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CITY OF SURREY

Elgin, Barbara, and Anderson Creeks

Integrated Stormwater Management Plans

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PROJECT 307076-04854 - ELGIN, BARBARA, AND ANDERSON CREEKS

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EXECUTIVE SUMMARY

This report presents the development of an Integrated Stormwater Management Plan (ISMP) for the Elgin, Barbara, and Anderson Creek watersheds. The plan includes the following components:

- A review of the watersheds' general characteristics as well as the biophysical, hydrological, and geological / hydrogeological conditions in the Study Area;
- Development of a Study Area Vision including goals to support the City of Surrey's (the City's) management of the health of the watersheds;
- Development of an Implementation Plan to assist the City's achievement of the Vision; and
- Adaptation of Metro Vancouver's draft Monitoring and Adaptive Management Framework to facilitate the City's evaluation of progress toward achieving the Vision and identification of potential threats to the health of the Study Area.

General Characteristics

The 720 ha Study Area is located in Surrey, south of the Nicomekl River, and consists of three creek catchments: the Elgin, Barbara, and Anderson Creeks. Historically, the area has consisted of suburban residential lots but has been developed over the past 20 years to include multi-family residential, commercial, and industrial properties. A 115 ha portion of the undeveloped Sunnyside Acres Urban Forest is located in the southern region of the Study Area.

Under anticipated zoning conditions provided in the City's 2013 draft Official Community Plan (OCP) document, the Study Area has an estimated 54% effective impermeable area (EIA). The current (2013) and future anticipated zoning composition of the Study Area is summarized in the following table.

Zoning Category	Current Contributing Area (ha)	Future Anticipated Contributing Area (ha)	Percentage Change
Suburban	216	189	-4%
Green Space	180	174	-1%
Roadways	118	118	0%
Urban	97	84	-1%
Multiple Residential	43	63	+3%
Cemetery	25	25	+2%
Commercial	12	31	<1%
Institutional	12	18	+1%
Industrial	9	10	<1%
Agricultural / Golf Course	8	6	<1%

Biophysical Assessment

On May 28, 2013, WorleyParsons staff walked the Elgin, Barbara, and Anderson creek alignments from their respective confluences with the Nicomekl River to their headwaters to assess the substrate materials, infrastructure, and riparian vegetation within the creek corridors and to identify creek conditions and infrastructure that adversely affect fish habitat.

Staff noted that the condition of Salmonid habitat (based on creek substrate materials, riparian cover, and channel complexity) was rated as moderate to high in the lower reaches of all three creeks. The ratings decreased as staff moved upstream due to barriers to fish passage and ephemeral nature of the channels (i.e., creek flow is not constant in the upstream portions of the creeks).

Concurrent to walking the creeks, staff collected sediment and water quality samples for all three creeks at their confluences with the Nicomekl River.

Vision

A Study Area Vision was created to identify the desired direction for stormwater management for the three creeks. Mission and vision statements were developed through public and stakeholder consultation to facilitate the communication of the Vision.

Mission statement:

> *To manage the health of the Elgin, Barbara, and Anderson Creeks so they are capable of supporting a diverse ecosystem without sacrificing their ability to service the surrounding urban community by providing efficient drainage and the opportunity to enjoy and appreciate the natural environment.*

Vision statement:

> *The Elgin, Barbara, and Anderson Creeks are vital community resources that enhance the local ecosystem by providing protected areas for riparian vegetation and habitat for aquatic species. Local residents benefit from the drainage capacity of the creeks and the opportunities to enjoy and appreciate the natural environment that they provide. The City of Surrey, supported by stakeholder groups and organizations, will steward these resources so that they are available for future generations.*

Goals

Seven specific goals were developed to assist the City achieving the objectives of the mission statement without compromising the values of the vision statement. The goals are summarized in the following table.

Goal	Relevant Figures	Key Stakeholders	Recommendations
Goal No. 1 - Protect, Maintain, and Enhance Aquatic Habitat in the Elgin, Barbara, and Anderson Creeks	M, N, O	Engineering Department Environmental Advisory Committee Sunnyside Acres Heritage Society Nicomekl Enhancement Society	1. Identify and prioritize locations where barriers to fish passage should be removed. 2. Manage riparian areas (refer to Goal No. 2). 3. Reduce sedimentation (refer to Goal No. 3). 4. Increase groundwater contributions to creek base flows (refer to Goal No. 6). 5. Future culverts should be designed with provisions for fish passage. 6. Continue to support local stakeholder groups in their efforts to improve watershed health within the Study Area. 7. Identify and prioritize locations where channel complexing techniques can be implemented.
Goal No. 2 - Protect, Maintain, and Enhance Riparian Areas throughout the Elgin, Barbara, and Anderson Creek Watersheds	M, N, O	Engineering Department Parks, Recreation and Culture Department Sunnyside Acres Heritage Society Nicomekl Enhancement Society	1. Avoid disturbing riparian areas. 2. Increase public awareness of the importance of riparian areas. 3. Continue to enforce the leave strip requirements at existing and under-development properties. 4. Remove invasive species and replant with native species. 5. Replant areas exhibiting mono-culture vegetation with native species.
Goal No. 3 - Address Erosion and Sedimentation Issues	M, N, O	Engineering Department	1. Avoid disturbing natural vegetation within creek channels and, when disturbance is unavoidable, restore channels using vegetative cover selected by an RPBio. 2. Implement wet weather infrastructure as part of capital works and development projects to reduce peak runoff flows. 3. Implement bed and bank stabilizing materials and infrastructure, with preference given to bio-engineered solutions, to mitigate localized bank instabilities caused by erosion. 4. Continue to require the submission of erosion and sediment control plans for all capital and development construction sites.
Goal No. 4 - Maintain Efficient Drainage	P	Engineering Department	1. Implement wet weather infrastructure as part of capital works and development projects to reduce peak runoff flows. 2. Replace undersized major culverts to convey the 100-year flow. 3. Implementing flood control devices at the Elgin and Anderson Creek confluences with the Nicomekl River to account for potentially higher river levels resulting from climate change. 4. Maintain a minimum topsoil depth of 450 mm in landscaped areas.

Goal	Relevant Figures	Key Stakeholders	Recommendations
Goal No. 5 - Address Potential Contaminant Sources	J	Engineering Department Parks, Recreation and Culture Department Planning & Development Department	1. Continue to monitor in-stream water quality. 2. Identify industrial and commercial operations whose practices could result in the improper disposal of waste water or release of contaminants and work with them to develop and implement best practices. 3. Continue to require the installation of oil interceptors, or equivalent infrastructure, at parking lots and gas stations. 4. Review current operation and maintenance practices relating to non-point source contaminants and compare them to best management practices 5. Encourage golf courses and cemeteries within the Study Area to adopt best management maintenance practices. 6. Implement biological filtration methods. 7. Implement stormwater infrastructure that captures first flush runoff flows originating from areas zoned for industrial and / or commercial use 8. Continue to enforce the City's pesticide by-law. 9. Continue to encourage the use of organic fertilizers.
Goal No. 6 - Protect Groundwater Resources	J	Engineering Department Planning & Development Department	1. Implement wet weather infrastructure as part of capital works and development projects to promote groundwater infiltration. 2. Limit groundwater infiltration at locations with potential sub-surface contaminant sources. 3. Continue to require developers to observe maximum lot coverage and roof lead disconnection requirements.
Goal No. 7 - Maintain the Health of the Sunnyside Acres Urban Forest	E	Parks, Recreation and Culture Department Sunnyside Acres Heritage Society	1. Continue to monitor for, and decommission, unauthorized trails. 2. Continue to address the root rot disease issue afflicting Douglas-fir trees. 3. Continue to educate the public on the Forest's ecological importance.

Guidance for Infill and Small Developments

Due to the land use composition and ongoing development projects in the Study Area, it is predicted that small and infill residential properties will comprise the majority of long-term development permit applications. This type of development project is typically undertaken by residents and local developers who may not be aware of how development activities can impact the health of watersheds.

A series of actions and best management practices (BMPs) were identified to provide guidance on sustainable development intended to protect, maintain, and enhance watershed health. Table Q and Table R summarize these items in Section 3.6.

Implementation Plan

An Implementation Plan was developed to assist the City in meeting the Goals and achieving the Vision for the Study Area. The Implementation Plan consists of 15 items divided into the following categories:

- **Initiatives**: projects that will address a specific issue;
- **Strategies**: techniques that can be applied to address issues throughout the watershed;
- **Long Range Opportunities**: potential solutions to issues that may be identified in the future through long-term monitoring; and
- **Monitoring Infrastructure**: infrastructure that will facilitate the monitoring framework discussed in Section 5.

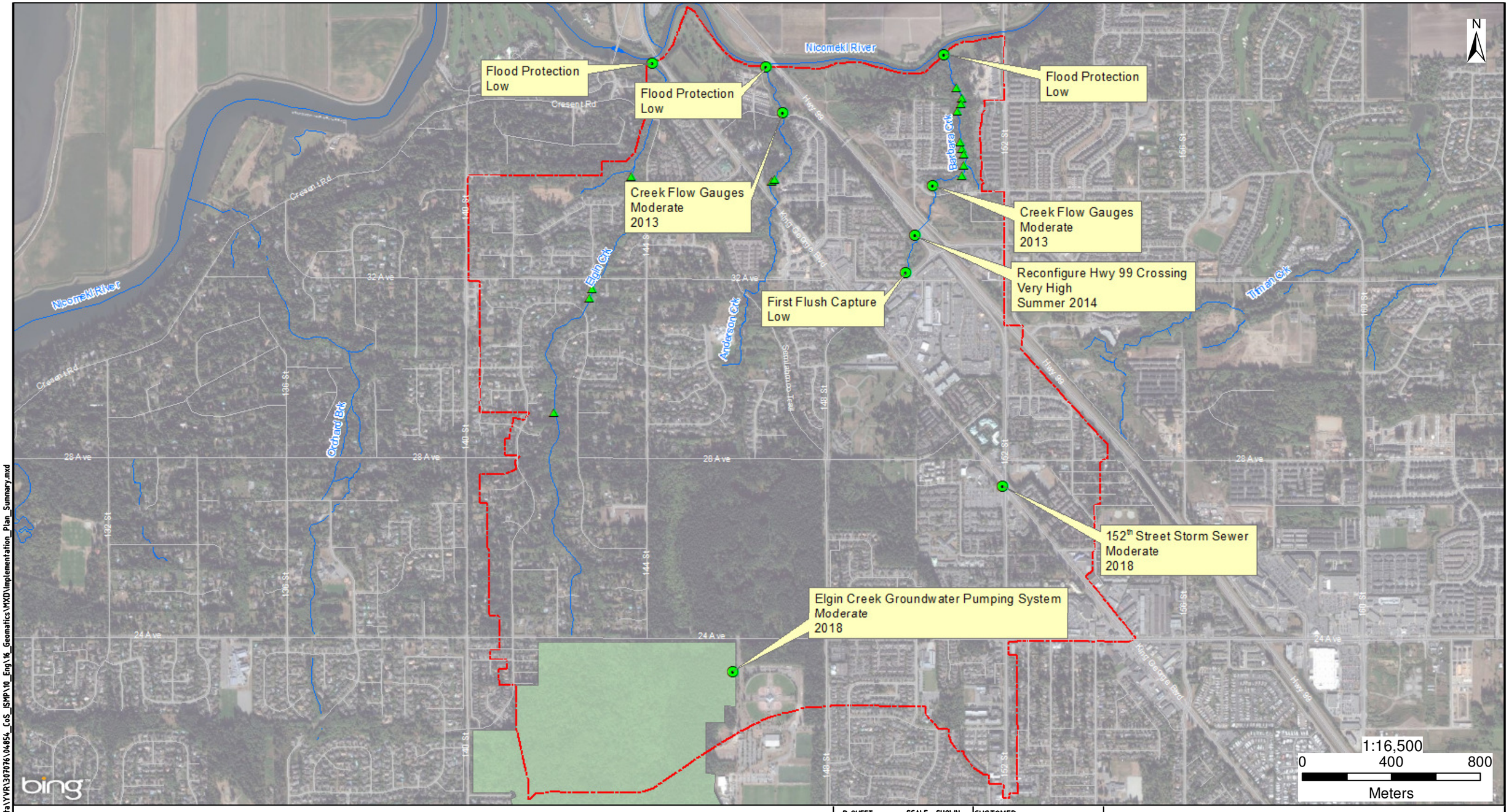
A summary of these components is provided in Appendix 4. The Implementation Plan is summarized in the following table, ranked based on the recommended order in which they should be implemented. A map showing the locations of selected implementation plan items is shown on Figure AA.

Priority	Item	Type	Actions Involved	Desired Outcome	Stakeholders	Recommended Schedule	Estimated Cost
Very High	Control and Manage Chemical Usage and Disposal	Strategy	1. Identify industrial and commercial operators whose practices could result in the release of contaminants to the storm sewer. 2. Work with identified operators to develop and implement BMPs. 3. Monitor pesticide usage and enforce the Pesticide Bylaw.	To address the potential release of contaminants into the creeks in order to protect the health of aquatic habitat.	Engineering Department Bylaw Enforcement Division Parks, Recreation, and Culture Department Industrial and Commercial Operators Property Owners	Ongoing	NA
Very High	Manage Non-point Source Contaminants	Strategy	1. Review current operation and maintenance practices. 2. Consider whether practices are consistent with BMPs (See Table V). 3. Consider altering practices to match BMPs.	To address the potential release of contaminants into the creeks in order to protect the health of aquatic habitat.	Engineering Department Bylaw Enforcement Division Parks, Recreation, and Culture Department Residents Businesses	Review current practices by 2014	NA
High	Implement Wet Weather Green Infrastructure	Strategy	1. Implement wet weather green infrastructure as suited for the desired application and outcome.	To reduce the volume of runoff entering the creeks during storm events to reduce peak creek flow volumes and velocities and promote groundwater recharge.	Engineering Department Planning and Development Department Developers	Ongoing	Bioswales: \$9 to \$10 per m^2 drained Rain Gardens: \$20 to \$27 per m^2drained Permeable Pavement: \$100 to \$120 per m^2 drained

Priority	Item	Type	Actions Involved	Desired Outcome	Stakeholders	Recommended Schedule	Estimated Cost
High	Bank Stabilization	Long-range Opportunity	1. Continue to monitor the creeks for signs of bank instabilities. 2. Assess known bank instabilities using a prioritization system. 3. Implement bank stabilization infrastructure at high priority locations, with consideration given to bio-engineered solutions.	To stabilize bank materials at sites with a high potential for causing damage to existing structures or degradation of aquatic habitat.	Engineering Department	Monitor every two years or as required	Varies
High	Raise Public Awareness of Riparian Areas	Strategy	1. Develop online or print material to inform the public of the importance of riparian areas and how they contribute to watershed health.	To reduce anthropogenic impacts on riparian areas.	Engineering Department Parks, Recreation, and Culture Department	2015	NA
High	Control and Manage Invasive Plants	Strategy	1. Continue to raise public awareness of invasive plant issues. 2. Consider implementing BMPs (See Table BB).	To control the presence of invasive plants to preserve the biodiversity of riparian areas.	Engineering Department Parks, Recreation, and Culture Department ISCMV Sunnyside Acres Heritage Society Residents Contractors Developers	2015	NA

Priority	Item	Type	Actions Involved	Desired Outcome	Stakeholders	Recommended Schedule	Estimated Cost
High	Review Capital and Development Projects	Strategy	1. Review capital projects at conceptual stage and development projects at application stage for the possibility of implementing infrastructure that will improve watershed health. 2. Review capital and development projects for compliance with runoff related requirements.	To facilitate the implementation of infrastructure that will contribute to a healthy watershed.	Engineering Department Parks, Recreation, and Culture Department	Ongoing	NA
High	Protect the Sunnyside Acres Urban Forest	Strategy	1. Continue to manage the Forest per the recommendations in the Sunnyside Acres Urban Forest Access and Recreation Management Plan (2002).	To maintain the health of the Sunnyside Acres Urban Forest and facilitate responsible and sustainable access.	Parks, Recreation, and Culture Department Sunnyside Acres Heritage Society	Ongoing	NA
High	Reconfigure Hwy 99 Crossing	Initiative	1. Design bio-engineered weir. 2. Apply for a Water Act Approval. 3. Construct bio-engineered weir.	To reroute low creek flows from the 150 St. storm sewer to Barbara Creek to match original design.	Engineering Department DFO Ministry of Forests, Lands, and Natural Resource Operations	Construct by September 2014	$25,000 to $35,000
Moderate	152 St. Storm Sewer	Initiative	1. Reconfigure the sewer (Option 1). 2. Secure the manhole covers (Option 2).	To mitigate potential sewer surcharge which could adversely impact driving conditions on 152 St. and King George Blvd.	Engineering Department	Construct by 2018	Option 1: $110,000 to $120,000 Option 2: $10,000 to $12,000

Priority	Item	Type	Actions Involved	Desired Outcome	Stakeholders	Recommended Schedule	Estimated Cost
Moderate	Elgin Creek Groundwater Pumping System	Initiative	1. Connect the pumping system to the City's SCADA system.	To facilitate an assessment of the system performance and to improve pump operation.	Engineering Department	Connect by 2018	$10,000 to $12,000
Moderate	Creek Flow Gauges	Monitoring Infrastructure	1. Install creek flow gauges on the Barbara and Anderson Creeks and connect them to the City's SCADA system.	To facilitate the long-term monitoring of flow patterns in support of the Monitoring Framework.	Engineering Department	Install and connect to SCADA system by 2018	$20,000 to $25,000
Moderate	Water Quality Monitoring	Monitoring Infrastructure	1. Implement a water quality monitoring program.	To facilitate the long-term monitoring of water quality parameters in support of the Monitoring Framework.	Engineering Department	2018	NA
Low	First Flush Capture	Long-range Opportunity	1. Establish a sampling station at the storm sewer outfall to Barbara Creek at the 32 Ave Diversion. 2. Monitor discharge to quantify the first flush effect. 3. Determine whether capturing first flush flows could improve downstream aquatic habitat conditions.	To determine whether first flush capture would provide benefit by reducing the contaminant loading to Barbara Creek.	Engineering Department	Baseline conditions and during first flush storm	NA
Low	Flood Protection	Long-range Opportunity	1. Consider the long-term implementation of flood control infrastructure at the confluences of the Nicomekl River and the creeks.	To protect low lying properties should the water level in the Nicomekl River increase as predicted due to climate change.	Engineering Department BC MoE	Review sea level rise projection reports as they become available	NA



Legend

- Moderate Priority Bank Stabilization Site
- Implementation Plan Item
- Creeks
- Road
- Strategy 7: Protect Sunny Side Acres Urban Forest
- Study Area

Sources: City of Surrey, Bing Map Aerial

B SHEET SCALE: SHOWN

OneWay™ to zero harm

Date:	29/04/2014
Drawn by:	Y.M.
Edited by:	Y.M.
App'd by:	A.T.

CUSTOMER

CITY OF SURREY the future lives here.

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Implementation Plan Summary

WORLEYPARSONS PROJECT No.	FIG No.	REV
307076-04854	AA	0

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SAVE DATE & TIME: 19/12/2013 3:51:25 PM

USER NAME: Ashling.Mulcahy
ISSUING OFFICE: BURNABY GIS

Monitoring and Adaptive Management Framework

A Monitoring and Adaptive Management Framework was developed (using Metro Vancouver's 2013 draft Monitoring and Adaptive Management Framework Report as a template) to enable the City to complete the following tasks:

- Assess, holistically, creek health using water quality, hydrologic, and benthic invertebrate indicators;
- Evaluate the progress being made toward achieving the Vision;
- Track whether the ISMP's recommendations are being implemented and whether they are proving to be effective;
- Identify impacts and threats to the health of the Study Area;
- Use a mechanism to alter ISMPs at a citywide level to address changing regulatory and climatic conditions; and
- Report the status of the components listed above.

ABBREVIATIONS / DEFINITIONS

Abbreviation / Definition	Description
Adaptive Management Practices	A collection of actions, infrastructure, and strategies that can be selected to address degradation of watershed health caused by anthropogenic activities
Anthropogenic	The influence of human beings on the natural environment
Aquifer	An underground layer of water-bearing permeable rock or unconsolidated materials through which groundwater easily moves
Arithmetic Mean	The average value of a data set calculated as the sum of the values in the data set divided by the number of values
B-IBI	Benthic Index of Biotic Integrity - a multi-metric index that links the health of the invertebrate community to overall watershed health
Benthic Invertebrates	Small organisms that live in or on the bottom of creek sediments and are strongly affected by their surrounding environment making them a strong aquatic habitat health indicator
Best Management Practices	Practices that are based on scientific research to allow users / operators to meet standards and/or achieve objectives in a sustainable fashion
Bio-engineered	Engineered infrastructure that incorporates or encourages the growth of organic material, often as a means of stabilizing bank materials
Brunisolic	One of three forested soil orders in Canada
Catchment	The area from which creek flows conveyed to a defined point of the creek are generated from surface runoff
CCME	Canadian Council of Ministers of the Environment
CFU / 100 mL	Colony-forming Units per 100 millilitres of water
Channel Complexing	Reconfiguration of creek sections to include enhanced aquatic habitat such as deep pools, step pools, and/or side channels
Conductivity	The ability of a solution to conduct electricity, measured in micro Siemens per centimeter
Confluence	The point at which two or more bodies of water meet
Contaminants	Chemical elements or compounds that can negatively impact aquatic habitat conditions
Conveyance	The transportation of water from one point to another, typically within pipes, ditches, or creek channels
COSMOS	City of Surrey Mapping Online System
Design Storm	A pre-defined precipitation pattern that mimics local conditions during an intense rainfall event based on storm duration and return period
Detention Ponds	Constructed ponds to which runoff flows are routed during large storm events for temporary storage to reduce the likelihood of downstream erosion or flooding
Dissolved Oxygen	The amount of oxygen dissolved in creek flow with a direct impact on fish and anaerobic organism populations
dia.	Diameter

Abbreviation / Definition	Description
EIA	Effective Impervious Area - a measure of the total impermeable surface area which drains to the creeks and storm sewers within the Study Area
EMS	Ecosystem Management Study
Ephemeral	An element or attribute which lasts for a brief time, such as a stream which is dry except following large storm events
ESC	Erosion and Sediment Control
First Flush	The effect whereby heavy metals and chemical compounds build up on a surface during a period of dry weather and are subsequently transported to storm sewers via runoff during a storm
Floodbox	A culvert installed through a dyke that only permits the passage of water from the land side to the water side of the dyke
Gaining Stream	A stream into which groundwater is discharged
Geometric Mean	The average factor of a data set whose factors contribute to a product (e.g., rates of return) calculated as the product of the factors in the data set raised to the inverse of the number of factors
GIN	Green Infrastructure Network
GIS	Geographic Information System
ha	Hectares
Holistic	An approach wherein the management of a system is considered as a whole due to the interconnectedness of its components
Hydraulic	The study of the behavior of fluids in motion, particularly in conduits and channels
Hydrologic	The study of the movement, distribution, and quality of water
Hydrometric	The study of components of the hydrologic cycle
Hyetograph	A graphical representation of rainfall intensity over time
Impervious	A surface that impedes the transmission of water such as concrete
Infill Development	The subdivision of a single or multiple lots to facilitate increased housing density
Initiatives	Projects that will address a specific issue
Invasive Species	Introduced plant species that can disrupt or dominate a bio-region
ISMP	Integrated Stormwater Management Plan
ISO	International Organization for Standardization
Leave Strips	A setback from the high water mark in which structures are not permitted
LiDAR	A remote sensing technology used to develop topographical models
Long-range Opportunities	Potential solutions to issues that may be identified in the future through long-term monitoring
Losing Stream	A stream from which groundwater is derived
LWD	Large Woody Debris
m	Metres

Abbreviation / Definition	Description
m^3	Cubic metres
masl	Metres above sea level
mg/kg	Milligram of a chemical element or compound in a kilogram of sampled sediment
mm	Millimetres
MAMF	Monitoring and Adaptive Management Framework
MoE	Ministry of Environment
Monitoring Infrastructure	Infrastructure that will facilitate the monitoring framework
Mono-culture	Areas exhibiting low vegetative diversity
OCP	Official Community Plan - a collection of objectives and policies that guide the City's planning decisions
Oil Interceptors	A device through which surface runoff is routed in order to separate hydrocarbons and grit and retains it for future disposal
Overstory canopy	The uppermost layer within a forest canopy
Professional Biologist	A scientist who has obtained a Registered Professional Biologist (RPBio) designation from the College of Applied Biology of British Columbia
pH	The measure of acidity or alkalinity in aqueous solutions
QEP	Qualified Environmental Professional - an applied scientist or technologist, registered with an organization constituted under an Act with experience in riparian assessment
RDL	Reporting Detection Limit - the lowest concentration or units at which a chemical can be reliably measured
Return Period	An estimate of the period over which a discrete event will occur at least one time (used in risk analysis)
Riffle	A section of the creek in which flow maintains a higher velocity and turbulence resulting in a coarsely graded bed material
Riparian	Ecosystems that border a creek or other watercourse that act as a transition between water and land and play an essential role in maintaining the health of aquatic habitat by providing filtration, nutrients, and shelter
Root Rot	A disease caused by a fungus that affects the roots of evergreen tree species
Salmonid	A family of fish including salmon, trout, chars, graylings, and whitefish
Saturated Infiltration Rate	The rate (in mm/h) at which water will infiltrate into soil which has reached its saturation point
SCADA	Supervisory Control and Data Acquisition - a system that remotely acquires data and sends automated commands in real time
Scour	The effect whereby creek bank soils are eroded by high flow velocities
Secondary Land Use Plans	Community / neighbourhood level plans that support the OCP
Shrub Layer Vegetation	Vegetation consisting of shrubs and ferns between the forest floor and the understory

Abbreviation / Definition	Description
Substrate	The granular material that composes the bottom of a creek or other watercourse
Study Area	The drainage catchment containing the Elgin, Barbara, and Anderson Creek sub-catchments in addition to five minor sub-catchments
SWMM	Storm Water Management Model
Strategies	Techniques that can be applied to address issues throughout the Study Area
Taxa	Groups of one or more populations of organisms that comprise a unit
Taxonomic	The practice of classifying organisms
Temp	Temperature
TIA	Total Impervious Area - a measure of the total impermeable surface area in the Study Area
Turbidity	The measurement of nephelometric turbidty units (NTUs) to estimate the amount of total suspended solids in a water sample
µg/L	Microgram(1/1,000,000 of a gram) of a chemical element or compound contained in a litre of sampled water
µg/kg	Microgram of a chemical element or compound contained in a kilogram of sampled sediment
Understory Vegetation	Vegetation comprised of seedlings and saplings that do not penetrate the forest canopy
UPA	Units per Acre
USDA	United States Department of Agriculture
UTM	Universal Transverse Mercator - a projected coordinate system used by the City
Water Act Approval	A requirement of the Water Act to receive a written authorization from the Ministry of Forests, Lands and Natural Resource Operations to make changes in and about a stream that are of a complex nature (i.e., projects that include water diversions or environmental impacts)
Watershed	The area from which creek flows generated from surface runoff, for the creek in its entirety, are derived
Weir	A physical barrier to creek flow used to control the direction of or quantity of flow
WWGI	Wet Weather Green Infrastructure - infrastructure that collects, conveys, detains, retains, and/or infiltrates stormwater runoff in a sustainable fashion (e.g., bioswales, rain gardens, permeable pavement)

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Appendices

1. INTRODUCTION

The City of Surrey Engineering Department (the City) has engaged WorleyParsons Canada Services Ltd. (WorleyParsons) to prepare an Integrated Stormwater Management Plan (ISMP) for the Elgin, Barbara, and Anderson Creek watershed areas (collectively referred to as the Study Area).
The following report is presented as four distinct Stages, as illustrated in Figure A.

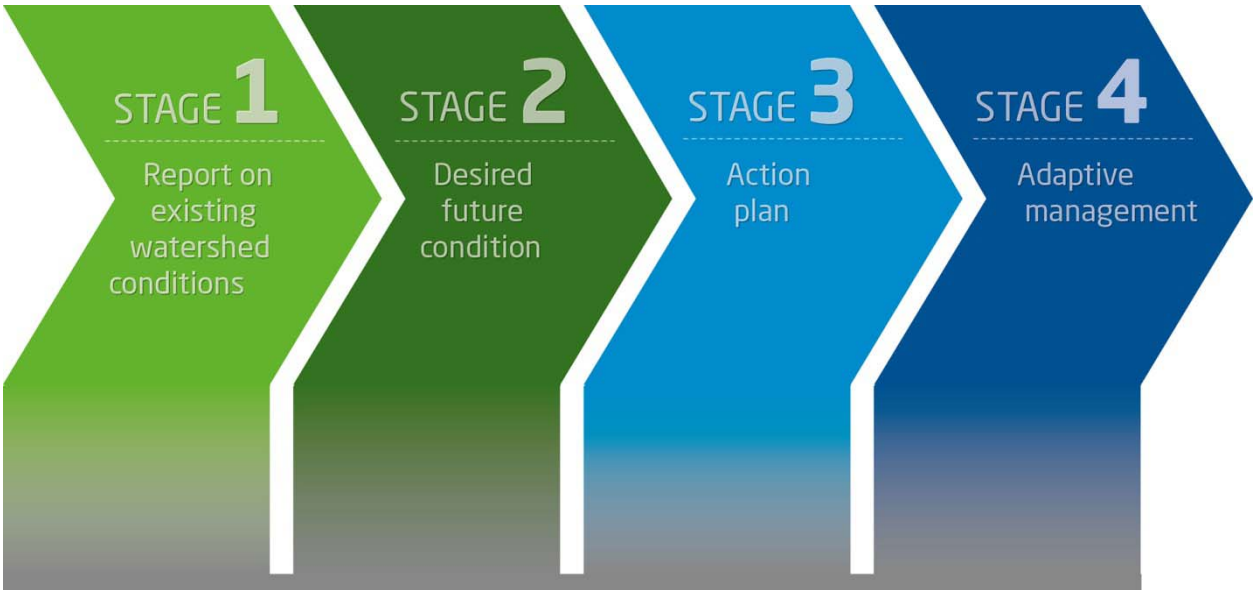


Figure A Watershed Blueprint

The content and structure of this report were based on the City's Request for Proposal document No. 4812-708, dated December 7, 2012 and WorleyParsons Proposal No. 307076-04296-0021, dated January 10, 2013.

1.1 Objectives

The primary objective of the Study is to assist City staff in guiding future growth within the Study Area over a 20-year period. To meet this objective, the Study provides clear guidelines and requirements that support sustainable development within the Study Area, while maintaining or enhancing the health of the Elgin, Barbara, and Anderson Creek watersheds.

To support the achievement of the primary objective, each Stage includes a series of secondary objectives and tasks, as illustrated in Table A.

Table A Secondary Objectives

Stage	Secondary Objective(s)	Purpose	Tasks
Stage 1 What do we have?	To determine baseline conditions within the Study Area.	To improve the understanding of the natural and anthropogenic processes that impact the health of the watersheds and to establish initial conditions for Stage 4's Monitoring Framework.	To assess the Study Area's land usage, hydrological, natural hazard, biophysical, infrastructure, and recreational characteristics.
Stage 2 What do we want?	To develop a vision for the Study Area.	To guide the development of stormwater objectives, indicators, and targets, which incorporate the views and opinions of the public.	To engage the public and stakeholders to determine the desired direction of stormwater management in the Study Area.
Stage 3 How do we get there?	To develop an implementation plan.	To provide the City with a strategic plan for implementing initiatives, strategies, long-range opportunities, and monitoring infrastructure that will address the vision's stormwater management objectives.	To develop and prioritize components of the implementation plan
Stage 4 How do we stay on track?	To develop an adaptive management framework.	To provide the City with a means of monitoring and evaluating progress made towards achieving the vision's stormwater management objectives.	To develop a program to monitor environmental and hydrologic parameters and an adaptive management plan to provide a mechanism to alter the ISMP to respond to environmental, regulatory, and socio-economic changes, using Metro Vancouver's Draft Monitoring and Adaptive Management Framework report as a template

1.2 Overview

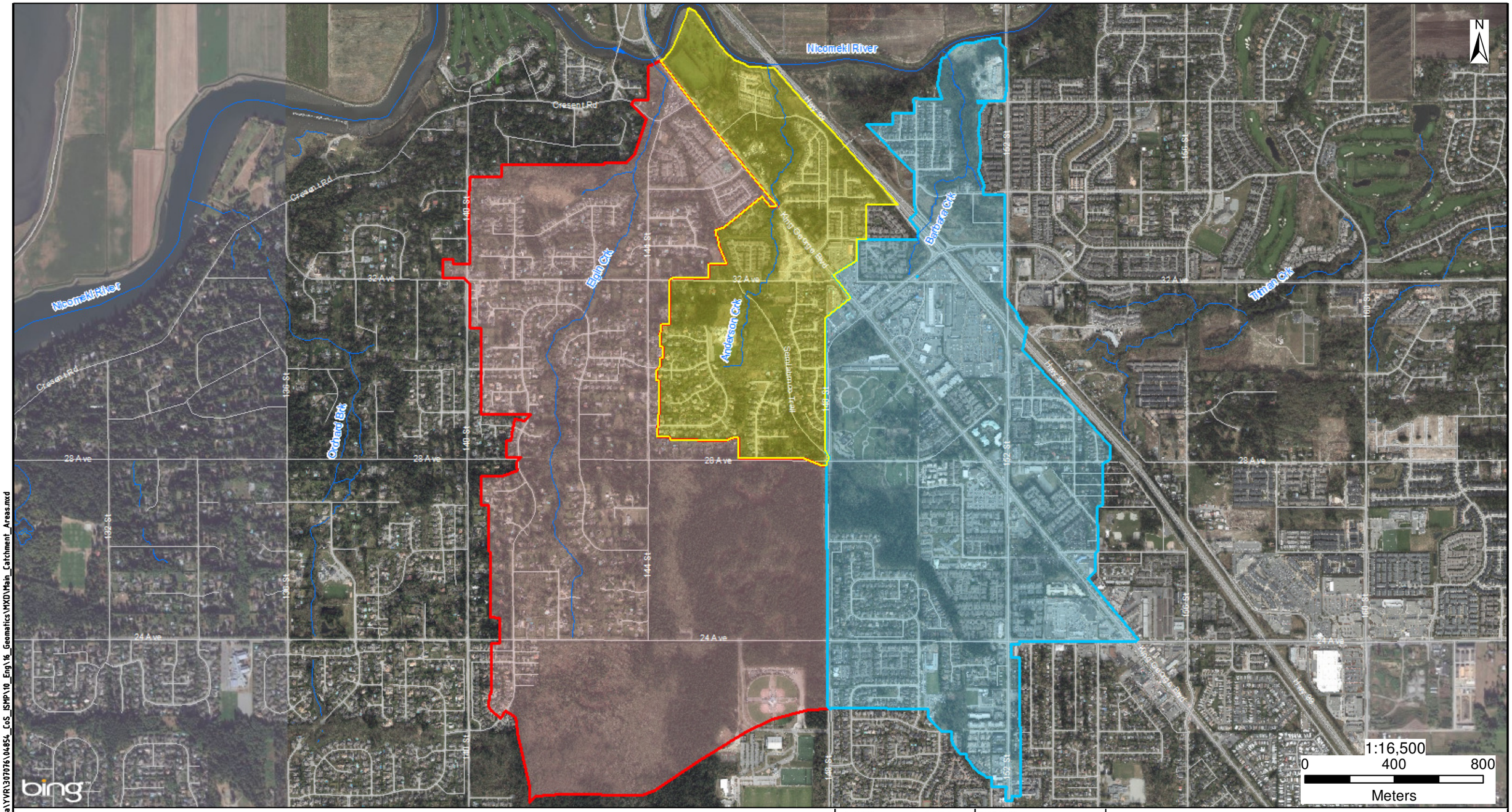
The Study Area is comprised of 720 ha of developed land located in the southern portion of Surrey, British Columbia (BC) representing the combined watershed areas for the Elgin, Barbara, and Anderson Creeks. It is roughly bounded to the north by the Nicomekl River, to the east by 152 Street (St.) and 156 St., to the south by 20 Avenue (Ave.) and 24 Ave., and to the west by 140 St. as illustrated in Figure B.

The Study Area is serviced by a series of ditches and storm sewer mains that collect and convey stormwater runoff to the Elgin, Barbara, and Anderson Creeks which discharge to the Nicomekl River. There are also three separate outfalls to the Nicomekl which drain small sub-catchments within the Study Area.

Historically, the Study Area has been comprised of large, suburban properties; however, there have been subsequent development periods that have introduced urban, multi-family, commercial, and industrial properties. This change to land usage has impacted runoff patterns and creek flow regimes due to the resulting increase in impermeable area (i.e., hard surfaces such as asphalt and roofing restrict the infiltration of stormwater resulting in increased runoff volumes discharged to the creeks during rain events and decreased groundwater discharged to the creek during the summer).

1.3 Data Registry

WorleyParsons compiled a data registry identifying the various documents collected to inform the ISMP study and prepared to support the preparation of this report (see Appendix 1).



Legend

- Anderson Catchment
- Barbara Catchment
- Elgin Catchment
- Creeks
- Road

Sources: City of Surrey, Bing Map Aerial

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Study Area Overview

WORLEYPARSONS PROJECT No.	FIG No.	REV
307076-04854	B	0

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2. STAGE 1 - "WHAT DO WE HAVE?"

The subsequent sections assess and discuss the existing conditions within the Study Area relating to the following characteristics:

- Study Area Overview, including:
  - Physiography - the general topography of the catchments and creek related physical features;
  - Meteorology - the regional weather and climate patterns;
  - Land Usage - the current and future zoning of properties;
  - Aquatic Habitat and Riparian Area - qualitative descriptions of aquatic habitat conditions and riparian areas;
  - Geology / Hydrogeology - the predominant soil characteristics and general behaviour of groundwater;
- Hydrological Assessment - computational model that synthesizes creek flows to identify potential erosion sites and undersized infrastructure; and
- Biophysical Assessment - quantitative assessment of water and sediment quality and benthic invertebrate health as indicators of watershed health.

2.1 Study Area Overview

The Study Area consists of three creek catchments: the Elgin, Barbara, and Anderson Creeks all of which discharge to the Nicomekl River.

Elgin Creek

The Elgin Creek catchment is the largest of the three catchments, measuring 343 ha, and is composed of large suburban lots and the Sunnyside Acres Urban Forest in the catchment headwaters. The catchment comprises two sub-catchments: the Elgin and King George.

Runoff in the Elgin sub-catchment is conveyed to Elgin Creek via a series of drainage ditches and storm sewers. The sub-catchment includes three municipally owned detention / retention ponds, with an estimated storage capacity of 2,930 m^3. Elgin Creek discharges freely to the Nicomekl River between the City's sea dam and the King George Highway Bridge. It was estimated that the sub-catchment includes up to 33% effective impervious area (EIA) under future anticipated zoning conditions.

Runoff in the King George sub-catchment is conveyed to the Nicomekl River via a trunk storm sewer, which discharges freely immediately upstream of Elgin Creek. The trunk sewer includes a high flow diversion discharging to Elgin Creek which services the properties west of the Elgin Creek between the 32 Ave. and 34 Ave. corridors. It was estimated that the sub-catchment includes 55% EIA under current zoning conditions and up to 53% EIA under future anticipated zoning conditions.

Barbara Creek

The Barbara Creek catchment measures 260 ha and is composed of primarily urban single and multiple family residential lots in addition to a large (25 ha) cemetery as well as suburban, institutional, commercial, and industrial properties. The catchment is also bisected by the Highway 99 and King George Highway corridors, both of which contribute significant impermeable surface area.

Runoff in the catchment is conveyed through a series of storm sewers to wetlands located northwest of the Highway 99 overpass at 32 Ave. During low flow, this runoff is routed to a trunk storm sewer which discharges to the Nicomekl River downstream of 152 St. with a portion of runoff routed through a culvert to Barbara Creek during high flows. Barbara Creek discharges freely to the Nicomekl River immediately upstream of the storm sewer discharge. It should be noted that this flow routing regime is not as presented in the as-built record drawings of the drainage infrastructure or as would be expected of best management practice in which base flows to Barbara Creek would be maintained with the trunk sewer serving as high flow relief.

The trunk storm sewer and Barbara Creek both collect additional runoff downstream of the Highway 99 crossing. The catchment includes three municipally owned detention / retention ponds, with an estimated storage capacity of 1,300 m^3. It was estimated that the catchment includes 65% EIA under current zoning conditions and 73% EIA under future anticipated zoning conditions.

Anderson Creek

The Anderson Creek catchment measures 105 ha and is composed primarily of suburban and urban residential lots. Runoff in the catchment is conveyed to Anderson Creek via a series of drainage ditches and storm sewers. The catchment includes two municipally owned detention / retention ponds, with an estimated storage capacity of 5,670 m^3. Anderson Creek discharges freely to the Nicomekl River between Highway 99 and 152 St. It was estimated that the catchment includes 50% EIA under current zoning conditions and 65% EIA under future anticipated zoning conditions.

2.1.1 Physiography

The Study Area topography is variable, ranging from an elevation of 1 metre above sea level (masl) in the low lying areas along the Nicomekl River, to 118 masl in the Sunnyacres Urban Forest located in the headwaters of the Elgin and Anderson Creeks.

The Study Area is generally graded from the headwaters in the south to the Nicomekl River to the north, with the creeks located within ravines with riparian vegetation. These ravines become progressively deeper moving downstream until the creeks near their confluences with the Nicomekl River and the creek cross section becomes wider and shallower due to a decrease in channel slope.

