement	180 St: 90-88 Ave	NCP driven	$ 509,000	$ 509,000		
13245	Storm Sewer	180 St: 91-92 Ave	NCP driven	$ 134,000	$ 134,000		
13246	Storm Sewer	092 Ave: 176-177 St	NCP driven	$ 220,000	$ 220,000		
13247	Storm Sewer	177 St: 93-92 Ave	NCP driven	$ 217,000	$ 217,000		
13248	Storm Sewer	176 St: 90A-92 Ave	NCP driven	$ 809,000	$ 809,000		
13249	Storm Sewer	092 Ave: 173A-176 St	NCP driven	$ 47,000	$ 47,000		
13251	Storm Sewer	184 St. 91A-90 Ave	NCP driven	$ 482,000	$ 482,000		
13262	Water Quality Pond	090 Ave/187 St	NCP driven	$ 1,439,000	$ 1,439,000		
13263	Water Quality Pond	814 St/90 Ave	NCP driven	$ 1,679,000	$ 1,679,000		
13264	Water Quality Pond	180 St/91 Ave	NCP driven	$ 1,738,000	$ 1,738,000		
13265	Water Quality Pond	90A Ave/Hwy 15	NCP driven	$ 2,967,000	$ 2,967,000		
13266	Water Quality Pond	173A St/92 Ave	NCP driven	$ 2,122,000	$ 2,122,000		
Total				**$ 13,227,000**	**$ 13,227,000**	**$ -**	**$ -**

APPENDIX G

STORMWATER MANAGEMENT IN ANNIEDALE / TYNEHEAD NEIGHBOURHOOD

preliminary list was screened for applicability to Anniedale-Tynehead. **Table A.2 in Appendix C** offers potential LID options for use with the various land use types proposed for the neighbourhood. As will be discussed in the next section, with the exception of single family residential areas, developers will be able to choose which LID measures will be installed on each property and inclusion of **Table A.2** is not intended to preclude developers from proposing other applicable LID measures.

Proposed Servicing Plan

The proposed servicing plan consists of a mix of public and private measures that together will meet the stormwater servicing objectives discussed in the previous section. **Figure 7.7A** shows the locations for proposed ponds (both detention and water quality) and trunk storm sewers. A general layout of local sewers is also shown for illustrative purposes as well. **Figure 7.7B** provides additional detail of pipe routing at the proposed ponds. **Table 7.5** provides specific details related to trunk storm sewer and pond sizing, water quality control requirements and on-site stormwater measures.

The alignments and dimensions of all proposed facilities shown on **Figure 7.7A** are conceptual and must be confirmed at the time of design. Specifically, the locations for ponds may be adjusted somewhat at time of design as long as the objectives and design criteria of this servicing plan are still met.

No upgrades are proposed for the lowland flood control system identified in the Upper Serpentine Pump Station Functional Plan. As noted previously, the changes in runoff conditions within the NCP area can be accommodated by the current lowland system as long as the measures identified in this proposed servicing plan are implemented. As shown on **Figure 7.7A**, there are several ditches in the transitional zone between the NCP area and the lowland flood control system that may require general conveyance improvements to ensure that runoff reaches the lowland system; the extent of these improvements should also be confirmed at design. An allowance for this work has been included in the cost estimates for the servicing plan.

The first developer in a sub-catchment requiring a detention or water quality pond shall secure the land and construct the pond before or as development begins.

In conjunction with the proposed infrastructure features previously described, the following LID requirements are proposed:

- For single family residential properties – Provide 300 mm of amended growing media ("top soil") for all yard area; discharge roof leaders directly to yards, not to the storm sewer[8];
- All other land use types, including high density residential, commercial and industrial land uses – Meet the requirements listed in **Table 7.5**; developers may choose from among a variety of LID measures to meet the requirements, some examples of which are provided in **Table A.2** in **Appendix C**; and
- Local roads – Use parallel exfiltration-type storm sewer systems; provide 300 mm of amended growing media ("top soil") for boulevards; install rain gardens in traffic calming bulges.

[8] This has been standard practice in the City for a number of years. It is fully consistent with LID approaches to stormwater management and is regularly included in requirements and guidelines for LID in other jurisdictions across North America.

It shall be the responsibility of the owners of private property to maintain and repair as necessary LID features installed on that property.

Groundwater Issues

As previously discussed in Part 7.1 for "Soils and Groundwater", a local groundwater flow condition is present in the Anniedale-Tynehead in the upper, near surface soils layers. This is a result of well-drained soils overlying highly impermeable soils. Construction of roads and utilities can intercept this local groundwater, leading to the development of artificial springs in cut areas, with resulting potential for icing on pavement and sidewalks, and rerouted groundwater through the utility trenches. To control this, French drains shall be installed upslope of sidewalks and roads in cut areas and clay dams shall be installed in utility trenches on steep slopes (greater than 10% or as determined through geotechnical analysis).

Flood Control and Soil Erosion

The servicing plan proposed for the Anniedale-Tynehead neighbourhood specifically addresses the need to manage runoff to prevent flooding of areas outside the area. The proposed stormwater facilities, that is, the detention ponds and LID measures, are sized to meet the requirements of flood control. In conjunction with the proposed stormwater measures, the lowland flood control system will continue to operate as planned and, as a result, induced flooding in the agricultural area due to development will not occur.

The proposed stormwater measures are also sized to meet the requirements of erosion control of watercourses within and outside the neighbourhood. Soil erosion that could occur during construction will be addressed through application and enforcement of the City's existing Erosion and Sediment Control Bylaw.

Environmental Considerations

Department of Fisheries and Oceans Canada (DFO) recommend that the Anniedale-Tynehead NCP include measures to reduce impacts to fish and fish habitat through the application of current stormwater/rainwater management practices, and that all new (and updated) planning processes over the long-term also address stormwater based on current and relevant guidelines. Stormwater management needs to integrate stormwater infrastructure planning with relevant municipal planning processes (e.g. Official Community Plans, Neighbourhood Concept Plans, recreation and parks plans, and strategic transportation plans) in order to address the impacts of stormwater/rainwater on fish and fish habitat. DFO has been providing advice to proponents at the Environmental Review Committee on a site-by-site basis; however, DFO staff suggest that it is more appropriate and effective to consider impacts from stormwater/rainwater on a watershed scale in order to reduce adverse impacts to watercourses and aquatic life.