2.1.2 Meteorology

Climate

Climate normals were collected for the following nearby meteorological monitoring stations operated by the City:

- Surrey Municipal Hall station (to the north of the Study Area); and
- White Rock Sewage Treatment Plant (STP) station (to the south of the Study Area).

The overall climate regime in the Study Area is generally temperate oceanic (Köppen climate classification Cfb), characterised by dry summer months with rain the remainder of the year.

The Surrey Municipal Hall station is at an elevation of 76 masl and is located north of the site, while the White Rock STP station is at an elevation of 13 masl and located south of the site. Precipitation varies slightly between the stations, which indicates an influence from local weather patterns. Therefore, although the station elevations and proximity appear to represent the Study Area well, natural land formations, consisting of hills and waterways, exist which could affect the relevance of the meteorological records collected for the Study Area.

Temperature

Average monthly temperature ranges from 2.7 deg. C to 17.5 deg. C at the Surrey Municipal Hall station and 4.1 deg. C to 17.2 deg. C at the White Rock station. A minimum normal temperature of -0.2 deg. C and a maximum normal temperature of 22.6 deg. C have been recorded at the Surrey Municipal Hall while a minimum normal temperature of 1.4 deg. C and a maximum normal temperature of 21.4 deg. C have been recorded at the White Rock STP.

Precipitation

Table B presents the average monthly precipitation depths for both stations, based on precipitation records from 1971 to 2000.

Table B Average Monthly Precipitation

Month	Surrey Municipal Hall (% of annual)	White Rock STP (% of annual)
January	176 mm (12.8%)	144 mm (13.1%)
February	140 mm (10.2%)	107 mm (9.7%)
March	125 mm (9.1%)	96 mm (8.7%)
April	99 mm (7.2%)	75 mm (6.8%)
May	81 mm (5.9%)	67 mm (6.1%)
June	64 mm (4.7%)	56 mm (5.1%)
July	47 mm (3.4%)	40 mm (3.6%)
August	46 mm (3.4%)	43 mm (3.9%)
September	60 mm (4.4%)	51 mm (4.6%)
October	129 mm (9.4%)	103 mm (9.3%)
November	209 mm (15.3%)	166 mm (15.1%)
December	195 mm (14.2%)	154 mm (14.0%)
Total	**1,371 mm**	**1,102 mm**

The long-term total annual precipitation trends at the White Rock STP station between 1963 and 2002 are shown in Figure C. Due to a lack of data, both temporal and spatial, it is difficult to determine a long-term rainfall trend with reasonable certainty.

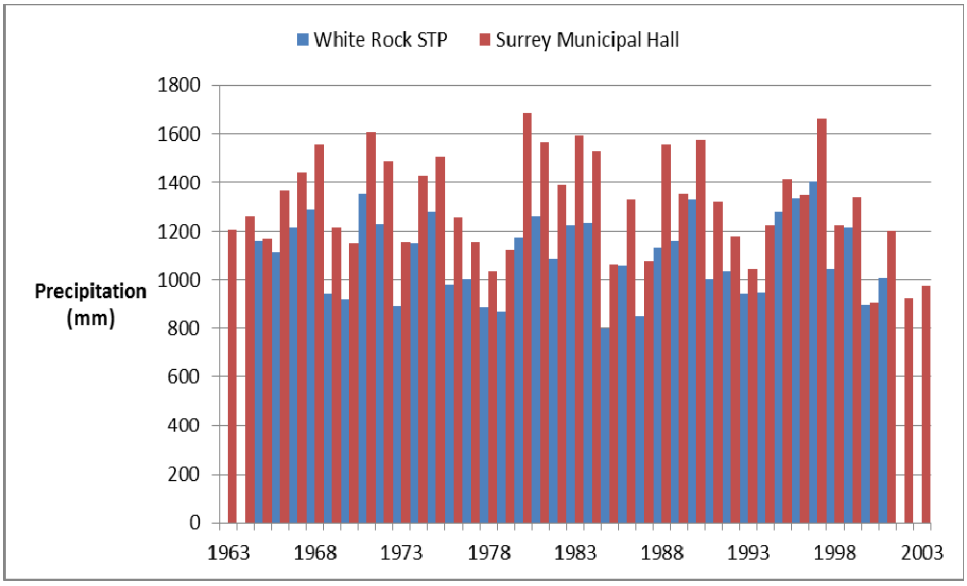


Figure C Total Annual Precipitation at White Rock STP

Snowfall

Average monthly snowfall amounts and corresponding snow depths were retrieved from Environment Canada's Historical Climate Data. Snowfall is minimal in the Study Area and accounts for only 4% and 3% of precipitation at the Surrey Municipal Hall and White Rock STP station, respectively. Snowfall typically occurs between October and March (most frequently in January) and snowmelt generally occurs soon after the snowfall. There is no peak snowmelt rate which contributes notable higher surface water flow rates within the Study Area.

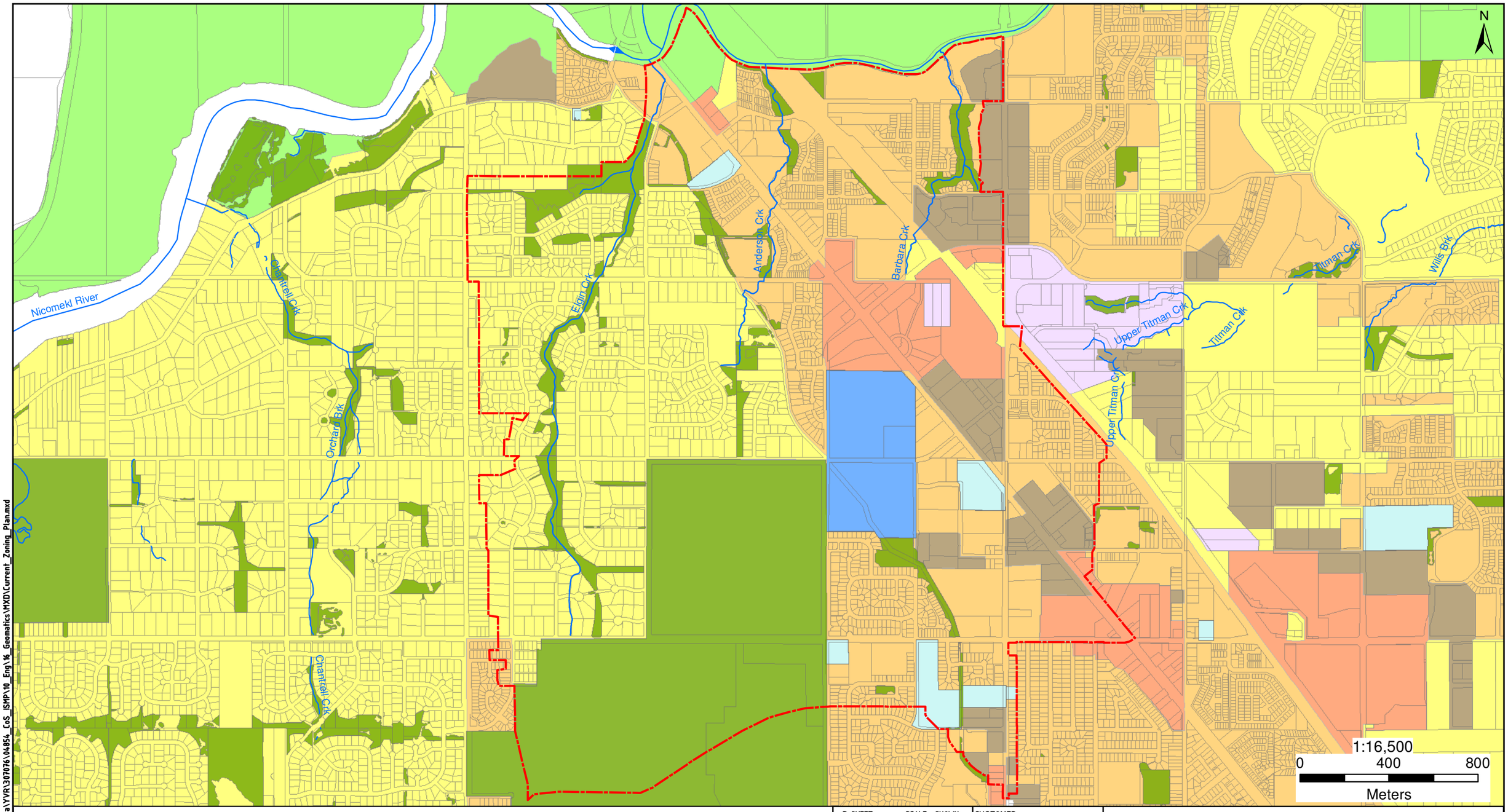
2.1.3 Land Usage Assessment

The current and future zoning compositions were assessed in order to estimate the impermeable area within the Study Area. Impermeable area is directly related to the volume of water that is discharged to the creeks and is a key component of the hydrological model discussed in Section 2.2.1

Current Zoning Composition

Knowledge of the current zoning composition was required to develop an understanding of surface flow and creek discharge patterns within the Study Area. The City's Geographic Information Systems (GIS) data was reviewed to determine the different zoning categories, and their distribution, within the Study Area. Similar zones were grouped together to create zoning categories based on their overall designation. For example, the RA, RA-G, RH, and RH-G zoning categories are all shown as suburban residential.

As shown on Figure D, the Study Area is composed primarily of properties zoned as single family suburban and urban properties with small pockets of properties zoned as multiple residential, commercial, industrial, agricultural, public assembly, and cemetery. A large group of properties in the southwest portion of the Study Area are designated as green space; consequently, they are primarily composed of undeveloped areas (Sunnyside Acres Urban Forest) and developed permeable surfaces (recreation fields). Table C provides a breakdown of the zoning composition.



Legend

- Study Area
- Property Lot Outline
- Creeks

Zoning Categories

- Agricultural / Golf Course
- Commercial
- Industrial
- Multiple Residential
- Suburban
- Urban
- Green Space
- Institutional
- Cemetery

Sources: City of Surrey

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Current Zoning Composition

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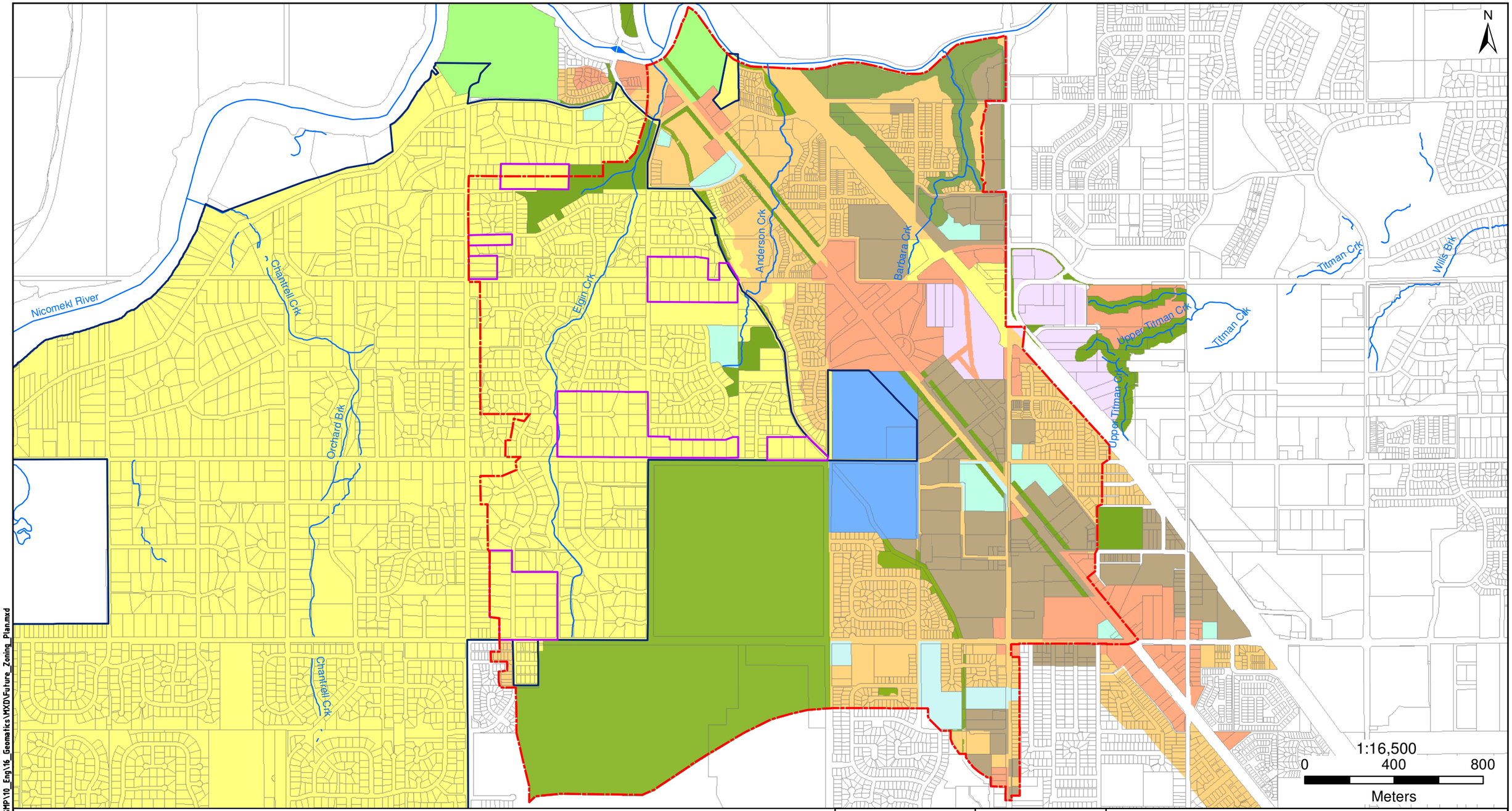
Table C Zoning Composition Breakdown

Zoning Category	Estimated Contributing Area (ha)	Estimated Contributing Area (%)
Suburban	216	30
Green Space	180	25
Roadways	118	16
Urban	97	13
Multiple Residential	43	6
Cemetery	25	4
Commercial	12	2
Institutional	12	2
Industrial	9	1
Agricultural / Golf Course	8	1

Future Zoning Composition

A prediction of the future zoning composition was required to estimate whether a significant change in creek flow patterns is expected to result if the Study Area was developed to the maximum allowable extent over the next 20 years.

The future zoning composition outlined in the City's 2013 Draft Official Community Plan (OCP) and pertinent Secondary Land Use Plans were reviewed to define the anticipated future zoning composition, presented as Figure E. Table D provides a breakdown of the results.



Legend

- Study Area
- Property Lot Outline
- Creeks

Zoning Categories

- Agricultural / Golf Course
- Commercial
- Industrial
- Multiple Residential
- Suburban
- Urban
- Green Space
- Institutional
- Cemetery
- Suburban Subdivision Exception Area
- Suburban Density Exception Area

Sources: City of Surrey

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Future Zoning Composition

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WORLEYPARSONS PROJECT No.	FIG No.	REV
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Table D Breakdown of Results

Zoning Category	Estimated Contributing Area (ha)	Estimated Contributing Area (%)	Estimated Change from Existing (%)
Suburban	189	26	-4
Green Space	174	24	-1
Roadways	118	16	0
Urban	84	12	-1
Multiple Residential	63	9	+3
Commercial	31	4	+2
Cemetery	25	4	<1
Institutional	18	3	+1
Industrial	10	1	<1
Agricultural / Golf Course	6	1	<1

The analysis was based on the assumption that Suburban properties will undergo infill development (i.e., the subdivision of lots to facilitate increased housing density) to the maximum permissible extent. The Land Uses and Densities section of the OCP defines the following two exception areas which limit the infill development of Suburban properties which apply to the Elgin and Anderson Creek catchment areas:

- Suburban Density Exception Area limits the density of suburban lots to 2 units per acre (UPA); and
- Suburban Subdivision Exception Areas limits the density of suburban lots to 1 UPA.

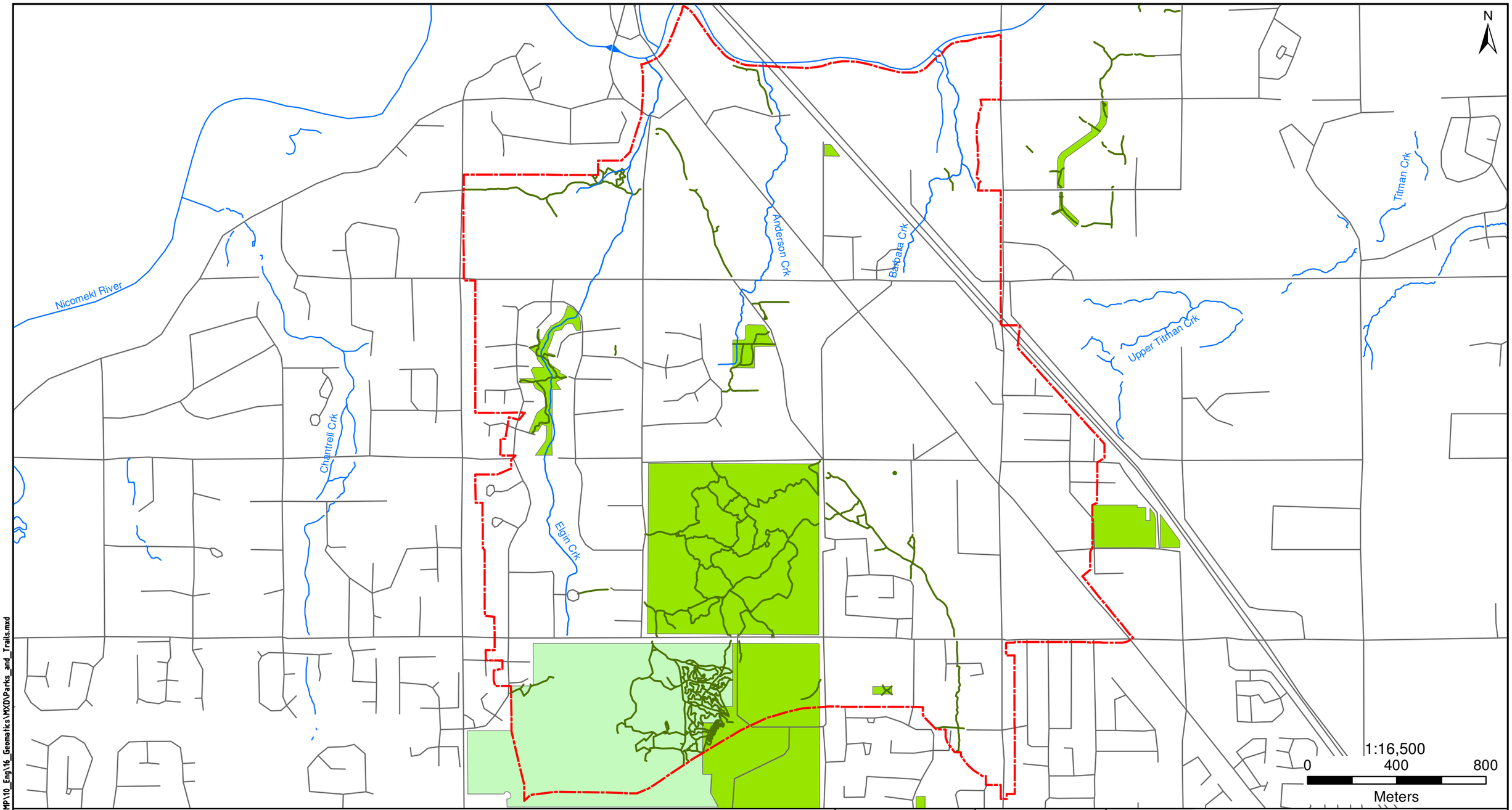
Suburban lots not located within these areas were reclassified as ‘urban’ lots as it is anticipated that they will ultimately be redeveloped or subdivided to the gross density subdivision density with the provision of parkland to the City.

The slight change in zoning composition is as expected as the majority of the Study Area has already been developed over the past 20 years; however, changes in development strategy (e.g., the approval of developments with increased density to account for housing shortfalls) could affect the zoning composition which, in turn, would increase the impervious area and significantly change the hydrological assessment discussed in Section 2.2.

2.1.4 Recreational Facilities

Existing recreational infrastructure, such as parks and trails, often provide the opportunity to enhance watershed health through the implementation of stormwater management infrastructure (including wetlands and rain gardens) and the restoration of creeks and riparian corridors. The infrastructure within the Study Area is shown on Figure F and includes a number of parks (including the South Surrey Athletic Park and the Sunnyside Acres Urban Forest) and trails (including a portion of the historic Semiahmoo Trail).

The Sunnyside Acres Urban Forest is a 150 ha natural woodland located in the southeast region of the Study Area at the headwaters of Elgin Creek. The Forest is divided by 24 Ave. with the portion north of 24 Ave. the Forest containing nature and interpretive hiking trails and the portion south containing a Wildlife Nature Reserve to which public access is prohibited. Sunnyside Acres is owned by the City and managed and maintained by the City's Parks, Recreation, and Culture Department. Additionally, the Sunnyside Acres Heritage Society, Sunnyside Acres Urban Forest Advisory Committee, and the Surrey Off-Road Cycling Enthusiasts support the City through stewardship and volunteer activities.



Legend

- Study Area
- Creeks
- Road
- Trail
- Urban Forest
- Park

Sources: City of Surrey

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Parks and Trails

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The following parks are located within the Study Area:

- Sunnyside Park;
- South Surrey Athletic Park;
- Semiahmoo Trail Park;
- Winter Crescent Park;
- Elgin Estates Park;
- Meridian Park;
- Meridian by the Sea Park;
- Rosemary Height Park; and
- Neighbourhood Park.

Running through the Study Area from the Elgin Centre to 20 Ave. is the Semiahmoo Trail - one of the region's most prominent and historical trails. The trail begins just beyond the upper end of the Barbara Creek Catchment and crosses Anderson Creek at 32 Ave. before ending adjacent to the Elgin Creek crossing at Crescent Road (Rd.). The trail is managed and maintained by the City with support provided by the Friends of Semiahmoo Trail organization.

The following trails are located within the Sunnyside Acres Urban Forest:

- The Wally Ross Trail;
- The Aldergrove Trail;
- The Fern Trail;
- The Maple Trail;
- The Salal Trail;
- The Trillium Trail;
- The Douglas-fir Nature Trail;
- The Moss Trail;
- The Vine Maple;
- Stellar's Jay; and
- The Chickadee Loop.

2.1.5 Aquatic Habitat and Riparian Area

On May 28, 2013, WorleyParsons staff walked the Elgin, Barbara, and Anderson creek alignments from their respective confluences with the Nicomekl River to their headwaters to assess the substrate materials, infrastructure, and riparian vegetation within the creek corridors and to identify creek conditions and infrastructure that adversely affect fish habitat. Based on measurements taken at the nearby Chantrell Creek Elementary rain gauge, 5.5 mm of rain fell over the three days preceding the site visit, with an additional 6.5 mm of rain on the day of the site visit.

Figure G, Figure H, and Figure I identify the locations of the creek sections that were assessed as well as their key biophysical parameters.

Elgin Creek Section No. 1 - Nicomekl Confluence

The confluence with the Nicomekl River is under backwater influence from the River which itself is controlled by the sea dam immediately downstream of the confluence. Consequently, a brackish slough extends from the confluence to 60 m upstream where the creek leaves a well forested ravine. The riparian vegetation on both banks of this creek section is limited due to commercial and residential developments. Through this section, the creek maintained an average channel width of 2.5 m and wetted width of 1.5 m with a bed composed primarily of deposited silty material. At the time of the site visit, water depth ranged from 0.6 m in the pools to 0.1 m in the riffles.

Elgin Creek Section No. 2 - Confluence to Crescent Rd.

The creek then passes through a series of runs, riffles and pools extending from the slough to the culvert crossing of Crescent Rd. Through this section, the creek maintained an average channel width of 2.5 m (wetted width of 1.5 m) with a bed composed of mixed sands and gravels. Staff noted finer sediments near channel margins and pools as well as several small gravel bars within the main stem of the creek located behind large woody debris (LWD) and debris jams.

Photo A Rock Weir

At the time of the site visit, water depth ranged from 0.6 m in the pools to 0.1 m in the riffles.
A series of rock weirs are located in the creek channel, likely placed to add complexity and oxygen diffusion into the water column; however, this has resulted in the erosion of channel banks at these locations.

The understory vegetation ranged from 50% cover to 85% cover and was composed primarily of vine maple, sword fern, and salmonberry while the overstory canopy cover averaged 40% to 60% and was dominated by red alder, western redcedar, and big-leaf maple. The shrub layer vegetation was limited, consisting primarily of salmonberry and vine maple.

The creek is conveyed under Crescent Rd. through a 25 m-long, 900 mm dia. culvert which could act as a barrier to fish passage during low flow conditions.

Elgin Creek Section No. 3 - Crescent Rd. to 34 Ave.

Staff classified this section of the creek as run with intermittent riffles and main stem pools formed by debris jams. Through this section, the creek maintained a channel width of 3 m to 5 m with a bed composed of coarse sands and gravels at riffles and run sections and fines and silt at pools. Staff noted boulders and cobbles in the steeper ravine sections of the channel due to erosional cutting of the ravine banks. At the time of the site visit, water depth ranged from 0.35 m in the deeper pools to 0.1 m in the riffles.

Photo B Riffle Upstream of Crescent Road Culvert

Stream habitat is diverse in this section of channel, including a combination of step-pools, LWD, sediment wedges (gravel bars), boulders, overstory canopy development, and understory cover. Understory shrub layer vegetation is generally limited to patches of sword fern, salmonberry, and vine maple beneath the overstory. The overstory canopy provided approximately 85% cover, and was composed of western redcedar, western hemlock, red alder, and big-leaf maple.

Photo C Typical Channel Profile

Salmonid habitat value ratings for this section are high for rearing and spawning given the amount of instream cover, overstory cover, and a variety of suitable substrates; however, staff noted several debris jams noted throughout the lower portion of Elgin Creek, forming several potential fish passage barriers during low flow conditions.

Photo E Typical Riffle-Run with Diverse Riparian Cover

Approximately 100 m upstream of Crescent Rd., an ephemeral tributary enters Elgin Creek from the left bank. The creek is conveyed under a pedestrian walkway located at the end of 34 Ave. through a fish passable, 8 m-long, 1 m by 1.2 m concrete box culvert.

Photo D Debris Jam and Sediment Wedge

Photo F Upstream of Box Culvert

Elgin Creek Section No. 4 - 34 Ave. to 32 Ave.

Staff classified this section of the creek as being dominated by intermittent riffles and pools with slower glides through a forested ravine. Through this section, the creek maintained an average channel width of 2.5 m (wetted width of 1 m) with a bed composed of coarse sand, gravel, and cobbles at riffles and run sections and fines and silt at pools. Staff noted that habitat complexing is provided through a combination of pools, LWD, and boulders. Staff estimated the canopy cover at 75% near the pedestrian walkway, composed primarily of big-leaf maple, western redcedar and red alder.

Downstream of 32 Ave., the creek becomes much more overgrown with understory cover. The understory and shrub layer vegetation is predominately composed of sword fern, vine maple, red huckleberry, and salmonberry. The channel gradient through this section increases resulting in faster flows creating a series of step-pools.

Salmonid habitat value ratings for rearing and spawning are low to medium in the lower reach near 34 Ave. and low near 32 Ave. due to the absence of suitable spawning gravel, the increased number of potential migration barriers, and ephemeral nature of surface flows.

The creek is conveyed under 32 Ave. through a 17 m-long 1,200 mm dia. concrete culvert fitted with fish passage baffles and a trash screen on the upstream end.

Elgin Creek Section No. 5 - 32 Ave. to Northcrest Drive

This section of creek is at a reduced gradient resulting in a bed composed of silt and sand with an average channel width of 1.6 m (wetted width of 0.7 m). At the time of the site visit, water depth ranged from 0.3 m in the pools to 0.1 m in the run sections.

Staff estimated the canopy cover at 70%, composed of red alder, western redcedar, western hemlock, and douglas fir, and the understory cover at 15%, composed of vine maple, salmonberry, skunk cabbage, sword fern, red elderberry, and red huckleberry.

The creek is conveyed under Northcrest Drive through a 36 m-long 1,500 mm dia. elliptical corrugated metal culvert fitted with fish passage baffles and a trash screen on the upstream end.

Elgin Creek Section No. 6 - Northcrest Drive to 28 Ave.

The creek flows through a residential development upstream of Northcrest Drive. Consequently, much of the riparian vegetation has been removed, providing less than an estimate 20% canopy cover. The creek bed is composed of mixed gravels, sand, cobbles and occasional boulders.

Salmonid habitat value ratings for rearing and spawning are moderate, provided there is sufficient water flows to overwintering pools, riparian vegetation for thermal refuge, and instream cover in the more exposed residential areas.

Elgin Creek Section No. 7 - 28 Ave. to 24 Ave.

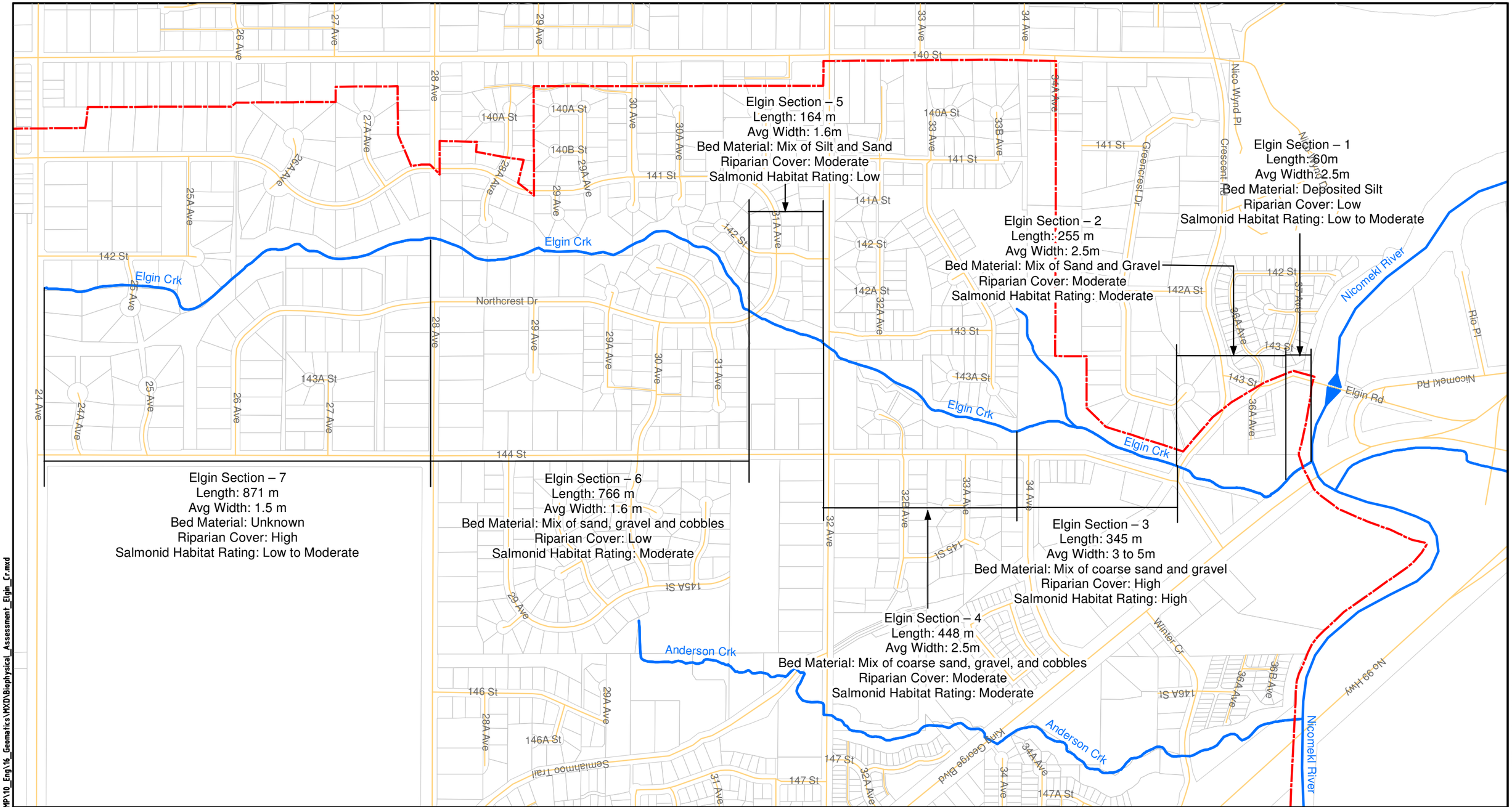
Through this section the creek maintains an average channel width of 1.5 m (wetted width of 0.5 m) with LWD located periodically along the creek alignment. Staff estimated the canopy cover at 85% composed of big-leaf maple, red alder, western redcedar and western hemlock with understory vegetation including vine maple, red elderberry, and salmonberry.

The creek is conveyed under 24 Ave. through twin 43 m-long, 450 mm dia. concrete culverts.

Photo G Deep Pool Habitat

Elgin Creek Section No. 8 - Upstream of 24 Ave.

The uppermost section of Elgin Creek was mostly dry at the time of the assessment. Staff estimated the canopy cover at 100% composed of red alder and big-leaf maple with dense hardhack and understory cover. Salmonid habitat value ratings for rearing and spawning are low due to the lack of suitable gravel substrate or deep pool habitat in addition to the ephemeral flow regime.



Legend

- Study Area
- Creek/River
- Road
- Property Lot

1:7,500

0 150 300

Meters

Sources: City of Surrey

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Biophysical Assessment
Elgin Creek

WORLEYPARSONS PROJECT No.	FIG No.	REV
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Anderson Creek Section No. 1 - Nicomekl River Confluence to Winter Crescent

The confluence with the Nicomekl River is situated on a floodplain with a low channel gradient composed primarily of sands with fines and silts along channel margins. Staff estimated the canopy cover at 45% composed of reed canary grass, Himalayan blackberry, creeping buttercup, and red alder. Staff noted evidence of beaver activity within the floodplain. Salmonid habitat value ratings for rearing and spawning are moderate to high within sections of the creek with gravel substrate.

Photo H Confluence of Nicomekl River and Anderson Creek

Photo I Evidence of Beaver Activity in Floodplain

The creek is conveyed under Winter Crescent through a 13 m-long, 900 mm dia. concrete culvert.

Photo J Culvert Crossing at Winter Crescent

Anderson Creek Section No. 2 - Winter Crescent to King George Highway

This section of creek, extending approximately 200 m upstream of the confluence, is located within a well-confined ravine and includes both riffles and step-pools. The bed is composed of silt and sand with abundant woody debris. The overstory consists of douglas fir, big-leaf maple, western hemlock, western redcedar, red alder and vine maple while the understory consists of red alder, salmonberry, common horsetail, Himalayan blackberry, and grasses. The creek is conveyed under King George Highway through a 31 m-long, 900 mm dia. culvert.

Anderson Creek Section No. 3 - King George Highway to 32 Ave.

This section of creek is located in a residential area maintaining an average channel width of 1.2 m with a bed composed of silt and sand. The overstory vegetation consists of douglas fir, big-leaf maple, western hemlock, western redcedar, red alder, and vine maple while the understory vegetation consists of red alder, salmonberry, common horsetail, Himalayan blackberry and grasses. Salmonid habitat value ratings for spawning and rearing are low due to the lack of instream and riparian cover and LWD through this residential area. The creek is conveyed under 32 Ave. through a 12 m-long, 600 mm dia. concrete culvert.

Anderson Creek Section No. 4 - 32 Ave. to Semiahmoo Trail

A number of weirs have been installed immediately upstream of the 32 Ave. crossing in order to create ornamental fish ponds on private property. These weirs have the potential to act as a barrier to upstream fish migration. The overstory vegetation through this section consists of vine maple and douglas fir while the understory vegetation consists of thimbleberry, lady fern, sword fern, and introduced shrubs.

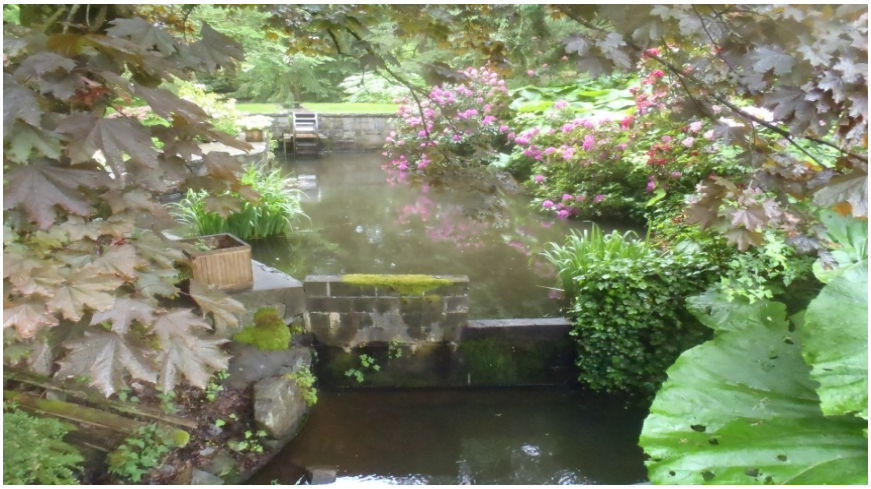
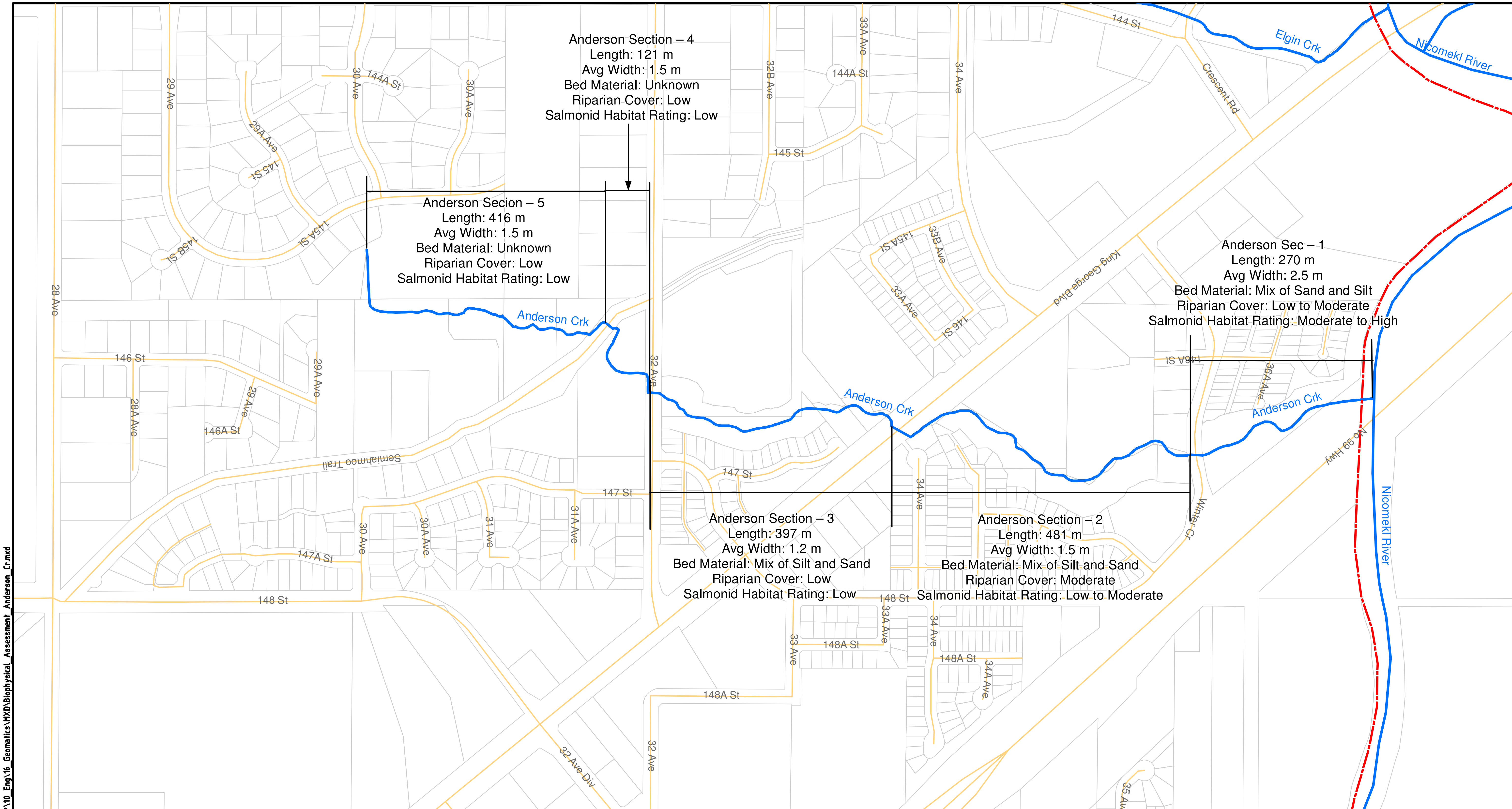


Photo K Ornamental Ponds South of 32 Ave.

The creek is conveyed under Semiahmoo Trial through a 13 m-long, 1,050 mm dia. concrete culvert.

Anderson Creek Section No. 5 - Upstream of Semiahmoo Trail

The uppermost portion of Anderson Creek is dominated by duckweed, rushes, and junipers and is partially obstructed by a rock wall fish barrier located upstream of Semiahmoo Trail on private property. Staff concluded that the creek had low salmonid rearing and spawning habitat value beyond this point due to the extensive anthropogenic impacts.



Legend

- Study Area
- Creek/River
- Road
- Property Lot

N

1:5,000

0 100 200

Meters

Sources: City of Surrey

B SHEET	SCALE: SHOWN
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Biophysical Assessment
Anderson Creek

WORLEYPARSONS PROJECT No.	FIG No.	REV
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Barbara Creek Section No. 1 - Nicomekl River Confluence to 34 Ave.

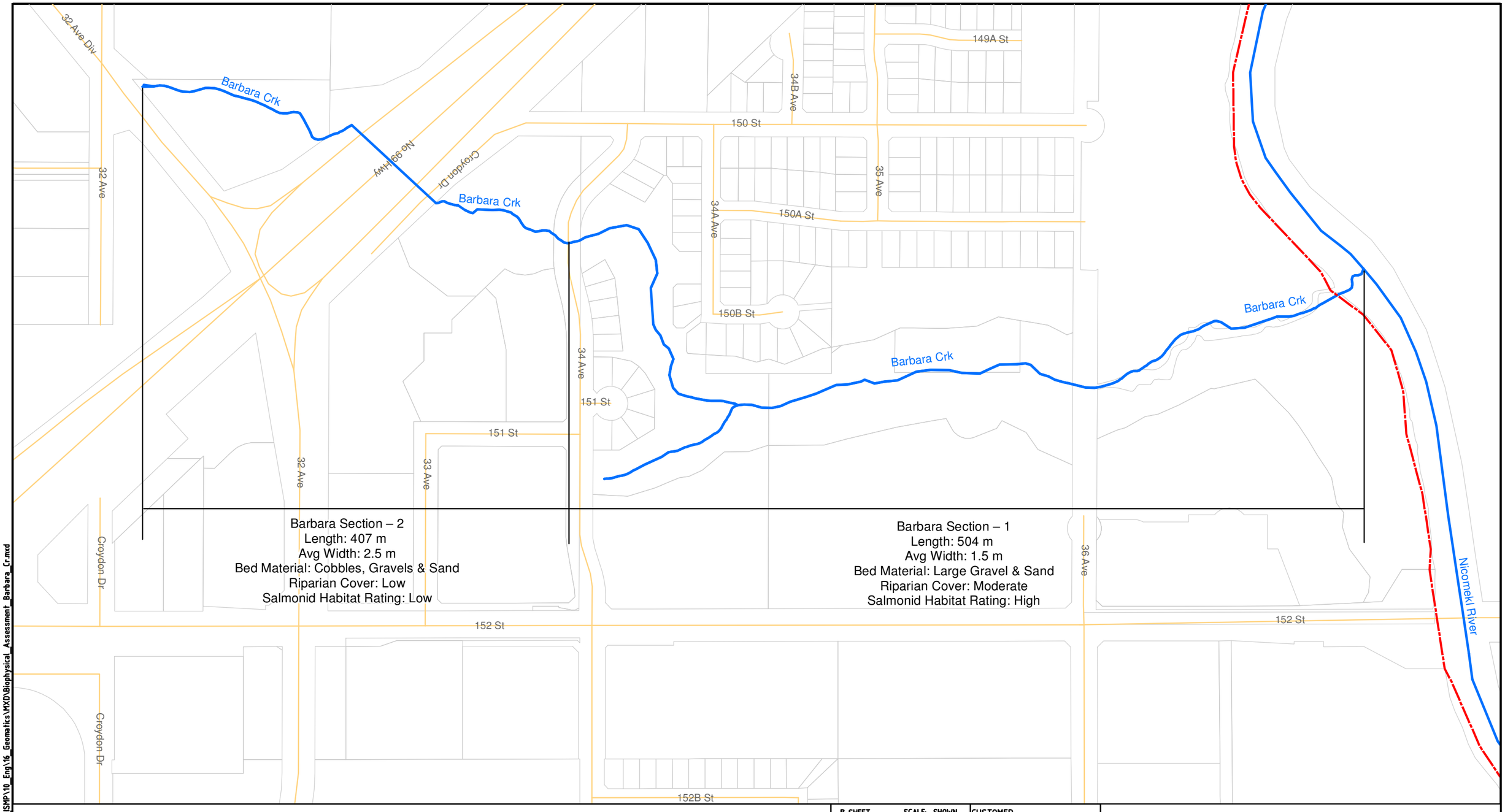
The confluence with the Nicomekl River consists of a well-defined, low gradient channel containing riffles and shallow glides with occasional pools. Staff noted several low-flow fish passage barriers as the channel gradient increased upstream of the confluence. The channel maintains an average width of 1.5 m with a bed composed primarily of large gravels and sands with sections of fines and in-stream grasses. The overstory vegetation consists primarily of western redcedar, western hemlock, vine maple, big-leaf maple, and red alder while the understory consists of reed canary grass, sword fern, Himalayan blackberry, and salmonberry.

The creek passes under a bridge at 34 Ave. which does not likely constrict normal flows. The Salmonid habitat value ratings for spawning and rearing are high between the confluence and this structure.

Photo L Downstream of 34 Ave. Bridge

Barbara Creek Section No. 2 - Upstream of 34 Ave.

This section of creek maintains an average width of 2.5 m (wetted width of 1.5 m) with a bed composed of cobbles, gravels, and sands with silt and finer sediments along channel margins and behind channel obstructions. A fish habitat channel was recently constructed within the BC Hydro right-of-way likely as part of a compensation package; however, it was dry at the time of the site visit.
Additional compensation works, including cabled log structures, have also been installed within Barbara Creek. Riparian cover through this section includes red alder, pacific willow, Nootka rose, and red-osier dogwood.



Legend

- Study Area
- Creek/River
- Road
- Property Lot

Sources: City of Surrey

N

1:3,000

0 50 100

Meters

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Biophysical Assessment
Barbara Creek

WORLEYPARSONS PROJECT No.	FIG No.	REV
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Photo M Outlet of Compensation Channel to Barbara Creek

Photo N In-stream Compensation Works

Salmonid habitat value ratings for spawning and rearing through this section are low to moderate due to a lack of spawning gravels and intermittent riparian cover; however, once fully established, the fish habitat compensation and restoration techniques and right-of-way replanting efforts along Barbara Creek may increase the fish habitat productivity.

The creek is conveyed under Highway 99 through a 47 m-long, 900 mm dia. corrugated metal pipe. During a subsequent site visit during a prolonged period of dry weather, the upstream end of the culvert was dry with all creek flows conveyed through a supplemental box culvert which discharges to a storm sewer rather than the creek during low flows. Additionally, staff noted evidence of beaver activity, including blockage of the culvert and the creation of a weir, which could act as barriers to fish passage. Due to these barriers, the Salmon habitat value ratings for spawning and rearing upstream of Highway 99 are low and the assessment did not continue beyond the Highway 99 culvert.

Photo O Downstream of Highway 99 Culvert

Photo P Upstream of Highway 99 Culvert

2.1.6 Geology / Hydrogeology

Assessment of the geology and hydrogeology within the Study Area was required to achieve the following objectives:

- Estimate the effectiveness of stormwater management tools that rely on rainwater infiltration;
- Delineate areas where rainwater infiltration should be limited or avoided; and
- Approximate the relationship between rainwater infiltration and groundwater.

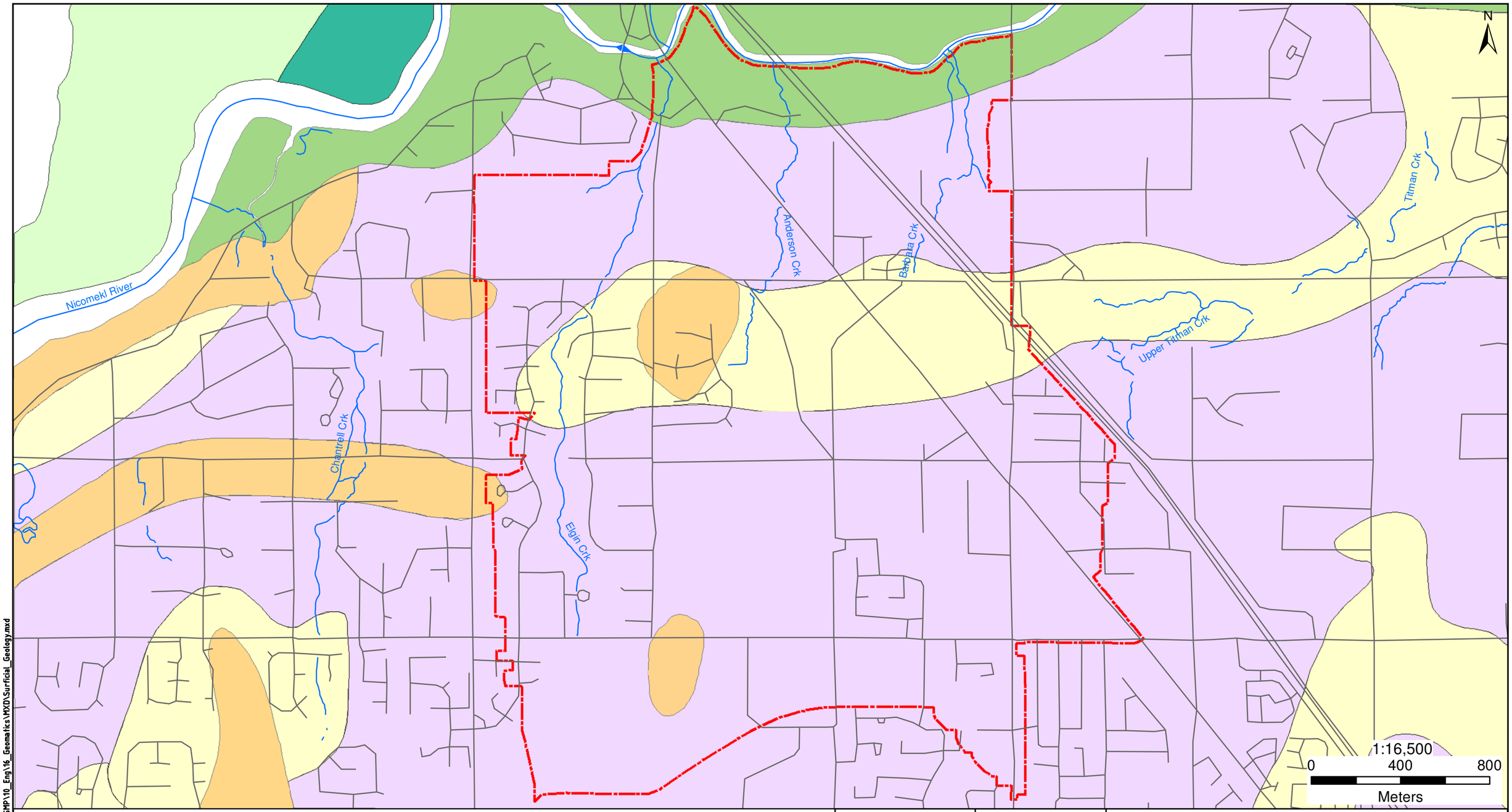
To assess these items, the following section discusses the surficial soils and their associated infiltration potential, the properties of the groundwater aquifers and the generalized groundwater flow direction, and the interaction of groundwater and surface water within the Study Area.

Surficial Soils

The surficial geology of the Study Area is predominantly composed of Pleistocene sediments, specifically Capilano Sediments and Vashon Drift, as well as a small amount of postglacial salish sediments surrounding the Nicomekl River as shown in Figure J.

Capilano Sediments, classified as Cb or Cd, cover 95% of the Study Area. Cb soils are composed of raised beach, medium to coarse sands containing fossil marine shell casts and typically form 1 m- to 5 m-thick layers. Cd soils are composed of marine and glaciomarine stony to stoneless silt loam to clay loam with minor sand and silt containing marine shells and typically form 3 m- to 30 m-thick layers (Geological Survey of Canada [GSC] 1976). These sediments were deposited during glacial retreat when the sea level was higher than present day levels and thicken from the west to the east (Hicock and Armstrong 1985). The Vashon Drift (VA) soils are a lodgment till composed of a sandy loam matrix and minor flow till containing lenses and interbed of glaciolacustrine laminated stony silt (GSC 1976). These sediments were deposited via direct glacial runoff or in situ directly from the ice (Hicock and Armstrong 1985). Along the banks of the Nicomekl River are bog, swamp, and shallow lake deposits (SAb) generally consisting of lowland peats up to 8 m-thick overlying overbank fines (GSC 1976).

These surficial sediments are underlain by the Kitsilano Formation of the Eocene Age. The formation is made up of undivided sedimentary rocks such as conglomerate, sandstone and shale with thin lignite, and igneous intrusions consisting of lesser basalt flows; sills; and minor pryoclastics (BC Water Resource Atlas).



Legend

- Study Area
- Creeks
- Road

Sediment types

- Vashon Drift

Capilano Sediments

- Cd: Marine/glaciomarine loam
- Ca: Raised Marine Sand to Gravel
- Cb: Raised Beach Sands

Salish Sediments

- SAh: Lowland stream and channel fill
- SAb: Lowland peat
- SAd: Lowland organic loam

Sources: City of Surrey

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Surficial Geology

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Infiltration Potential

The surficial soils in the Study Area provide limited conditions for rainwater infiltration due to their low relative infiltration capabilities (Sigma Resource Consultants Ltd. 1978). As the Capilano Sediments (Cd) and Vashon Drift soils consist primarily of silt and silt loam, they can be classified as Group C soils using the United States Department of Agriculture (USDA) hydrologic soil group system. The saturated infiltration rate for this soil group can be in the range of 4.3 mm/h to 6.8 mm/h, less than the saturated infiltration rate of 12.5 mm/h typically required for the implementation of rainwater infiltration infrastructure (e.g., infiltration trenches or permeable swales).

Although these soils present limited opportunities for infiltration, it is likely that runoff from smaller storm events could be effectively infiltrated using rainwater infiltration infrastructure modified to include storm sewer connections. These connections would permit the collection of runoff from larger storm events to prevent ponding in and around the rainwater infiltration infrastructure. Similarly, landscaped areas containing a thick layer of topsoil could be installed to provide sufficient capacity to store runoff and facilitate slow infiltration through the underlying soils to prevent excessive ponding in the surrounding area.

Conversely, the narrow band of Capilano Sediments (Cb) soils in the Study Area, composed of coarse sands and classified as Group A or B, provides excellent conditions for rainwater infiltration with estimated saturated infiltration rates ranging from 25 mm/h to 60 mm/h; however; this also results in an increase to the vulnerability of groundwater to surface contamination due to the absence of a cover of protective low permeability soils.

Surface Contaminant Migration

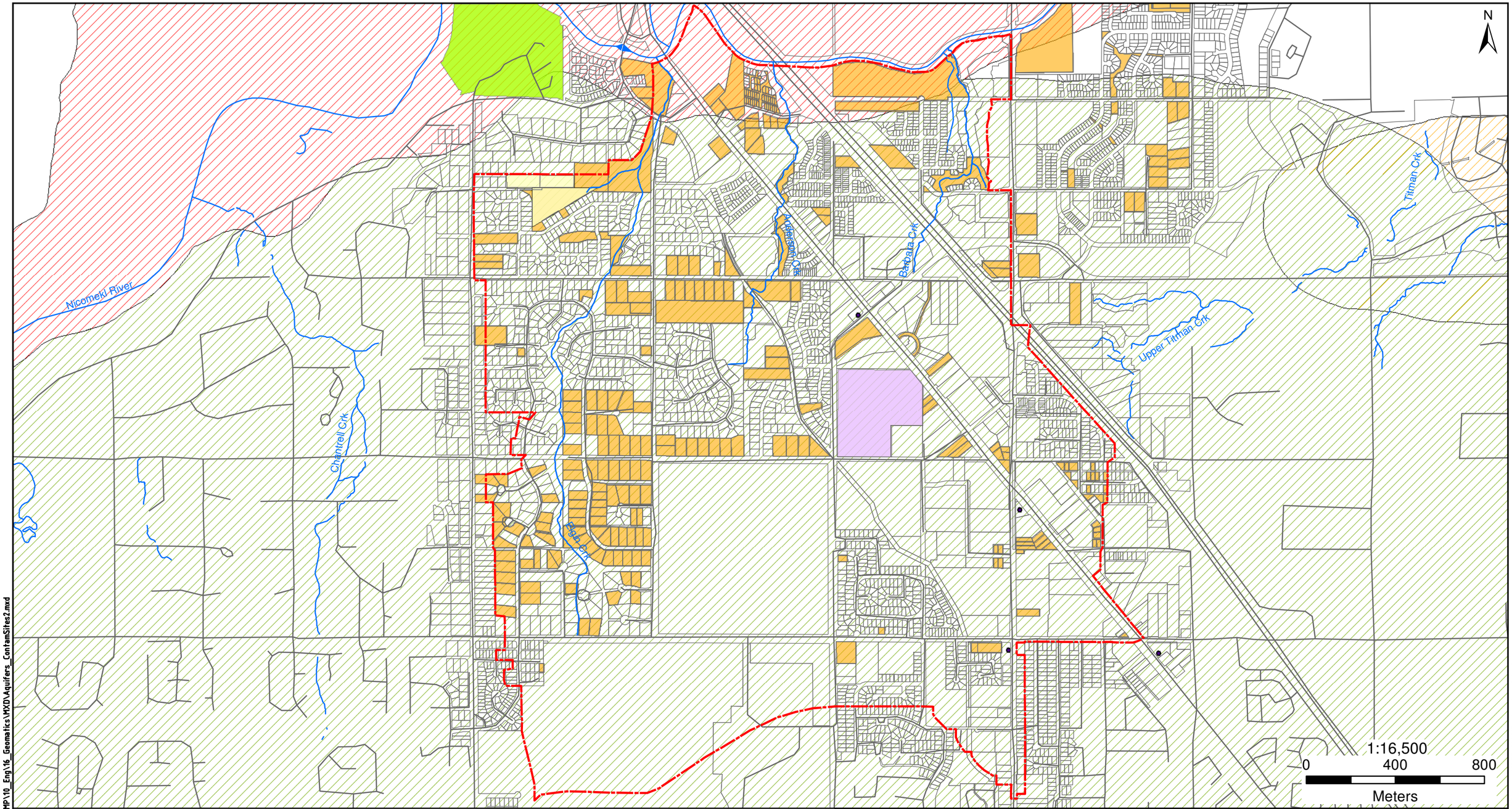
Due to the potential for the mobilization of near surface contaminants to the groundwater table and/or surface water features, the installation of rainwater infiltration infrastructure at certain properties in and along the narrow band of Groups A and B soils (including gas stations and properties with septic beds) should be approached with caution. Similarly, within this region, the installation of rainwater infiltration at properties that disperse large quantities of fertilizers and other chemicals, such as cemeteries and golf courses, may require the implementation of specific water quality mitigation measures (these properties and locations are highlighted in Figure K).

Where Group C soils are present, rainwater infiltration infrastructure may not prove to be effective for stormwater management due to the low infiltration potential. In these areas, surface contaminants will most likely migrate off-site as overland flow during storm events. Site-specific studies should be completed in these regions to identify suitable Wet Weather Green Infrastructure that will detain or retain rainwater and, if required, treat runoff to remove contaminants.

Aquifers

The Whiterock Aquifer covers a 40 km^2 area underlying much of White Rock and Southwest Surrey, including the Study Area. It is composed of sands and gravels with moderate domestic water use demand, high productivity (high yield), and low vulnerability to contamination from surface activities (BC Water Resources Atlas).

A portion of the Nicomekl-Serpentine Aquifer is located in the northern section of the Study Area. It is a confined sand and gravel aquifer associated with glaciomarine environments. Its domestic water use demand and productivity are both moderate and, due to limited hydraulic connections with surface water, its vulnerability to contamination due to surface activities is low (BC Water Resources Atlas).



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Aquifers and Potentially Contaminated Sites

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Additionally, an unnamed aquifer (designated as Aquifer No. 0056) is located approximately 1.5 km east of the Barbara Creek catchment boundary. It is small (approximately 1.7 km^2) and isolated; however, its demand and productivity are both moderate and its vulnerability is low (BC Water Resources Atlas). The aquifers are delineated in Figure K.

While no previous data exists on the groundwater flow regime of the watershed areas, it is the common understanding that groundwater recharges in the highlands and discharges in the lowlands. Therefore, groundwater flow is likely north to northwestward; from the higher elevations in the south of the Study Area towards the Nicomekl River, with discharge along the Nicomekl River and Boundary Bay. Since the aquifers present within the Study Area extend beyond the bounds of the watershed areas, there is the potential that contaminants could infiltrate high risk lands to the south and southeast of the Nicomekl River, causing eventual contamination of the groundwater and surface waters within the Study Area.

Although the vulnerability of contamination due to surface activities for all the aquifers within the Study Area has been characterized as low, the integrity of the confining materials should be reviewed when planning stormwater management techniques that may involve increasing infiltration above these aquifers. This is particularly important in the high risk areas identified in Figure K.

Groundwater Flows

A previous study noted that summer stream flows in Elgin Creek are generally derived from groundwater contributions and that the upper reaches of the creek (above 32 Ave.) have been known to experience periods of no flow between June and September (AE 2006). The same study recommends that the City provide a supplemental flow of 11 L/s to the headwaters of Elgin Creek, south of 24 Ave., during summer low flow conditions by pumping groundwater from Sunnyside Well No. 2, in addition to improvements to nearby, existing stormwater infrastructure. At this time, it is unclear how this option is performing. Connection of the pumping system to the City's SCADA system would facilitate a performance assessment.

It is likely that the Elgin Creek is classified as a losing stream (i.e., a stream from which groundwater is derived) in these upper reaches while in the lower reaches closer to the Nicomekl River, where the water table is more likely to be close to or at the ground surface, Elgin Creek is classified as a gaining stream (i.e., a stream into which groundwater is discharged).

Although groundwater flow studies have not been undertaken in the Barbara Creek or Anderson Creek watersheds, it is likely that, due to their similarity and proximity to the Elgin Creek watershed, they will exhibit similar groundwater flow patterns.

2.2 Hydrological Assessment

Assessment of the Study Area's creek flow patterns resulting from rainfall events was required to achieve the following objectives:

- Identify locations where there is a high potential for erosion to occur;
- Identify stormwater management infrastructure that is potentially undersized; and
- Provide baseline creek flow conditions.

The following sections discuss the development of a hydrologic / hydraulic model that simulates runoff and creek / sewer flows within the Study Area and provides a tool that can simulate changes to creek flow that could result from changes to housing density and land usage.

2.2.1 Effective Impermeable Area

Effective impermeable area (EIA) is a measure of the total impermeable surface area which drain to the creeks and storm sewers within the Study Area (i.e., rain that falls on these surfaces will be conveyed to the Nicomekl River without infiltration losses). An estimate of the EIA within the Study Area was required to simulate runoff conditions within each of the three creek catchments. Total impermeable surface area can include paved roadways, parking lots, driveways, and sidewalks in addition to non-residential buildings. The remaining surfaces within the Study Area are considered to be permeable.

By analyzing the colour of the pixels contained within the City's 2012 aerial photograph, paved and vegetated surface areas were identified within the Study Area based on pixel cover. The total building surface area within the Study Area was also identified based on GIS data provided by the City which delineated existing buildings within the Study Area. These surface area estimates comprised the total impermeable area (TIA).

To promote rainwater infiltration, residential buildings are not permitted to connect gutter leads directly to municipal storm sewers. While the majority of the runoff from these buildings would be discharged onto permeable surfaces such as lawns and gardens, it seems likely that some gutter leads would discharge onto driveways. It also seems likely that there are some non-compliant properties that either did not disconnect their gutter leads, or have reconnected them since construction. To account for the disconnection of residential property gutter leads, the TIA was reduced by 80% of the single family residential building surface area, based on the assumption that approximately 20% of this area still drains into the storm sewer. The residential building surface area was estimated based on the percentage of properties zoned as Suburban or Urban.

Table E summarizes the TIA and EIA estimates for all three creek catchments within the Study Area.

Table E TIA and EIA Estimate Summary

Catchment	TIA (ha)	Total Building Surface Area (ha)	Percentage Residential	Residential Building Surface Area (ha)	EIA (ha)
Elgin Creek	145	25.0	99%	24.8	125
Barbara Creek	168	50.9	92%	4.5	164
Anderson Creek	109	16.1	28%	14.3	97.1

It was assumed that the gutter leads of multiple family residential buildings within the Study Area are not commonly disconnected. The EIA results presented in the Table E are based on the future anticipated zoning conditions.

It is common practice to calibrate the EIA estimate to existing rainfall and creek flow records; however this proved to be impractical. The available flow records for the flow gauge located at the downstream end of the Elgin Creek crossing of 32 Ave. included instantaneous flows that are significantly less than those estimated by the project team based on the depth of flow in the upstream culvert. As the flow gauge was recently relocated and calibrated, the City may consider confirming the EIA estimate once sufficient flow records are available.

2.2.2 Hydrologic / Hydraulic Model

A hydrologic / hydraulic computational model (the Model) was developed for each catchment using XP Software's XP-SWMM software package. The software simulates runoff and channelized flow conditions based on input parameters (including rainfall rates, infiltration rates, percentage of imperviousness, catchment shape, channel roughness; area; and perimeter, and outfall water depth) over small time steps to synthesize continuous flow data.

Model Development

The dimensions and elevations from the GIS data and as-built record drawings stored on the City's COSMOS website were used to develop the model nodes (e.g., manholes, culvert inlets / outlets, ponds, and outfalls) and links (e.g., creek reaches, ditches, and storm sewer mains) that comprise the model. The creek channel dimensions were defined based upon the estimated channel dimensions included in the latest Ravine Assessment report (Web Engineering 2011), where available, in addition to cross sections generated from the LiDAR digital elevation surface.

Hydrometric Data

A series of design storms with separate return periods and durations was compiled using the design storms included in the City's Engineering Design Criteria Manual (City of Surrey 2005). The following two flow conditions were considered:

- Instantaneous peak flow resulting from the 2-, 5-, and 100-year return period high intensity storms to assess erosion potential in creek reaches and stormwater infrastructure capacity issues; and
- Sustained wet weather flow during the 2- and 25-year return period long duration storm to assess the storage capability of detention / retention ponds and to estimate the extent of flooding at outfalls.

The modelling results indicated that, due to the relatively small catchment areas, runoff from all points within the catchments would contribute to flow at the discharge points within one hour of the start of the design storm. Consequently, only the one-hour duration design storms were utilized to assess peak instantaneous flows and velocities within the creeks. As the Study Area is located approximately equidistant to the two rain gauges for which design storm information is provided (Surrey Municipal Hall and White Rock STP), the design storms were generated using the greater intensity listed for the two locations at each time interval. Figure L illustrates the hyetographs for the 2-, 5-, and 100-year high intensity storms.

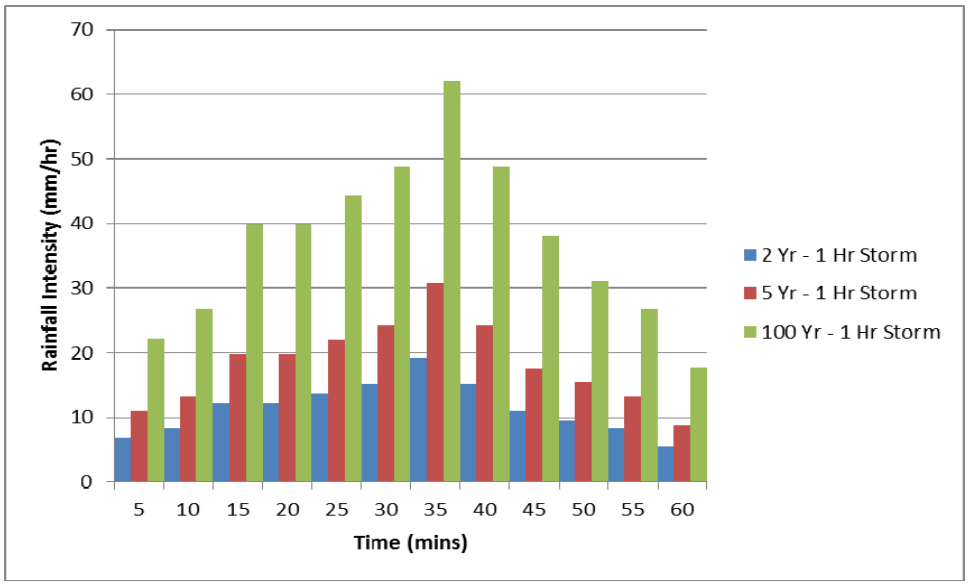


Figure L High Intensity Storm Hyetographs

The long duration storms recorded from November 26 to 28, 1996 and from January 29 to 30, 1997, respectively, were used as the 2- and 25-year return period rainfall data. Both events were recorded in South Surrey. Figure M illustrates the hyetographs for the 2- and 25-year long duration storms.

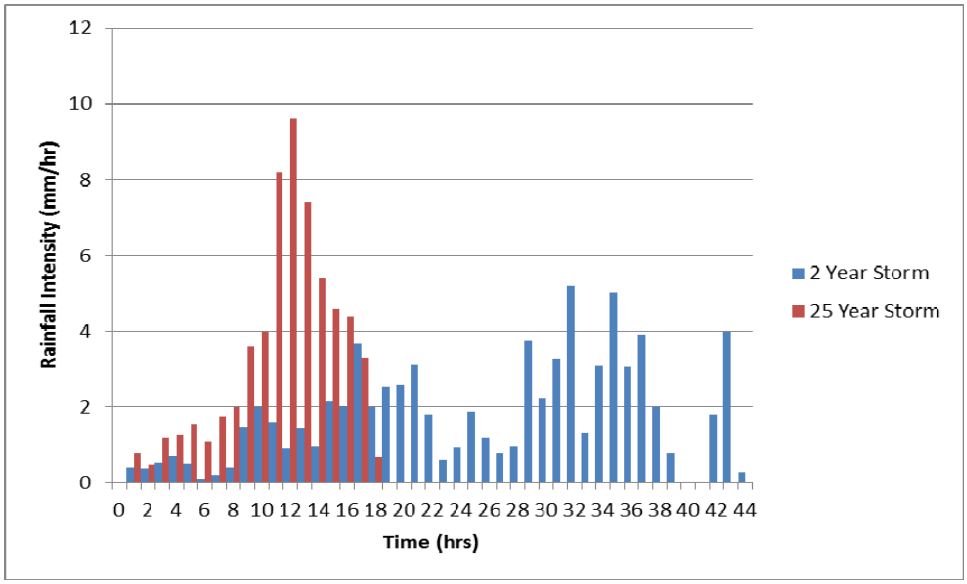


Figure M Long Duration Storm Hyetographs

Infiltration Rates

The Horton infiltration methodology was selected as the basis for simulated infiltration and based the following infiltration parameters on the soil classifications discussed in Section 2.1.6:

- Maximum (unsaturated) infiltration rate: 76 mm/h;
- Minimum (saturated) infiltration rate: 5 mm/h; and
- Decay rate of infiltration: 0.00115 sec^{-1}.

Sub-catchments

The catchment was divided into 84 sub-catchments based on grading, property boundaries, and drainage infrastructure. Other than the Sunnyside Acres Urban Forest, sub-catchments do not exceed 20 ha in size. Each sub-catchment was assigned runoff parameters including: percentage impervious, area, and width. The width parameter is a measure of how quickly runoff is conveyed to a channel or conduit based on average overland flow path length.

The percentage impervious was estimated by analyzing the future anticipated zoning composition of each sub-catchment including zoning categories, road surfaces, and green spaces and applying pre-set percentage imperviousness to each category based on those provided in the City's Engineering Design Criteria Manual (Surrey 2004). The future anticipated zoning condition was selected as it varies only marginally from the existing condition and represents a more densely zoned catchment containing more impervious area. Table F includes the sub-catchment composition categories and their corresponding percentage of imperviousness.

Table F Sub-catchment Composition

Composition Category	% Impervious	Composition Category	% Impervious
Suburban Acreage	50	Institutional	80
Suburban ½ Acreage	55	Agricultural	0
Single Family	65	Cemetery	20
Multiple Family	65	Golf Course	20
High Density Multiple Family	80	Green Space	0
Commercial	90	Roadway	100
Industrial	90	---	---

2.3 Potential Erosion Sites

An important aspect of maintaining a healthy watershed is the identification and remediation, where appropriate, of sites with known bank instabilities and the potential for erosion control issues. These sites include locations with visual indications of erosion, identified in the 2011 Ravine Stability Assessment (Web Engineering 2011), supplemented by sites identified as having a potential for erosion based on model simulations results.

The hydraulic model was used to identify creek reaches where there is a high potential of erosion issues due to the predicted high velocity flows during large storm events. Creek reaches were identified as likely erosion sites if the simulated peak instantaneous flow velocity exceeded any of the following criteria:

- 1 in 2 year peak storm event flow velocity greater than 1.0 m/s;
- 1 in 5 year peak storm event flow velocity greater than 1.5 m/s; or
- 1 in 100 year peak storm event flow velocity greater than 2.0 m/s.

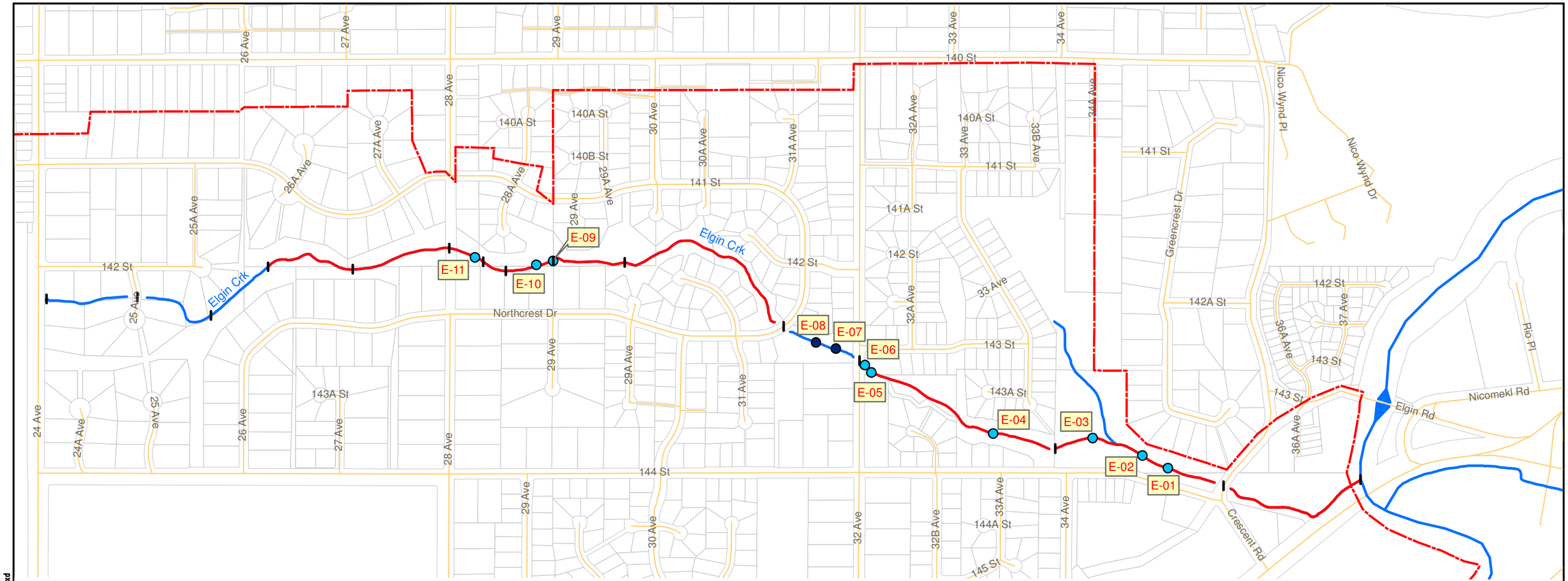
Table G identifies the creek reaches with a high potential of erosion issues based on the simulated results.

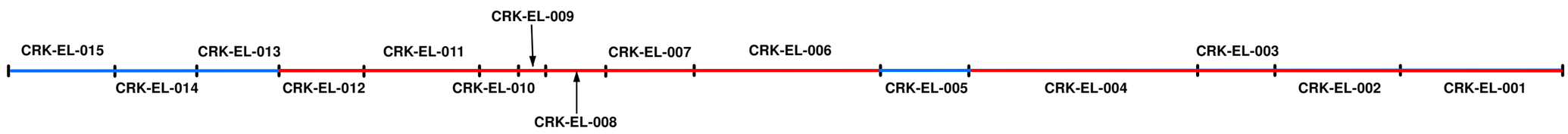
Table G Creek Reaches with High Potential of Erosion

Creek	Reach	Simulated Peak Instantaneous Velocity (m/s)		
		1 in 2 Year	1 in 5 Year	1 in 100 Year
Elgin	CRK-EL-001	1.50	1.73	1.98
	CRK-EL-002	1.61	1.63	1.69
	CRK-EL-003	2.13	2.52	3.05
	CRK-EL-004	1.41	1.68	1.99
	CRK-EL-005*	0.93	1.09	1.13
	CRK-EL-006	1.82	2.28	2.54
	CRK-EL-007	1.91	2.33	2.92
	CRK-EL-008	2.04	2.45	3.08
	CRK-EL-009	1.41	1.67	2.09
	CRK-EL-010	2.42	2.85	3.50
	CRK-EL-011	2.27	2.67	3.25
	CRK-EL-012	1.05	1.24	1.52
Barbara	CRK-BA-002	1.23	1.86	2.35
	CRK-BA-003	1.92	2.27	2.75
	CRK-BA-005	1.51	1.86	1.98
	CRK-BA-006	1.19	1.24	1.29
Anderson	CRK-AN-003	1.40	1.63	2.01
	CRK-AN-004	1.05	1.13	1.29

*Note: Although the predicted flow velocities do not exceed the criteria, visual evidence of erosion was noted in the 2011 Ravine Assessment (Web Engineering 2011).

The locations of the known and potential erosion sites are illustrated in Figure N, Figure O, and Figure P.





Legend

- Study Area
- Creek/River
- Road
- Property Lot
- Potential for Erosion

2011 Ravine Assessment - Erosion Sites

- Visual Erosion (Low Risk)
- Visual Erosion (Med Risk)
- E-01 Site Number

Sources: City of Surrey

N

1:7,500

0 100 200 300

Meters

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Erosion Sites Elgin Creek

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307076-04854	N	0

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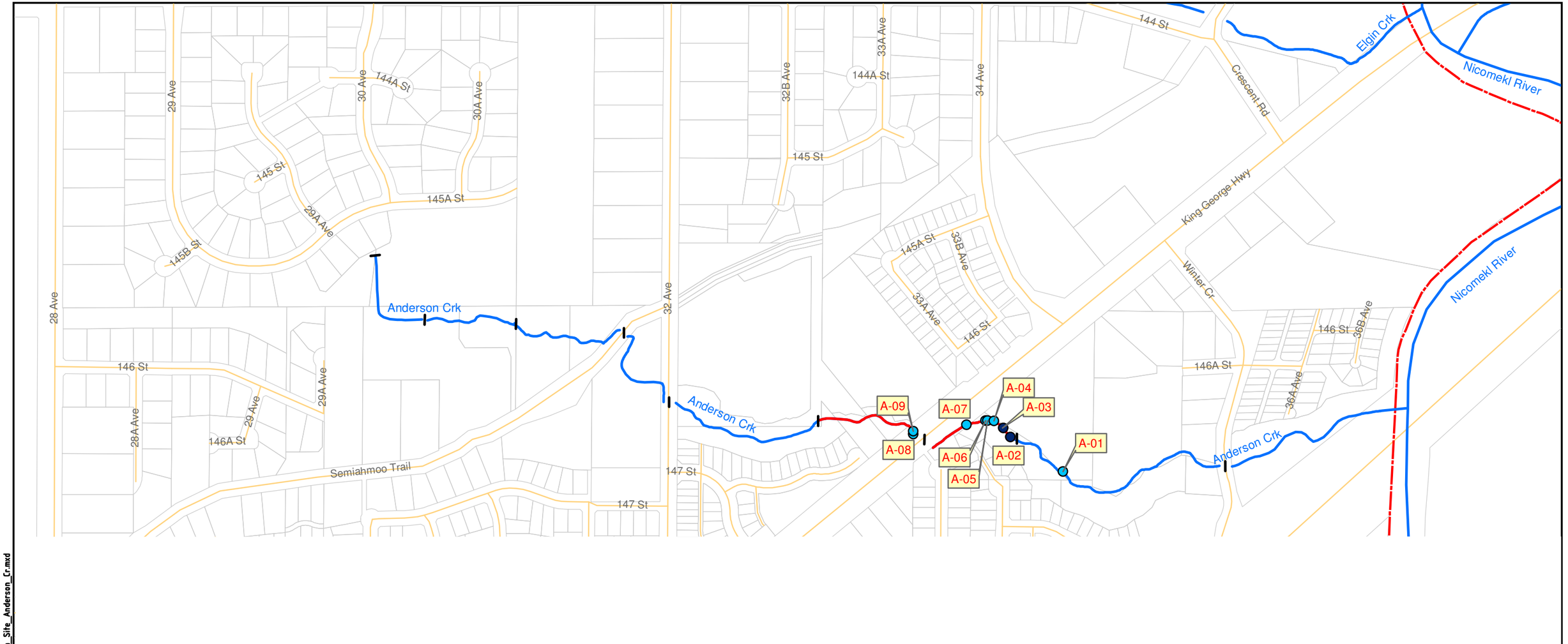
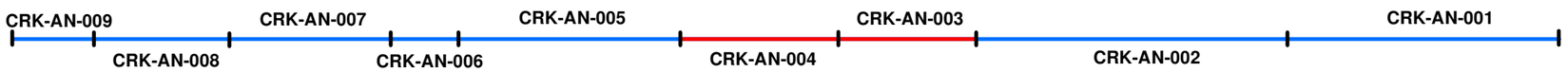
ISSUING OFFICE: BURNABY GIS





Legend

- Study Area
- Creek/River
- Road
- Property Lot
- Potential for Erosion

2011 Ravine Assessment - Erosion Sites

- Visual Erosion (Low Risk)
- Visual Erosion (Med Risk)
- A-01 Site Number

Sources: City of Surrey

N

1:5,000

0 100 200

Meters

B SHEET SCALE: SHOWN

OneWay™ to zero harm

Date:	30/04/2014
Drawn by:	Y.M.
Edited by:	Y.M.
App'd by:	A.T.