Additionally, DFO has requested that the GVRD standards and DFO guideline standards be met in all plans as well as for all property developments in areas under NCP, proposed local development areas and for individual property development. Stormwater/rainwater management should include application of Low Impact Development (LID) wherever technically feasible, which should be supported by infrastructure as overflow systems.

DFO recommends that planning and development processes adopt the GVRD Source Control Design Guidelines (2005), and meet at minimum the DFO **"Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat"**.

Preliminary discussions have taken place with DFO staff regarding the conceptual layout of city utilities, and the possible locations of watercourse crossings, all of which generally follow the conceptual road layout for the NCP. Each watercourse crossing requires DFO approval. An assessment of what is most appropriate for the crossing must be prepared by a Registered Biologist or other approved professional. DFO preference is for clear span crossings extending from bank to bank across Class 'A' watercourses. Culvert crossings may trigger the environmental review process and habitat compensation. Where approved by DFO, directional drilling is the preferred method of pipe installation over open cut construction methods. The assessment and design of all crossings should also consider wildlife migration and watercourse setbacks from top of bank.

The Bothwell Drive area is an area of interest to DFO due to the Serpentine River and may require additional assessment and riparian enhancements.

Proposed construction activitity, both on-site and off-site, may require a Sediment and Erosion Control Permit as issued by the City under the Erosion and Sediment Control By-law. The by-law sets mandatory standards ensuring Best Management Practices are implementated and managed to limit the amount of sediment and sediment laden water entering the City drainage systems.

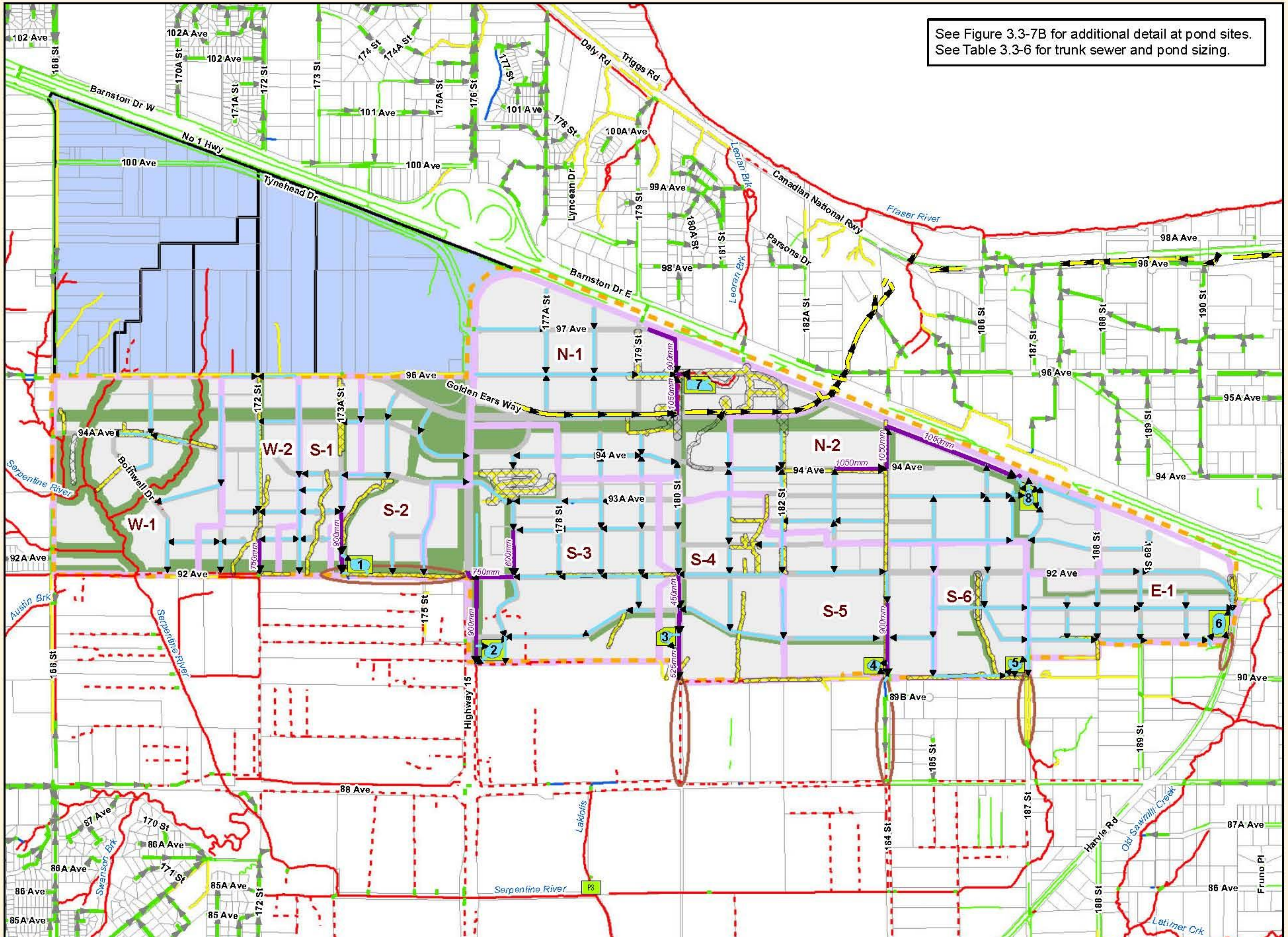
7.3 TEN YEAR SERVICING PLAN AND INFRASTRUCTURE COSTS

The cost estimates for the Development Cost Charge (DCC) eligible infrastructure are based on the principle that development is responsible for funding the services that front, and/or are adjacent to, the development lands. DCC eligible items include trunks, detention and water quality ponds and other items that serve overall catchments equal to or greater than 20 hectares in size.

Costs for Proposed Stormwater Controls

Costs for trunk storm sewers, minor ditch improvements, and detention and water quality ponds are shown in **Tables A.3 and A.4 (Appendix C)**. The total estimated DCC eligible infrastructure costs for these improvements are **$26.6 million**, including engineering, administration, contingencies and land purchase costs.

10 Year Servicing Plan
There are no projects currently identified in the 10 Year Servicing Plan that fall within the study area.



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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Anniedale/Tynehead NCP Stage 2 - Drainage

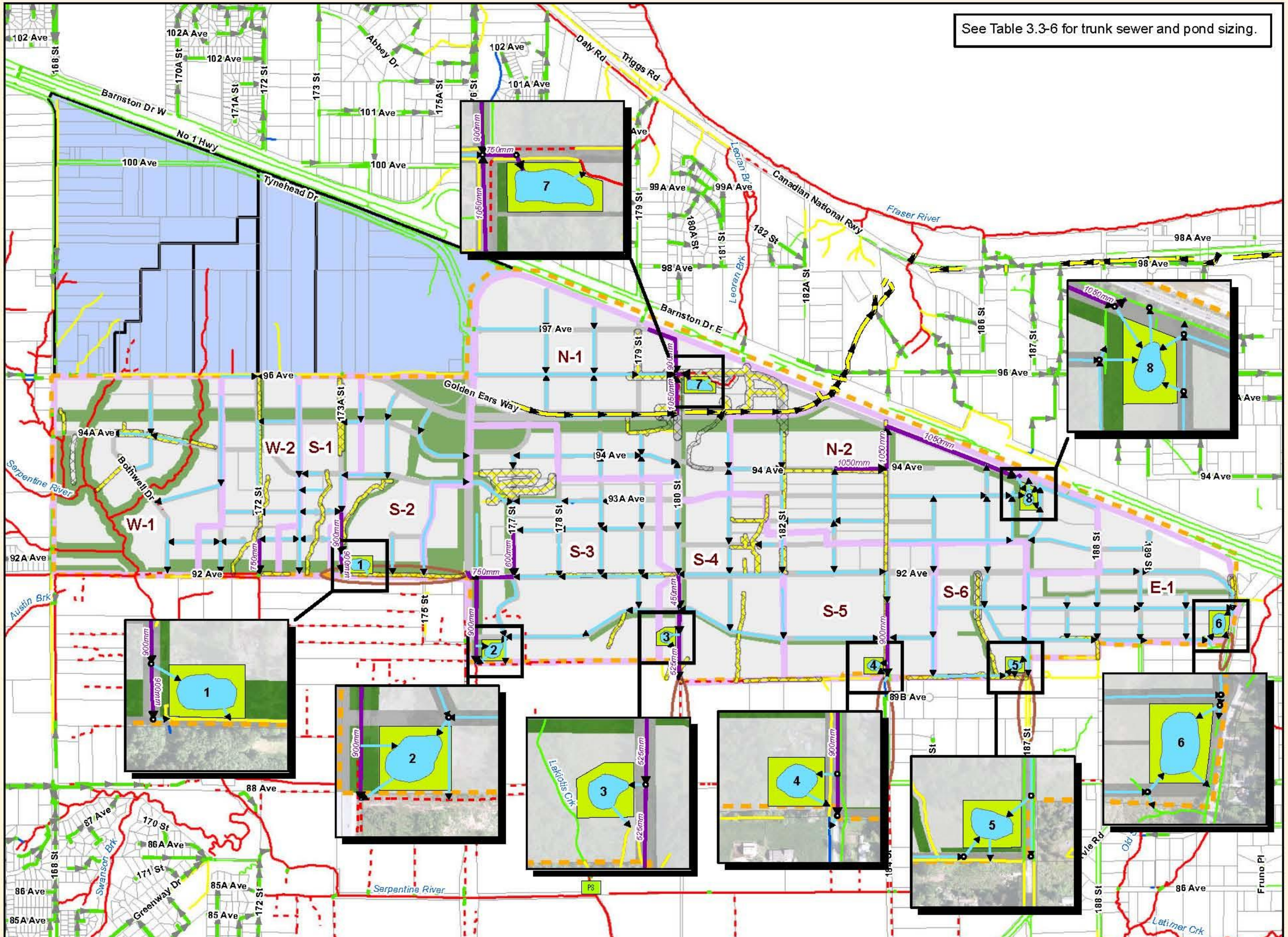
Proposed Infrastructure

Figure 7.7a

URBANSYSTEMS.

1:15,000

0 250 500 1,000
Metres



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)
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- Existing Pump Station
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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

Anniedale/Tynehead NCP Stage 2 - Drainage

Proposed Pond Details

1:15,000
(Pond Detail 1:5,000)

0 250 500 1,000
Metres

Figure 7.7b

URBANSYSTEMS.

U:\Projects_VAN\1072\0173\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\StormwaterFigures_Phase2\Figure 3.3-7B - Pond Detail.mxd Last revised by: bpauls on 03/02/2012 at 9:42:11 AM

Table 7.5 Details of Proposed Stormwater Servicing Plan, by Subcatchment

(Refer to Figures 7.7A and 7.7B for general layout of proposed stormwater systems)