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Erosion Sites
Anderson Creek

WORLEYPARSONS PROJECT No.	FIG No.	REV
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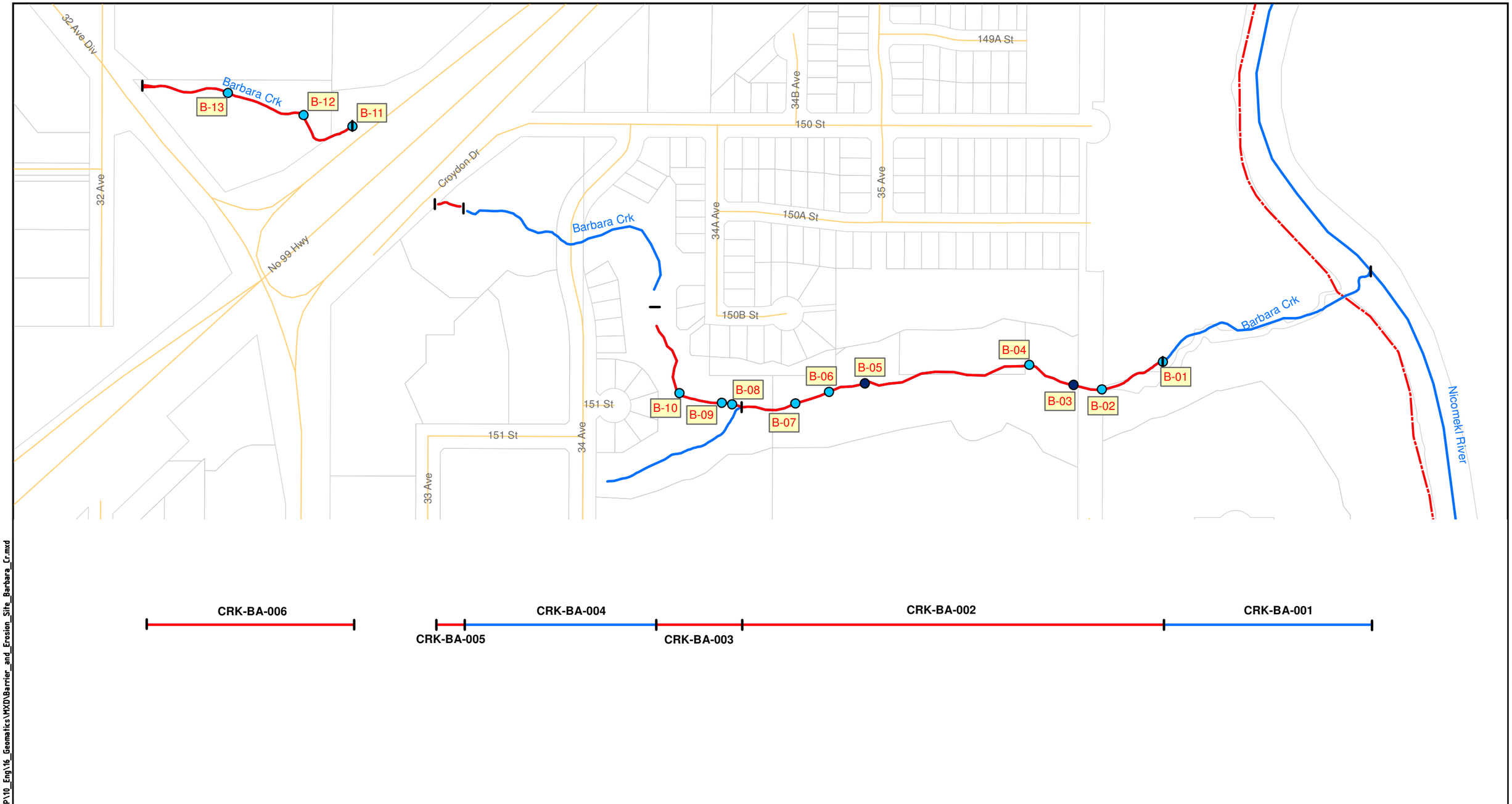

Legend

- Study Area
- Creek/River
- Road
- Property Lot
- Potential for Erosion

2011 Ravine Assessment - Erosion Sites

- Visual Erosion (Low Risk)
- Visual Erosion (Med Risk)
- B-01 Site Number

Sources: City of Surrey

N

1:3,000

0 50 100

Meters

B SHEET SCALE: SHOWN

OneWay™ to zero harm

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Erosion Sites
Barbara Creek

WORLEYPARSONS PROJECT No.	FIG No.	REV
307076-04854	P	0

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ISSUING OFFICE: BURNABY GIS

2.4 Potential Stormwater Infrastructure Flooding

In order to prevent potential damage to public and private property, stormwater infrastructure should have sufficient capacity to convey runoff during high intensity storm events. The City's Engineering Design Criteria Manual (Surrey 2004) requires that minor systems (local municipal storm sewers) be capable of conveying runoff flow resulting from the 5-year high intensity storm and that major systems (municipal trunk storm sewers and creek culverts) be capable of conveying flows resulting from the 100-year high intensity storm. Based on these conditions, the Model predicts that flooding is likely to occur upstream of the stormwater infrastructure identified in the following Table H and Table I and as shown on Figure Q.

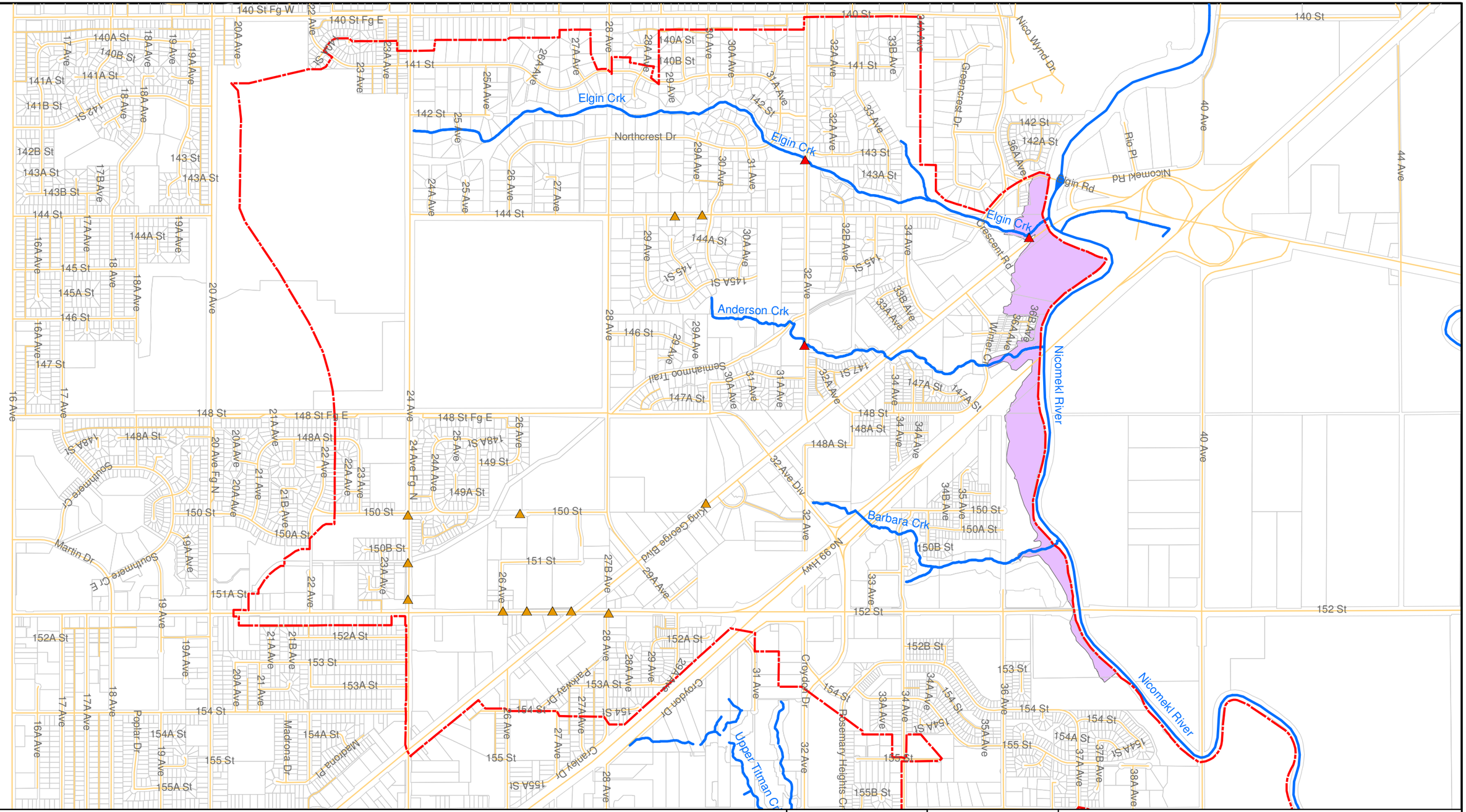
Table H Minor System Infrastructure Flooding

Catchment	Model ID of Infrastructure	Surrey ID of Infrastructure	Location	Diameter (mm)	Predicted Peak Instantaneous Flow (L/s)	Predicted Cause of Flooding
Elgin	STM-EL-802	1000759881	144 St at 30 Ave	300	209	Undersized
	STM-EL-803	1000759882	144 St south of 30 Ave	300	216	Undersized
Barbara	STM-BA-118	1000738306	2880 152 St	450	718	Undersized
	STM-BA-160	1000738349	3033 King George Blvd	1050	3,940	Downstream Infrastructure Constraints
	STM-BA-174	1000738289	152 St south of King George Blvd	525	1,020	Downstream Infrastructure Constraints
	STM-BA-175	1000738357		525	939	
	STM-BA-176	1000738365		525	937	
	STM-BA-177	1000738384		525	1,030	
	STM-BA-193	1001596210	24 Ave west of 152 St	375	357	Downstream Infrastructure Constraints
	STM-BA-195	1000761620	24 Ave west of 152 St	375	385	Downstream Infrastructure Constraints
	STM-BA-198	1000738322	24 Ave at 150B St	375	239	Downstream Infrastructure Constraints
	STM-BA-218	1000738368	2688 150 St	450	733	Undersized

Table I Major System Infrastructure Flooding

Catchment	Model ID of Infrastructure	Surrey ID of Infrastructure	Location	Diameter (mm)	Predicted Peak Instantaneous Flow (m^3/s)	Predicted Cause of Flooding
Elgin	CUL-EL-003	1000756524	Elgin Creek at 32 Ave	1200	6.89	Outlet Control
	STM-EL-001	1000753604	King George Blvd at Nicomekl River	900	2.81	Undersized
Anderson	CUL-AN-003	1000753671	Anderson Creek at 32 Ave	600	1.57	Undersized

It should be noted that STM-EL-001 is not located adjacent to any properties and that the predicted water level elevation at CUL-AN-003 is below the road surface elevation. Although the infrastructure listed in Table H is undersized to convey the predicted 100-year peak flow, it is unlikely that this will pose any threat to the public or property.



Legend

- Study Area
- Creek/River
- Road
- Property Lot
- Estimated Flood Extent (Year 2100, 1 in 200 Year Flood Event)
- Potential Flooding of Major Infrastructure (1 in 100 Year Storm Event)
- Potential Flooding of Minor Infrastructure (1 in 5 Year Storm Event)

Sources: City of Surrey

N

1:15,000

0 250 500

Meters

B SHEET SCALE: SHOWN

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Flooding Sites and Extents

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WORLEYPARSONS PROJECT No.	FIG No.	REV
307076-04854	Q	0

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ISSUING OFFICE: BURNABY GIS

2.4.1 Outfalls

Water levels in the Nicomekl River rise during long duration storm events, which will likely result in localized flooding at creek and storm sewer discharge points. A recent floodplain study predicts that the 200-year flood level along this reach of the Nicomekl River will reach 3.1 m by the year 2100 due to the projected impacts of climate change. During long duration storm events, the creeks and major storm systems within the Study Area could surcharge causing flooding as they discharge to the Nicomekl River without any means of preventing backflow from the river. Based on these conditions, and the assumption that they will correspond to the 25-year long duration rainfall event, the Model predicts that flooding is likely to occur at the locations shown in Table J and on Figure Q.

Table J Outfall Flooding (Year 2100)

Catchment	Model ID of Infrastructure	Surrey ID of Infrastructure	Location	Diameter / Depth (mm)	Predicted Peak Flood Level (m)
Elgin	STM-EL-001	1000753604	King George Blvd at Nicomekl River	900	3.78
Anderson	CRK-AN-001	1000788181	Nicomekl River to Winter Crescent	1.8	3.27

2.5 Biophysical Assessment

An understanding of the biophysical conditions within the Study Area was required to achieve the following objectives:

- Assess the concentrations of contaminants within creek flows;
- Estimate the strength of benthic communities; and
- Qualitatively and quantitatively assess the overall biophysical conditions of the creeks.

The following sections discuss water quality testing and desktop reviews undertaken by WorleyParsons to assess these components of watershed health.

2.5.1 Water Quality

As part of the bio-physical assessment, sediment and water quality samples were collected at the respective confluences of the Nicomekl River and the Elgin, Barbara, and Anderson Creeks and analyzed to estimate concentrations of contaminants listed in the Compendium of Approved Freshwater Quality Guidelines (BC MOE 2010), Compendium of Working Freshwater Quality Guidelines (BC MOE 2006) Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2011). The guidelines and analysis results are included in Appendix 2.

Table K indicates the parameters which exceeded the applicable guideline concentrations.

Table K Select Water and Sediment Quality Data

Type	Parameter	Guideline Concentration	Elgin Creek Concentration	Barbara Creek Concentration	Anderson Creek Concentration
Water	Arsenic	5.0 µg/L	8.2 µg/L	6.0 µg/L	3.0 µg/L
	Chromium (hexavalent)	1.0 µg/L	4.7 µg/L	3.1 µg/L	1.2 µg/L
Sediment	Arsenic	5.90 mg/kg	5.84 mg/kg	4.49 mg/kg	9.82 mg/kg
	Benzo(a)pyrene	31.9 µg/kg	26.0 µg/kg	< 10.0 µg/kg	37.0 µg/kg
	Pyrene	53 µg/kg	49.0 µg/kg	14.0 µg/kg	83.0 µg/kg

Note: Highlighted concentrations exceed the applicable guidelines.

Arsenic is known to be evident in urban settings, especially where pesticides have been used. Pyrenes are also frequently associated with anthropogenic activities, such as paving of roads or parking lots; however, no meaningful conclusions should be drawn from a single sampling event at a single location for each creek. Recommendations for future study would include a more comprehensive water and sediment sampling program to coincide with a more inclusive benthic monitoring program.

Table L In situ Water Quality Data

Parameter	Elgin Creek	Barbara Creek	Anderson Creek
Temp (deg. C)	12.2	14.1	13.5
pH	7.75	7.61	7.71
Dissolved Oxygen (mg/L)	9.3	9.6	8.7
Conductivity (µS)	70	110	121
Turbidity (mg/L)	1.81	2.50	3.30

All in- situ parameters in Table L are within the applicable guidelines and would support a fish population at each creek's sampling location (confluence with Nicomekl River). Fish (coho fry) were observed in each sampling area at the time of assessment. A more extensive in situ fish sampling program would be beneficial in determining stream health upstream of the creek confluence and also help identify point sources for potential contaminants entering the watershed.

2.5.2 Benthic Assessment

Biological indicators are especially useful in a comprehensive water quality program as they reflect the habitat conditions in the aquatic system as well as water quality conditions over a longer term than isolated point-source water quality sampling. The Benthic Index of Biotic Integrity (B-IBI) uses values associated with benthic invertebrate (i.e., invertebrates found in stream substrate) communities and has been successfully incorporated into many water quality monitoring programs in the Pacific Region. The several hundred identifiable invertebrates found in creeks in the Pacific Northwest can be used to determine different levels of effect on habitat caused by human activities (Fore et al. 1996).

The B-IBI description incorporates several types of benthic data which are synthesized into a single number depicting overall biological condition. The B-IBI is a multi-metric index in which several metrics of the invertebrate community are calculated, and given a score, and then those scores are combined to give the index value. Metrics such as the number of pollution tolerant taxa, the total number of taxa, and population attributes such as the number of long-lived taxa or predator taxa are used to assess the health of the community.

These metrics, once combined into a single index score, indicate the relative health of the system and are correlated to ratings and descriptions. The ratings used for this analysis consist of the following: Healthy, Compromised, Impaired, Highly Impaired, and Critically Impaired. More details on the definitions of these ratings are provided in the Discussion section.

While the B-IBI system provides a good indication of the current health of the watershed, it is important to note that it does not take into consideration the health of the watershed prior to development. For instance, the creeks within the Study Area service relatively small and narrow catchments. Even prior to development, it is likely that flows in the creek would fluctuate greatly both seasonally (i.e., very low flows during extended periods of dry weather) and in response to large storm events. As these flow patterns would both be detrimental to the health of benthic communities, it is possible that the pre-development creeks would have received unfavourable grades.

Similarly, the B-IBI system does not take into account the prevailing land usage within the watershed. As such, it is highly unlikely that any urban creek could achieve the “Compromised” or “Healthy” grades typically reserved for undisturbed or rural creeks.

Therefore, it is advisable to qualitatively assess the creeks in comparison to similar, nearby creeks and to use the B-IBI scores to identify which aspects of the benthic community have changed over time.

Metrics

Once samples were collected, they were packaged and shipped for professional analysis and identification of invertebrates to the “lowest practical taxonomic level” and ten summary parameters or metrics were calculated. These metrics were then summed to provide the index score for the B-IBI, or the B-IBI Score. A description of each metric is provided below (Streamkeepers 2005).

- Taxa Richness and Composition Total Taxa Richness: The total number of unique taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Ephemeroptera Taxa Richness: The total number of unique mayfly (Ephemeroptera) taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Plecoptera Taxa Richness: The total number of unique stonefly (Plecoptera) taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Trichoptera Taxa Richness: The total number of unique caddisfly (Trichoptera) taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Number of Long-lived Taxa: The total number of unique long-lived taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Number of Intolerant Taxa: The total number of unique intolerant taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Percent Tolerant Individuals: The total number of tolerant individuals counted in each replicates, divided by the total number of individuals in that replicate, and multiplied by 100. The numbers from the three replicates are then averaged for this metric.
- Number of Clinger Taxa: The total number of unique clinger taxa identified in each replicate. The numbers from the three replicates are then averaged for this metric.
- Percent Predator Individuals: The total number of predator individuals counted in each replicates, divided by the total number of individuals in that replicate, and multiplied by 100. The numbers from the three replicates are then averaged for this metric.
- Percent Dominance: The sum of individuals in the three most abundant taxa in each replicate, divided by the total number of individuals in that replicate, and multiplied by 100. The numbers from the three replicates are then averaged for this metric.

The value of each metric is calculated for each replicate, and then the average of the metrics is used to determine the index score. The sum of the index scores for each of the 10 metrics is the B-IBI Score, used to determine the health rating for the sample reach. Table M identifies the criteria for the index scores for each metric.

Table M Scoring Criteria for B-IBI Metrics

Metrics	Scoring Criteria - Index Scores		
Total Taxa Richness	0 to <14	14 to 28	>28
Ephemeroptera Taxa Richness	0 to <3.5	3.5 to 7	>7
Plecoptera Taxa Richness	0 to 2.7	2.7 to 5.3	>5.3
Trichoptera Taxa Richness	0 to <2.7	2.7 to 5.3	>5.3
Number of Long-lived Taxa	0 to <4	4 to 8	>8
Number of Intolerant Taxa	0 to <2	2 to 4	>4
Percent Tolerant Individuals	>44	27 to <44	<27
Number of Clinger Taxa	0 to <8	8 to 16	>16
Percent Predator Individuals	0 to <4.5	4.5 to 9	>9
Percent Dominance	>74	55 to 74	0 to <55

Source: http://www.clallam.net/streamkeepers/html/benthic_index.html

The sum of each index score produces the B-IBI Score. The maximum B-IBI Score is 50, if each metric were scored a 5 for all 10 metrics. A value near 50 indicates that the sampled stream is close to the maximum potential for streams in a natural state in that area. The minimum value for a B-IBI Score is 10, which would indicate that the sampled stream's biological health is in poor condition. Descriptions for score ratings are provided in Table N.

Table N "Grading" System for B-IBI Scores

Total BIBI Score	Grade	Definition
50 to 46	Healthy	Ecologically intact, supporting the most sensitive life forms.
44 to 36	Compromised	Showing signs of ecological degradation. Impacts expected to one or more salmon life stages.
34 to 28	Impaired	Healthy ecosystem functions demonstrably impaired. Cannot support self-sustaining salmon populations.
26 to 18	Highly Impaired	Highly adverse to salmon and various other life forms.
18 to 10	Critically Impaired	Unable to support a large population of once-native life forms.

Source: http://www.clallam.net/streamkeepers/html/benthic_index.html

Results

B-IBI analyses for Elgin Creeks were conducted in Spring 2012 and summarized for each metric value, as outlined in Table O. Additional information from each sample site can also be derived by examining the individual metrics that compose the B-IBI Score.

Table O City of Surrey - Benthic Index of Bionic Integrity, Spring 2012

Raincoast Applied Ecology Sample ID	RAE12CS088	RAE12CS089	RAE12CS090
SITE name	Elgin Creek	Elgin Creek	Elgin Creek
Site ID	EL1-1	EL1-2	EL1-3
Sample date	08/05/2012	08/05/2012	08/05/2012
Proportion of sample used	70.00%	83.33%	60.00%
	Count	**Count**	**Count**
METRIC VALUES			
Taxa richness	15	22	21
E richness	4	4	4
P richness	2	2	2
T richness	2	2	4
INTOLERANT taxa richness	1	3	2
Clinger richness	7	9	9
LL richness	1	1	2
% tolerant	0.00	0.00	0.00
% predator	2.29	2.09	2.83
% dominance (3)	68.58	55.22	48.82
METRIC SCORES			
Taxa richness	3	3	3
E richness	1	1	1
P richness	1	1	1
T richness	1	1	1
INTOLERANT taxa richness	1	3	1
Clinger richness	1	3	3
LL richness	1	1	1

Raincoast Applied Ecology Sample ID	RAE12CS088	RAE12CS089	RAE12CS090
% tolerant	5	5	5
% predator	1	1	1
% dominance (3)	3	5	5
Sample Score	18	24	22
SITE Score			**22**
2011 Score			**17.3**

The Site Score for Elgin Creek resulted in a B-IBI Grading of “Highly Impaired”. Table O includes the B-IBI Site Scores from the 2011 sampling report (Raincoast Applied Ecology) for comparative purposes. The Site Score for Elgin Creek has substantially improved.

Discussion

Results indicate that the B-IBI site scores were relatively low for both Elgin and Anderson Creeks, which were consistent with those scores observed in various neighbouring creeks in the city of Surrey. While it is understandable that creeks in an urban setting will not achieve “Compromised” or “Healthy” site scores evidenced in undisturbed rural or undisturbed settings, it is important to examine what factors are leading to the impairment of these urban drainages.

The 10 factors contributing to each of the specific B-IBI metrics can be analyzed to further understand the derivation of the Site Score and understand the ecological health of a given stream. Karr and Chu (1999) identified that changes in the total number of benthic taxa can be utilized to assess and predict changes in ecosystem processes such as, rates of leaf litter processing and storage of organic matter (bio-mass). They also found that percent predators within a sample reflected the complexity of the invertebrate trophic structure, and the stability of the invertebrate community in the face of constant stressors.

Further research by Kiffney and Clements (1994) suggests that:

- The number of Ephemeroptera taxa in a sample are generally reduced when toxic chemicals such as heavy metals are present;
- The number of Plecoptera taxa in a sample disappear as riparian vegetation is lost and sediment clogs the interstitial spaces among cobbles; and
- The number of Plecoptera taxa tends to decline at less intense levels of human influence than the number of Trichoptera or Ephemeroptera taxa.

The individual matrices for Elgin and Anderson Creeks were typically low for each parameter with the exception of % Tolerance and % Dominance. Tolerant animals are present at most stream sites, but as disturbance increases, they represent an increasingly large percentage of the assemblage. This assertion is further supported by the % Dominance scores; whereby, the sum of individuals is dominated by the three most abundant taxa in each replicate. Both values indicate a lack of bio-diversity (mono-culture) in the aquatic environment that is typical of many urban stormwater channels.

Invertebrate fauna in these streams are constantly subjected to anthropogenic and natural disturbances such as, invasive species, urbanization and roads (hard surfaces), and the effects of climate change. Macroinvertebrate communities and productivity can be altered, which can affect higher trophic levels (e.g., fish production) and other stream processes (e.g., organic matter processing).

Invasive Species

Invasive species within riparian habitats can have lasting effects on headwater stream functioning due to the direct linkage between riparian forests and stream processes. The abundance and diversity of invertebrates in small streams can be altered by changes in microclimate, energy availability, and habitat that results from loss of tree species within the riparian zone. Attempts to manage terrestrial invaders associated with mono-culture riparian forest canopies, or invasive species, increases the use of pesticides, which can also have significant impacts to the aquatic environment. Indirectly, these changes can affect stream functioning through reductions in the survival, growth, and emergence of macro-invertebrate shredders and detrital processing organisms.

Urbanization and Roads

The replacement of forested land and natural riparian habitats with impervious or low permeability surfaces such as roads, parking lots, recreation facilities, rooftops, and lawns alters the hydrology and geomorphology of streams. Increases in surface water runoff and storm flows introduce contaminants from vehicles and paved surfaces into urban streams, which in turn, results in degradation of water quality, increases in bacterial populations, algae, turbidity, and increases of runoff into nearby streams. Sediment runoff from construction sites and paved surfaces also increases instream sediment deposition that can result in habitat loss. Urbanization in urban watersheds containing small streams typically results in less diverse invertebrate communities consisting of pollution-tolerant species.

Global Climate Change

The consequences of global climate change on invertebrates in small streams will vary greatly spatially and temporally; thereby, making it difficult to predict potential effects. Generally, precipitation and evaporation are expected to become more variable over time. Some regions of the world will become wetter, while others will become drier, affecting runoff patterns. Increased temperatures as a result of global climate change will reduce snow cover and also affect hydrologic patterns in small streams.

Shifts in hydrologic patterns (e.g., flooding, drying) will impact the transport of nutrients, organic matter, and habitats available for colonization by benthic invertebrates.

Changes in, or removal of riparian vegetation due to climate change may alter the quality and quantity of detrital inputs (e.g., leaf litter) to headwater streams and downstream reaches, by altering ecosystem processes, as well as invertebrate life histories and species composition. The timing and duration of small stream channel drying or intermittent flows as the climate is altered may result in altered organic matter in stream channels and associated invertebrate production. It may also result in a shift from large-bodied, long-lived taxa representative in perennial channels to small-bodied, short-lived taxa that are typical of ephemeral streams.

2.5.3 Recommendations

The following list provides a summary of potential broad mitigation strategies that could improve the ecological health of watersheds and drainages in the Study Area, given the industrial and anthropogenic constraints placed on them.

- Protect and enhance headwater feeder creeks to increase the diversity of benthic drift flowing into main channels;
- Where physical constraints permit in the creek right-of-way, look for opportunities to construct deep pool, side channel, or step-pool habitat to provide a more complex array of instream habitat and diverse benthic community; these pool systems may also help to buffer stream systems against storm runoff events and help emergent salmonids during overwintering or juvenile rearing phases of their life cycles;
- Avoid disturbance of riparian canopy where possible, especially at road crossings and bridges;
- Selectively remove and destroy all invasive plant species and replant with native species;
- Replant less diverse areas exhibiting natural mono-culture riparian vegetation (e.g., Salmonberry) with native species, peculiarly species with higher leaf-litter and nitrogen-fixing capabilities;
- Minimize hard surface run-off where practical with intermittent green spaces to intercept runoff;
- Avoid dumping grass cuttings and woody debris along stream embankments; and
- Clean all garbage and construction out of creeks and riparian management zones.

Overall mitigation strategies are discussed in greater detail in Sections 3 and 4.

3. STAGE 2 - "WHAT DO WE WANT?"

The creation of a Study Area Vision was required to document the desired direction for stormwater management and to guide the development of an implementation plan as part of Stage 3. The Vision includes the following:

- The views, opinions, and goals of the public and key stakeholders;
- A vision statement that expresses the values held by the community and stakeholders;
- A mission statement that defines the broad purpose and objectives relating to stormwater management in the Study Area;
- Goals required to achieve the Vision; and
- Recommendations on how to achieve the Goals.

3.1 Public Consultation

WorleyParsons hosted a public consultation kiosk on Saturday, June 22, 2013, at the South Surrey Recreation Centre. The posters shown as Figure R, Figure S, and Figure T were on display as part of the kiosk.

The purpose of the kiosk was to inform the public of the project and to receive the public's input on the overall health of the Elgin, Barbara, and Anderson Creek watershed areas. The public was asked to complete a brief questionnaire, as shown on Figure U, which was used to gauge the importance the public ascribes to several attributes of watershed health. The questionnaire could also be completed via the City Speaks website. In total, 15 completed questionnaires were submitted.

SOLUTION:

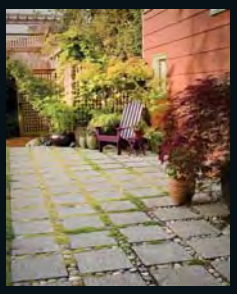
GREEN INFRASTRUCTURE

Provide input to inform the watershed vision by completing the survey at **www.surrey.ca/engineering**

There are many things you can do to help improve the health of your watershed:

- Install a rain barrel at your home to capture rooftop runoff and reuse the water for gardening
- Build a rain garden
- Use water permeable pavers on your patio

photo courtesy of the City of Vancouver



www.surrey.ca/engineering

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Figure R - Public Consultation Poster No. 1: "Solution: Green Infrastructure"

THREATS TO CREEKS AND THE WATERSHED

Provide your input online, please take the survey at:
www.surrey.ca/engineering

HUMAN ACTIVITY

Dumping garbage and releasing pollutants affects water quality

Removing vegetation decreases bank stability

Building unauthorized trails along and across creek channels can cause erosion

EROSION

High creek flows can result in the erosion of creek banks. This can reduce water quality and threaten properties located above the creek.

DEBRIS

Debris, particularly at culverts, can impede creek flow. This can lead to flooding upstream which can damage vegetation, cause erosion, and poor property drainage.

www.surrey.ca/engineering

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Figure S - Public Consultation Poster No. 2: "Threats to Creeks and the Watershed"

ABOUT THE INTEGRATED STORMWATER MANAGEMENT PLAN

To maintain or improve the health of the Elgin, Barbara and Anderson Creeks, the City of Surrey is developing an integrated Stormwater Management Plan. This plan will outline a framework for managing the quantity and quality of runoff entering the natural creeks and identifies locations where the creeks can be enhanced.

CITY OF SURREY'S ROLE

The City of Surrey balances the interests of environmental protection, residents, engineering and land development so that the community can grow in a sustainable way.

Provide input to inform the watershed by completing the survey at **www.surrey.ca/engineering**

www.surrey.ca/engineering

CITY OF SURREY
the future lives here.

13408

Figure T - Public Consultation Poster No. 3: "About the Integrated Stormwater Management Plan"

Have Your Say

Elgin, Barbara and Anderson Creek Watersheds

1. A healthy watershed provides many benefits to the community, from providing a quiet walking trail to efficiently draining your neighbourhood after it rains. Please rank, in order of importance, the following based on the value each attribute adds to the watershed. (1 being most important, and 6 being least important):

_____ Recreational opportunities	_____ Reduction of erosion and sediment issues
_____ Nature appreciation	_____ Efficient drainage
_____ Diversity of plants and animals	_____ Other (Please specify) _____

2. A watershed's health can be determined based on several indicators including the quality of water flowing in creeks and whether creek banks are vegetated. How do you rate the health of the watershed? (Check one)

☐ The watershed appears to be very healthy	☐ The watershed appears to be in poor health
☐ The watershed appears to be healthy	☐ The watershed appears to be in very poor health
☐ The watershed appears to be in reasonable health, but could be improved	☐ Don't know

3. The health of a watershed can be threatened by several sources related to human activity. Please indicate whether you are aware of the presence of any of the following threats and indicate approximately where they occur (i.e., creek name and the nearest cross-streets). (Check all that apply)

	Health Threats	**Location(s)**
☐	Release of pollutants into the creeks (e.g., fertilizers in high concentrations, commercial chemicals)	_____
☐	Unauthorized trails along and across the creek channel	_____
☐	Erosion of creek banks	_____
☐	Barriers to fish passage (e.g., beaver dams, debris across creek or culverts)	_____
☐	Poor water quality (e.g., oil sheen on water, suds in water, garbage in water)	_____
☐	Flooding of properties and in the creeks	_____
☐	Poor drainage causing stagnant water	_____
☐	Creek banks and buffer area are poorly vegetated or contain invasive species	_____
☐	Other (Please specify) _____	_____

4. The implementation of Wet Weather Green Infrastructure (WWGI) can enhance watershed health by facilitating the infiltration, capture, reuse and detention of runoff. Please rank, in order of desirability, the following WWGI based on which you would most like to see in your neighbourhood. (1 being most desirable and 4 being least desirable)

Photo Source: City of Surrey Rosemary Heights NCP

____ Bioswales – These vegetated open channels promote groundwater infiltration and runoff cleansing and detain runoff so that it takes longer to reach natural channels.

Photo Source: WorleyParsons Canada Ltd.

____ Rain Gardens – These gardens are used to temporarily detain runoff from large surfaces such as paved parking lots, promoting groundwater infiltration and absorption by the garden's vegetation.

Photo Source: jamestownmacadam.com

____ Permeable Pavement or pavers – This hard surface is capable of supporting the weight of vehicles while also permitting the transmission of water from the top surface to the underlying soils and promotes groundwater infiltration.

Photo Source: University of Minnesota Duluth

____ Vegetated filter strips – These vegetated surfaces intercept and slow sheet flow from impervious surfaces promoting runoff cleansing and groundwater infiltration.

5. Do you practice, or are you interested in practicing, any of the following rainwater management techniques at your residence? (Check all that apply)

☐ Rainwater collection (e.g., rain barrels)
☐ Hardscape features (e.g., permeable pavement)
☐ Other (Please specify) _____
☐ Landscape features (e.g., rain gardens)
☐ Volunteer activities (watershed cleanup, participate on watershed council)

The following sections describe the five questions included in the questionnaire along with a summary of the responses.

3.1.1 Question No. 1

Rank, in order of importance, the following based on the value each attribute adds to the watershed.

The intent of this question was to prioritize six attributes relating to watershed health based on public opinion. The attributes were scored based on the submitted rankings with the No. 1 ranking assigned six points, reduced by one point for each subsequent ranking.

The scores for each watershed health attribute are presented in Figure V.

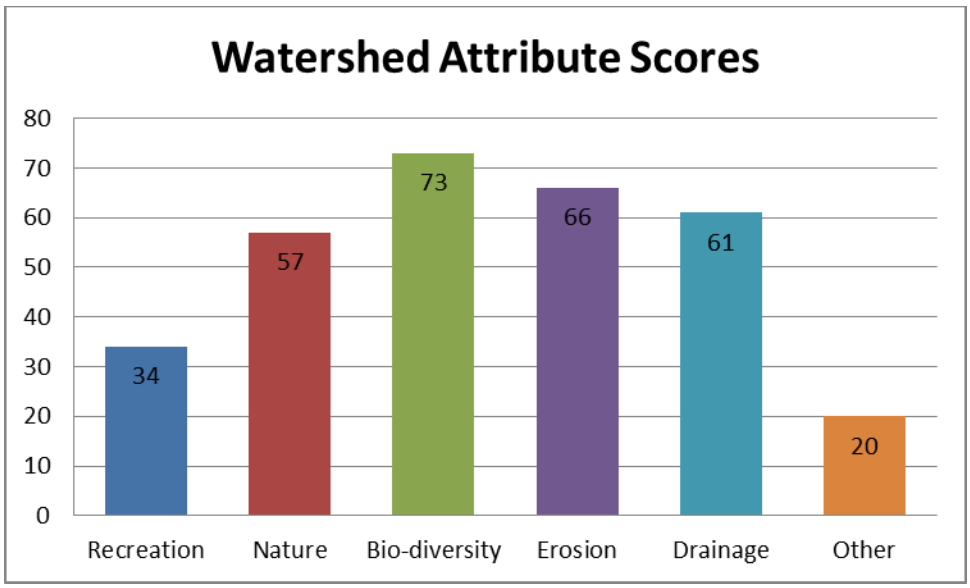


Figure V Watershed Attribute Scores

These results indicate that the public is primarily interested in maintaining a diverse ecosystem; this was corroborated by discussions between staff and residents at the public consultation kiosk. The results also indicate that the public is interested in issues related to erosion, efficient drainage, and the natural environment, all of which coincide with the bio-diversity attribute.

3.1.2 Question No. 2

How do you rate the health of the watershed?

The intent of this question was to determine how the public perceived the overall health of the watershed in the Study Area. The results of this question are presented in Figure W.

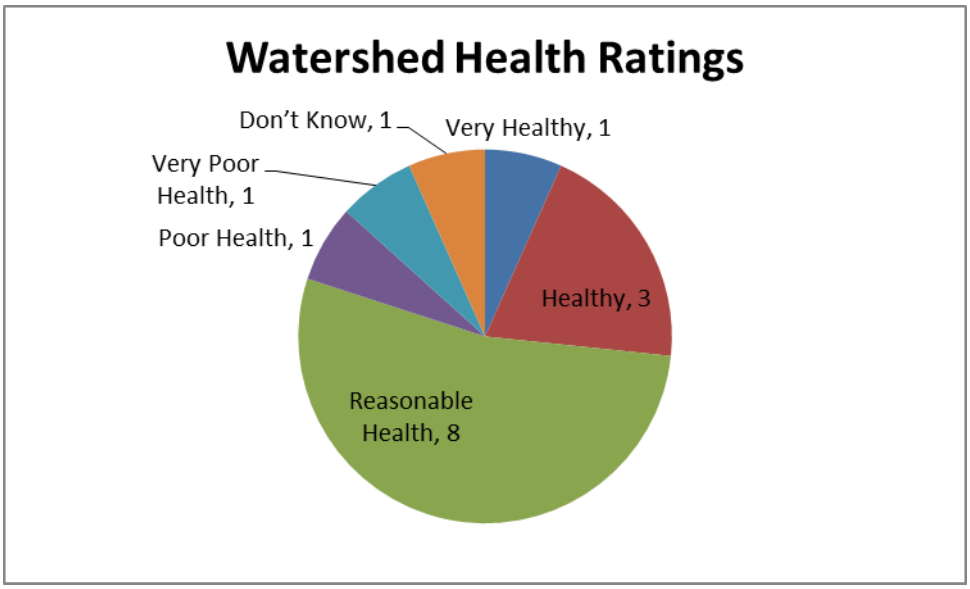


Figure WWatershed Health Ratings

These results indicate that the public perceives the watershed to be in reasonable to good health. Given the urban context of the creeks, this sentiment matches the results of the biophysical assessment discussed in Section 2.5.

3.1.3 Question No. 3

Indicate whether you are aware of the presence of any of the following threats.

The intent of this question was to identify the presence, and in some circumstances, the locations of potential threats to the health of watersheds in the Study Area. The results of this question are presented in Figure X.