Sub-Catchment	Area (ha)	Discharge Point(s)			Peak Flows (24 hour duration) (m^3/s)		Trunk Storm Sewer Data	Pond Data	Other Requirements
		Existing	Future	Acquisition/Construction Requirements	Existing	Future, with Controls Implemented	(Design Flows based on 30 minute duration storm)		Water Quality and LID Requirements, applicable throughout Anniedale-Tynehead Neighbourhood
W-1	121.1 (47.7)	Four unnamed creeks traverse the sub-catchment; all discharge to Serpentine River	Same	N/A	2 year: 1.22 5 year: 1.71 100 year: 3.18	2 year: 1.27 5 year: 1.73 100 year: 3.86	N/A	N/A	**Water Quality Controls:** • Remove >80% of Total Suspended Solids • Remove Oil & Grease to <10 mg/L Provide oil/water separators for parking lots in commercial, industrial, institutional and multi-family residential usage. **On-Site LID Requirements:** • Provide 300 mm of amended topsoil on all single family residential lawn areas; • Discharge roof leaders in single family residential lots directly to lawns (not to the storm sewer); and • Capture and retain on site 50% of the Mean Annual Rainfall depth (that is, 35 mm in 24 hours, which is equivalent to 350 m^3 per hectare of impervious surface) on all high density and multi-family residential, commercial and industrial lots. Typical capture volumes for various land use designations are: • Village commercial (90% impervious) – 315 m3/ha • Cluster residential 4-6 upa (50% impervious) – 175 m3/ha • Cluster residential 6-10 upa (57% impervious) – 200 m3/ha • Cluster residential 10-15 upa (65% impervious) – 230 m3/ha • Low density urban 6-10 upa (57% impervious) – 200 m3/ha • Medium high density residential 10-15 upa (65% impervious) –
W-2	39.8 (23.1)	Discharge to west-flowing ditch, north side of 92 Ave	Same	N/A	2 year: 0.40 5 year: 0.56 100 year: 1.04	2 year: 0.43 5 year: 0.57 100 year: 1.37	**172 Street** Design flow (100 yr): 2.27 m^3/s Diameter: 750 mm Length: 150 m	N/A	
N-1	63.9	Discharge to upper Leoran Brook	Same	N/A	2 year: 0.50 5 year: 0.67 100 year: 1.06	2 year: 0.50 5 year: 0.67 100 year: 1.39	**97 Avenue** Design flow (100 yr): 2.14 m^3/s Diameter: 900 mm Length: 250 m **180 Street** Design flow (100 yr): 1.18 m^3/s Diameter: 1050 mm Length: 160 m **96 Avenue** Design flow (100 yr): 2.25 m^3/s Diameter: 1050 mm Length: 65 m	**Pond 7 (Detention Pond)** Design flow in (5 yr): 1.56 m^3/s Design flow out (pre-5yr): 0.67 m^3/s Active detention volume: 9,585 m^3 Estimated excavation volume: 23,000 m^3 Pond surface footprint at maximum stage: 6,420 m^2 Site footprint: 1.23 ha	
N-2	55.9	To Hwy 1 cross culvert	Same	N/A	2 year: 0.44 5 year: 0.58 100 year: 0.92	2 year: 0.44 5 year: 0.58 100 year: 1.22	**94 Avenue** Design flow (100 yr): 2.54 m^3/s Diameter: 1050 mm Length: 200 m **184 Street** Design flow (100 yr): 3.00 m^3/s Diameter: 1050 mm Length: 150 m **Along Hwy 1 Frontage** Design flow (100 yr): 3.28 m^3/s Diameter:1050 mm Length: 600 m	**Pond 8 (Water Quality Pond)** Design Flow (2 yr): 1.37 m^3/s Minimum water quality treatment volume: 2,500 m^3 Estimated excavation volume: 7,250 m^3 Pond surface footprint at maximum stage: 1,000 m^2 Site footprint: 0.50 ha Incorporate bypass system for flows exceeding the design flow	
E-1	30.9	Eastern and northern areas drain to ditch on west side of Harvie Rd, then to unnamed branch of	Same	Ditch improvements, as required, to ditch along Harvie Rd (100 m); to be	2 year: 0.50 5 year: 0.70 100 year: 1.41	2 year: 0.48 5 year: 0.70 100 year: 1.61	N/A	**Pond 6 (Detention Pond)** Design flow in (5 yr): 1.11 m^3/s Design flow out (pre-5yr): 0.70 m^3/s Active detention volume: 4,040 m^3 Estimated excavation volume: 11,720 m3	