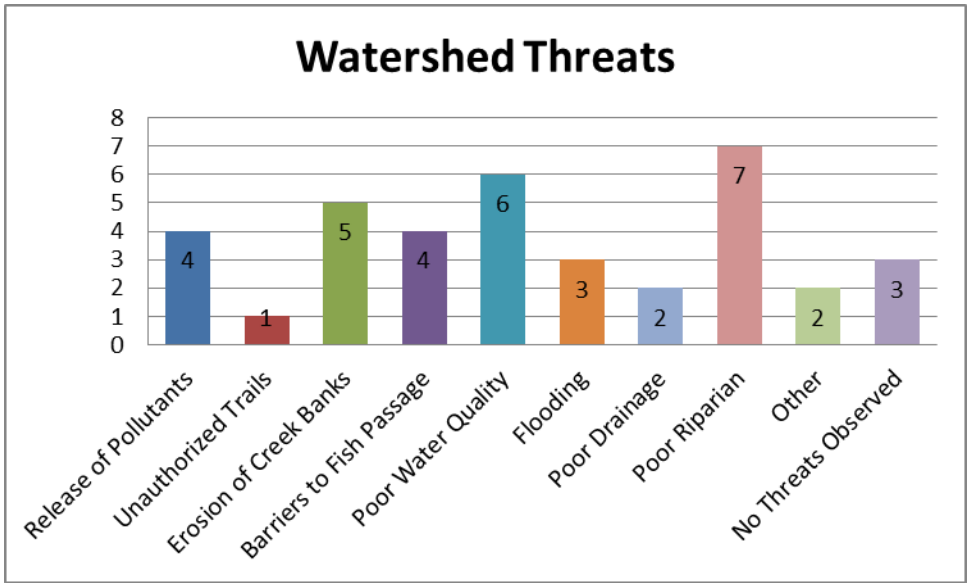


Figure X Watershed Threats

These results indicate that the public has identified threats relating to riparian area, water quality, erosion, and aquatic habitat.

3.1.4 Question No. 4

Rank, in order of desirability, the following Wet Weather Green Infrastructure (WWGI) based on which you would most like to see in your neighbourhood.

The intent of this question was to determine which WWGI the public prefers. The WWGI were scored based on the submitted rankings with the No. 1 ranking assigned four points, reduced by one point for each subsequent ranking.

The scores for each WWGI are presented in Figure Y.

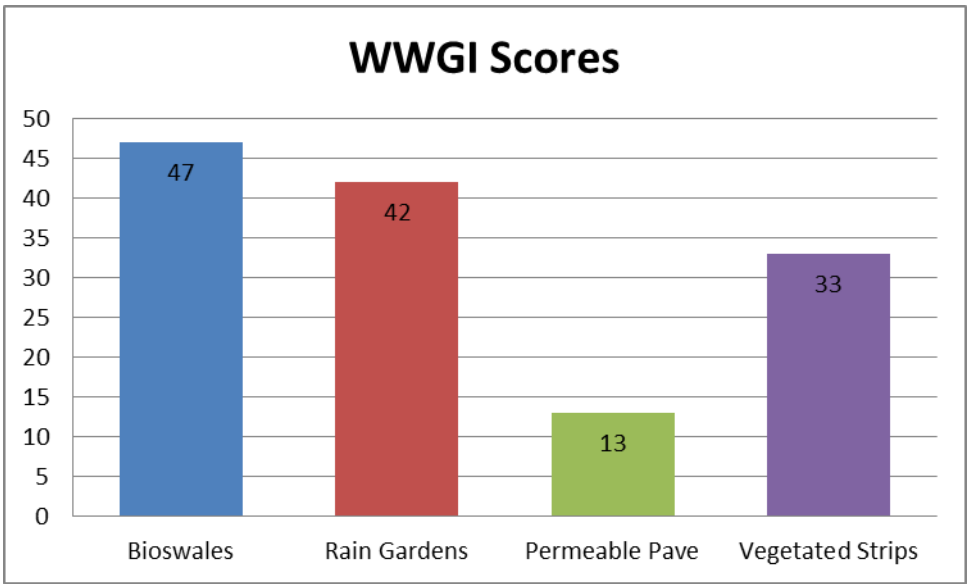


Figure Y WWGI Scores

The results indicate that the public would prefer for the City to consider selecting bioswales and rain gardens when implementing WWGI in the Study Area.

3.1.5 Question No. 5

Do you practice, or are you interested in practicing, any of the following rainwater management techniques at your residence?

The intent of this question was to determine what actions the public would be willing to take to improve watershed health in the Study Area. The results of this question are presented in Figure Z.

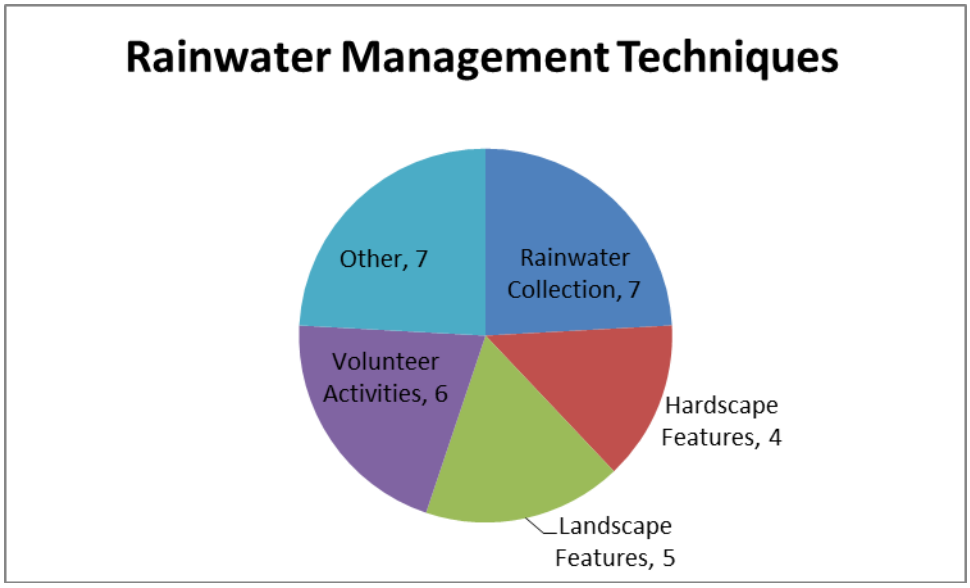


Figure Z Rainwater Management Techniques

The results indicate that the public is employing, or is interested in employing, several rainwater management techniques with the rainwater collection being the most popular technique.

3.2 Stakeholder Engagement

Following public consultation, stakeholders were contacted and asked to respond to the following questions:

1. What are your areas of concern relating to the health of the watersheds (e.g., erosion / sedimentation issues, riparian health, etc.)? Please rank your concerns based on the order they should be addressed, from highest to lowest.
2. Does your organization currently have any specific objectives intended to improve the health of the watersheds?

3. Is your organization willing to support the City of Surrey Engineering department to develop and/or implement policies and projects that will improve the health of the watersheds? If so, what type of support are you willing to offer (i.e., monitoring, stream clean-up, application / enforcement of policies)?

Replies were received from the following stakeholder groups and organizations, and are included in Appendix 3:

- Sunnyside Acres Heritage Society;
- Nicomekl Enhancement Society; and
- City of Surrey Parks, Recreation and Culture Department.

The responses indicated that the protection of riparian areas to augment aquatic habitat conditions is considered to be of primary importance. The two societies indicated that they are very willing to support the conservation and water management activities of the City's Engineering Department.

3.3 Mission and Vision Statements

The mission and vision statements, which summarize the objectives and values of the community and stakeholders, facilitate the communication of the Vision. Although they contain similar content, each is required to answer the question: "What do we want?"

3.3.1 Mission Statement

A mission statement concisely defines the broad purpose and objectives of the community and stakeholders. The following mission statement was developed to incorporate the results of Question No. 1 from the public consultation.

> *To manage the health of the Elgin, Barbara, and Anderson Creeks so they are capable of supporting a diverse ecosystem without sacrificing their ability to service the surrounding urban community by providing efficient drainage and the opportunity to enjoy and appreciate the natural environment.*

3.3.2 Vision Statement

A vision statement expresses the values held by the community and stakeholders. The following vision statement was developed to support the objectives of the Mission Statement.

> *The Elgin, Barbara, and Anderson Creeks are vital community resources that enhance the local ecosystem by providing protected areas for riparian vegetation and habitat for aquatic species. Local residents benefit from the drainage capacity of the creeks and the opportunities to enjoy and appreciate the natural environment that they provide. The City of Surrey, supported by stakeholder groups and organizations, will steward these resources so that they are available for future generations.*

3.4 Goals

Specific Goals were developed to assist the City in achieving the objectives of the mission statement without compromising the values of the vision statement. The Goals are presented with a discussion of the following:

- **Context** - Description of how this Goal relates to watershed management and how / where it occurs in the Study Area;
- **Potential Strategies** - Summary of what can be done to achieve the Goal;
- **Key Stakeholders** - Discussion of who will champion this Goal and who will provide the support or services required to achieve the Goal;
- **Related Policies and Criteria** - Discussion of the documents, regulations, policies, and criteria that are monitored and enforced by the City and other government agencies that are relevant to the achievement of the Goal; and
- **Recommendations** - Summary of the recommended actions and strategies the City should implement to facilitate the achievement of the Goal. These recommendations should be implemented or applied across the entire Study Area; however, they may not be feasible in all situations.

The Goals were generated and prioritized based on the results of the public consultation, stakeholder engagement, and Stage 1 investigations.

3.4.1 Goal No. 1 - Protect, Maintain, and Enhance Aquatic Habitat in the Elgin, Barbara, and Anderson Creeks

Context

The Elgin, Barbara, and Anderson Creeks are classified as Class A streams (i.e., they are potentially inhabited year-round by salmonid species); however, the upper portions of the Elgin, Barbara, and Anderson Creeks provide poor conditions to support aquatic life. Aquatic habitat in these creeks is degraded by the presence of the following natural and anthropogenic impacts:

- Barriers to upstream fish passage including drops at culvert outlets and in-stream debris jams;
- Limited riparian cover increasing in-stream temperature, reducing natural filtration of runoff borne pollutants, and reducing nutrient input;
- Deposition of sediments results in covers gravel bed materials becoming covered and loss of salmonid spawning beds and habitat for invertebrate species; and
- Ephemeral flows during extended dry periods preventing upstream fish passage.

While addressing these issues will likely improve aquatic habitat conditions, it should be noted that the pre-development conditions were likely poor (as discussed in Section 2.5.2). Consequently, it may be difficult to provide the necessary aquatic habitat conditions required to support a robust salmonid population.

The results of the biophysical assessment of the creeks are summarized on Figure G, Figure H, and Figure I.

Potential Strategies

Aquatic habitat conditions can be maintained and/or enhanced through the implementation of the following strategies:

- Removal of barriers to fish passage;
- Installation of infrastructure that promotes fish passage (e.g., fish baffles in culverts);
- Protection of riparian corridors through the establishment of leave strips and setbacks;
- Mitigation of upstream erosion sites to reduce sediment transport and deposition;
- Augmentation of summer base flows by promoting groundwater recharge and, where feasible, supplying supplemental creek flows; and
- Implementation of channel complexing (e.g., deep pools, step pools, and side channels).

Key Stakeholders

This goal will be championed by the City's Engineering Department who will select and prioritize sites at which aquatic habitat enhancements are to be implemented. As available funding is limited, the City should carefully consider which mitigation strategies and projects should be implemented with consideration given to estimated costs as well as the potential benefits to aquatic habitat.

The Environmental Advisory Committee (EAC) will support this goal, when requested, by reviewing proposed mitigation strategies and projects, and by providing comments and advice to Surrey City Council.

The City should continue to leverage the capabilities and contributions of local stakeholder groups - including the Sunnyside Acres Heritage Society and Nicomekl Enhancement Society - and continue to support their efforts to improve watershed health within the Study Area. The City should also continue to support governmental agencies and adhere to their regulations.

As these measures may be implemented as capital works or as land development projects, the activities associated with this goal will be completed by contractors and, when applicable, by the development community.

Related Policies and Criteria

The City is in the process of compiling a Green Infrastructure Network (GIN) of the natural elements (e.g., streams, parks) and the connections between them. This system will enhance the City's environmental mapping and will incorporate the previously identified Environmentally Sensitive Areas (e.g., riparian corridors). The GIN will be incorporated into the Official Community Plan (OCP) and will inform the development of a Biodiversity Conservation Strategy.

One of the key objectives included in the City's draft OCP is to "identify, protect, and manage Surrey's significant natural ecosystems". The OCP includes the following tasks, intended to assist the City in achieving the aquatic habitat component of this objective:

- D1.1 - Utilize the Ecosystem Management Study (EMS) and the Biodiversity Conservation Strategy to guide the management and protection of Surrey's diverse ecosystems;
- D1.2 - Establish plans, strategies, and policies to protect, enhance, and manage the EMS and GIN;
- D1.3 - Identify and continue to work toward identifying and protecting sensitive fisheries zones including aquatic habitats, wetlands, and riparian areas as defined in conjunction with other agencies;
- D1.4 - Preserve riparian areas and watercourses in their natural state and link them with upland natural areas to develop a connected network of natural;
- D1.9 - Encourage ecological restoration of riparian and/or significant natural areas to improve stream health, to support biodiversity, and to improve ecological health of the GIN;
- D1.10 - Support and partner with senior governments, Metro Vancouver, and other local governments and agencies to protect sensitive ecosystems in Surrey;
- D1.12 - Work with the development community, and community groups including watershed stewardship groups, environmental groups, and the City's EAC, to identify opportunities to enhance biodiversity at all levels;
- D1.17 - Consider biodiversity objectives in the design and review of all capital projects, and the review of all development applications; and
- D1.18 - Incorporate wildlife habitat considerations into capital project planning and construction including using narrower roads, wildlife bridges, or large culvert underpasses, where feasible.

The City is currently developing a Biodiversity Conservation Strategy that will act as a policy framework and establishing biodiversity goals and targets and conservation priorities.

Recommendations

To protect, maintain, and enhance aquatic habitat, WorleyParsons recommends that the City and stakeholders:

1. Identify and prioritize locations where barriers to fish passage should be removed;
2. Manage riparian areas (refer to Goal No. 2);
3. Reduce sedimentation (refer to Goal No. 3);
4. Increase groundwater contributions to creek base flows (refer to Goal No. 6);
5. Ensure that future culverts are designed with provisions for fish passage;
6. Continue to support local stakeholder groups in their efforts to improve watershed health within the Study Area; and
7. Identify and prioritize locations where channel complexing techniques can be implemented.

3.4.2 Goal No. 2 - Protect, Maintain, and Enhance Riparian Areas throughout the Elgin, Barbara, and Anderson Creek Watersheds

Context

Vital to maintaining favourable aquatic habitat conditions is the health of riparian areas adjacent to the creeks and throughout the watershed areas. Healthy riparian areas provide the following benefits to creeks:

- Provision of the majority of the food items and organic material required to support the aquatic food chain;
- Generation of large organic debris, which provides cover and habitat for young fish;
- Provision of shade, which helps to regulate favourable water temperatures and dissolved oxygen saturation levels;
- Filtration of water borne contaminants transported in runoff, preventing them from entering the creek channel;
- Provision of cover and shelter for aquatic species; and
- Stabilization of bank materials.

Although the City has established leave strips adjacent to watercourses, the riparian cover adjacent to the Elgin, Barbara, and Anderson Creeks was largely categorized as low or moderate, as shown on Figure G, Figure H, and Figure I.

As the creeks are often in close proximity to private properties, this is likely due to anthropogenic disturbances (e.g., landscaping and unauthorized trails) within the leave strips.

The health of riparian areas can be compromised by the presence of invasive species and mono-culture areas (i.e., areas exhibiting low vegetative diversity). These will often inhibit the establishment of a mixture of vegetative species, each of which contribute individual benefits to the health of riparian areas and aquatic habitat. For example, areas composed largely of Salmonberry may produce less leaf litter, provide less shade, and do not provide the nitrogen fixation required to promote plant growth.

Potential Strategies

In addition to the leave strips established by the City, the following strategies can be implemented to protect, maintain, and enhance riparian areas:

- Limitation of disturbances to the riparian corridors, particularly at road crossings and bridges;
- Improvement of public awareness regarding the importance of riparian areas and the harm caused by disturbances to these areas;
- Removal of invasive species without the use of herbicides or other chemicals; and
- Replanting of mono-culture areas with diverse vegetative species.

Key Stakeholders

This goal will be championed by the City's Engineering Department who will select and prioritize sites at which riparian enhancement measures are to be implemented. The City's Parks, Recreation, and Culture Department should continue to monitor and remove invasive species within riparian areas. In addition, the City should develop and distribute educational material regarding the proper management of riparian areas and should continue to enforce leave strip widths adjacent to creeks.

The City should continue to leverage the capabilities and contributions of local stakeholder groups - including the Sunnyside Acres Heritage Society and Nicomekl Enhancement Society - and continue to support their efforts to improve watershed health within the Study Area. The City should also continue to support governmental agencies and adhere to their regulations. Where possible, groups such as the Surrey Youth Stewardship Squad should be utilized to remove invasive species and plant native species under the guidance of City staff. The City should encourage residents to follow proper vegetation management practices, particularly adjacent to creeks.

Related Policies and Criteria

Similar to aquatic habitat, the City's riparian areas will be compiled in the GIN and their management is a key objective of the OCP.

The City follows the Department of Fisheries and Oceans' Land Development Guidelines (1993) rather than the provincial Riparian Area Regulation. The Land Development Guidelines require the establishment of leave strips (i.e., a setback from the high water mark in which structures are not permitted) on either side of watercourses to protect riparian areas.

The width of these leave strips is predicated by the land usage adjacent to the watercourses, ranging from 15 m for residential / low density areas to 30 m for commercial / high density areas. The reduction of leave strips requires the submission of a site-specific study prepared by a Registered Professional Biologist (RPBio) as well as the approval of the City.

Recommendations

To protect, maintain, and enhance riparian areas, WorleyParsons recommends that the City and stakeholders:

1. Avoid disturbing riparian areas;
2. Increase public awareness of the importance of riparian areas;
3. Continue to enforce the leave strip requirements at existing and under-development properties;
4. Remove invasive species and replant with native species; and
5. Replant areas exhibiting mono-culture vegetation with native species.

3.4.3 Goal No. 3 - Address Erosion and Sedimentation Issues

Context

Erosion, the natural process whereby soil is removed from the creek bed and banks and is transported downstream, can significantly impact watershed health. Failure to address erosion can impact aquatic habitat through deposition of eroded soils and cause creek bank instabilities that can endanger private properties. Erosion typically occurs when the driving force generated by creek flows (a product of high flow velocities) exceeds the resisting force of creek bed materials (a product of the grain size of materials) and can occur at the outlets of culverts, through steep creek sections, and at channel constrictions or bends. Locations of potential and existing erosion are shown in Figure N, Figure O, and Figure P.

Potential Solutions

Erosion can be mitigated using the following techniques:

- Preservation of natural vegetation within creek channels;
- Planting of vegetative cover selected by an RPBio if disturbance of natural vegetation is unavoidable;
- Implementation of wet weather infrastructure such as bioswales and raingardens to promote retention and/or infiltration of runoff, thereby reducing creek peak flows;
- Divert high flows to storm sewers;

- Implementation of bio-engineered bed and bank stabilizing materials - such as live staking and joint planting - to disperse driving force energy and limit the exposure of native bank materials to scour; and
- Installation of structural bed and bank stabilizing materials and infrastructure, such as riprap; rock gabions; or vegetated structures to disperse driving force energy and limit the exposure of native bank materials to scour.

Implementing these techniques will typically reduce sedimentation issues; as the erosion of soils is reduced, less sediment is transported downstream.

In addition to the erosion of creek beds and banks, construction sites can be a significant source of eroded soils, particularly when erosion and sediment control (ESC) measures are not in place or are poorly implemented. These soils can be transported by overland or channelized flow to creek channels. Contractors and developers must continue to design, implement, maintain, and monitor appropriate ESC measures that are in place during the construction period.

Key Stakeholders

This goal will be championed by the City's Engineering Department who will select and prioritize sites at which erosion mitigation measures are to be implemented. This will include exploring opportunities to implement wet weather infrastructure as part of planned capital projects (e.g., road expansions and facility renovations) and proposed developments.

As these measures may be implemented as capital works or as land development projects, the activities associated with this goal will be completed by contractors and, when applicable, by the development community.

Related Policies and Criteria

The Surrey Drainage Policy, contained in the Engineering Design Criteria Manual (2004), includes the following directives:

- Surrey will utilize stormwater management methods to limit peak flow discharges to natural creeks;
- Surrey will combine in-stream fish enhancement works with erosion control works to limit the impact of urban development where approved by the senior government environmental agencies; and
- Surrey will enforce as much as possible, the silt discharge guidelines set by the Ministry of Environment, Lands and Parks and require Developers to meet those standards.

Metro Vancouver's Best Management Practices Guide for Stormwater (1999) provides extensive guidance for the preparation of construction site ESC plans including descriptions of several ESC techniques and practices.

As the Elgin, Barbara, and Anderson Creeks are classified as salmon bearing, any works that take place within the creek channels will be governed by the federal Fisheries Act and must be referred to the Department of Fisheries and Oceans (DFO) for approval. Furthermore, any changes made to the creeks will be regulated by the British Columbia Water Act and will require a notification or approval depending on the complexity and duration of the project.

Recommendations

To address erosion and sedimentation issues, WorleyParsons recommends that the City and stakeholders (including developers):

1. Avoid disturbing natural vegetation within creek channels and, when unavoidable, restore channels using vegetative cover selected by an RPBio;
2. Implement wet weather infrastructure as part of capital works and development projects to reduce runoff flows;
3. Implement bed and bank stabilizing materials and infrastructure, with preference given to bio-engineered solutions, to mitigate localized bank instabilities caused by erosion; and
4. Continue to require the submission of erosion and sediment control plans for all capital and development construction sites.

3.4.4 Goal No. 4 - Maintain Efficient Drainage

Context

In addition to providing aquatic habitat, the Elgin, Barbara, and Anderson Creeks provide an efficient and safe means of conveying large stormwater flows to the Nicomekl River. This can limit the impacts to the public during large storm events (e.g., flooding of properties, damage to road and sewer infrastructure); however, routing large flow volumes through the creeks can degrade the creek channels and could lead to bank instabilities, loss of aquatic habitat and riparian area, and damage to private properties adjacent to the creeks.

In extreme circumstances, the capacity of in-stream infrastructure could be exceeded during storm events with a return period greater than 100 years resulting in overtopping of roadways and potentially damaging infrastructure and property. The locations of potentially undersized infrastructure are discussed in Section 2.4.

As the creek confluences with the Nicomekl River are not controlled (i.e., water from the Nicomekl River can flow up the creek channels) the areas surrounding the confluences can be subjected to flooding when the Nicomekl River rises to extreme water levels. With consideration of climate change, the 200-year water level is predicted to increase to 3.1 m by the year 2100. Based on existing ground conditions, the anticipated flooding extents associated with this water level could extend onto private properties.

Potential Solutions

Flooding can be mitigated using the following techniques:

- Routing of a portion of high flows into storm sewers;
- Replacement of undersized major culverts;
- Implementation of flood control devices including dykes and flood boxes at creek confluences with the Nicomekl River; and
- Implementation of wet weather infrastructure such as bioswales and raingardens to promote retention and/or infiltration of runoff, thereby reducing creek flow.

Key Stakeholders

This goal will be championed by the City's Engineering Department who will select and prioritize sites at which flood mitigation measures are to be implemented. This will include exploring opportunities to implement wet weather infrastructure as part of planned capital projects (e.g., road expansions and facility renovations) and proposed developments.

As these measures may be implemented as capital works or as land development projects, the activities associated with this goal will be completed by contractors and, when applicable, by the development community.

Related Policies and Criteria

Similar to erosion and sediment issues, drainage within the watersheds is governed primarily by the Surrey Drainage Policy. Additionally, the Engineering Design Criteria Manual includes the following criteria related to stormwater infrastructure capacity:

- A minor system conveyance capacity up to the 1:5-year return period storm to minimize inconvenience of frequent surface runoff; and
- A major system conveyance capacity up to the 1:100-year return period storm to provide safe conveyance of flows to minimize damage to life and property.

Recommendations

To address potential flooding issues, WorleyParsons recommends that the City and stakeholders (including developers):

1. Implement wet weather infrastructure as part of capital works and development projects to reduce runoff flows;
2. Replace undersized major culverts to convey the 100-year flow; and
3. Implement flood control devices at the Elgin and Anderson Creek confluences with the Nicomekl River to account for higher river levels resulting from climate change.

4. Maintain a minimum topsoil depth of 450 mm in landscaped areas.

3.4.5 Goal No. 5 - Address Potential Contaminant Sources

Context

The health of creeks can be impacted by the release of contaminants within the watersheds. These contaminants can be generated from natural processes (e.g., erosion and sedimentation) and anthropogenic activities (e.g., by-products of industrial processes and hydrocarbon spills) and transported to the creeks by overland runoff, storm sewer conveyance, or groundwater flows. Long-term health concerns or death of aquatic organisms can result when the concentration of contaminants are at toxic levels. Contaminants can be generated from either point sources (i.e., a discrete and stationary source from which contaminants may be discharged such as a sewer discharge pipe or container) or non-point sources (i.e., larger, diffuse processes such as roadway runoff).

The commercial and industrial operations located in the Barbara Creek catchment are potential point sources of contaminants. Inadequate containment or improper disposal practices employed by these operations can increase the likelihood of the release of contaminants.

The application of fertilizers can lead to the release of nutrients (e.g., nitrogen and phosphorus) causing a proliferation of certain algae. An overabundance of these algae can impact aquatic habitat conditions by affecting degrading water quality parameters required to support aquatic organisms (e.g., dissolved oxygen and temperature).

The location of potential sources of groundwater contamination (e.g., gas stations and septic fields) and surface runoff contamination (e.g., fertilizer application at cemeteries and golf courses) is shown on Figure K.

Potential Solutions

Water quality concerns can be mitigated using the following strategies:

- Address major point sources of potential contamination as they are identified;
- Install oil interceptors at parking lots and gas stations;
- Dispose of industrial and commercial waste water appropriately;
- Follow non-point source best management practices (BMPs);
- Limit the use of chemical fertilizers and pesticides;
- Implement, where feasible, biological measures for filtering runoff (e.g., vegetative strips and wetlands); and
- Capture and dispose of first flush runoff flows (i.e., runoff which follows an extended period of dry weather and that may contain a high concentration of contaminants).

Key Stakeholders

This goal will be championed by the City's Engineering and supported by the Parks, Recreation, and Culture Department and by and the Planning and Development Department. They will be responsible for the following:

- Monitoring in-stream water quality;
- Identifying major sources of contamination including commercial and industrial operations improperly disposing of waste water;
- Addressing potential sources of contamination as part of the development process;
- Following operation and maintenance BMPs related to non-point source contaminants;
- Encouraging heavy fertilizer users to adopt best management maintenance practices including the use of slow release organic fertilizers;
- Continuing to discourage the public's use of pesticides and non-organic fertilizers; and
- Review capital projects for possible installation of stormwater infrastructure to capture first flush runoff.

Related Policies and Criteria

Freshwater quality and sediment quality parameters related to the protection of aquatic life are regulated by Canadian Environmental Quality Guidelines (CCME 2011). They include criteria for long-term concentrations of various chemicals and compounds in fresh water and sediment. The Compendium of Approved Freshwater Quality Guidelines (BC MOE 2010) provides criteria for additional water quality parameters (e.g., temperature, pH, turbidity, and dissolved oxygen).

The City of Surrey Bylaw No. 17160 regulates the usage of pesticides on private and City owned properties.

Recommendations

To address potential water quality concerns, WorleyParsons recommends that the City and stakeholders:

1. Continue to monitor in-stream water quality;
2. Identify industrial and commercial operations whose practices could result in the improper disposal of waste water or release of contaminants and work with them to develop and implement BMPs;
3. Continue to require the installation of oil interceptors, or equivalent infrastructure, at parking lots and gas stations;

4. Review current operation and maintenance practices relating to non-point source contaminants and compare them to BMPs;
5. Encourage golf courses and cemeteries within the Study Area to adopt best management maintenance practices;
6. Implement biological filtration methods;
7. Implement stormwater infrastructure that captures first flush runoff flows originating from areas zoned for industrial and/or commercial use;
8. Continue to enforce the City's pesticide bylaw; and
9. Continue to encourage the use of organic fertilizers.

3.4.6 Goal No. 6 - Protect Groundwater Resources

Context

During extended dry periods, groundwater is often the only source of creek flows, providing the minimum flows required to maintain favourable aquatic habitat conditions. The availability of clean water from groundwater is, therefore, an important component of watershed health. Due to the elevation change across the Study Area, it is likely that the contributing flows from groundwater are limited in the upper portions of the creeks, where the groundwater table is less likely to be at or near the ground surface.

Groundwater is recharged by the infiltration of rain water through permeable ground surfaces; however, as watersheds are developed, much of the permeable surface is built upon (e.g., road surfaces, parking lots, and houses) thereby limiting infiltration and the availability of groundwater. Wet weather green infrastructure (e.g., permeable pavement) can collect water that would normally be transported to the creeks via storm sewers and infiltrate all or some of it to promote groundwater recharge. Similarly, runoff flows from permeable surfaces (e.g., roofs) can be routed to permeable surfaces.

The infiltration potential of a watershed is also governed by the composition of its surficial soils. Surficial soils with a high sand content can transmit a higher volume of water through to sub-surface aquifers than soils containing primarily silt or clay. Figure J shows the estimated extents of various surficial soil classifications in the Study Area.

The groundwater table is vulnerable to contamination from sub-surface sources including septic fields and hydrocarbon storage tanks. Infrastructure that would promote groundwater infiltration should be discouraged at locations where these devices are sources are present.

Potential Solutions

Groundwater resources can be protected and enhanced using the following strategies:

- Utilize wet weather green infrastructure that promotes groundwater recharge;

- Limit groundwater infiltration at locations with potential sub-surface contaminant sources;
- Route runoff from impermeable surfaces to permeable surfaces; and
- Require developers to retain a specified percentage of each lot as permeable surface.

Key Stakeholders

This goal will be championed by the City's Engineering Department who will select and prioritize sites at which wet weather green infrastructure is to be implemented, including as part of planned capital projects and proposed developments. The City's Planning and Development Department will review development applications to ensure that groundwater infiltration is limited at locations with potential sub-surface contaminant sources and will continue to require that developers retain permeable surfaces.

As these measures may be implemented as capital works or as land development projects, the activities associated with this goal will be completed by contractors and, when applicable, by the development community.

Related Policies and Criteria

The City of Surrey Zoning Bylaw No. 12000 (1993) controls the amount of permeable surfaces on private properties by specifying the maximum lot coverage (i.e., the amount of the lot that can be taken up by structural elements) for the various zoning categories. The Engineering Design Criteria Manual (2004) requires that roof drains discharge to splash pads rather than connecting directly to storm sewers, thereby routing runoff flows from the impermeable roof surface to the permeable lawn surface.

Recommendations

To protect and enhance the availability of groundwater for the purposes of creek recharge, WorleyParsons recommends that the City and stakeholders (including developers):

1. Implement wet weather infrastructure as part of capital works and development projects to promote groundwater infiltration;
2. Limit groundwater infiltration at locations with potential sub-surface contaminant sources; and
3. Continue to require developers to observe maximum lot coverage and roof lead disconnection requirements.

3.4.7 Goal No. 7 - Maintain the Health of the Sunnyside Acres Urban Forest

Context

The Sunnyside Acres Urban Forest (the Forest) provides many benefits to the Surrey residents including providing recreational and nature appreciation opportunities. It also contributes to the health of the Elgin and Anderson watershed areas through the following:

- Rainwater infiltration - the largely permeable surface allows for significant infiltration, which reduces the volume of creek flows during large storm events;
- Rainwater interception - the extensive tree canopy reduces the volume of creek flows;
- Organic material generation, which supports aquatic species in the creeks;
- Support for a diverse array of plants including endangered plant communities; and
- Provision of critical wildlife habitat and supports rare animal species.

Although the Forest is protected, it is still threatened by anthropogenic activities including the creation of unauthorized trails and dumping of refuse and natural processes including root rot disease which has afflicted many mature Douglas-fir trees.

Potential Solutions

The threats to the Forest can be mitigated using the following strategies:

- Decommission unauthorized trails throughout the Forest;
- Install no dumping of waste signs around the perimeter of the Forest;
- Educate the public on the Forest's ecological importance; and
- Create a containment belt around trees afflicted with root rot.

Key Stakeholders

This goal will be championed by the City's Parks, Recreation, and Culture Department which will continue to manage and maintain the Forest. The City should continue to leverage the capabilities and contributions of local stakeholder groups, including the Sunnyside Acres Heritage Society, and continue to support their efforts to improve watershed health within the Study Area.

Related Policies and Criteria

Guidance on the management of the Forest is provided by the Sunnyside Acres Urban Forest Access and Recreation Management Plan (2002).

Recommendations

To maintain the health of the Sunnyside Acres Urban Forest, WorleyParsons recommends that the City and stakeholders:

1. Continue to monitor for and decommission unauthorized trails;
2. Continue to address the root rot disease issue afflicting Douglas-fir trees; and
3. Continue to educate the public on the Forest's ecological importance.

3.5 Summary of Goals and Recommendations

Table P compiles the following elements:

- The Goals;
- The report figures relevant to each Goal;
- The stakeholders expected to contribute towards the achievement of each Goal; and
- The recommendations that will assist in achieving each Goal.

Table P Summary of Goals

Goal	Relevant Figures	Key Stakeholders	Recommendations
Goal No. 1 - Protect, Maintain, and Enhance Aquatic Habitat in the Elgin, Barbara, and Anderson Creeks	M, N, O	Engineering Department Environmental Advisory Committee Sunnyside Acres Heritage Society Nicomekl Enhancement Society	1. Identify and prioritize locations where barriers to fish passage should be removed. 2. Manage riparian areas (refer to Goal No. 2). 3. Reduce sedimentation (refer to Goal No. 3). 4. Increase groundwater contributions to creek base flows (refer to Goal No. 6). 5. Future culverts should be designed with provisions for fish passage. 6. Continue to support local stakeholder groups in their efforts to improve watershed health within the Study Area. 7. Identify and prioritize locations where channel complexing techniques can be implemented.
Goal No. 2 - Protect, Maintain, and Enhance Riparian Areas throughout the Elgin, Barbara, and Anderson Creek Watersheds	M, N, O	Engineering Department Parks, Recreation, and Culture Department Sunnyside Acres Heritage Society Nicomekl Enhancement Society	1. Avoid disturbing riparian areas. 2. Increase public awareness of the importance of riparian areas. 3. Continue to enforce the leave strip requirements at existing and under-development properties. 4. Remove invasive species and replant with native species. 5. Replant areas exhibiting mono-culture vegetation with native species.

Goal	Relevant Figures	Key Stakeholders	Recommendations
Goal No. 3 - Address Erosion and Sedimentation Issues	M, N, O	Engineering Department	1. Avoid disturbing natural vegetation within creek channels and, when disturbance is unavoidable, restore channels using vegetative cover selected by an RPBio. 2. Implement wet weather infrastructure as part of capital works and development projects to reduce peak runoff flows. 3. Implement bed and bank stabilizing materials and infrastructure, with preference given to bio-engineered solutions, to mitigate localized bank instabilities caused by erosion. 4. Continue to require the submission of erosion and sediment control plans for all capital and development construction sites greater than 2,000 m^2.
Goal No. 4 - Maintain Efficient Drainage	P	Engineering Department	1. Implement wet weather infrastructure as part of capital works and development projects to reduce peak runoff flows. 2. Replace undersized major culverts to convey the 100-year flow. 3. Implement flood control devices at the Elgin and Anderson Creek confluences with the Nicomekl River to account for potentially higher river levels resulting from climate change. 4. Maintain a minimum topsoil depth of 450 mm in landscaped areas.
Goal No. 5 - Address Potential Contaminant Sources	J	Engineering Department Parks, Recreation, and Culture Department Planning and Development Department	1. Continue to monitor in-stream water quality. 2. Identify industrial and commercial operations whose practices could result in the improper disposal of waste water or release of contaminants and work with them to develop and implement best practices. 3. Continue to require the installation of oil interceptors, or equivalent infrastructure, at parking lots and gas stations. 4. Review current operation and maintenance practices relating to non-point source contaminants and compare them to BMPs. 5. Encourage golf courses and cemeteries within the Study Area to adopt best management maintenance practices. 6. Implement biological filtration methods. 7. Implement stormwater infrastructure that captures first flush runoff flows originating from areas zoned for industrial and / or commercial use 8. Continue to enforce the City's pesticide bylaw. 9. Continue to encourage the use of organic fertilizers.

Goal	Relevant Figures	Key Stakeholders	Recommendations
Goal No. 6 - Protect Groundwater Resources	J	Engineering Department Planning and Development Department	1. Implement wet weather infrastructure as part of capital works and development projects to promote groundwater infiltration. 2. Limit groundwater infiltration at locations with potential sub-surface contaminant sources. 3. Continue to require developers to observe maximum lot coverage and roof lead disconnection requirements.
Goal No. 7 - Maintain the Health of the Sunnyside Acres Urban Forest	E	Parks, Recreation, and Culture Department Sunnyside Acres Heritage Society	1. Continue to monitor for, and decommission, unauthorized trails. 2. Continue to address the root rot disease issue afflicting Douglas-fir trees. 3. Continue to educate the public on the forest's ecological importance.

3.6 Guidance for Infill and Small Developments

Due to the land use composition and ongoing development projects in the Study Area, it was predicted that small and infill residential properties will comprise the majority of long-term development permit applications. This type of development project is typically undertaken by residents and local developers who may not be aware of how development activities can impact the health of watersheds. This section of the report is intended to provide guidance on sustainable development by identifying required actions and best management practices (BMPs) that protect, maintain, and enhance watershed health.

Table Q summarizes the actions related to watershed health that must be completed before and during development.

Table R summarizes the BMPs that contribute to watershed health. These BMPs should be implemented and adhered to at all development sites; however, in situations where they prove to be unfeasible, alternatives BMPs should be sought.

Table Q Actions for Infill and Small Development Projects

Action	Applicable To	Tasks Involved	Objective
Protect riparian areas	Properties adjacent to natural watercourses and parks	• Do not place structures within prescribed "leave strip", typically 15 m for residential properties. • If a reduction in "leave strip" is desired, a site specific study must be prepared by a Registered Professional Biologist (RPBio) and submitted to the City for approval	The health and productivity of a riparian area can be significantly reduced due to the encroachment of structures limiting the area's ability to support natural watercourses by providing food, shade and shelter for aquatic species; bank stabilization; and water quality benefits
Prevent Erosion and Sedimentation	All properties in the Study Area	• Ensure that site discharge does not contain more than 75 mg/L of Total Suspended Solids (TSS) • Developers of sites less than 2,000 m^2 (1/2 Acre) should refer to the City's Erosion and Sediment Control on Small Construction Sites guide and implement BMPs (discussed below) • Developers of sites greater than 2,000 m^2 should refer to the City's Erosion and Sediment Control on Large Construction Sites guide and must submit an Erosion and Sediment Control Plan to the City for approval	Eroded soils can migrate from construction sites and deposit in natural watercourses. This sedimentation can significantly impact aquatic habitats
Protect Groundwater Resources	All properties in the Study Area	• Adhere to maximum lot coverage requirements contained in the City's Zoning By-Law • Do not connect roof downspouts to the City's storm sewer system or ditches. Discharge from downspouts should be dispersed across a permeable surface (e.g., lawn or garden)	Groundwater feeds creeks during extended periods of dry weather, contributing to the health of aquatic habitats by maintaining minimum creek flows. Impermeable areas (e.g. roofs, driveways) prevent the infiltration of rain water thereby limiting groundwater recharge and the availability of groundwater

Table R BMPs for Infill and Small Development Projects

BMP	Relevant Goals	Tasks Involved	Objective
Avoid Disturbing Riparian Areas	2 – Protect, Maintain, and Enhance Riparian Areas	• Plan construction activities such equipment and personnel do not enter riparian areas • Store materials a distance away from riparian areas • Install snow fencing to prevent access to riparian areas	Disturbance of a riparian area can damage existing plants thereby reducing the health of the area and potentially creating conditions that promote the introduction of invasive species
Manage Invasive Plant Species	2 – Protect, Maintain, and Enhance Riparian Areas	• Identify invasive species by referring to the ISCMV's List of Target Species • Remove invasive species using mechanical means • Dispose of removed invasive species properly (i.e., dry out, bag, and send to landfill rather than disposal through green waste program) • Reseed bare soil immediately after disturbance • Plant native species that establish quickly	Invasive plant species can affect the biodiversity of riparian areas by suppressing the native plants required to sustain aquatic species
Implement Erosion and Sedimentation Control (ESC) measures	3 – Address Erosion and Sedimentation Issues	• Protect nearby catchbasins with approved materials (e.g., filter fabric sock or donut) • Schedule regular road sweeping • Provide gravel access pads for vehicle access • Install perimeter control measures (e.g., silt fence, straw wattles) • Cover exposed soils with straw • Cover stockpiled materials with tarps or other impermeable materials • On-site water management during construction (e.g., interceptor ditches with check dams)	To reduce the quantity of eroded soils generated within the watershed to limit the effects of sedimentation on aquatic habitat

BMP	Relevant Goals	Tasks Involved	Objective
Promote Groundwater Infiltration and Bio-Retention	3 – Address Erosion and Sedimentation Issues 4 – Maintain Efficient Drainage 6 – Protect Groundwater Resources	• Install and maintain WWGI (including infiltration swales, bio swales, rain gardens, and permeable pavement). WWGI are discussed in Section 4.2.3 and summarized in Appendix 4. • Maintain a minimum topsoil depth of 450 mm in landscaped areas • Grade the property so that storm runoff flows to garden areas • Install a rain barrel(s) to capture roof runoff for re-use on landscaped areas	To reduce the volume of surface runoff that is conveyed to natural watercourses thereby reducing in-stream velocities and erosion potential as well as increasing the volume of infiltrated runoff and groundwater recharge

4. STAGE 3 - "HOW DO WE PUT THIS INTO ACTION?"

An Implementation Plan is required to assist the City in achieving the Vision for the Study Area.