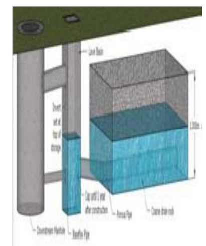
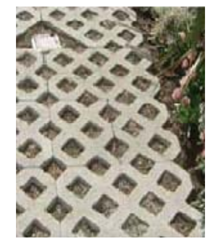
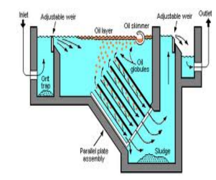
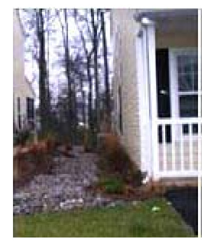
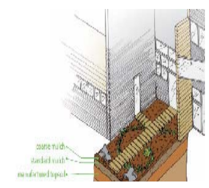
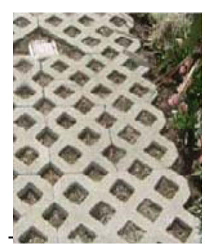
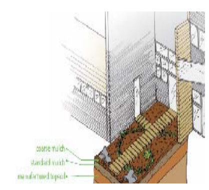
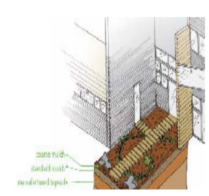
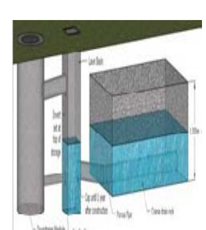
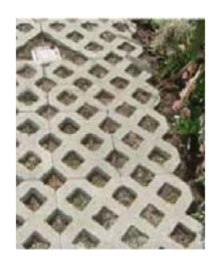
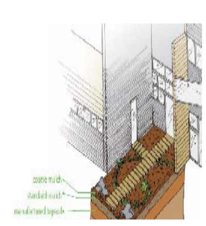
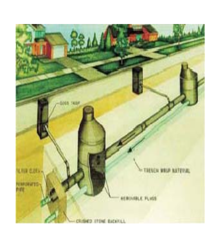
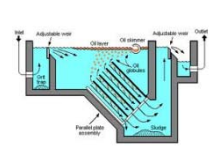
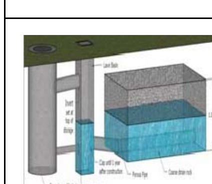
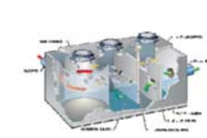
Sub-Catchment	Area (ha)	Discharge Point(s)			Peak Flows (24 hour duration) (m^3/s)		Trunk Storm Sewer Data	Pond Data	Other Requirements
		Existing	Future	Acquisition/Construction Requirements	Existing	Future, with Controls Implemented	(Design Flows based on 30 minute duration storm)		Water Quality and LID Requirements, applicable throughout Anniedale-Tynehead Neighbourhood
		Old Sawmill Creek under the road; Western areas drain to ditches along 188 St and 189 St, which feed upper end of the same branch of Old Sawmill Creek		confirmed at design				Pond surface footprint at maximum stage: 3,100 m^2 Site footprint: 0.71 ha	230 m3/ha • Medium high density residential 15-25 upa (65% impervious) – 230 m3/ha • High density residential 25-45 upa (90% impervious) – 315 m3/ha • High density residential 30-45 upa (90% impervious) – 315 m3/ha • Industrial Low Impact (90% impervious) – 315 m3/ha • Industrial Business Park (90% impervious) – 315 m3/ha **Local Roads:** • Install parallel, exfiltration-type storm sewer systems • Provide 300 mm of amended topsoil in boulevards • Install in traffic calming bulges
S-1	16.1 (53.5)	Discharge to east-flowing ditch, north side of 92 Ave	Same	Ditch improvements, as required, west of Pond 1 site (in S-2) (200 m); to be confirmed at design	2 year: 0.46 5 year: 0.59 100 year: 0.85	2 year: 0.49 5 year: 0.67 100 year: 1.41	N/A	N/A	
S-2	30.4	Discharge to east-flowing ditch, north side of 92 Ave, thence to Hwy 15 ditch	Same	Ditch improvements, as required (350 m); to be confirmed at design	2 year: 0.26 5 year: 0.33 100 year: 0.49	2 year: 0.32 5 year: 0.49 100 year: 1.53	**173A Street** Design flow (100 yr): 3.08 m^3/s Diameter: 900 mm Length: 150 m	**Pond 1 (Water Quality Pond)** Design Flow (2 yr): 0.32 m^3/s Minimum water quality treatment volume: 1,370 m^3 Estimated excavation volume: 3,975 m^3 Pond surface footprint at maximum stage: 1,125 m^2 Site footprint: 0.64 ha	
S-3	64.6	To Hwy 15 ditches	Same	N/A	2 year: 0.56 5 year: 0.71 100 year: 1.03	2 year: 0.68 5 year: 1.03 100 year: 3.24	**177 Street** Design flow (100 yr): 0.84 m^3/s Diameter: 600 mm Length: 170 m **92 Avenue** Design flow (100 yr): 0.92 m^3/s Diameter:750 mm Length: 150 m **176 Street / Hwy 15** Design flow (100 yr): 3.87 m^3/s Diameter: 900 mm Length: 350 m	**Pond 2 (Water Quality Pond)** Design Flow (2 yr): 0.68 m3/s Minimum water quality treatment volume: 2,900 m^3 Estimated excavation volume: 8,410 m^3 Pond surface footprint at maximum stage: 1,160 m^2 Site footprint: 0.74 ha Incorporate bypass system for flows exceeding the design flow	
S-4	32.6	To lowland ditch within narrow (10 m) 180 St ROW	Same	Acquire additional 5 m ROW along existing 10 m ROW (400 m) and improve ditch, as required, south to 88 Ave (400 m);	2 year: 0.28 5 year: 0.36 100 year: 0.52	2 year: 0.34 5 year: 0.52 100 year: 1.64	**180 Street** Design flow (100 yr): 0.63 m^3/s Diameter:450 mm Length: 150 m **180 Street** Design flow (100 yr): 1.50 m^3/s Diameter:525 mm	**Pond 3 (Water Quality Pond)** Design Flow (2 yr): 0.34 m^3/s Minimum water quality treatment volume: 1,470 m^3 Estimated excavation volume: 4,250 m^3 Pond surface footprint at maximum stage: 590 m^2 Site footprint: 0.47 ha	

Sub-Catchment	Area (ha)	Discharge Point(s)			Peak Flows (24 hour duration) (m^3/s)		Trunk Storm Sewer Data	Pond Data	Other Requirements
		Existing	Future	Acquisition/Construction Requirements	Existing	Future, with Controls Implemented	(Design Flows based on 30 minute duration storm)		Water Quality and LID Requirements, applicable throughout Anniedale-Tynehead Neighbourhood
				to be confirmed at design			Length: 270 m	Incorporate bypass system for flows exceeding the design flow	
S-5	30.7	Ditch and short section (200 m) of 450 mm storm sewer along 184 St	Same	Remove storm sewer and restore / improve ditch system south to 88 Ave (400 m); to be confirmed at design (Note: Work could be coordinated with upgrade of 184 St in future)	2 year: 0.27 5 year: 0.34 100 year: 0.49	2 year: 0.32 5 year: 0.49 100 year: 1.54	**184 Street** Design flow (100 yr): 3.47 m^3/s Diameter:900 mm Length: 290 m	**Pond 4 (Water Quality Pond)** Design Flow (2 yr): 0.32 m^3/s Minimum water quality treatment volume: 1,380 m^3 Estimated excavation volume: 4,000 m^3 Pond surface footprint at maximum stage: 550 m^2 Site footprint: 0.46 ha Incorporate bypass system for flows exceeding the design flow	
S-6	18.5	Ditch along west side of 187 St	Same	Ditch improvements, as required south to culvert under Harvie Rd (250 m); to be confirmed at design	2 year: 0.16 5 year: 0.20 100 year: 0.30	2 year: 0.19 5 year: 0.30 100 year: 0.93	N/A	**Pond 5 (Water Quality Pond)** Design Flow (2 yr): 0.19 m^3/s Minimum water quality treatment volume: 830 m^3 Estimated excavation volume: 2,410 m^3 Pond surface footprint at maximum stage: 375 m^2 Site footprint: 0.45 ha Incorporate bypass system for flows exceeding the design flow	

Notes:

1. Refer to **Figures 7.7A and 7.7B** for general layout of proposed trunk storm sewers and ponds.
2. Areas listed in parentheses are for the NCP portion of the sub-catchment only.
3. Ditch improvements include general cleaning, establishing consistent cross section and profile slope, and minor capacity expansion, as required.
4. Pond footprints are based on a minimum 10 m buffer around the pond at maximum stage plus 600 mm freeboard.
5. Sizes and dimensions for trunk sewers and ponds are preliminary and must be confirmed at desig

Table A.2 Potential BMP/LID Options for Anniedale/Tynehead NCP Area

LAND USE	BMP/LID OPTIONS	ILLUSTRATIONS		
Village Commercial	1. Pre-fab infiltration trenches or Drain rock Infiltration trenches 2. Permeable Pavement 3. Oil-water separator			
Cluster Residential 4-6 upa Cluster Residential 6-10 upa	1. Disconnected Roof leaders 2. Enhanced topsoil on lawns (depth to be determined later) 3. Rain barrels (rainwater harvesting)			
Cluster Residential 10-15 upa Medium Density 10-15 upa Medium High Density 15-25 upa	1. Permeable Pavement 2. Planter boxes 3. Enhanced topsoil on lawns (depth to be determined later)			
Low Density Urban 6-10 upa	1. Disconnected Roof leaders 2. Enhanced topsoil on lawns (depth to be determined later)			
Cluster Residential 10-15 upa Medium Density 10-15 upa Medium High Density 15-25 upa High Density Residential 25-45 upa High Density Residential 30-45 upa	1. Pre-fab infiltration trenches or Drain rock Infiltration trenches 2. Permeable Pavement 3. Planter boxes			
Road ROW	1. Enhanced topsoil (depth to be determined later) 2. Infiltration Swale 3. Pervious storm sewers			
Industrial Low Impact Industrial Business Park	1. Oil-water separator (Parking lot) 2. Hydro-dynamic Separator 3. Filter Insert for Catchbasins 4. Pre-fab infiltration chamber or Drainrock infiltration trenches 5. Green Roof 6. Infiltration pond/Constructed wetland	 	 	 
All	1. Diversion sewer 2. Detention / WQ ponds 3. Ditch Upgrade/ Pump station Upgrade			

Based on the BMP/LID table (AECOM) provided by the City on January 11, 2011

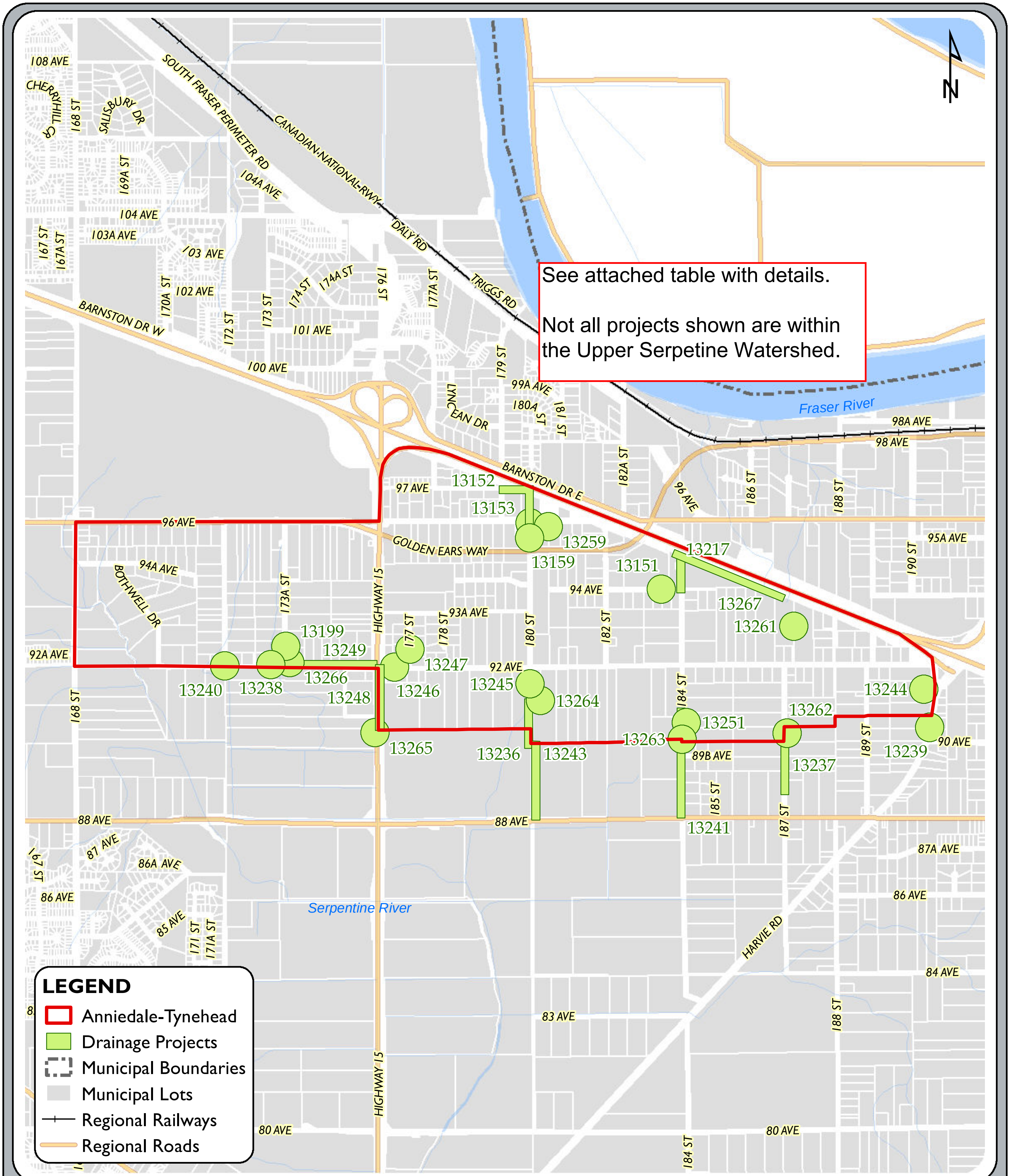


FIGURE 8.3 - Drainage
Anniedale-Tynehead (Program 1676)

SCALE: 1:26,000

GIS SECTION

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The data provided is compiled from various sources and IS NOT warranted as to its accuracy or sufficiency by the City of Surrey.
This information is provided for information and convenience purposes only. Lot sizes, legal descriptions and encumberances must be confirmed at the Land Title Office.