The Implementation Plan presents and discusses the following components:

- **Initiatives**: projects that will address a specific issue;
- **Strategies**: techniques that can be applied to address issues throughout the watershed;
- **Long-range Opportunities**: potential solutions to issues that may be identified in the future through long-term monitoring; and
- **Monitoring Infrastructure**: infrastructure that will facilitate the monitoring framework discussed in Section 5.

The following sections discuss the components of the Implementation Plan including the estimated capital costs (where applicable), stakeholders, and priority associated with each activity. A summary of these components is provided in Appendix 4.

4.1 Initiatives

Initiatives are focused infrastructure that the City can implement at a specific site to address stormwater and environmental management issues to realize the Vision's Goals.

4.1.1 Initiative No. 1 - Reconfigure Hwy 99 Crossing

As discussed in Section 2.1.5, the Barbara Creek crossing of the Hwy 99 corridor, located northwest of the 32 Ave. Diversion does not appear to be configured such that it will maintain a link between Barbara Creek downstream of Hwy 99 and the wetland located west of Hwy 99. The crossing consists of a 900 mm circular culvert (with an invert elevation of 32.05 m) to convey base flows to the creek and a 1,500 mm box culvert (with an invert elevation of 31.45 m) to convey high flows to a storm sewer along 150 St. The two culverts were designed to be separated by a lock block weir to control the separation of flows; however, the weir has been compromised and its crest is lower than the invert of the base flow culvert, as shown in Photo Q.

Photo Q Existing Lock Block Weir

Consequently, base flows are being routed away from the creek resulting in ephemeral flows downstream, creating a barrier to fish passage, as shown in Photo R.

Photo R Downstream End of Hwy 99 Culvert

Reconfiguration of this crossing is required in order to eliminate the barrier to fish passage and restore creek base flows immediately downstream of the Hwy 99 crossing. The City should consider installing a bio-engineered weir structure similar to the detail shown in Figure 1, Appendix 4. This style of weir utilizes natural materials and does not require extensive maintenance. It will also create a small pool at the upstream end of the base flow culvert that will allow fish to rest during migration and facilitate access to an upstream wetlands area.

To satisfy the requirements of Section 9 of the BC Water Act, the City will likely have to apply for an Approval from the Ministry of Forests, Lands, and Natural Resource Operations to implement the weir as it involves an alteration to the flow pattern of a natural watercourse. This portion of the creek has an "A" classification (i.e., it has the potential to be inhabited by salmonids year round). Consequently, the construction period for the weir may be limited to the months of August and September.

A summary of the considerations related to reconfiguring the Hwy 99 crossing is provided in Table S

Table S Summary of Initiative No. 1 - Reconfigure Hwy 99 Crossing

Consideration	Details
Goals Addressed	Nos.1 and 4
Estimated Costs	$25,000 to $30,000
Stakeholders	Engineering Department, DFO, Ministry of Forests, Lands, and Natural Resource Operations
Relevant Documents and Regulations	Engineering Design Criteria Manual (Surrey 2005), Federal Fisheries Act (2012), BC Water Act (Approval)
Priority	High
Recommended Schedule	Construct by September 2015

4.1.2 Initiative No. 2 - 152 St. Storm Sewer

As discussed in Section 2.4, the Model results indicate that the storm sewer located on the west side of 152 St., south of King George Boulevard (Blvd.), will surcharge during the 5-year high intensity storm. This could result in approximately 1,500 m^3 of stormwater being discharged from the sewer.
It is unlikely that this would threaten any residential properties as this portion of 152 St. was built with concrete gutters that would convey the flow downhill to the north; however, this could adversely affect driving conditions on 152 St. and King George Blvd., both of which are major arterial roads. During extreme storm events, flooding of these roads could impede the safe passage of emergency vehicles and personnel. The City should implement one of the following options.

Option No. 1 - Reconfigure the Storm Sewer

To mitigate the potential risk of flooding, the City could reconfigure the existing storm sewer located southwest of the 152 St. and King George Blvd. intersection. This would involve the installation of approximately 120 m of 750 mm dia. and 30 m of 600 mm dia. concrete sewer mains and two 1,050 mm dia. concrete manholes, as shown in Figure 2, Appendix 4. The Model results indicate that this new configuration would mitigate the potential flooding concerns on 152 St.

A summary of the considerations related to reconfiguring the storm sewer is provided in Table T.

Table T Summary of Initiative No. 2 - 152 St. Storm Sewer Option No. 1

Consideration	Details
Goals Addressed	No. 4
Estimated Costs	$110,000 to $120,000
Stakeholders	Engineering Department
Relevant Documents and Regulations	Engineering Design Criteria Manual
Priority	Moderate
Recommended Schedule	Construct by 2018

Option No. 2 - Secure the Manhole Covers

As an alternative, the City could secure manholes along the 152 St. storm sewer alignment, as shown in Figure 3, Appendix 4. This would involve the replacement of four existing manhole frames and covers with sealable manhole frames and covers. Although this would still allow water to discharge through catch basins, it should significantly reduce the volume of water discharged from the sewer thereby reducing the potential road safety concern.

A summary of the considerations related to securing the manhole covers is provided in Table U.

Table U Summary of Initiative No. 2 - 152 St. Storm Sewer Option No. 2

Consideration	Details
Goals Addressed	No. 4
Estimated Costs	$10,000 to $12,000
Stakeholders	Engineering Department
Relevant Documents and Regulations	Engineering Design Criteria Manual (Surrey 2005)
Priority	Moderate
Recommended Schedule	Construct by 2018

4.1.3 Initiative No. 3 - Elgin Creek Groundwater Pumping System

A groundwater pumping system was implemented to provide consistent base flows to the lower reaches of Elgin Creek during periods of dry weather. Volunteer groups have historically maintained fish populations with approximate base flows of 7.6 L/s. The pump system is designed to provide 18 L/s of supplemental flows in the headwaters of the creek, near Softball City. Due to potential infiltration losses, this should yield creek flows of approximately 8 L/s at the Crescent Rd. crossing of Elgin Creek.

At present, this system is operating without being connected to the City's supervisory control and data acquisition (SCADA) system. Consequently, it is difficult to assess the system's performance, specifically whether its operating cycle coincides with downstream low flow conditions.

To better realize the potential benefits of the pumping system (i.e., maintaining year-round base flows will enhance the downstream aquatic habitat) the City should connect the pump to its SCADA system. This would allow the City to synchronize the pump with the flow gauge located at 32 Ave. so that the pump only operates during periods of low flow. This would also facilitate an assessment of the overall system performance, including confirmation that the pump operates at the appropriate flow rate.

A summary of the considerations relating to connecting the Elgin Creek groundwater pumping system to the City's SCADA system is provided in Table V and in Figure 4, Appendix 4.

Table V Summary of Initiative No. 3 - Elgin Creek Groundwater Pumping System

Consideration	Details
Goals Addressed	Nos. 1 and 6
Estimated Costs	$10,000 to $12,000
Stakeholders	Engineering Department
Priority	Moderate
Recommended Schedule	Connect by 2018

4.2 Strategies

Strategies are comprised of a set of tools and techniques that the City can implement throughout the Study Area to address stormwater and environmental management issues to achieve the Vision's Goals.

4.2.1 Strategy No. 1 - Control and Manage Chemical Usage and Disposal

Chemicals used in commercial and industrial operations can, due to inadequate containment or improper disposal, be conveyed to natural watercourses through storm sewers. This can result in the degradation of aquatic habitat due to the harmful chemical compounds they contain.

The City should identify commercial and industrial operators whose practices could result in the release of contaminants into the storm sewer and work with them to develop and implement BMPs such that chemicals and other waste products do not enter the storm sewer system.

Similarly, pesticides, applied on properties in the watersheds, can migrate into the creeks and degrade aquatic habitat. The City should continue to monitor the usage of pesticides on City owned and private properties and enforce the limited use of pesticides per Bylaw No. 17160.

A summary of the considerations related to controlling and managing chemical usage and disposal is provided in Table W and in Figure 5, Appendix 4.

Table W Summary of Strategy No. 1 - Control and Manage Chemical Usage and Disposal

Consideration	Details
Goals Addressed	Nos. 1 and 5
Stakeholders	Engineering Department, Bylaw Enforcement Division, Parks, Recreation, and Culture Department, Industrial and Commercial Operators, Property Owners
Relevant Documents	Bylaw No. 17160
Priority	Very High
Recommended Schedule	Ongoing

4.2.2 Strategy No. 2 - Manage Non-point Source Contaminants

The management of non-point source contaminants can greatly improve downstream water quality and can be achieved by following operation and maintenance-related BMPs. Non-point sources can be categorized as follows:

- Roads and Boulevards - contaminants, including heavy metals as well as construction and maintenance waste products, can accumulate on roads and on paved boulevards and be transported to creeks via storm sewer infrastructure during storm events;
- Municipal Utilities - contaminants can be introduced into storm sewers through runoff, wastewater cross-connections, and illicit discharge; and
- Waste Management - solid waste includes everything from small pieces of litter to illegally dumped large household items.

The City should review its current operation and maintenance practices and consider whether changes are required in order to follow the BMPs identified in Table X.

Table X Best Management Practices for Managing Non-point Source Contaminants

Category	Practice	Considerations	Stakeholders
Roads and Boulevards	Street Sweeping	• Curbed streets should be swept regularly, typically once a month for curbed streets and possibly more frequently for high traffic and industrial areas. • Use dry cleaning methods (avoiding wet cleaning and flushing). • Keep accurate logs of street sweeping activities.	Engineering Department
	Painting	• Follow safe paint handling procedures (e.g., do not transfer or load paint near catch basins - store and dispose of paint products per manufacturer's specifications). • Line painting should be scheduled for dry weather periods. • Bridge painting procedures should include plugging or covering nearby catch basins, provisions for capturing materials for structures over creeks (e.g., suspended netting or tarps), capture and dispose of clean-up water.	Engineering Department Contractors
	Construction and Repairs	• Construction and Repair works should be scheduled for dry weather periods. • Protect nearby catch basins and ditches with silt fences, filter fabric, or other catch basin inserts. • Store construction and repair materials to limit the possibility of distribution by wind or runoff. • Wash equipment off-site or in designated and contained areas. • Streets should be cleaned by a street sweeper or vacuum truck and the job site should be thoroughly cleaned following the completion of the works or as needed.	Engineering Department Contractors Developers
	Ice and Snow Management	• Spreading equipment should be routinely calibrated to prevent over-application of de-icing salt and sand, particularly near creek crossings. • Consider using alternative de-icing and anti-icing agents to mitigate in-stream chloride load.	Engineering Department
	Sidewalk Cleaning	• Sweep, collect, and dispose of debris prior to washing sidewalks. • Direct wash water towards landscaped areas.	Residents Businesses Facility Operators

Category	Practice	Considerations	Stakeholders
Roads and Boulevards (continued)	Graffiti Removal	• Graffiti removal should be scheduled for dry weather periods. • If a cleaning solution is not used, direct wash water into a landscaped area. • If a cleaning solution is used, plug nearby catch basins and dispose of wash water off-site or in the sanitary sewer. • Consider using a waterless and non-toxic chemical cleaning method.	Engineering Department Facility Operators
Drainage Infrastructure	Cleaning	• Remove sediments and debris from catch basins and mains in areas with high contaminant loads prior to the fall. • Clean catch basin sumps so that accumulations do not exceed 40% of the sump capacity. • Maintain logs of cleaning activities, including amount of waste collected and inspection reports, to identify problem areas. • Develop a flushing schedule for mains with sediment problems and capture flushed effluent for disposal to the sanitary sewer. • Clean trash racks prior to the fall and during the periods of wet weather.	
	Illegal / Illicit Discharge	• During maintenance or inspection activities, note evidence of discharge containing chemicals or having an odour. • Investigate potential discharge points (e.g., smoke tests and dye testing) to identify discharge source (e.g., cross-connections and disposal via catch basins). • Require elimination of illegal / illicit discharge by owner and/or operator.	Engineering Department Bylaw Enforcement Residents Businesses
	Stenciling	• Stencil catch basins to indicate that collected runoff discharges to fish bearing creeks.	Engineering Department Volunteers
Waste Management	Illegal Dumping	• Maintain a log of known illegal dumping hot spots including frequency, type, and quantity of materials, and modes of dumping. • Regularly inspect and clean hot spots. • Post no dumping of waste signs at hot spots.	Engineering Department Bylaw Enforcement Division
	Litter	• Install litter receptacles in areas where large quantities of litter are frequently observed.	Engineering Department Parks, Recreation, and Culture Department

Notes:

(1)Best Management Practices derived from California Stormwater BMP Handbook – Municipal (January 2003)

A summary of the considerations related to managing non-point source contaminants is provided in Table Y and in Figure 6, Appendix 4.

Table Y Summary of Strategy No. 2 - Manage Non-point Source Contaminants

Consideration	Details
Goals Addressed	Nos. 1 and 5
Stakeholders	Engineering Department, Contractors, Residents, Businesses Parks, Recreation, and Culture Department
Relevant Documents	California Stormwater BMP Handbook - Municipal
Priority	Very High
Recommended Schedule	Review current practices by 2014

4.2.3 Strategy No. 3 - Implement Wet Weather Green Infrastructure

The implementation of Wet Weather Green Infrastructure (WWGI) can provide the following benefits that would improve overall health of the Elgin, Barbara, and Anderson watersheds:

- Reduction of the volume of runoff entering the creeks during storm events resulting in reduced peak creek flow volumes and velocities;
- Groundwater recharge for WWGI that facilitates stormwater infiltration resulting in increased base flows fed from groundwater; and
- Aesthetic improvements and enhanced nature appreciation in the case of rain gardens and bioswales.

As discussed in Section 0, the public prefers that the City selects bioswales and rain gardens for implementation in neighbourhood settings. The City may also consider implementing permeable pavement as part of capital projects involving its parks and civic facilities.

A summary of the considerations related to implementing WWGI is provided in Table Z and in Figures 7, 8, and 9, Appendix 4.

Table Z Summary of Strategy No. 3 - Implement Wet Weather Green Infrastructure

Consideration	Details
Goals Addressed	Nos. 1, 3, 4, and 6
Estimated Costs	Variable
Stakeholders	Engineering Department, Planning and Development Department, Developers
Relevant Documents	Engineering Design Criteria Manual, Stormwater Source Control Design Guidelines (Greater Vancouver Sewerage & Drainage District 2012)
Priority	High
Recommended Schedule	Ongoing

The City and developers should implement the following options if they suit the desired application and outcomes. The options are summarized in Table AA.

Option No. 1 - Bioswales

Bioswales are vegetated open channels that facilitate the infiltration, filtration, attenuation, and some bio-retention of stormwater runoff while still being capable of conveying large runoff flows resulting from extreme storm events. Bioswales are one of the most diverse forms of WWGI as they can be implemented to manage stormwater runoff in the following settings and contexts:

- New developments;
- Existing road corridors;
- Ditch in-fill;
- Parks and green spaces; and
- At the periphery of parking lots.

Bioswales can provide aesthetic appeal, occupy a small footprint, and can be maintained relatively easily. They can be implemented over soils with low infiltration capabilities with the inclusion of an infiltration trench and connection to the storm sewer for high flow relief. Bioswales can be planted with grass or other hardy, native plant species and can service a large area (typically 100 times the surface area of the bioswale).

Bioswales are susceptible to aesthetic damage due to human activity (e.g., wheel ruts and foot traffic), particularly when the underlying soils are saturated.

A typical bioswale cross section is shown in Figure 5, Appendix 4.

Option No. 2 - Rain Gardens

Rain gardens are vegetated spaces that facilitate bio-retention, infiltration, filtration, and attenuation of stormwater runoff. Rain gardens are typically designed to retain runoff from small storm events. Curb planters are a specific type of rain garden installed adjacent to roadways that can retain runoff from small storm events and also convey runoff flows resulting from larger storm events. Rain gardens can be implemented to manage stormwater runoff in the following settings:

- Aesthetic features of new developments;
- Existing road corridors;
- Private properties; and
- Large civic and commercial facilities.

Rain gardens can serve as attractive and prominent landscaping features and can reduce maintenance costs compared to traditional landscaping as less irrigation is required. Similar to bioswales, they can be implemented over soils with low infiltration capabilities with the inclusion of a drain system connected to the storm sewer.

Rain gardens require a larger footprint than bioswales, service a smaller area comparative to bioswales, and can be more difficult to maintain. To limit the possibility of contamination, care must be taken so that the bottom of the rain garden soils does not coincide with the top of the groundwater table.

The rain garden located at the South Surrey Recreation Centre is shown in Figure 6, Appendix 4.

Option No. 3 - Permeable Pavement

Permeable pavement consists of a pervious hard surface (i.e., a surface that permits the transmission of water while being of sufficient strength to accommodate vehicular movement) that facilitates infiltration and filtration of stormwater runoff. Although the results of the public consultation indicate that permeable pavement is not the preferred choice for implementation in a neighbourhood context, this WWGI can be implemented to reduce a property's effective impervious area, and is particularly suited for large parking lots.

Unlike bioswales and rain gardens, permeable pavement cannot manage stormwater runoff from adjacent impervious surfaces requiring the implementation of additional infrastructure to collect and convey runoff. The cost to implement permeable pavement can be prohibitive, at as much as three times the cost of traditional paved surfaces, with correspondingly higher maintenance costs. Stormwater runoff containing surface contaminants (e.g., motor oil) can potentially infiltrate into the groundwater table through permeable pavements, bypassing on-site oil interception devices.

WWGI Selection

The selection of WWGI will depend on the desired application (i.e., a combination of the location, context, soil conditions, and desired outcomes associated with implementation of a WWGI).

Table BB indicates which options are suitable for a variety of applications. As discussed in Section 2.1.6, WWGI should not be implemented at locations with potential sub-surface contaminant sources.

Table AA Summary of WWGI Options

Option	Benefits	Potential Issues	Estimated Installation Costs (1)	Estimated Cost per Area Served
Bioswale (with infiltration trench)	Moderate Infiltration Moderate Filtration Low Attenuation Low Bioretention Moderate Aesthetic Appeal Small footprint Large Service Area Low Maintenance	Prone to aesthetic damage caused by vehicular and pedestrian traffic	\$90 to \$100 per m^2	\$9 to \$10 per m^2 based on a surface area ratio of 1:10
Rain Garden (with drain system)	High Infiltration High Filtration Moderate Attenuation High Bioretention High Aesthetic Appeal Moderate Service Area	Moderate Maintenance Possibility of groundwater contamination	\$300 to \$400	\$20 to \$27 per m^2 based on a surface area ratio of 1:15
Permeable Pavement	High Infiltration Moderate Filtration	High Maintenance Possibility of groundwater contamination Small Service Area	\$100 to \$120 per m^2	\$100 to \$120 per m^2 based on a surface area ratio of 1:1

Notes:

(1)Capital cost estimates used were provided in the Assessment of Life Cycle Costs for Low Impact Development Stormwater Management Practices report (Toronto and Region Conservation and University of Toronto 2013)

Table BB WWGI Applications

Application	Bioswale	Bioswale with Infiltration Trench	Rain Garden	Rain Garden with Drain System	Permeable Pavement
Local Roadway (Group C or D Soils)	No	Yes	No	Yes, as curb planter	No
Local Roadway (Group A or B Soils)	Yes	Yes	Yes, as curb planter	Yes, as curb planter	No
Site Drainage	Yes	Yes	No	No	No
Reduction in Site Runoff	Yes	Yes	Yes	Yes	Yes
Parking Lots	Yes	Yes	Yes	Yes	Yes

4.2.4 Strategy No. 4 - Raise Public Awareness of Riparian Areas

The anthropogenic activities of the public (e.g., over fertilizing, unauthorized refuse dumping, and encroachment into riparian areas) can adversely impact the overall health of the watersheds in the Study Area. This is commonly due to a lack of understanding as to the importance of specific aspects of the watershed, their interrelationship, and the consequences of harmful activities.

Increasing public awareness can reduce the occurrence of harmful activities and increase the effectiveness of enforcement programs. This process can be broken down into the following categories:

- Riparian Areas;
- Invasive Plants (discussed in Section 4.2.5); and
- Pesticide Usage.

The City should develop online or print material that informs the public of the importance of riparian areas and how they contribute to the health of watersheds (e.g., supply aquatic habitat with food and organic material, provision of shade, cover, habitat for aquatic species, and stabilization of bank materials) and what the public can do to protect them (e.g., avoid dumping refuse, creating unauthorized trails, and containing invasive plants).

A summary of the considerations related to raising the public's awareness of riparian areas is provided in Table CC and in Figure 10, Appendix 4.

Table CC Summary of Strategy No. 4 - Raise Public Awareness of Riparian Areas

Consideration	Details
Goals Addressed	Nos. 1 and 2
Stakeholders	Engineering Department, Parks, Recreation, and Culture Department
Relevant Documents	Riparian Area Regulations (BC MoE 2004)
Priority	High
Recommended Schedule	Ongoing

4.2.5 Strategy No. 5 - Control and Manage Invasive Plants

As discussed in Section 2.5, the presence of invasive plants can affect the biodiversity of riparian areas by suppressing the native plants required to sustain aquatic species. The Vegetation Management Strategy (Surrey 2002) recommends that the spread of invasive plants be controlled using the following methods:

- **Prevention**: including early detection and containment of invasive plants; and
- **Suppression**: including the removal of invasive plants by physical, chemical, and biological means in addition to prescribed burning.

The City should implement some or all of the BMPs summarized in Table DD.

Table DD Best Management Practices for Controlling and Managing Invasive Plants

Category	Practice / Initiative	Description	Stakeholder(s)
Prevention - Detection	List of Invasive Plant Species	Adopt the Invasive Species Council of Metro Vancouver's (ISCMV's) list of target species including profiles for each species which include photos, descriptions, impacts, and recommended control methods.	Engineering Department Parks, Recreation, and Culture Department
Prevention - Detection	Raise Public Awareness	The following practices can facilitate the early detection of invasive plant species: • Provide a link to the target species profiles on the City's invasive plants website so that is easily accessible by the public; • Provide clear procedures for reporting the locations of invasive plants on the City's website; • Provide relevant target species profiles to contractors and developers prior to the start of construction near riparian areas; and • Post signs at trailheads within the Sunnyside Acres Urban Forest that inform trail users of invasive plants in the area and request that the locations of invasive plants are reported.	Engineering Department Parks, Recreation, and Culture Department Sunnyside Acres Heritage Society
Prevention - Detection	Inspect Riparian Area	The City should consider undertaking periodic inspections of creek corridors areas for the presence of invasive plants. This could coincide with the bi-annual ravine assessments.	Engineering Department
Prevention - Containment	Control Site Disturbance near Riparian Areas	The following practices can limit the spread and establishment of invasive plants at construction sites near riparian areas: • Treat all on-site invasive plants prior to commencing construction; • Clean equipment and machinery thoroughly prior to demobilizing from the site; • Where practical, reseed bare soil immediately after disturbance; • Fill material must originate from invasive plant-free locations; and • Use straw or hay for erosion control that has been certified invasive plant-free.	Engineering Department Parks, Recreation, and Culture Department Developers Contractors

Category	Practice / Initiative	Description	Stakeholder(s)
Prevention - Containment	Encourage Responsible Residential Gardening	The following practices can limit the spread and establishment of invasive plants at residential properties: • Distribute the City's existing Invasive Plants Brochure (2013) and Yardwaste Brochure (2013) pamphlets to the public; and • Encourage the public to remove invasive species on their property and dispose of them properly (i.e., dry out, bag, and landfill rather than disposal through green waste program or in park areas).	Engineering Department Parks, Recreation, and Culture Department Residents
Suppression	Removal	The following practices can be used to effectively remove invasive plants from City properties: • Assess whether removal would result in loss of wildlife habitat or other negative consequences; • Use physical or mechanical means to remove invasive plants; • Use herbicide to remove invasive plants only when physical means would be impractical; • Dispose of removed plants properly; and • Continue to encourage residents to volunteer to remove invasive plants.	Engineering Department Parks, Recreation, and Culture Department
Suppression	Plant Native Species	Planting native species that will establish quickly at disturbed sites will prevent the spread of invasive plants.	Engineering Department Parks, Recreation, and Culture Department

A summary of the considerations related to controlling and managing invasive plants is provided in Table EE and in Figure 11, Appendix 4.

Table EE Summary of Strategy No. 5 - Control and Manage Invasive Plants

Consideration	Details
Goals Addressed	Nos. 1 and 2
Stakeholders	Engineering Department, Sunnyside Acres Heritage Society, ISCMV, Parks, Recreation, and Culture Department, Residents, Contractors, Developers
Relevant Documents	Invasive Plant Brochure (Surrey 2013), Yardwaste Brochure (Surrey 2013), Vegetation Management Strategy (Surrey 2002)
Priority	High
Recommended Schedule	Within two years

4.2.6 Strategy No. 6 - Review Capital and Development Projects

Capital and development projects represent opportunities to integrate sustainable stormwater management and improve watershed health. The City should continue to review capital projects at the conceptual stage and development projects at the application stage for the following opportunities:

- Removal of barriers to fish passage;
- Implementation of WWGI;
- Implementation of channel complexing techniques; and
- Installation of culverts with provisions for fish passage.

Capital and development projects can also adversely impact the health of the watersheds due to poor site erosion, sediment control, and damage caused to riparian areas. The City should continue to review capital and development projects for compliance with the following requirements:

- Adherence to leave strips from riparian areas;
- Submission of and adherence to erosion and sediment control plans; and
- Adherence to maximum lot coverage requirements.

A summary of the considerations related to reviewing capital and development projects is provided in Table FF and in Figure 12, Appendix 4.

Table FF Summary of Strategy No. 6 - Review Capital and Development Projects

Consideration	Details
Goals Addressed	Nos.1, 2, 3, 4, and 6
Stakeholders	Engineering Department, Planning and Development Department, Parks, Recreation, and Culture Department
Relevant Documents	Engineering Design Criteria Manual, Official Community Plan (2013), Best Management Practices Guide for Stormwater (Metro Vancouver 1999);
Priority	High
Recommended Schedule	Ongoing

4.2.7 Strategy No. 7 - Protect the Sunnyside Acres Urban Forest

The Sunnyside Acres Urban Forest (the Forest) accounts for approximately 16% of the Study Area and is located in the headwaters of the Elgin and Anderson Creeks. It represents a significant portion of the riparian habitat that contributes nutrients to the creeks and enables groundwater recharge via the infiltration of rainwater through its permeable ground surface. The Forest is currently threatened by anthropogenic activities (e.g., creation and use of unauthorized trails and dumping of refuse) and by root rot disease.

As discussed in Section 2.7, the Forest is managed by the City's Parks, Recreation, and Culture Department in accordance with the Sunnyside Acres Urban Forest Access and Recreation Management Plan (2002). The City should continue to manage the Forest pursuant with the Plan's recommendations:

- Decommission unauthorized trails throughout the Forest;
- Install "no dumping of waste" signs around the perimeter of the Forest;
- Educate the public on the Forest's ecological importance; and
- Create a containment belt around trees afflicted with root rot.

The City should monitor the extent of the root rot disease and consider allocating additional resources if the number of afflicted trees increases significantly.

A summary of the considerations related to protecting the Sunnyside Acres Urban Forest is provided in Table GG and in Figure 12, Appendix 4.

Table GG Summary of Strategy No. 7 - Protect the Sunnyside Acres Urban Forest

Consideration	Details
Goals Addressed	No. 7
Stakeholders	Parks, Recreation, and Culture Department supported by the Sunnyside Acres Heritage Society
Relevant Documents	Sunnyside Acres Urban Forest Access and Recreation Management Plan (2002)
Priority	High
Recommended Schedule	Ongoing

4.3 Long-range Opportunities

Long range opportunities are comprised of a set of initiatives and strategies that may be implemented to address issues identified during long-term monitoring.

4.3.1 Long-range Opportunity No. 1 - Bank Stabilization

As discussed in Section 2.3, there are a number of locations in the Study Area that are either currently experiencing bank instability or are at risk of bank instability due to potentially high flow velocities predicted by the Model. The City should continue to monitor the condition of these locations through periodic ravine assessment studies. In order to determine whether bank stabilization is required at a particular location, the City should consider utilizing the methodology described below for identifying remediation priorities.

Prioritization System

The City should consider using a scoring system to prioritize the remediation of each bank instability location identified in the ravine assessment studies. An example of a prioritization system was developed to identify the high priority sites for bank stabilization, taking into account the results of ravine assessments and model predictions, is provided in Table HH.

Table HH Bank Instability Prioritization System Example

Criteria	Description	Range (Score)
Consequence	The potential for damage to existing structures if the bank instability worsens	• High: Residences (60) • Medium: Secondary Structures (30) • Low: No Structures (0)
Probability	The probability, based on visual assessment, that the bank instability will worsen over the next two years	• High (10) • Medium (5) • Low (0)
Visual Change	Whether a visual change was noted from the previous ravine assessment or a new location	• Yes (10) • No (0)
Predicted Peak Velocity	The peak flow velocities results for the 2-, 5-, and 100- year storm events predicted by the Model (scored out of 20)	• 2-Year < 1.0 m/s (0) • 2-Year > 1.0 m/s (4) • 5-Year > 1.5 m/s (6) • 100-Year > 2.0 m/s (10)

Each location should be prioritized based on its score:

- Very High (>80): this site should be reviewed by a qualified Geotechnical Engineer and, if required, should be remediated as a priority;
- High (60 to 79): this site should be reviewed by a qualified Geotechnical Engineer and, if required, should be remediated within the next one to two years;
- Moderate (30 to 59): this site should continue to be monitored and should be considered for remediation if work occurs nearby; and
- Low (<30): this site should be revisited during the next ravine assessment, no other action is required.

The prioritization of the bank instability locations identified in the 2011 ravine assessments are presented in Table II.

Based on this example prioritization system, the locations of potential bank instability are considered low to moderate priority for remediation at this time. The prioritization should be updated following future ravine assessments to identify which, if any, areas of instability should be considered priority for stabilization. The intent of the prioritization system presented is to supplement the results of the ravine assessment, with the addition of predicted flow velocities at the areas of potential instability.
No conclusion on bank stability should be construed from the prioritization presented in Table II and the reader should refer to the current ravine stability report for details on the stability of each location. Prior to remediation, an inspection should be undertaken by a qualified geotechnical engineer.

Table II Bank Instability Remediation Priority (Ranking System Only - Not To Be Relied Upon for Determination of Bank Stability)

Bank Instability Location	Ravine Stability Report Results [(1)]			SWMM Model Results			Score
	Consequence	Probability	Visual Change	2-Year Predicted Velocity (m/s)	5-Year Predicted Peak Velocity (m/s)	100-Year Predicted Peak Velocity (m/s)	
E-01	Low	Low	Yes	1.60	1.63	1.68	20
E-02	Low	Low	Yes	1.60	1.63	1.68	20
E-03	Low	Low	Yes	2.08	2.53	2.97	30
E-04	Low	Low	No	1.37	1.70	1.92	10
E-05	Low	Low	Yes	1.37	1.70	1.92	20
E-06	Low	Low	Yes	1.37	1.70	1.92	20
E-07	Medium	Medium	No	0.86	1.01	1.01	35
E-08	Medium	Medium	Yes	0.86	1.01	1.01	45
E-09	Low	Low	Yes	1.88	2.29	2.88	30
E-10	Low	Low	No	2.04	2.46	3.09	20
E-11	Low	Low	No	2.42	2.85	3.50	20
A-01	Low	Low	Yes	0.91	1.01	1.22	10
A-02	Low	Medium	Yes	1.31	1.53	1.91	30
A-03	Low	Medium	Yes	1.31	1.53	1.91	30
A-04	Low	Low	Yes	1.31	1.53	1.91	20
A-05	Low	Low	Yes	1.31	1.53	1.91	20
A-06	Low	Low	No	1.31	1.53	1.91	10
A-07	Low	Low	Yes	1.31	1.53	1.91	20
A-08	Low	Low	Yes	1.00	1.12	1.28	14

Bank Instability Location	Ravine Stability Report Results [1]			SWMM Model Results			Score
	Consequence	Probability	Visual Change	2-Year Predicted Velocity (m/s)	5-Year Predicted Peak Velocity (m/s)	100-Year Predicted Peak Velocity (m/s)	
A-09	Low	Low	Yes	1.00	1.12	1.28	14
B-01	Low	Low	Yes	1.23	1.64	2.05	30
B-02	Low	Low	Yes	1.23	1.64	2.05	30
B-03	Low	Medium	Yes	1.23	1.64	2.05	35
B-04	Low	Low	Yes	1.23	1.64	2.05	30
B-05	Low	Medium	Yes	1.23	1.64	2.05	35
B-06	Low	Low	Yes	1.23	1.64	2.05	30
B-07	Low	Low	Yes	1.23	1.64	2.05	30
B-08	Low	Low	Yes	1.48	1.95	2.40	30
B-09	Low	Low	No	1.48	1.95	2.40	20
B-10	Low	Low	Yes	1.48	1.95	2.40	30
B-11	Low	Low	Yes	1.19	1.21	1.29	14
B-12	Low	Low	Yes	1.19	1.21	1.29	14
B-13	Low	Low	Yes	1.19	1.21	1.29	14

Notes:

[1]Ravine Assessment Report (Web Engineering 2011)

At locations where bank stabilization is required, the City should implement bio-engineered solutions (e.g., green retaining walls, live staking, terracing).

A summary of the considerations related to implementing bank stabilization is provided in Table JJ and in Figure 13, Appendix 4.

Table JJ Summary of Long-range Opportunity No. 1 - Bank Stabilization

Consideration	Details
Goals Addressed	Nos. 1 and 3
Stakeholders	Engineering Department
Relevant Documents	Engineering Design Criteria Manual
Priority	High
Monitoring Schedule	Two years or as required

4.3.2 Long-range Opportunity No. 2 - First Flush Capture

Extended periods of dry weather can cause the surface buildup of heavy metals and chemical compounds. This can result in a first flush (i.e., the result of a storm that generates sufficient runoff to transport all or most of these built-up contaminants) discharging runoff flows to the creeks containing contaminants that are harmful to aquatic species.

The upper portion of the Barbara Creek watershed is composed of properties that are largely impervious on which the first flush effect is more pronounced (e.g., industrial, commercial, institutional, cemetery land uses). It is possible that capturing the first flush from this area could improve downstream water quality and fish habitat conditions. The City should establish a sampling station at the storm sewer outfall to Barbara Creek at the 32 Ave. Diversion to monitor the first flush effect and determine whether capturing first flush flows could improve downstream aquatic habitat conditions.

A summary of the considerations related to assessing the possibility of capturing first flush flows at Barbara Creek is provided in Table KK and in Figure 14, Appendix 4.

Table KK Summary of Long-range Opportunity No. 2 - First Flush Capture Assessment

Consideration	Details
Goals Addressed	Nos. 1 and 5
Stakeholders	Engineering Department
Priority	Low
Monitoring Schedule	Baseline conditions and during first flush storm

4.3.3 Long-range Opportunity No. 3 - Flood Protection

The 200-year water level in the Nicomekl River is predicted to increase to 3.1 m by the year 2100. This could result in the extension of the floodplain and lead to flooding of private properties adjacent to the River. To prepare for this, the City should consider the long-term implementation of flood control infrastructure including diking along the River and floodboxes at the confluences of the River and the creeks.

A summary of the considerations related to implementing flood protection along the Nicomekl River is provided in Table LL and in Figure 14, Appendix 4.

Table LL Summary of Long-range Opportunity No. 3 - Flood Protection

Consideration	Details
Goals Addressed	No. 4
Stakeholders	Engineering Department, BC MoE
Relevant Documents	Drainage, Ditch, and Dike Act
Priority	Low
Monitoring Schedule	Review sea level rise projection reports as they become available

4.4 Monitoring Infrastructure

Monitoring infrastructure will facilitate the monitoring framework discussed in Section 5.

4.4.1 Monitoring Infrastructure No. 1 - Creek Flow Gauges

A monitoring framework will require accurate flow records for all three creeks. These records will facilitate the City's identification of changes in flow patterns which may result from the implementation of strategies and initiatives. This will be discussed further in Section 5.1.4.

The implementation of creek flow gauges is discussed in the subsequent sections.

Proposed Anderson Creek Gauge

The City should install a level gauge downstream of the Winter Crescent culvert crossing. This gauge would be similar to the Elgin Creek level gauge and would be connected to the City's SCADA system. The recommended location would be representative of the majority of the catchment and is located on City-owned land; however, some additional work may be required to improve its accessibility.

A summary of the considerations related to installing a gauge at Anderson Creek is provided in Table MM.

Table MM Summary of Proposed Anderson Creek Gauge

Consideration	Details
Stakeholders	Engineering Department
Estimated Total Costs	$20,000 to $25,000
Priority	Moderate
Recommended Schedule	2018

Proposed Barbara Creek Gauge

The City should install a level gauge downstream of the 34 Ave. bridge crossing. This gauge would be similar to the Elgin Creek level gauge and would be connected to the City's SCADA system. The recommended location is accessible and would be representative of the majority of the catchment and is located on City-owned land.

A summary of the considerations related to installing a gauge at Barbara Creek is provided in Table NN.

Table NN Summary of Proposed Barbara Creek Gauge

Consideration	Details
Stakeholders	Engineering Department
Estimated Total Costs	$20,000 to $25,000
Priority	Moderate
Recommended Schedule	2018

4.4.2 Monitoring Infrastructure No. 2 - Water Quality Monitoring

A monitoring framework requires a water quality sampling program; this will enable changes in water quality, which may result from the implementation of strategies and initiatives, to be identified. The program could also assist in the identification of potential sources of contamination. This will be discussed further in Section 5.1.3.

The City should institute a sampling program to test water quality at strategic locations in the watersheds. This program would involve periodic measurement of the following water quality parameters:

- Temperature;
- Dissolved oxygen;
- pH;

- Conductivity;
- Turbidity;
- E.coli;
- Fecal coliforms;
- Nitrate;
- Total Iron;
- Total Cadmium;
- Total Copper;
- Total Lead; and
- Total Zinc.

This would require the establishment of water sampling stations on Anderson Creek and Barbara Creek to supplement the existing sampling station located on Elgin Creek, upstream of Crescent Rd.

A summary of the considerations related to establishing a water quality monitoring program is provided in Table OO.

Table OO - Summary of Water Quality Monitoring

Consideration	Details
Stakeholders	Engineering Department
Priority	Moderate
Recommended Schedule	2018

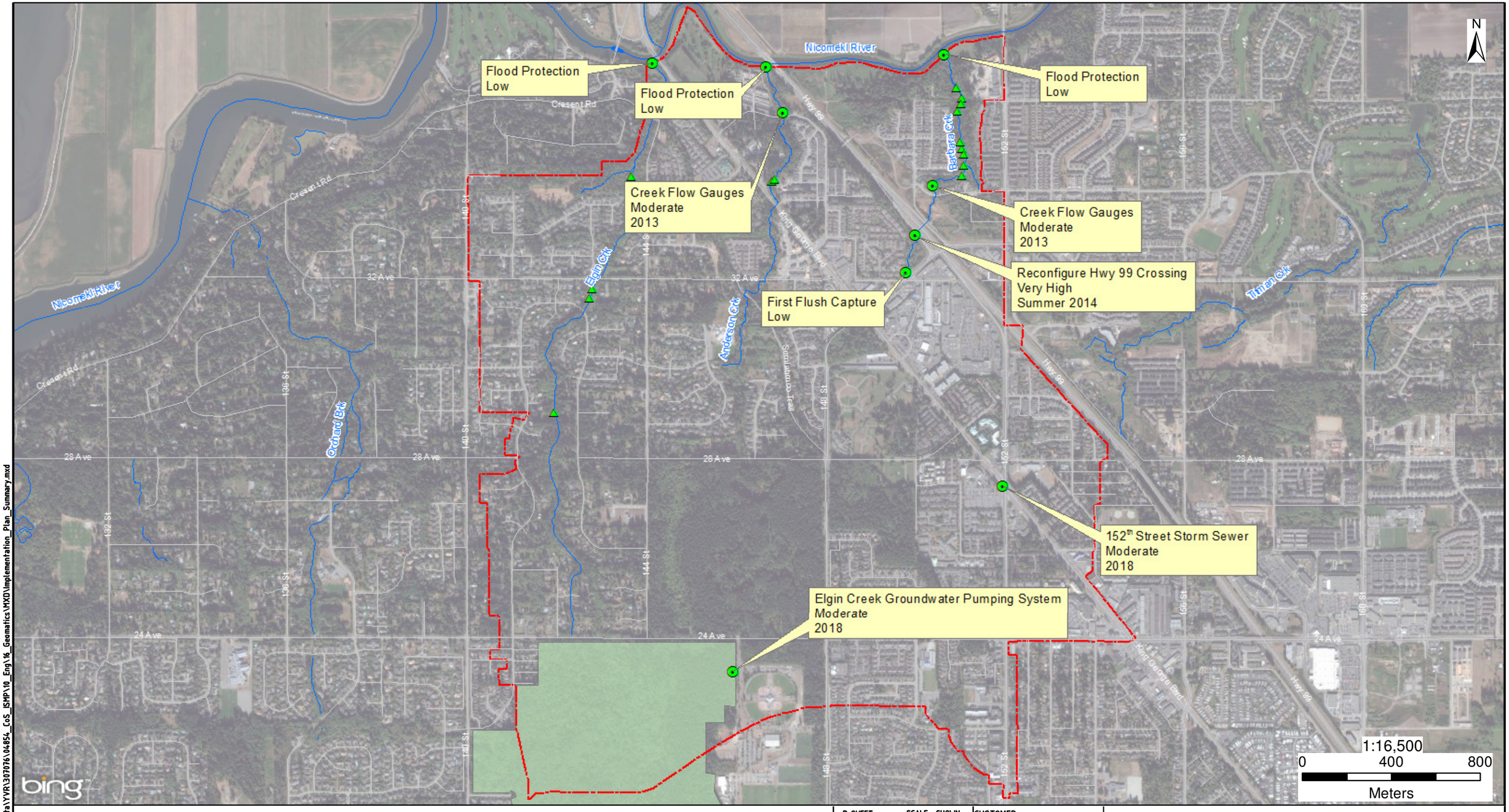
4.5 Implementation Plan Summary

Table PP compiles the initiatives, strategies, long-range opportunities, and monitoring infrastructure that comprise the Implementation Plan, presented in the recommended order in which they should be implemented. A map showing the locations of selected implementation plan items is shown on Figure AA.

Table PP Implementation Plan Summary

Priority	Item	Type	Actions Involved	Desired Outcome	Stakeholders	Goals Addressed	Recommended Schedule	Estimated Cost
Very High	Control and Manage Chemical Usage and Disposal	Strategy	1. Identify industrial and commercial operators whose practices could result in the release of contaminants to the storm sewer. 2. Work with identified operators to develop and implement BMPs. 3. Monitor pesticide usage and enforce the Pesticide Bylaw.	To address the potential release of contaminants into the creeks in order to protect the health of aquatic habitat.	Engineering Department Bylaw Enforcement Division Parks, Recreation, and Culture Department Industrial and Commercial Operators Property Owners	1 and 5	Ongoing	N/A
Very High	Manage Non-point Source Contaminants	Strategy	1. Review current operation and maintenance practices. 2. Consider whether practices are consistent with BMPs (See Table V). 3. Consider altering practices to match BMPs.	To address the potential release of contaminants into the creeks in order to protect the health of aquatic habitat.	Engineering Department Bylaw Enforcement Division Parks, Recreation, and Culture Department Residents Businesses	1 and 5	Review current practices by 2014	N/A
High	Implement Wet Weather Green Infrastructure	Strategy	1. Implement wet weather green infrastructure as suited for the desired application and outcome.	To reduce the volume of runoff entering the creeks during storm events to reduce peak creek flow volumes and velocities and promote groundwater recharge.	Engineering Department Planning and Development Department Developers	1, 3, 4, and 6	Ongoing	Bioswales: \$9 to \$10 per m^2 drained Rain Gardens: \$20 to \$27 per m^2drained Permeable Pavement: \$100 to \$120 per m^2 drained
High	Bank Stabilization	Long-range Opportunity	1. Continue to monitor the creeks for signs of bank instabilities. 2. Assess known bank instabilities using a prioritization system. 3. Implement bank stabilization infrastructure at high priority locations, with consideration given to bio-engineered solutions.	To stabilize bank materials at sites with a high potential for causing damage to existing structures or degradation of aquatic habitat.	Engineering Department	1 and 3	Monitor every two years or as required	Varies
High	Raise Public Awareness of Riparian Areas	Strategy	1. Develop online or print material to inform the public of the importance of riparian areas and how they contribute to watershed health.	To reduce anthropogenic impacts on riparian areas.	Engineering Department Parks, Recreation, and Culture Department	1 and 2	2015	N/A
High	Control and Manage Invasive Plants	Strategy	1. Continue to raise public awareness of invasive plant issues. 2. Consider implementing BMPs (See Table BB).	To control the presence of invasive plants to preserve the biodiversity of riparian areas.	Engineering Department Parks, Recreation, and Culture Department ISCMV Sunnyside Acres Heritage Society Residents Contractors Developers	1 and 2	2015	N/A

Priority	Item	Type	Actions Involved	Desired Outcome	Stakeholders	Goals Addressed	Recommended Schedule	Estimated Cost
High	Review Capital and Development Projects	Strategy	1. Review capital projects at conceptual stage and development projects at application stage for the possibility of implementing infrastructure that will improve watershed health. 2. Review capital and development projects for compliance with runoff related requirements.	To facilitate the implementation of infrastructure that will contribute to a healthy watershed.	Engineering Department Parks, Recreation, and Culture Department	1, 2, 3, 4, and 6	Ongoing	N/A
High	Protect the Sunnyside Acres Urban Forest	Strategy	1. Continue to manage the Forest per the recommendations in the Sunnyside Acres Urban Forest Access and Recreation Management Plan (2002).	To maintain the health of the Sunnyside Acres Urban Forest and facilitate responsible and sustainable access.	Parks, Recreation, and Culture Department Sunnyside Acres Heritage Society	7	Ongoing	N/A
High	Reconfigure Hwy 99 Crossing	Initiative	1. Design bio-engineered weir. 2. Apply for a Water Act Approval. 3. Construct bio-engineered weir.	To reroute low creek flows from the 150 St. storm sewer to Barbara Creek to match original design.	Engineering Department DFO Ministry of Forests, Lands, and Natural Resource Operations	1 and 4	Construct by September 2014	$25,000 to $35,000
Moderate	152 St. Storm Sewer	Initiative	1. Reconfigure the sewer (Option 1). 2. Secure the manhole covers (Option 2).	To mitigate potential sewer surcharge which could adversely impact driving conditions on 152 St. and King George Blvd.	Engineering Department	4	Construct by 2018	Option No. 1: $110,000 to $120,000 Option No. 2: $10,000 to $12,000
Moderate	Elgin Creek Groundwater Pumping System	Initiative	1. Connect the pumping system to the City's SCADA system.	To facilitate an assessment of the system performance and to improve pump operation.	Engineering Department	1 and 6	Connect by 2018	$10,000 to $12,000
Moderate	Creek Flow Gauges	Monitoring Infrastructure	1. Install creek flow gauges on the Barbara and Anderson Creeks and connect them to the City's SCADA system.	To facilitate the long-term monitoring of flow patterns in support of the Monitoring Framework.	Engineering Department	---	Install and connect to SCADA system by 2018	$20,000 to $25,000
Moderate	Water Quality Monitoring	Monitoring Infrastructure	1. Implement a water quality monitoring program.	To facilitate the long-term monitoring of water quality parameters in support of the Monitoring Framework.	Engineering Department	---	2018	N/A
Low	First Flush Capture	Long-range Opportunity	1. Establish a sampling station at the storm sewer outfall to Barbara Creek at the 32 Ave Diversion. 2. Monitor discharge to quantify the first flush effect. 3. Determine whether capturing first flush flows could improve downstream aquatic habitat conditions.	To determine whether first flush capture would provide benefit by reducing the contaminant loading to Barbara Creek.	Engineering Department	1 and 5	Baseline conditions and during first flush storm	N/A
Low	Flood Protection	Long-range Opportunity	1. Consider the long-term implementation of flood control infrastructure at the confluences of the Nicomekl River and the creeks.	To protect low lying properties should the water level in the Nicomekl River increase as predicted due to climate change.	Engineering Department BC MoE	4	Review sea level rise projection reports as they become available	N/A



Legend

- Moderate Priority Bank Stabilization Site
- Implementation Plan Item
- Creeks
- Road
- Strategy 7: Protect Sunny Side Acres Urban Forest
- Study Area

Sources: City of Surrey, Bing Map Aerial

B SHEET SCALE: SHOWN

OneWay™ to zero harm

Date:	29/04/2014
Drawn by:	Y.M.
Edited by:	Y.M.
App'd by:	A.T.

CUSTOMER

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Implementation Plan Summary

WORLEYPARSONS PROJECT No.	FIG No.	REV
307076-04854	AA	0

FILE LOCATION: \\WorleyParsons.com\CA\Data\VYR\307076\04854_CoS_ISMP\10_Eng\16_Geomatics\MXD\Implementation_Plan_Summary.mxd

PLOT DATE & TIME: 19/12/2013 3:51:25 PM
SAVE DATE & TIME: 19/12/2013 3:51:25 PM

USER NAME: Ashling.Mulcahy
ISSUING OFFICE: BURNABY GIS

5. STAGE 4 - "HOW DO WE STAY ON TARGET?"

With a Monitoring and Adaptive Management Framework (the Framework), the City can complete the following tasks:

- Assess - holistically - creek health using water quality, hydrologic, and benthic invertebrate indicators;
- Evaluate the progress being made toward achieving the Vision;
- Track whether the ISMP's recommendations are being implemented and whether they are proving to be effective;
- Identify impacts and threats to the health of the Study Area;
- Use a mechanism to alter ISMPs at a citywide level to address changing regulatory and climatic conditions; and
- Report the status of the components listed above.

The following sections discuss the components of the Framework, including the frequency of monitoring, indicators used to assess monitoring results, reporting of the results and implementation of ISMP recommendations, and the adaptive management process.

5.1 Monitoring

This section of the ISMP was prepared using Metro Vancouver's 2013 draft Monitoring and Adaptive Management Framework report (the MAMF report 2013) as a template. The goals of the Framework are summarized in Table QQ.

Table QQ Framework Goals

Goal No.	Goal Type	Goal Description
1	Primary	Monitor and protect watershed health.
2	Primary	Assess the implementation and effectiveness of the ISMP.
3	Secondary	Use a weight of evidence approach to monitoring watershed health.
4	Secondary	Prescribe a monitoring framework for data directly related to watershed health.
5	Secondary	Include monitoring indicators which provide useful information in the absence of long-term data records and/or calibrated watershed models.
6	Secondary	Provide guidance for technically sound and consistent monitoring practices.
7	Secondary	Link monitoring outcomes to relevant adaptive management practices.
8	Secondary	Stimulate continuous improvements in watershed health.

An important component of the approach outlined in the MAMF report is the use of a weight of evidence approach. This approach combines an array of indicators of watershed health relating to water quality, hydrologic, and benthic invertebrate parameters to generate overall scores for the health of each watershed in the Study Area. The approach requires that:

- Indicators are quantifiable and scientifically defensible;
- Indicators should, where possible, be established with categories or thresholds to simplify the assessment of monitoring results; and
- Indicators should be synthesized qualitatively.

5.1.1 System Classification

The MAMF report, distinguishes the following three types of systems:

- Lower gradient streams - natural watercourses, ditches, and canals with gradients of less than 1%;
- Higher gradient streams - natural watercourses with gradients greater than 1%; and
- Piped systems - storm sewers.

These classifications determine what parameters should be monitored, as shown in Figure BB.

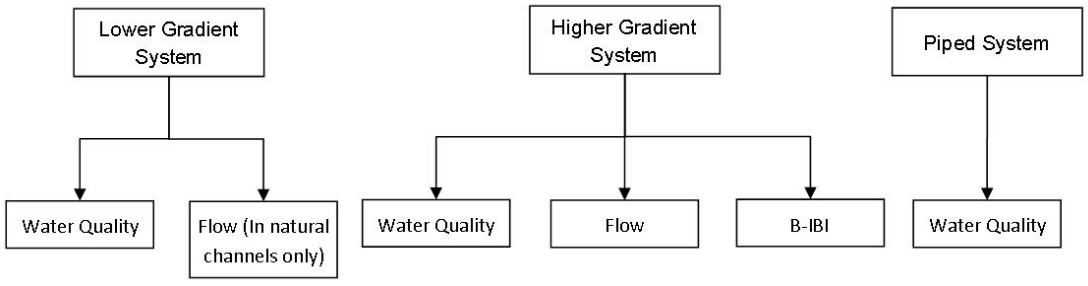

Figure BB Monitoring Programs Required for System Types

The Study Area consists of three higher gradient streams (e.g., Elgin, Barbara, and Anderson Creeks), in addition to two major piped systems at King George Highway and 150 St. Consequently, the City should monitor the water quality, hydrometric, and benthic invertebrate related indicators of the Elgin, Barbara, and Anderson Creeks and should consider monitoring the water quality indicators of both major piped systems.

5.1.2 Monitoring Frequency

The City should assess the indicators of watershed health in the Study Area every five years; however, the City may elect to collect indicator data on a more frequent basis to be consistent with their current monitoring schedule (e.g., benthic invertebrate data is currently collected every two years). In such cases, the City can either conduct an assessment based on the mean value or the "worst case" value of each parameter.

5.1.3 Water Quality Monitoring

Water quality monitoring will allow the City to determine whether the concentrations of specific contaminants are within Provincial guideline limits.

Water Quality Parameters

The MAMF report recommends that water quality monitoring should consist of the following two subsets of water quality parameters:

1. Core monitoring program consisting of five mandatory in situ parameters and eight mandatory parameters requiring laboratory testing; and
2. Supplemental program consisting of parameters that the City may elect to monitor based on watershed characteristics and land usages.

The core monitoring water quality parameters, summarized in Table RR, can be either priority indicators (i.e., significantly linked to watershed health assessment) or secondary indicators (i.e., supporting information for watershed health assessment). Included in the table are the units of measurement, type of sampling, and recommended reporting detection limit (RDL) (i.e., the lowest concentration or units at which a chemical can be reliably measured), associated with each indicator.

The City should also consider monitoring the supplemental water quality parameters summarized in Table SS as the concentrations of these contaminants collected as part of Stage 1 of this study exceeded the applicable provincial guidelines for freshwater and sediment quality.

Table RR Core Monitoring Water Quality Parameters

Parameter	Units	Type	RDL
Dissolved Oxygen	mg/L	In Situ	The greater of: • 0 mg/L to 20 mg/L ±0.2 mg/L; or • 2% of the reading
pH	Relative units	In Situ	0.2 Units
Water Temperature	deg. C	In Situ	±0.2 deg. C
Conductivity	µS/cm	In Situ	1 µS/cm
Turbidity	NTU	In Situ	0.1 NTU
Nitrate (as Nitrogen)	mg/L	Nutrient Sample	Less than or equal to 0.005 mg/L
E. Coli (Freshwater)	CFU/100 mL	Microbiological Sample (Membrane Filtration)	50 CFU/100 mL or less
Fecal Coliforms (Freshwater)	CFU/100 mL	Microbiological Sample (Membrane Filtration)	50 CFU/100 mL or less
Total Iron	µg/L	Low Level ICMPS (Metals)	As recommended by testing laboratory
Total Cadmium	µg/L	Low Level ICMPS (Metals)	As recommended by testing laboratory
Total Copper	µg/L	Low Level ICMPS (Metals)	As recommended by testing laboratory
Total Lead	µg/L	Low Level ICMPS (Metals)	As recommended by testing laboratory
Total Zinc	µg/L	Low Level ICMPS (Metals)	As recommended by testing laboratory

Table SSSupplemental Water / Sediment Quality Parameters

Parameter	Type	Guideline Limit	Exceedances Noted In
Arsenic	Water	5.0 µg/L	All creeks
Chromium (hexavalent)	Water	1.0 µg/L	All creeks
Arsenic	Sediment	5.90 mg/kg	Anderson Creek
Benzo(a)pyrene	Sediment	31.9 µg/kg	Anderson Creek
Pyrene	Sediment	53 µg/kg	Anderson Creek

Data Collection

Each five-year monitoring cycle can be divided into two sampling periods:

- The wet season - between November and December; and
- The dry season - between July and August.

During each sampling period, a total of five samples should be collected, preferably once a week and over a period of 30 days or less.

Sampling locations should be selected following a qualitative reconnaissance of each watershed in the Study Area. Each location should meet the following requirements:

- Representative of the watershed;
- Located downstream of the majority of the watershed's sub-catchments;
- Not in close proximity to disturbed areas (e.g., cleared land); and
- Not in close proximity to localized disturbances (e.g., erosion sites or storm sewer outlets).

Collection should be undertaken by a Qualified Environmental Professional (QEP) using grab sampling directly by hand or by an extendible sample pole where required due to limited access. The QEP should be an applied scientist or technologist registered with a professional organization and with recognized experience in collecting water samples and knowledge of the safe handling of equipment and chemicals required to undertake the sampling. A single QEP should collect all water samples during the monitoring cycle.

At each sampling location, the following information should be recorded:

- Location's UTM coordinates;
- Name of QEP;
- Date and time of sampling;
- Description of site conditions including weather, water level and flow, substrate characteristics, and water clarity; and
- Record of equipment calibration.

The QEP should also record the in situ water quality parameters discussed in the following section and should provide a photographic record of the site including photos of the creek channel upstream and downstream of the sampling location and the substrate at the sampling location.

Samples should be analyzed by a testing laboratory with an ISO 17025 accreditation for the recommended water quality parameters. The QEP should complete, on-site, any chain-of-custody documentation provided by the testing laboratory. Transportation, handling, and storage of samples should be done per instructions provided by the testing laboratory.

Data Assessment

The core monitoring program suggested in the MAMF report includes a three tiered “traffic light” approach to water quality assessment. The intent of this system is to generate simple rankings of water quality conditions based on quantitative data collected for each monitored water quality parameter and Provincial Water Quality guidelines. The system assigns the following rankings to priority water quality indicators:

- Green Level - Suggests that the level of this water quality parameter is acceptable (i.e., does not exceed Provincial guidelines), based on the sampling;
- Yellow Level - Suggests that the level of this water quality parameter is, based on the sampling, approaching a level of concern or has exceeded Provincial guidelines; and
- Red Level - Suggests that the level of this water quality parameter has, based on the sampling, exceeded Provincial guidelines.

Rankings are also assigned to secondary water quality indicators to support the interpretation of priority indicator rankings and to contribute to the identification of contaminant sources. The City should also consider assigning rankings to the supplemental water quality parameters shown in Table SS. Each water quality parameter ranking should be based on the arithmetic mean of the data collected during the monitoring cycle for that parameter, with the exception of microbiological parameters which should be based on the geometric mean. The suggested ranking thresholds for the water quality parameters that the City should consider monitoring are provided in Table TT.

The core monitoring program suggests the following actions are undertaken given the water quality rankings at a given sampling location:

- If all priority indicators receives a Green ranking then water quality monitoring should continue on a five-year cycle; or
- If one or more priority indicators receive a Yellow or Red ranking, then the City should consider undertaking supplemental monitoring of the indicator(s) and/or implementing adaptive management actions from the citywide Adaptive Management Plan that would address potential contaminant sources.

Table TT Water Quality Ranking Thresholds

Parameter	Units	Green Level	Yellow Level	Red Level
Dissolved Oxygen	mg/L	11 or greater	Less than 11 to 6.5	Less than 6.5
pH	Relative Units	6.5 to 9.0	Less than 6.5 to 6.0 or greater than 9.0 to 9.5	Less than 6.0 or greater than 9.5
Water Temperature (Low Flow Summer)	Deg. C	Less than 16	16 to 18	Greater than 18
Water Temperature (Wet Weather Fall / Winter)	Deg. C	7 to 12	5 to 7 or 12 to 14	Less than 5 or greater than 14
Conductivity	µS/cm	Less than 50	50 to 200	Greater than 200
Turbidity	NTU	Less than 5	5 to 25	Greater than 25
Nitrate (as Nitrogen)	mg/L	Less than 2	2 to 5	Greater than 5
E. Coli (Freshwater) - Geometric Mean	CFU/100 mL	Less than 77	77 to 385	Greater than 385
Fecal Coliforms	CFU/100 mL	Less than 200	200 to 1,000	Greater than 1,000
Iron*	µg/L	Less than 800	800 to 5,000	Greater than 5,000
Cadmium*	µg/L	Less than 0.03	0.03 to 0.15	Greater than 0.15
Copper*	µg/L	Less than 3	3 to 11	Greater than 11
Lead*	µg/L	Less than 5	5 to 30	Greater than 30
Zinc*	µg/L	Less than 6	6 to 40	Greater than 40
Arsenic**	µg/L	Less than 4	4 to 6	Greater than 6
Chromium (Hexavalent)**	µg/L	Less than 1	1 to 2	Greater than 2
Arsenic (Sediment)***	mg/kg	Less than 15	15 to 40	Greater than 40

Parameter	Units	Green Level	Yellow Level	Red Level
Benzo(a)pyrene (Sediment)***	µg/kg	Less than 700	700 to 2,000	Greater than 2,000
Pyrene (Sediment)***	µg/kg	Less than 800	800 to 2,000	Greater than 2,000

*Threshold levels based on a hardness approximating 100 mg/L $CaCO_3$

**Threshold levels based on the long-term, freshwater concentration limits provided in the Water Quality Guidelines for the Protection of Aquatic Life (2011)

***Threshold levels based on the probable effect levels (PELs) provided in the Sediment Quality Guidelines for the Protection of Aquatic Life (2011)

5.1.4 Hydrologic Monitoring

Flow monitoring will allow the City to determine whether drainage patterns within the Study Area are altered over time by changes to land usage and/or the implementation of the recommendations discussed in Section 4. The MAMF report recommends the monitoring of seven hydrologic parameters derived from a year-long, or longer, flow record. As it is difficult to synthesize creek flow data for the pre-development conditions in the Study Area, the City will not be able to establish target thresholds that mimic pre-development conditions. Instead, the City should establish targets based on observed changes to the parameters discussed below.

Flashiness

The flashiness of a watercourse generally indicates how its flow patterns respond to a storm event (i.e., flow rates in a "flashy" watercourse tend to change quickly and over a short time period in response to a storm event).

A suitable indicator of flashiness is T_{Qmean}, the proportion of the number of days over a year during which daily discharge exceeds the annual average daily discharge. As T_{Qmean} decreases, the flashiness of the watercourse increases which can negatively impact aquatic habitat conditions. The target for this parameter should be a stable or increasing trend.

Low Flows

Sustained or extreme low flow rates can negatively impact aquatic habitat conditions as regions of the stream can become temporarily disconnected from other sections and existing habitat can be reduced due to the resulting drop in water levels. Low flow rates can be impacted by practices associated with land development as the resulting increase to impervious area causes less surface runoff that contributes to groundwater recharge. Section 3.4.6 contains several recommendations for improving groundwater infiltration that could contribute to increased low flow rates.

Low Pulse Count

The low pulse count is the number of times the daily flow volume is less than half of the mean annual discharge volume. This threshold represents a critical flow below which aquatic habitat conditions will degrade. The target for this parameter should be a stable or decreasing trend.

Low Pulse Duration

The low pulse duration is the average length of each period over which the daily flow volume remains below half of the mean annual discharge volume during a calendar year. Prolonged low pulse duration is preferred to a series of intermittent low pulses. The target for this parameter should be a stable or increasing trend.

Summer Baseflow

The summer baseflow is the average of the daily discharge volumes recorded from July through September, excluding volumes with a seven-day antecedent rainfall depth of more than 1 mm. This value is representative of the creek flow derived from groundwater sources. The target for this parameter should be a stable trend.

Winter Baseflow

The summer baseflow is the average of the daily discharge volumes recorded from November through March, excluding volumes with a seven-day antecedent rainfall depth of more than 1 mm. This value is representative of the creek flow derived from groundwater sources. The target for this parameter should be a stable or increasing trend.

High Flows

High flows rates can negatively impact aquatic habitat conditions due to erosion, sedimentation, and high flow velocities. High flow rates can be impacted due to practices associated with land development as the increased impervious area and stormwater sewers convey an increased volume of surface water to the creeks quickly when compared to pre-development conditions.

High Pulse Count

The high pulse count is the number of times the daily flow volume exceeds twice the mean annual discharge volume. If the daily flow volume does not exceed this value in any given year, the 80^{th} percentile flow should be used as the high pulse threshold. The target for this parameter should be a stable or decreasing trend.

High Pulse Duration

The high pulse duration is the average length of each period during which daily flow volume exceeds twice the mean annual discharge volume, or the 80^{th} percentile flow as discussed above. The target for this parameter should be a stable or increasing trend.

Data Collection

During each five-year monitoring cycle, the City should maintain, as a minimum, a year-long flow record for each of the creeks in the Study Area. The data collected should be of Grade A quality, per the requirements as defined in the Manual of British Columbia Hydrometric Standards (MoE 2009) and summarized in Table UU.

Table UU Grade A Data Quality Requirements

Criteria	Description
Meter Calibration	Meter is calibrated and the validity of calibration is confirmed
Meter Field Verification	At least annually
Water Level Gauge Type	Recorder
Water Level Gauge Reading / Sensor Accuracy	2 mm or less
Channel Condition	Stable channel, measurements are consistent with rating curve, relatively straight reach, minimal weeds or boulders
Minimum Number of Bench Marks	3
Number of Manual Flow Measurements per Year	5 or more, or at least once when Rating Curve is stable
Number of Level Checks per Year	2 or more, or at least once when Ref. Gauge, Benchmarks are stable
Discharge Rating Accuracy	<7%
Data and Calculation Reviewed for Anomalies	Yes
Results Are Compared with Other Stations and/or Other Year for Check	Yes

The collection of Grade A quality data for the Study Area would require additional monitoring locations on Barbara and Anderson Creeks to supplement the existing, permanent level gauge on Elgin Creek. Although monitoring at these locations could be achieved with temporary flow monitoring devices, the City should consider installing permanent monitoring infrastructure linked to the City's SCADA system at these locations. This would avoid the need to re-establish monitoring infrastructure and rating curves every five years and would provide a longer flow record.

Permanent monitoring infrastructure would require the installation of level gauges on Barbara and Anderson Creeks in addition to the existing, permanent level gauge on Elgin Creek. These gauges could be installed as permanent infrastructure and linked to the City's SCADA system, as discussed in Section 4.4.1. Alternatively, a level gauge could be deployed at each location for one year during each monitoring cycle.

5.1.5 Benthic Invertebrate

Benthic invertebrate sampling will provides the City with quantitative data which can indicate the overall condition of aquatic and riparian habitat in the Study Area. The MAMF report recommends monitoring 10 summary parameters (or metrics) which - when summed - will provide a Benthic Index of Biotic Integrity (B-IBI) score. The B-IBI system and the following parameters are discussed in Section 2.5.2:

- Taxa Richness and Composition Total Taxa Richness;
- Ephemeroptera (Mayfly) Taxa Richness;

- Plecoptera (Stonefly) Taxa Richness;
- Trichotera (Caddisfly) Taxa Richness;
- Number of Long-lived Taxa;
- Number of Intolerant Taxa;
- Percent Tolerant Individuals;
- Number of Clinger Taxa;
- Percent Predator Individuals; and
- Percent Dominance.

The B-IBI system is a good indicator of the current health of the watershed, but it does not consider the pre-development conditions or the realistic conditions that could be achieved in an urban context. The system's rankings were developed for high gradient creeks with coarse substrate and are not necessarily applicable to the creeks in the Study Area. Instead, B-IBI scores should be used to monitor trends over time.

Data Collection

Benthic invertebrate sampling should be undertaken per the protocols and procedures described in the MAMF report and the GVRD B-IBI Field Guide for Benthic Macroinvertebrate Sampling and Habitat Analysis (EVS 2003) and summarized as follows:

- Site selection - Downstream of stormwater point sources, representative of the watershed, and at riffle habitat, but not under tidal influence;
- Equipment - Surber 250 µm mesh, pre-labelled; leak-proof plastic sample bottles, handheld GPS, 10% buffered formalin solution;
- Methodology - Collect three replicate samples per stream consisting of a composite of three Surber placements; and
- Testing - Samples sent to a qualified taxonomist, preferably certified by the Society for Freshwater Biology.

5.1.6 Reporting

At the end of each monitoring cycle, summary sheets will be prepared to report the water quality, hydrologic, and benthic invertebrate indicators for each watershed in the Study Area. The City should consider using the sample reporting sheet shown in Figure 1 in Appendix 5. These reporting sheets should be submitted with a cover sheet - a sample of which is shown in Figure 2 in Appendix 5 - that provides contextual information relating to the watershed.

Photos of the following should be compiled into a photographic record as part of each monitoring cycle and for each watershed in the Study Area:

- Creek substrate at water quality monitoring location or the outfall / manhole if monitoring occurs on a piped system;
- Upstream view from the water quality monitoring location;
- Downstream view from the water quality monitoring location;
- Flow monitoring location including equipment set-up; and
- Benthic sampling location.

The City should also monitor status of the components of the implementation plan detailed in Section 3.6. Progress made on the recommendations should be reported in the format shown in Table VV.

Table VV Sample ISMP Implementation Reporting Table

Component	Description of Actions Taken (Year Implemented)
Reconfigure Hwy 99 Crossing	Installed bio-engineered weir to direct water to Barbara Creek (2014)
Implement Wet Weather Green Infrastructure	Incorporated WWGI into seven capital road projects since 2014 (ongoing)
Monitoring Infrastructure - Creek Flow Gauges	Installed creek level gauges at Barbara and Anderson Creeks (2017)

5.2 Adaptive Management

The MAMF report recommends that municipalities should take a citywide approach to adaptive management planning that incorporates the monitoring results of each watershed within the municipality. This approach will facilitate the prioritization of issues affecting watershed health throughout the City, which will be more cost effective and efficient than focusing on several overlapping issues spread throughout multiple watersheds. The prioritization of these issues, and associated mitigation strategies, should be based on the following considerations:

- Value of the watershed for aquatic life and human health / safety;
- Potential that mitigation can prevent further watershed degradation;
- Potential that mitigation can improve watershed health;
- Severity of exceedance relative to the relevant thresholds / targets;
- Number of contaminants exceeding the thresholds / targets; and
- Opportunities to mitigate through alternative funding resources.

5.2.1 Adaptive Management Practices

Adaptive management practices are a collection of actions, infrastructure, and strategies that can be selected to address degradation of watershed health caused by anthropogenic activities. The MAMF report recommends the following adoption of the following adaptive management practices, some of which overlap with the Study's Implementation Plan and the City's current operational and planning practices:

- Source controls - infrastructure or operational measures that limit runoff flow at or near where they are generated;
- Runoff detention facilities - infrastructure that conveys runoff flows to a central storage location;
- Runoff pollution control - infrastructure or operational measures that prevent the release of contaminants to the creeks;
- Runoff treatment - infrastructure that removes contaminants from surface runoff;
- In-stream habitat rehabilitation - infrastructure and enhancements that improve aquatic habitat conditions;
- Riparian habitat rehabilitation - enhancements and strategies that improve riparian habitat conditions;
- Supplemental monitoring;
- Land use and transportation planning;
- Outreach programs - encourage behaviours that benefit watershed health; and
- Mitigation of construction impacts - measures to limit the generation and transport of sediment and potential contaminants from active construction sites.

6. REFERENCES

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Appendix 1 Data Registry

WorleyParsons
resources & energy

CITY OF SURREY ISMP
DATA REGISTER

ITEM NO.	FILE NAME	DESCRIPTION	FILE TYPE	CATEGORY	SOURCE	FILE LOCATION	DATE
1	Surrey_Contacts	List of relevant contacts within the council	pdf	Misc	JMO	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\05_Project_Mgmt\23_Proj_Mgmt_Shared\03_Contacts	08-Apr-13
2	Design Request Form	Form to be used to request design support	pdf	Misc	JMO	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\05_Project_Mgmt\23_Proj_Mgmt_Shared\03_Contacts	08-Apr-13
3	Cougar_Creek_ISMP	Previous ISMP for Cougar Creek	pdf	Previous study	Surrey website	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	08-Apr-13
4	DrainageReportList	List of all Surrey drainage reports	pdf	Previous study	Surrey website	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	08-Apr-13
5	ISMP Terms of Reference Template	MetroVan guidance document	pdf	Guidance document	Online	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Guidance Documents	08-Apr-13
6	ISMP Planning Guidebook	ISMP planning guidance	pdf	Guidance document	Online	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Guidance Documents	08-Apr-13
7	surreyrain_export_chantrellcreek	Rainfall data for Chantrell Creek, from 2000 to 2012	xls/csv	Hydrology data	FlowWorks	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Rainfall data	08-Apr-13
8	surreyrain_export_surreymunicipalhall	Rainfall data for Municipal Hall, from 2000 to 2012	xls/csv	Hydrology data	FlowWorks	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Rainfall data	08-Apr-13
9	Surrey_Aerial_Workspace	Workspace containing aerial photography	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyAerialPhotography	08-Apr-13
10	drnCatchmentsSHP	All catchment areas	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
11	drnDetentionPondsSHP	Location and details of all detention ponds	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
12	drnDevicesSHP	All drainage devices (catchbasins, etc)	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
13	drnLateralsSHP	Lateral drains connecting into main drains	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
14	drnMainsSHP	Main drainage system - contains size, material and type	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
15	drnManholesSHP	All manhole locations	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
16	drnNodesSHP	Nodes for main drainage system pipes	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
17	drnOpenChannelsSHP	All open channel drainage	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
18	drnWaterBodiesSHP	All watercourses, lakes and ponds	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyDrainage	08-Apr-13
19	IndALRSHP	Agricultural land reserve	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyEnvironment	08-Apr-13
20	prkNaturalAreasSHP	Natural areas (forest, grassland, etc)	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyEnvironment	08-Apr-13
21	facBuildings	Polygons of all buildings within Surrey	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
22	FacFacilities	City facilities - schools, parks, library, sports grounds, etc	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
23	facSchoolCatchments	School catchments	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
24	facSchools	Locations of all schools	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
25	IndALR	Surrey Agricultural Land Reserve	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
26	IndBIAs	Surrey Business Improvement Areas	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
27	IndLUCBoundaries	Land use commission boundaries	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
28	IndOfficalCommunityPlan	Land use zones and boundaries	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
29	IndZoningBoundaries	All development, agricultural and residential zones	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
30	SurreyBoundaries	Land use zones and boundaries	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyPlanning	08-Apr-13
31	cadAddressesSHP	Addresses for building layers	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyProperty	08-Apr-13
32	cadLotsSHP	Property lots and boundaries	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyProperty	08-Apr-13
33	cadRightOfWaysSHP	Municipal rights of way	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyProperty	08-Apr-13
34	cadSurveyMonumentsSHP	Municipal survey monuments	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyProperty	08-Apr-13
35	sanLateralsSHP	Lateral sanitary connectors to main system	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreySanitary	08-Apr-13
36	sanLiftStationsSHP	Pump station locations	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreySanitary	08-Apr-13
37	sanMainsSHP	Sanitary mains - inc size and length	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreySanitary	08-Apr-13
38	sanManholesSHP	Manhole locations	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreySanitary	08-Apr-13
39	sanNodesSHP	Nodes for sanitary system	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreySanitary	08-Apr-13
40	sanValvesSHP	Valves in system - inc type and material	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreySanitary	08-Apr-13
41	trnBarriers	Traffic barriers	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
42	trnCurbs	Roadside curbs	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
43	trnMedians	Median barriers and central reservations	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
44	trnNonMotorizedRoutesSHP	Walkways, bike paths, etc	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
45	trnPolesSHP	Streetlights, hydro poles, etc	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
46	trnRoadCentrelinesSHP	Road centrelines - inc name, material, etc	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
47	trnRoadEdgesSHP	Road edges - open with centrelines	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
48	trnSidewalksSHP	Sidewalks	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
49	trnTrafficSignalsSHP	Traffic lights and pedestrian signals	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyTransportation	08-Apr-13
50	wtrHydrantsSHP	Fire hydrant locations	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyWater	08-Apr-13
51	wtrMainsSHP	Water main system - inc size, type and material	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyWater	08-Apr-13
52	wtrMetersSHP	Water meter locations	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyWater	08-Apr-13
53	wtrServiceConnectionsSHP	Main water service connections	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyWater	08-Apr-13
54	wtrValvesSHP	Valves in system - inc type and material	shp/tab/wor	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyWater	08-Apr-13
55	2005 Report	Ravine Stability Assessment 2005	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Ravine Stability Assessment	18-Apr-13
56	2009 Report	Ravine Stability Assessment 2009	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Ravine Stability Assessment	18-Apr-13
61	2011 Ravine Stability Assessment (RSA)	Ravine Stability Assessment report 2011	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
57	Lidar data	Lidar data for study area	txt	GIS data	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\05_GIS Files\SurreyLidar	18-Apr-13
58	2009 Benthic Sampling Report (July 2010)	2009 Benthic Invertibrate Sampling Program Report	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
59	2009 Benthic Sampling Report - Appendices	Appendices for Benthic Study	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
60	2011 Surrey Benthic Sampling Program - DRAFT Report + Appendices (Jul 2012) lowres	2011 Benthic Invertibrate Sampling Program Report	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
62	Barbara Creek 1998 Master Drainage Plan Update	Barbara Creek MDP (1998 update)	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
63	Crescent Beach Adaptation Study Report	Climate change adaptation study for Crescent Beach (just to t	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
64	Drainage Sub Basin A11 - Elgin	MDP sub-basin report for the Elgin (from 1978)	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
65	Elgin Creek MDP 1995 Update (folder)	Elgin Creek MDP (2005 update) plus appendices	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
66	Elgin Creek Base Flow Augmentation Investigation	Elgin Creek Base Flow Study (2006)	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
67	Elgin Creek Fish Barrier	Map (from COSMOS) of Elgin Creek fish barrier location	pdf	Misc	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
68	Elgin Memo report - final	Memo regarding Semiahmoo Trail (2005)	pdf	Misc	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
69	Elgin Road	Design drawing for Elgin Road crossing (2007)	pdf	Misc	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
70	Elgin_Lidar-A	Lidar of Elgin Road meeting Nicomekl	pdf	Misc	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
71	Fergus Creek ISMP	ISMP for Fergus Creek (2010)	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
72	Rosemary Heights Business Park & Live Work Area - NCP	Neighbourhood Concept Plan for Rosemary Heights Business	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
73	Rosemary Heights Central - NCP	Rosemary Heights NCP central	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
74	Rosemary Heights West - NCP	Rosemary Heights NCP west	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
75	Rosemary Hts Sanitary Odour Control	Wastewater treatment odour control study (2008)	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
76	Rosemary_Siphon_2	Transfer of North Slope Trunk and Rosemary Heights Siphon	pdf	Misc	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	24-Apr-13
77	NHC_FloodplainReview_Dec2012Final_NoMap Compressed	Serpentine, Nicomekl & Campbell Rivers - Climate Change Flo	pdf	Previous study	City of Surrey	\\CAYVRWPFIL01\Projects\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\Previous Reports	
78	Pond Data	As-builts and detention pond summaries	xls/csv	Hydrology data	City of Surrey	U:\YVR\307076\04854_CoS_ISMP\10_Eng\15_I_and_E\08_Water_Resources\01_Data Collection\7-Pond Data	22-Jul-13

Appendix 2 Guidelines and Analyses Results

Canadian Environmental Quality Guidelines Summary Table - Water Quality Guidelines for the Protection of Aquatic Life

Canadian Environmental Quality Guidelines Summary Table

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,1,1-Trichloroethane **CASRN** 71556	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2,2-Tetrachloroethene PCE (Tetrachloroethylene) **CASRN** 127184	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	110	1993	*No data*	Insufficient data	1993
1,1,2,2-Tetrachlorethane **CASRN** 79345	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2-Trichloroethene TCE (Trichloroethylene) **CASRN** 79-01-6	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	21	1991	*No data*	Insufficient data	1991
1,2,3,4-Tetrachlorobenzene **CASRN** 634662	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	1.8	1997	*No data*	Insufficient data	1997
1,2,3,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997