Date Printed: 19/11/2013 Cartographer: aw8 © City of Surrey
Source: G:\MAPPING\GIS\Maps\Recurring\10yrServicingPlan2014-23\Figure8-3_AnnidaleTynehead-D.mxd

Highlighted projects are within the Upper Serpentine Watershed; see attached Figure 8.3 for locations.

DRAINAGE

Program 1676 - Anniedale-Tynehead

Project ID	Project Name	Project Location	Priority	Total Cost	Growth Component	Non-Growth Component	External Funding
13151	200m of 1050mm diameter	094 Ave: 183 - 184 St Anniedale NCP	NCP Driven	371,000	371,000	-	-
13152	250m of 900mm diameter	097 Ave: 179 - 180 St; 180 St: 97 - 96 Ave Anniedale NC	NCP Driven	347,000	347,000	-	-
13153	65m of 1050mm diameter	096 Ave / 180 St Anniedale NCP	NCP Driven	108,000	108,000	-	-
13159	160m of 1050mm diameter	180 St: 96 Ave - Golden Ears Way. Anniedale NCP	NCP Driven	297,000	297,000	-	-
13199	150m of 900mm diameter	173A St: 92 - 93 Ave Anniedale NCP	NCP Driven	249,000	249,000	-	-
13217	150m of 1050mm diameter	184 St: 94 - 95 Ave Anniedale NCP	NCP Driven	279,000	279,000	-	-
13236	270m of 525mm diameter	180 St: 91 - 90 Ave Anniedale NCP	NCP Driven	266,000	266,000	-	-
13237	250m of ditch improvement	187 St: 89 - 90 Ave. Anniedale NCP	NCP Driven	34,000	34,000	-	-
13238	200m of ditch improvement	092 Ave: 173 - 173A St Anniedale NCP	NCP Driven	27,000	27,000	-	-
13239	100m of ditch improvement	Harvie Rd: 91 -90 Ave Anniedale NCP	NCP Driven	14,000	14,000	-	-
13240	150m of 750mm diameter	172 St: 93 - 92 Ave Anniedale NCP	NCP Driven	220,000	220,000	-	-
13241	400m of ditch improvement	184 St: 90 - 88 Ave Anniedale NCP	NCP Driven	54,000	54,000	-	-
13243	400m of ditch improvement and ROW	180 St: 90 - 88 Ave Anniedale NCP	NCP Driven	509,000	509,000	-	-
13244	Anniedale 6 detention pond	191 St / 91 Ave	NCP Driven	3,279,000	3,279,000	-	-
13245	150m of 450mm diameter	180 St: 91 - 92 Ave Anniedale NCP	NCP Driven	134,000	134,000	-	-
13246	150m of 750mm diameter	092 Ave: 176 - 177 St Anniedale NCP	NCP Driven	220,000	220,000	-	-
13247	170m of 600mm diameter	177 St: 93 - 92 Ave Anniedale NCP	NCP Driven	217,000	217,000	-	-
13248	350m of 900mm diameter	176 St: 90A - 92 Ave Anniedale NCP	NCP Driven	809,000	809,000	-	-
13249	350m of ditch improvement	092 Ave: 173A - 176 St Anniedale NCP	NCP Driven	47,000	47,000	-	-
13251	290m of 900mm diameter	184 St: 91A - 90 Ave Anniedale NCP	NCP Driven	482,000	482,000	-	-
13259	Anniedale 7 detention pond	096 Ave / 180 St Anniedale NCP	NCP Driven	4,888,000	4,888,000	-	-
13261	Anniedale 8 water quality pond	187 St / 93 Ave	NCP Driven	2,217,000	2,217,000	-	-
13262	Anniedale 5 water quality pond	090 Ave / 187 St	NCP Driven	1,439,000	1,439,000	-	-
13263	Anniedale 4 water quality pond	184 St / 90 Ave	NCP Driven	1,679,000	1,679,000	-	-
13264	Anniedale 3 water quality pond	180 St / 91 Ave	NCP Driven	1,738,000	1,738,000	-	-
13265	Anniedale 2 water quality pond	90A Ave / Hwy 15	NCP Driven	2,967,000	2,967,000	-	-
13266	Tynehead 1 water quality pond	173A St / 92 Ave Anniedale NCP	NCP Driven	2,122,000	2,122,000	-	-
13267	1050m of 1050mm diameter	South of Hwy 1: 184 - 187 St Anniedale NCP	NCP Driven	1,624,000	1,624,000	-	-
				26,637,000	**26,637,000**	**-**	**-**

Appendix H

Minimum Stormwater Management Requirements for Development in the Upper Serpentine Watershed

City of Surrey

Stormwater Management Requirements for Development
In the Upper Serpentine River Watershed

The City of Surrey has completed an integrated stormwater management plan (ISMP) for the Upper Serpentine River Watershed (see attached map showing watershed boundaries). The recommendations of the ISMP are intended to preserve and enhance the Upper Serpentine as a natural asset for the City; the recommendations cover both infrastructure improvements and other actions that the City will undertake and actions for which developers and residents will be responsible.

Based on the ISMP, the following *minimum stormwater management requirements* must be met for new development, re-development and in-fill development located within the watershed. The City encourages the use of adaptive site planning and other on-site rainwater management facilities to further contribute to watershed health.

Single Family and Multi-Unit (8 or less) Residential Lots

1. Maximum impervious surface area of each lot shall not exceed 50%. Impervious surface areas include buildings, sidewalks, driveways and parking areas, patios and decks, and any other hard surfaces that do not allow rainfall to soak into the ground.
2. All pervious surface areas shall receive 400 mm of amended growing medium as topsoil.
3. Roof leaders shall discharge to the lawn or to an approved on-site rainwater management facility; roof leaders shall not be connected directly to a storm sewer.

All other Commercial, Industrial and Institutional Properties

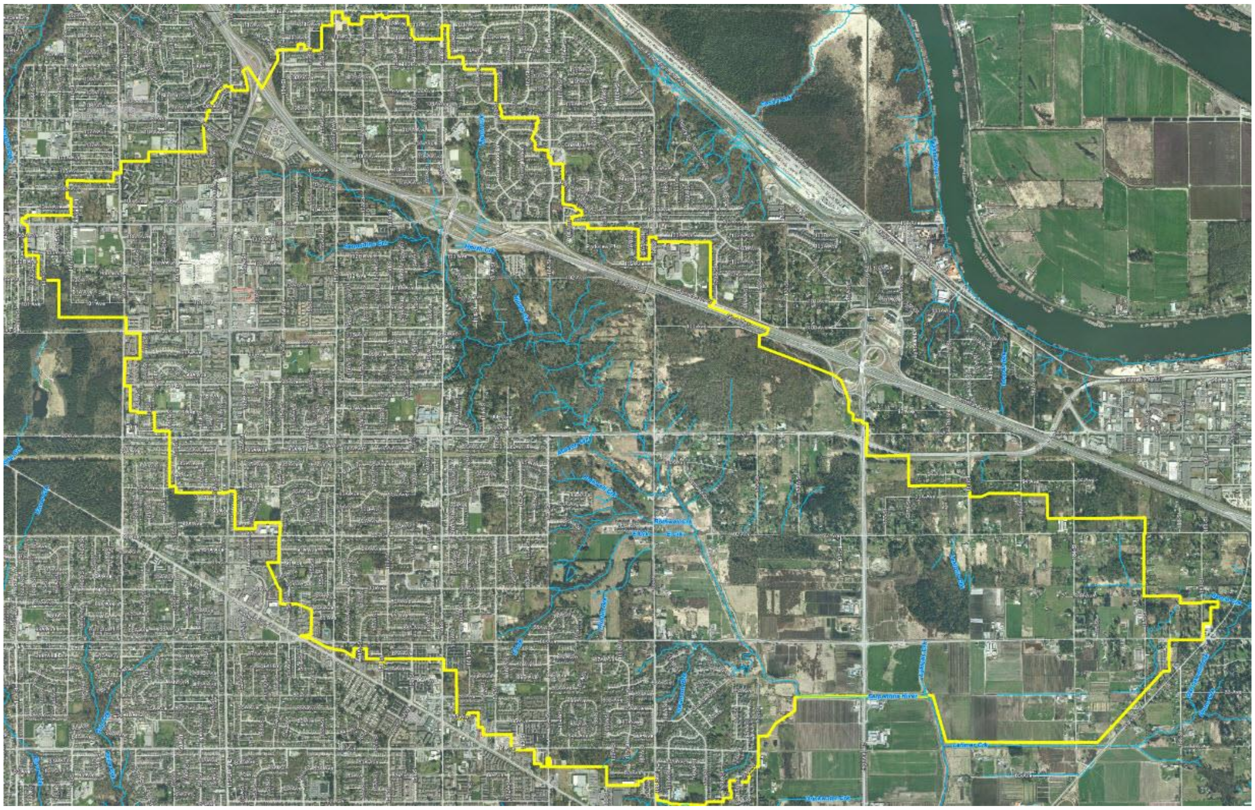
1. Maximum impervious surface area of each lot shall not exceed 90%. Impervious surface areas include buildings, sidewalks, driveways and parking areas, and any other hard surfaces that do not allow rainfall to soak directly into the ground.
2. All pervious surface areas shall receive 400 mm of amended growing medium as topsoil.
3. On-site rainwater management facilities shall be designed and installed to capture and retain rainfall at a minimum rate of 400 cubic metres per hectare (400 m^3/ha) of impervious surface.
4. When the City determines that a specific risk to water quality will be present, installation and use of specific runoff quality control devices or structural best management practices (BMPs) for runoff treatment and / or implementation of specific on-site “house-keeping” practices can be required. Examples include gas stations and sites with significant truck or heavy equipment traffic.

Definitions of adaptive site planning, source control, on-site rainwater management facility and structural best management practice are provided on the attached page.

On a case by case basis only, when significant site constraints exist for in-fill development, the City may relax these requirements or substitute alternative requirements.

General drainage servicing requirements described in the City’s “Design Criteria Manual”, dated May 2004, continue to apply to all development as well.

Upper Serpentine River Watershed



Attachment – Definitions

Adaptive Site Planning – Design practices that strive to reduce the amount of impervious area on a site and retain natural features, especially trees and riparian areas. These are generally applied at the site level but can be quite large in scale (i.e., watershed or regional).

Source Control – Installation of on-site rainwater management best management practices (BMPs) intended to reduce the total runoff volume leaving a site through reliance on retention, infiltration and evapotranspiration of rainwater. This approach is typically applied on an individual lot or building site.

On-site Rainwater Management Facility – Best management practices (BMPs) that rely on retention, infiltration and/or evapotranspiration of rainwater to function. Practices generally accepted by the City include rainwater harvesting (“rain barrels”), bioretention filters (including rain gardens, bioswales and manufactured “planter box” systems), infiltration trenches (including pre-fabricated infiltration structures and perforated storm sewers) and permeable pavement (including pervious asphalt and paver block systems).

Structural Best Management Practices – These are usually “end-of-pipe” type BMPs, generally intended to reduce peak runoff flows and enhance water quality prior to discharge to receiving waters or other offsite drainage systems. Structural BMPs include wet and dry ponds, stormwater wetlands and manufactured treatment systems (including oil/grit removal devices or “hydrodynamic separators”, oil separators, and media filter treatment systems). These BMPs are typically constructed in public ROW or as features on larger private developments (multi-unit dwellings such as large apartments and condominiums; commercial; industrial).

Amended Growing Medium (or Amended Soil) – Native or non-native soils that have had their soil properties (texture, depth, porosity, nutrients) amended to promote improved rainwater infiltration and retention through the addition of organic amendments and manipulation of soil infiltration properties. Subsoils beneath the amended soil are typically loosened or scarified to compensate for compaction that occurs during construction and to promote vertical infiltration of the rainwater.