Comments or questions? Contact us at info@ccme.ca

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3-Trichlorobenzene **CASRN** 87616	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	8	1997	*No data*	Insufficient data	1997
1,2,4,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
1,2,4-Trichlorobenzene **CASRN** 120801	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	24	1997	*No data*	5.4	1997
1,2-Dichlorobenzene **CASRN** 95501	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	0.7	1997	*No data*	42	1997
1,2-Dichloroethane **CASRN** 1070602	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	100	1991	*No data*	Insufficient data	1991
1,3,5-Trichlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
1,3-Dichlorobenzene **CASRN** 541731	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	150	1997	*No data*	Insufficient data	1997
1,4-Dichlorobenzene **CASRN** 106467	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	26	1997	*No data*	Insufficient data	1997
1,4-Dioxane		NRG	NRG	2008	NRG	NRG	2008
3-Iodo-2-propynyl butyl carbamate IPBC **CASRN** 55406-53-6	Organic Pesticides Carbamate pesticides	*No data*	1.9	1999	*No data*	*No data*	*No data*
Acenaphthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	5.8	1999	*No data*	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Acenaphthylene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	No data	1999	No data	No data	1999
Acridine PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**4.4**	1999	No data	Insufficient data	1999
Aldicarb **CASRN** 116063	Organic Pesticides Carbamate pesticides	No data	**1**	1993	No data	**0.15**	1993
Aldrin	Organic Pesticides Organochlorine compounds	No data	**~~0.004~~**	1987	No data	No data	No data
Aluminium	Inorganic	No data	**Variable**	1987	No data	No data	No data
Ammonia (total)	Inorganic Inorganic nitrogen compounds	No data	**Table**	2001	No data	No data	No data
Ammonia (un-ionized) **CASRN** 7664417	Inorganic Inorganic nitrogen compounds	No data	**19**	2001	No data	No data	No data
Aniline **CASRN** 62533	Organic	No data	**2.2**	1993	No data	Insufficient data	1993
Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.012**	1999	No data	Insufficient data	1999
Arsenic **CASRN** none	Inorganic	No data	**5**	1997	No data	**12.5**	1997
Atrazine **CASRN** 1912249	Organic Pesticides Triazine compounds	No data	**1.8**	1989	No data	No data	No data
Benzene **CASRN** 71432	Organic Monocyclic aromatic compounds	No data	**370**	1999	No data	**110**	1999
Benzo(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.018**	1999	No data	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**0.015**	1999	*No data*	Insufficient data	1999
Boron	Inorganic	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	NRG	NRG	2009
Bromacil **CASRN** 314409	Organic Pesticides	*No data*	**5**	1997	*No data*	Insufficient data	1997
Bromoxynil	Organic Pesticides Benzonitrile compounds	*No data*	**5**	1993	*No data*	Insufficient data	1993
Cadmium **CASRN** 7440439	Inorganic	*No data*	**Equation**	1996	*No data*	**0.12**	1996
Captan **CASRN** 133062	Organic Pesticides	*No data*	**1.3**	1991	*No data*	*No data*	*No data*
Carbaryl **CASRN** 63252	Organic Pesticides Carbamate pesticides	3.3	0.2	2009	5.7	0.29	2009
Carbofuran **CASRN** 1564662	Organic Pesticides Carbamate pesticides	*No data*	**1.8**	1989	*No data*	*No data*	*No data*
Chlordane	Organic Pesticides Organochlorine compounds	*No data*	**~~0.006~~**	1987	*No data*	*No data*	*No data*
Chloride	Inorganic	**640,000 µg/L or 640 mg/L**	**120,000 µg/L or 120 mg/L**	2011	**NRG**	**NRG**	2011
Chlorothalonil **CASRN** 1897456	Organic Pesticides	*No data*	**0.18**	1994	*No data*	**0.36**	1994
Chlorpyrifos **CASRN** 2921882	Organic Pesticides Organophosphorus compounds	0.02	0.002	2008	NRG	0.002	2008
Chromium, hexavalent (Cr(VI)) **CASRN** 7440473	Inorganic	*No data*	**1**	1997	*No data*	**1.5**	1997
Chromium, trivalent (Cr(III)) **CASRN** 7440473	Inorganic	*No data*	**8.9**	1997	*No data*	**56**	1997
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	Insufficient data	1999	*No data*	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Colour **CASRN** N/A	Physical	*No data*	**Narrative**	1999	*No data*	**Narrative**	1999
Copper	Inorganic	*No data*	**Equation**	1987	*No data*	*No data*	*No data*
Cyanazine **CASRN** 2175462	Organic Pesticides Triazine compounds	*No data*	**2**	**1990**	*No data*	*No data*	*No data*
Cyanide	Inorganic	*No data*	**5 (as free CN)**	1987	*No data*	*No data*	*No data*
Debris **CASRN** N/A	Physical	*No data*	*No data*	*No data*	*No data*	**Narrative**	1996
Deltamethrin **CASRN** 52918635	Organic Pesticides	*No data*	0.0004	1997	*No data*	Insufficient data	1997
Deposited bedload sediment	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Insufficient data	1999	*No data*	Insufficient data	1999
Di(2-ethylhexyl) phthalate **CASRN** 117817	Organic Phthalate esters	*No data*	**16**	1993	*No data*	Insufficient data	1993
Di-n-butyl phthalate **CASRN** 84742	Organic Phthalate esters	*No data*	**19**	1993	*No data*	Insufficient data	1993
Di-n-octyl phthalate **CASRN** 117840	Organic Phthalate esters	*No data*	Insufficient data	1993	*No data*	Insufficient data	1993
Dibromochloromethane	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	**Insufficient data**	1992	*No data*	**Insufficient data**	1992
Dicamba **CASRN** 1918009	Organic Pesticides Aromatic Carboxylic Acid	*No data*	**10**	1993	*No data*	*No data*	*No data*
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	*No data*	**~~0.001~~**	1987	*No data*	*No data*	*No data*
Dichlorobromomethane	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	**Insufficient data**	1992	*No data*	**Insufficient data**	1992
Dichloromethane Methylene chloride **CASRN** 75092	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	**98.1**	1992	*No data*	Insufficient data	1992

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	**0.2**	1987	*No data*	*No data*	*No data*
Diclofop-methyl **CASRN** 51338273	Organic Pesticides	*No data*	6.1	1993	*No data*	*No data*	*No data*
Didecyl dimethyl ammonium chloride DDAC **CASRN** 7173515	Organic Pesticides	*No data*	**1.5**	1999	*No data*	Insufficient data	1999
Diethylene glycol **CASRN** 111466	Organic Glycols	*No data*	**Insufficient data**	1997	*No data*	Insufficient data	1997
Diisopropanolamine DIPA **CASRN** 110974	Organic	*No data*	**1600**	**2005**	*No data*	**Insufficient data**	2005
Dimethoate **CASRN** 60515	Organic Pesticides Organophosphorus compounds	*No data*	**6.2**	1993	*No data*	Insufficient data	1993
Dinoseb **CASRN** 88857	Organic Pesticides	*No data*	0.05	1992	*No data*	*No data*	*No data*
Dissolved gas supersaturation **CASRN** N/A	Physical	*No data*	Narrative	1999	*No data*	Narrative	1999
Dissolved oxygen DO **CASRN** N/A	Inorganic	*No data*	**Variable**	1999	*No data*	**>8000 & Narrative**	1996
Endosulfan	Organic Pesticides Organochlorine compounds	0.06	0.003	2010	0.09	0.002	2010
Endrin	Organic Pesticides Organochlorine compounds	*No data*	**~~0.0023~~**	1987	*No data*	**No data**	*No data*
Ethylbenzene **CASRN** 100414	Organic Monocyclic aromatic compounds	*No data*	**90**	1996	*No data*	**25**	1996
Ethylene glycol **CASRN** 107211	Organic Glycols	*No data*	**192 000**	1997	*No data*	Insufficient data	1997
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**0.04**	1999	*No data*	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**3**	1999	*No data*	Insufficient data	1999
Fluoride	Inorganic	*No data*	**120**	2002	*No data*	**NRG**	2002
Glyphosate **CASRN** 1071836	Organic Pesticides Organophosphorus compounds	**27,000**	**800**	**2012**	**NRG**	**NRG**	**2012**
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	*No data*	**~~0.01~~**	1987	*No data*	*No data*	*No data*
Hexachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	**Insufficient data**	1997	*No data*	**Insufficient data**	1997
Hexachlorobutadiene HCBD **CASRN** 87683	Organic Halogenated aliphatic compounds	*No data*	**1.3**	1999	*No data*	*No data*	*No data*
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	*No data*	**0.01**	1987	*No data*	*No data*	*No data*
Imidacloprid **CASRN** 13826413		*No data*	**0.23**	2007	*No data*	**0.65**	2007
Iron	Inorganic	*No data*	**300**	1987	*No data*	*No data*	*No data*
Lead	Inorganic	*No data*	**Equation**	1987	*No data*	*No data*	*No data*
Linuron **CASRN** 41205214	Organic Pesticides	*No data*	**7**	1995	*No data*	*No data*	1995
Mercury **CASRN** 7439976	Inorganic	*No data*	**0.026**	2003	*No data*	**0.016**	2003
Methoprene **CASRN** 40596698		*No data*	**0.09 (Target Organism Management value: 0.53)**	2007	*No data*	Insufficient data	2007
Methyl tertiary-butyl ether MTBE **CASRN** 1634044	Organic Non-halogenated aliphatic compounds Aliphatic ether	*No data*	**10 000**	2003	*No data*	**5 000**	2003

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) MCPA **CASRN** 94746	Organic Pesticides	*No data*	2.6	1995	*No data*	4.2	1995
Methylmercury	Organic	*No data*	0.004	2003	*No data*	NRG	2003
Metolachlor **CASRN** 51218452	Organic Pesticides Organochlorine compounds	*No data*	7.8	1991	*No data*	*No data*	*No data*
Metribuzin **CASRN** 21087649	Organic Pesticides Triazine compounds	*No data*	1	1990	*No data*	*No data*	*No data*
Molybdenum	Inorganic	*No data*	73	1999	*No data*	*No data*	*No data*
Monobromomethane Methyl bromide	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Monochlorobenzene **CASRN** 108907	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	1.3	1997	*No data*	25	1997
Monochloromethane Methyl chloride	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Monochlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	7	1987	*No data*	*No data*	*No data*
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	1.1	1999	*No data*	1.4	1999
Nickel	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Nitrate **CASRN** 14797-55-8	Inorganic Inorganic nitrogen compounds	550,000 µg/L or 550 mg/L	13,000 µg/L or 13 mg/L	2012	1,500,000 µg/L or 1500 mg/L	200,000 µg/L or 200 mg/L	2012

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nitrite	Inorganic Inorganic nitrogen compounds	No data	60 NO_2-N	1987	No data	No data	No data
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	No data	1	2002	No data	0.7	2002
Nutrients		No data	Guidance Framework	2004	No data	Guidance framework	2007
Pentachlorobenzene **CASRN** 608935	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	6	1997	No data	Insufficient data	1997
Pentachlorophenol PCP	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	0.5	1987	No data	No data	No data
Permethrin **CASRN** 52645531	Organic Pesticides Organochlorine compounds	No data	0.004	2006	No data	0.001	2006
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	0.4	1999	No data	Insufficient data	1999
Phenols (mono- & dihydric) **CASRN** 108952	Organic Aromatic hydroxy compounds	No data	4	1999	No data	No data	No data
Phenoxy herbicides 2,4 D; 2,4-Dichlorophenoxyacetic acid	Organic Pesticides	No data	4	1987	No data	No data	No data
Phosphorus	Inorganic	No data	Guidance Framework	2004	No data	Guidance Framework	2007
Picloram **CASRN** 1918021	Organic Pesticides	No data	29	1990	No data	No data	No data
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	No data	~~0.001~~	1987	No data	~~0.01~~	1991
Propylene glycol **CASRN** 57556	Organic Glycols	No data	500 000	1997	No data	Insufficient data	1997
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	0.025	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
pH	Inorganic Acidity, alkalinity and pH	*No data*	6.5 to 9.0	1987	*No data*	7.0 to 8.7 & Narrative	1996
Quinoline PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	3.4	1999	*No data*	Insufficient data	1999
Reactive Chlorine Species total residual chlorine, combined residual chlorine, total available chlorine, hypochlorous acid, chloramine, combined available chlorine, free residual chlorine, free available chlorine, chlorine-produced oxidants	Inorganic Reactive chlorine compunds	*No data*	0.5	1999	*No data*	0.5	1999
Salinity	Physical	*No data*	*No data*	*No data*	*No data*	Narrative	1996
Selenium	Inorganic	*No data*	1	1987	*No data*	*No data*	*No data*
Silver	Inorganic	*No data*	0.1	1987	*No data*	*No data*	*No data*
Simazine **CASRN** 122349	Organic Pesticides Triazine compounds	*No data*	10	1991	*No data*	No data	*No data*
Streambed substrate	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Styrene **CASRN** 100425	Organic Monocyclic aromatic compounds	*No data*	72	1999	*No data*	*No data*	*No data*
Sulfolane Bondelane **CASRN** 126330	Organic Organic sulphur compound	*No data*	50 000	2005	*No data*	Insufficient data	2005
Suspended sediments TSS	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Tebuthiuron **CASRN** 34014181	Organic Pesticides	*No data*	1.6	1995	*No data*	Insufficient data	1995
Temperature	Physical Temperature	*No data*	Narrative	1987	*No data*	Narrative	1996

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Tetrachloromethane Carbon tetrachloride **CASRN** 56235	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	**13.3**	1992	*No data*	Insufficient data	1992
Tetrachlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	**1**	1987	*No data*	*No data*	*No data*
Thallium	Inorganic	*No data*	**0.8**	1999	*No data*	*No data*	*No data*
Toluene **CASRN** 108883	Organic Monocyclic aromatic compounds	*No data*	**2**	1996	*No data*	**215**	1996
Toxaphene	Organic Pesticides Organochlorine compounds	*No data*	**~~0.008~~**	1987	*No data*	*No data*	*No data*
Triallate **CASRN** 2303175	Organic Pesticides Carbamate pesticides	*No data*	**0.24**	1992	*No data*	*No data*	*No data*
Tribromomethane Bromoform	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	**Insufficient data**	1992	*No data*	**Insufficient data**	1992
Tributyltin	Organic Organotin compounds	*No data*	**0.008**	1992	*No data*	**0.001**	1992
Trichlorfon **CASRN** 52-68-6		**1.1**	**0.009**	2012	**NRG**	**NRG**	2012
Trichloromethane Chloroform **CASRN** 67663	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	**1.8**	1992	*No data*	Insufficient data	1992
Trichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	**18**	1987	*No data*	*No data*	*No data*
Tricyclohexyltin	Organic Organotin compounds	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Trifluralin **CASRN** 1582098	Organic Pesticides Dinitroaniline pesticides	*No data*	**0.2**	1993	*No data*	*No data*	*No data*

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Triphenyltin	Organic Organotin compounds	*No data*	0.022	1992	*No data*	*No data*	1992
Turbidity	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Uranium **CASRN** 7440-61-1	Inorganic	33	15	2011	NRG	NRG	2011
Zinc	Inorganic	*No data*	30	1987	*No data*	*No data*	*No data*

Chemical name	Chemical groups
No Chemicals with Data	

CCME Comments or questions? Contact us at info@ccme.ca

Canadian Environmental Quality Guidelines Summary Table - Sediment Quality Guidelines for the Protection of Aquatic Life

Canadian Environmental Quality Guidelines Summary Table

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg)	Concentration (µg/kg)	Date	Concentration (µg/kg)	Concentration (µg/kg)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
2-Methylnaphthalene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons PAHs	20.2	201	1998	20.2	201	1998
Acenaphthene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons PAHs	6.71	88.9	1998	6.71	88.9	1998
Acenaphthylene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons PAHs	5.87	128	1998	5.87	128	1998
Anthracene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons PAHs	46.9	245	1998	46.9	245	1998
Aroclor 1254	Organic Polyaromatic compounds Polychlorinated biphenyls PCBs	60	340	2001	63.3	709	2001
Arsenic **CASRN** none	Inorganic	5900	17 000	1998	7240	41 600	1998
Benzo(a)anthracene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons PAHs	31.7	385	1998	74.8	693	1998

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		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg)	Concentration (µg/kg)	Date	Concentration (µg/kg)	Concentration (µg/kg)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Benzo(a)pyrene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	31.9	782	1998	88.8	763	1998
Cadmium **CASRN** 7440439	Inorganic	600	3500	1997	700	4200	1997
Chlordane	Organic Pesticides Organochlorine compounds	4.5	8.87	1998	2.26	4.79	1998
Chromium (total) **CASRN** 7440-47-3	Inorganic	37 300	90 000	1998	52 300	160 000	1998
Chrysene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	57.1	862	1998	108	846	1998
Copper	Inorganic	35 700	197 000	1998	18 700	108 000	1998
Dibenz(a,h)anthracene	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	6.22	135	1998	6.22	135	1998
Dichloro diphenyl dichloroethane, 2,2-Bis (p-chlorophenyl)-1,1-dichloroethane DDD	Organic Pesticides Organochlorine compounds	3.54	8.51	1998	1.22	7.81	1998
Dichloro diphenyl ethylene, 1,1-Dichloro-2,2-bis(p-chlorophenyl)-ethene DDE	Organic Pesticides Organochlorine compounds	1.42	6.75	1998	2.07	374	1998
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	1.19	4.77	1998	1.19	4.77	1998
Dieldrin	Organic Pesticides Organochlorine compounds	2.85	6.67	1998	0.71	4.3	1998
Endrin	Organic Pesticides Organochlorine compounds	2.67	62.4	1998	2.67	62.4	1998

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		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg)	Concentration (µg/kg)	Date	Concentration (µg/kg)	Concentration (µg/kg)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	111	2355	1998	113	1494	1998
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	21.2	144	1998	21.2	144	1998
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	0.6	2.74	1998	0.6	2.74	1998
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	0.94	1.38	1998	0.32	0.99	1998
Lead	Inorganic	35 000	91 300	1998	30 200	112 000	1998
Mercury **CASRN** 7439976	Inorganic	170	486	1997	130	700	1997
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	34.6	391	1998	34.6	391	1998
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	1400	*No data*	2002	1000	*No data*	2002
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	41.9	515	1998	86.7	544	1998
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	34.1	277	2001	21.5	189	2001
Polychlorinated dibenzo-p-dioxins/dibenzo furans PCDDs, PCDFs	Organic Polyaromatic compounds Polychlorinated dioxins and furans	0.85 ng TEQ/kg dry weight	21.5 ng TEQ/kg dry weight	2001	0.85 ng TEQ/kg dry weight	21.5 ng TEQ/kg dry weight	2001
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	53	875	1998	153	1398	1998

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		Sediment Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/kg)	Concentration (µg/kg)	Date	Concentration (µg/kg)	Concentration (µg/kg)	Date
Chemical name	Chemical groups	ISQG	PEL		ISQG	PEL	
Toxaphene	Organic Pesticides Organochlorine compounds	0.1	No PEL derived	2002	0.1	No PEL derived	2002
Zinc	Inorganic	123 000	315 000	1998	124 000	271 000	1998

Chemical name	Chemical groups
No Chemicals with Data	

CCME Comments or questions? Contact us at info@ccme.ca

Laboratory Data - 04-Jun-2013

Success Through Science®

Your Project #: 307076-04854
Site Location: CITY OF SURREY
Your C.O.C. #: 40035401

Attention: Kurt Merrifield
WORLEYPARSONS CANADA SERVICES LTD
Suite 600 -4321 Still Creek Dr
BURNABY, BC
CANADA V5C 6S7

Report Date: 2013/06/04

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B343153
Received: 2013/05/29, 14:00

Sample Matrix: Sediment
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Elements by ICPMS (total)	3	2013/06/01	2013/06/03	BBY7SOP-00004	BCMOE-SALM
Moisture	3	N/A	2013/05/31	BBY8SOP-00017	Ont MOE -E 3139
Benzo[a]pyrene Equivalency	3	N/A	2013/06/03	BBY WI-00033	CCME Guidelines
PAH in Soil by GC/MS Lowlevel (Extended)	3	2013/05/30	2013/06/01	BRN SOP-00332 R5.0	EPA 8270D
Total LMW, HMW, Total PAH Calc	3	N/A	2013/06/03	BBY WI-00033	BC MOE Lab Method
Polychlorinated Biphenyls in Soil	3	N/A	2013/06/03	BBY8SOP-00036	EPA 8082A
pH (2:1 DI Water Extract)	3	2013/06/02	2013/06/02	BBY6SOP-00028	Carter, SSMA 16.2
Total Organic Carbon LECO Method (1,2)	3	2013/06/03	2013/06/03	CAL SOP-00243	LECO# 203-821-170

* Results relate only to the items tested.

(1) This test was performed by Maxxam Calgary Environmental
(2) Updated the RPD Limits from 50% to 35% as per standards. Updated on 2012/11/26.

Encryption Key

Namita Sahni
05 Jun 2013 11:46:51 -07:00

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Namita Sahni, Burnaby Project Manager
Email: NSahni@maxxam.ca
Phone# (604) 639-2614

==========

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B343153
Report Date: 2013/06/04

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

POLYCHLORINATED BIPHENYLS BY GC-ECD (SEDIMENT)

Maxxam ID		GM8504	GM8505	GM8506		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Polychlorinated Biphenyls						
Aroclor 1242	mg/kg	<0.030	<0.030	<0.030	0.030	6860739
Aroclor 1248	mg/kg	<0.030	<0.030	<0.030	0.030	6860739
Aroclor 1254	mg/kg	<0.030	<0.030	<0.030	0.030	6860739
Aroclor 1260	mg/kg	<0.030	<0.030	<0.030	0.030	6860739
Total PCB	mg/kg	<0.030	<0.030	<0.030	0.030	6860739
Surrogate Recovery (%)						
Hexabromobiphenyl (sur.)	%	79	86	78		6860739

PHYSICAL TESTING (SEDIMENT)

Maxxam ID		GM8504	GM8505	GM8506		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Physical Properties						
Moisture	%	33	45	16	0.30	6857256

MISCELLANEOUS (SEDIMENT)

Maxxam ID		GM8504	GM8505	GM8506		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Misc. Inorganics						
Total Organic Carbon (C)	%	1.6	0.76	0.41	0.020	6865180

RDL = Reportable Detection Limit

Maxxam Job #: B343153
Report Date: 2013/06/04

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

CSR/CCME METALS IN SOIL (SEDIMENT)

Maxxam ID		GM8504	GM8505	GM8506		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Physical Properties						
Soluble (2:1) pH	pH Units	6.84	6.59	7.15	0.010	6863975
Total Metals by ICPMS						
Total Aluminum (Al)	mg/kg	8110	10300	9500	100	6863970
Total Antimony (Sb)	mg/kg	0.17	0.36	0.23	0.10	6863970
Total Arsenic (As)	mg/kg	5.84	9.82	4.49	0.50	6863970
Total Barium (Ba)	mg/kg	51.4	59.2	34.9	0.10	6863970
Total Beryllium (Be)	mg/kg	<0.40	<0.40	<0.40	0.40	6863970
Total Bismuth (Bi)	mg/kg	<0.10	<0.10	<0.10	0.10	6863970
Total Cadmium (Cd)	mg/kg	0.102	0.182	0.169	0.050	6863970
Total Calcium (Ca)	mg/kg	2870	4330	3040	100	6863970
Total Chromium (Cr)	mg/kg	17.0	24.0	21.1	1.0	6863970
Total Cobalt (Co)	mg/kg	4.57	5.85	6.11	0.30	6863970
Total Copper (Cu)	mg/kg	8.35	16.6	15.2	0.50	6863970
Total Iron (Fe)	mg/kg	10800	18600	18100	100	6863970
Total Lead (Pb)	mg/kg	5.12	8.38	5.40	0.10	6863970
Total Magnesium (Mg)	mg/kg	2680	3980	4590	100	6863970
Total Manganese (Mn)	mg/kg	315	311	295	0.20	6863970
Total Mercury (Hg)	mg/kg	<0.050	<0.050	<0.050	0.050	6863970
Total Molybdenum (Mo)	mg/kg	0.20	0.49	0.42	0.10	6863970
Total Nickel (Ni)	mg/kg	12.2	15.6	16.1	0.80	6863970
Total Phosphorus (P)	mg/kg	390	463	350	10	6863970
Total Potassium (K)	mg/kg	288	477	340	100	6863970
Total Selenium (Se)	mg/kg	<0.50	<0.50	<0.50	0.50	6863970
Total Silver (Ag)	mg/kg	<0.050	<0.050	0.055	0.050	6863970
Total Sodium (Na)	mg/kg	140	227	143	100	6863970
Total Strontium (Sr)	mg/kg	20.1	29.4	16.0	0.10	6863970
Total Thallium (Tl)	mg/kg	<0.050	<0.050	<0.050	0.050	6863970
Total Tin (Sn)	mg/kg	0.41	1.03	0.31	0.10	6863970
Total Titanium (Ti)	mg/kg	516	689	682	1.0	6863970
Total Vanadium (V)	mg/kg	25.4	48.8	45.1	2.0	6863970
Total Zinc (Zn)	mg/kg	57.7	68.0	75.1	1.0	6863970
Total Zirconium (Zr)	mg/kg	1.05	1.42	2.45	0.50	6863970

RDL = Reportable Detection Limit

Maxxam Job #: B343153
Report Date: 2013/06/04

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

CCME PAH IN SEDIMENTS BY GC-MS (SEDIMENT)

Maxxam ID		GM8504		GM8505		GM8506		
Sampling Date		2013/05/27 08:00		2013/05/27 10:00		2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**RDL**	**COS-13-AND**	**RDL**	**COS-13-BAB**	**RDL**	**QC Batch**
Calculated Parameters								
Index of Additive Cancer Risk(IARC)	N/A	0.48	0.10	0.74	0.10	0.11	0.10	6858194
Benzo[a]pyrene equivalency	N/A	<0.10	0.10	<0.10	0.10	<0.10	0.10	6858194
Polycyclic Aromatics								
Naphthalene	mg/kg	<0.010(1)	0.010	<0.010(1)	0.010	<0.010(1)	0.010	6861689
2-Methylnaphthalene	mg/kg	<0.010(1)	0.010	<0.010(1)	0.010	<0.010(1)	0.010	6861689
Acenaphthylene	mg/kg	<0.0050(1)	0.0050	<0.0050(1)	0.0050	<0.0050(1)	0.0050	6861689
Acenaphthene	mg/kg	<0.0050(1)	0.0050	<0.0050(1)	0.0050	<0.0050(1)	0.0050	6861689
Fluorene	mg/kg	<0.010(1)	0.010	<0.010(1)	0.010	<0.010(1)	0.010	6861689
Phenanthrene	mg/kg	0.023(1)	0.010	0.030(1)	0.010	<0.010(1)	0.010	6861689
Anthracene	mg/kg	<0.010(1)	0.010	<0.010(1)	0.010	<0.010(1)	0.010	6861689
Fluoranthene	mg/kg	0.058(1)	0.010	0.087(1)	0.010	0.012(1)	0.010	6861689
Pyrene	mg/kg	0.049(1)	0.010	0.083(1)	0.010	0.014(1)	0.010	6861689
Benzo(a)anthracene	mg/kg	0.013(1)	0.010	0.020(1)	0.010	<0.010(1)	0.010	6861689
Chrysene	mg/kg	0.029(1)	0.010	0.049(1)	0.010	<0.010(1)	0.010	6861689
Benzo(b&j)fluoranthene	mg/kg	0.040(1)	0.010	0.066(1)	0.010	<0.010(1)	0.010	6861689
Benzo(k)fluoranthene	mg/kg	0.013(1)	0.010	0.018(1)	0.010	<0.010(1)	0.010	6861689
Benzo(a)pyrene	mg/kg	0.026(1)	0.010	0.037(1)	0.010	<0.010(1)	0.010	6861689
Indeno(1,2,3-cd)pyrene	mg/kg	0.022(1)	0.020	<0.040(2)	0.040	<0.020(1)	0.020	6861689
Dibenz(a,h)anthracene	mg/kg	<0.0050(1)	0.0050	<0.0080(2)	0.0080	<0.0050(1)	0.0050	6861689
Benzo(g,h,i)perylene	mg/kg	0.027(1)	0.020	0.048(1)	0.020	<0.020(1)	0.020	6861689
Low Molecular Weight PAH`s	mg/kg	0.023	0.010	0.030	0.010	<0.010	0.010	6857240
High Molecular Weight PAH`s	mg/kg	0.18	0.010	0.28	0.010	0.026	0.010	6857240
Total PAH	mg/kg	0.20	0.010	0.31	0.010	0.026	0.010	6857240
Surrogate Recovery (%)								
D10-ANTHRACENE (sur.)	%	120		122		120		6861689
D8-ACENAPHTHYLENE (sur.)	%	97		94		90		6861689
D8-NAPHTHALENE (sur.)	%	102		99		95		6861689
TERPHENYL-D14 (sur.)	%	121		115		115		6861689

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - RDL raised due to sample dilution.
(2) - RDL raised due to sample matrix interference.

Maxxam Job #: B343153
Report Date: 2013/06/04

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
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Package 1	8.7°C
Package 2	7.3°C

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

Maxxam Job #: B343153
Report Date: 2013/06/04

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
6857256	Moisture	2013/05/31					<0.30	%	0	20		
6860739	Hexabromobiphenyl (sur.)	2013/06/03	108	60 - 130	108	60 - 130	94	%				
6860739	Aroclor 1254	2013/06/03	90	70 - 110	98	70 - 110	<0.030	mg/kg	NC	50		
6860739	Aroclor 1242	2013/06/03					<0.030	mg/kg	NC	50		
6860739	Aroclor 1248	2013/06/03					<0.030	mg/kg	NC	50		
6860739	Aroclor 1260	2013/06/03					<0.030	mg/kg	NC	50		
6860739	Total PCB	2013/06/03					<0.030	mg/kg	NC	50		
6861689	D10-ANTHRACENE (sur.)	2013/06/01	112	60 - 130	103	60 - 130	104	%				
6861689	D8-ACENAPHTHYLENE (sur.)	2013/06/01	101	50 - 130	81	50 - 130	78	%				
6861689	D8-NAPHTHALENE (sur.)	2013/06/01	102	50 - 130	86	50 - 130	82	%				
6861689	TERPHENYL-D14 (sur.)	2013/06/01	114	60 - 130	97	60 - 130	95	%				
6861689	Naphthalene	2013/06/01	101	40 - 130	73	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	2-Methylnaphthalene	2013/06/01	95	40 - 130	77	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Acenaphthylene	2013/06/01	102	40 - 130	74	40 - 130	<0.00050	mg/kg	NC(1)	50		
6861689	Acenaphthene	2013/06/01	106	40 - 130	82	40 - 130	<0.00050	mg/kg	NC(1)	50		
6861689	Fluorene	2013/06/01	101	40 - 130	77	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Phenanthrene	2013/06/01	99	40 - 130	76	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Anthracene	2013/06/01	119	40 - 130	95	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Fluoranthene	2013/06/01	104	40 - 130	84	40 - 130	<0.0010	mg/kg	24.0(1)	50		
6861689	Pyrene	2013/06/01	115	40 - 130	90	40 - 130	<0.0010	mg/kg	27.0(1)	50		
6861689	Benzo(a)anthracene	2013/06/01	88	40 - 130	70	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Chrysene	2013/06/01	89	40 - 130	73	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Benzo(b&j)fluoranthene	2013/06/01	85	40 - 130	71	40 - 130	<0.0010	mg/kg	11.7(1)	50		
6861689	Benzo(k)fluoranthene	2013/06/01	108	40 - 130	85	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Benzo(a)pyrene	2013/06/01	102	40 - 130	79	40 - 130	<0.0010	mg/kg	NC(1)	50		
6861689	Indeno(1,2,3-cd)pyrene	2013/06/01	116	40 - 130	85	40 - 130	<0.0020	mg/kg	NC(2)	50		
6861689	Dibenz(a,h)anthracene	2013/06/01	119	40 - 130	81	40 - 130	<0.00050	mg/kg	NC(2)	50		
6861689	Benzo(g,h,i)perylene	2013/06/01	112	40 - 130	82	40 - 130	<0.0020	mg/kg	NC(1)	50		
6863970	Total Antimony (Sb)	2013/06/03	93	75 - 125	93	75 - 125	<0.10	mg/kg			102	70 - 130
6863970	Total Arsenic (As)	2013/06/03	89	75 - 125	89	75 - 125	<0.50	mg/kg			96	70 - 130
6863970	Total Barium (Ba)	2013/06/03	NC	75 - 125	100	75 - 125	<0.10	mg/kg			113	70 - 130
6863970	Total Beryllium (Be)	2013/06/03	98	75 - 125	95	75 - 125	<0.40	mg/kg				
6863970	Total Cadmium (Cd)	2013/06/03	98	75 - 125	95	75 - 125	<0.050	mg/kg			105	70 - 130
6863970	Total Chromium (Cr)	2013/06/03	NC	75 - 125	98	75 - 125	<1.0	mg/kg			115	70 - 130
6863970	Total Cobalt (Co)	2013/06/03	97	75 - 125	99	75 - 125	<0.30	mg/kg			102	70 - 130
6863970	Total Copper (Cu)	2013/06/03	NC	75 - 125	100	75 - 125	<0.50	mg/kg			94	70 - 130
6863970	Total Lead (Pb)	2013/06/03	101	75 - 125	101	75 - 125	<0.10	mg/kg			106	70 - 130
6863970	Total Manganese (Mn)	2013/06/03	NC	75 - 125	100	75 - 125	<0.20	mg/kg			111	70 - 130
6863970	Total Mercury (Hg)	2013/06/03	93	75 - 125	92	75 - 125	<0.050	mg/kg			108	70 - 130
6863970	Total Molybdenum (Mo)	2013/06/03	103	75 - 125	97	75 - 125	<0.10	mg/kg			116	70 - 130

Maxxam Job #: B343153
Report Date: 2013/06/04

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
6863970	Total Nickel (Ni)	2013/06/03	NC	75 - 125	101	75 - 125	<0.80	mg/kg			102	70 - 130
6863970	Total Selenium (Se)	2013/06/03	93	75 - 125	88	75 - 125	<0.50	mg/kg				
6863970	Total Silver (Ag)	2013/06/03	99	75 - 125	98	75 - 125	<0.050	mg/kg				
6863970	Total Strontium (Sr)	2013/06/03	NC	75 - 125	97	75 - 125	<0.10	mg/kg			111	70 - 130
6863970	Total Thallium (Tl)	2013/06/03	97	75 - 125	100	75 - 125	<0.050	mg/kg			100	70 - 130
6863970	Total Tin (Sn)	2013/06/03	95	75 - 125	95	75 - 125	<0.10	mg/kg				
6863970	Total Titanium (Ti)	2013/06/03	NC	75 - 125	99	75 - 125	1.7, RDL=1.0	mg/kg			118	70 - 130
6863970	Total Vanadium (V)	2013/06/03	NC	75 - 125	96	75 - 125	<2.0	mg/kg			114	70 - 130
6863970	Total Zinc (Zn)	2013/06/03	NC	75 - 125	93	75 - 125	<1.0	mg/kg			92	70 - 130
6863970	Total Aluminum (Al)	2013/06/03					<100	mg/kg			118	70 - 130
6863970	Total Calcium (Ca)	2013/06/03					<100	mg/kg			105	70 - 130
6863970	Total Iron (Fe)	2013/06/03					<100	mg/kg			107	70 - 130
6863970	Total Magnesium (Mg)	2013/06/03					<100	mg/kg			101	70 - 130
6863970	Total Phosphorus (P)	2013/06/03					<10	mg/kg			89	70 - 130
6863970	Total Bismuth (Bi)	2013/06/03					<0.10	mg/kg				
6863970	Total Potassium (K)	2013/06/03					<100	mg/kg				
6863970	Total Sodium (Na)	2013/06/03					<100	mg/kg				
6863970	Total Zirconium (Zr)	2013/06/03					<0.50	mg/kg				
6863975	Soluble (2:1) pH	2013/06/02			102	96 - 104			0.2	20		
6865180	Total Organic Carbon (C)	2013/06/03			105	75 - 125	<0.020	%	9.0	35	102	75 - 125

N/A = Not Applicable
RDL = Reportable Detection Limit
RPD = Relative Percent Difference
Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.
(1) - RDL raised due to sample dilution.
(2) - RDL raised due to sample matrix interference.

Maxxam Analytics International Corporation o/a Maxxam Analytics
4606 Canada Way, Burnaby, British Columbia Canada V5G 1K5 Tel (604) 734 7276 Toll-free (800) 665 8566 Fax (604) 630 0110 www.maxxam.ca

CHAIN OF CUSTODY RECORD

INVOICE INFORMATION:		REPORT INFORMATION (if differs from invoice):		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name:	#11343 WORLEYPARSONS CANADA SERVICE	Company Name:		Quotation #:	B11130	MAXXAM JOB #:	BOTTLE ORDER #:
Contact Name:	Kurt Merrifield	Contact Name:		P.O. #:		B343153	402004
Address:	Suite 600 -4321 Still Creek Dr	Address:		Project #:	307076-04854	CHAIN OF CUSTODY #:	PROJECT MANAGER:
	BURNABY BC V5C 6S7			Project Name:	CITY OF SURREY	C#402004-01-02	Namita Sahni
Phone:	(604)298-1616 Fax: (604)298-1625	Phone:	Fax:	Site #:			
Email:	kurt.merrifield@worleyparsons.com	Email:		Sampled By:	KM		

REGULATORY CRITERIA: CW. Trade Apworley parsons.com
- [x] CSR
- [x] CCME
- [x] BC Water Quality
- [ ] Other: _____

SPECIAL INSTRUCTIONS

SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

ANALYSIS REQUESTED (Please be specific):

TURNAROUND TIME (TAT) REQUIRED:

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Regular (Standard) TAT:
(will be applied if Rush TAT is not specified):
Standard TAT = 5 working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission):
1 Day ☐ 2 Day ☐ 3 Day ☐ Date Required: _____
Rush Confirmation Number: _____

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Metals Field Filtered ? (Y / N)	~~OC~~ TOC/METALS	PAH / PCB	# of Bottles	Comments
1	GM8504	COS-13-ELG	MAY 27, 2013	8:00	SED.	N	✓	✓	2	
2	GM8505	COS-13-AND	"	10.00	"	N	✓	✓	2	
3	GM8506	COS-13-BAB	"	12.00	"	N	✓	✓	2	
4										
5										
6										
7										
8										
9										
10										

B343153

*RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time:	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time:	# Jars Used and Not Submitted	Laboratory Use Only: Time Sensitive	Temperature (°C) on Receipt	Custody Seal Intact on Receipt
Kurt Merrifield/KURT MERRIFIELD	13/05/29	14:00	[illegible]	2013/05/29	14:00		☐	9.7 10.1 9.5 8	☐ Yes ☐ No

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

White: Maxxam Yellow: Client

Laboratory Data - 05-Jun-2013

Your Project #: 307076-04854
Site Location: CITY OF SURREY
Your C.O.C. #: 40035401

Attention: Kurt Merrifield
WORLEYPARSONS CANADA SERVICES LTD
Suite 600 -4321 Still Creek Dr
BURNABY, BC
CANADA V5C 6S7

Report Date: 2013/06/05

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B343148
Received: 2013/05/29, 14:00

Sample Matrix: Water
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Biochemical Oxygen Demand	3	2013/05/30	2013/05/30	BBY6SOP-00045	SM 5210
COD by Colorimeter	3	2013/05/30	2013/05/31	BBY6SOP-00024	SM - 5220D
Hardness (calculated as CaCO3)	3	N/A	2013/06/03	BBY7SOP-00002	EPA 6020A
Mercury (Dissolved) by CVAF	3	N/A	2013/05/31	BBY7SOP-00015	EPA 245.7
Na, K, Ca, Mg, S by CRC ICPMS (diss.)	3	N/A	2013/06/03	BBY7SOP-00002	EPA 6020A
Elements by CRC ICPMS (dissolved)	3	N/A	2013/05/31	BBY7SOP-00002	EPA 6020A
Nitrate + Nitrite (N)	3	N/A	2013/05/30	BBY6SOP-00010	SM 4500NO3-I
Nitrite (N) by CFA	3	N/A	2013/05/30	BBY6SOP-00010	EPA 353.2
Nitrogen - Nitrate (as N)	3	N/A	2013/05/31	BBY6SOP-00010	SM 4500NO3-I
Filter and HNO3 Preserve for Metals	3	N/A	2013/05/30	BBY6WI-00001	EPA 200.2
Phenols (4-AAP)	3	N/A	2013/05/31	BBY6SOP-00008	SM 5530
Orthophosphate by Konelab	3	N/A	2013/05/30	BBY6SOP-00013	SM 4500 P E
Sulphate by Automated Colourimetry	3	N/A	2013/05/30	BBY6SOP-00017	SM4500-SO42- E
Hydrocarbons (C10-C30) in Water - GC/FID	3	2013/05/30	2013/05/30	BBY8SOP-00029	BC Env. Lab Manual
Extrac. Petroleum HC in Water by GC/FID	3	2013/06/03	2013/06/04	BBY8SOP-00029	BC Env Lab Manual
Carbon (Total Organic)	3	N/A	2013/05/30	BBY6SOP-00003	SM-5310C

* Results relate only to the items tested.

Encryption Key

Diljeet Brar

05 Jun 2013 17:18:18 -07:00

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Namita Sahni, Burnaby Project Manager
Email: NSahni@maxxam.ca
Phone# (604) 639-2614

==========

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B343148
Report Date: 2013/06/05

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		GM8491	GM8492	GM8493		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
ANIONS						
Nitrite (N)	mg/L	<0.0050	0.0059	0.0122	0.0050	6859583
Calculated Parameters						
Filter and HNO3 Preservation	N/A	LAB	LAB	LAB	N/A	6857258
Nitrate (N)	mg/L	0.319	0.657	0.290	0.020	6856734
Demand Parameters						
Biochemical Oxygen Demand	mg/L	<6.0	<6.0	<6.0	6.0	6858450
Chemical Oxygen Demand	mg/L	21	<10	31	10	6857833
Misc. Inorganics						
Total Organic Carbon (C)	mg/L	6.46	3.23	5.58	0.50	6857298
Anions						
Dissolved Sulphate (SO4)	mg/L	3.77	8.47	4.22	0.50	6860731
Nutrients						
Orthophosphate (P)	mg/L	0.0197	0.0100	0.0207	0.0050	6860069
Nitrate plus Nitrite (N)	mg/L	0.319	0.662	0.302	0.020	6859493
Misc. Organics						
Phenols	mg/L	0.0067	0.0053	0.0086	0.0010	6860706

TOTAL PETROLEUM HYDROCARBONS (WATER)

Maxxam ID		GM8491	GM8492	GM8493		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Ext. Pet. Hydrocarbon						
EPH (C10-C19)	mg/L	<0.20	<0.20	<0.20	0.20	6866170
EPH (C19-C32)	mg/L	<0.20	<0.20	0.27	0.20	6866170
Hydrocarbons						
Total Extractables C10 to C30	mg/L	<0.20	0.28	0.44	0.20	6857301
Surrogate Recovery (%)						
O-TERPHENYL (sur.)	%	101	100	97		6857301

N/A = Not Applicable
RDL = Reportable Detection Limit

Maxxam Job #: B343148
Report Date: 2013/06/05

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

CCME DISSOLVED METALS IN WATER (WATER)

Maxxam ID		GM8491	GM8492	GM8493		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Misc. Inorganics						
Dissolved Hardness (CaCO3)	mg/L	34.7	55.2	23.1	0.50	6856702
Elements						
Dissolved Mercury (Hg)	ug/L	<0.010	<0.010	<0.010	0.010	6860502

RDL = Reportable Detection Limit

Maxxam Job #: B343148
Report Date: 2013/06/05

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

CCME DISSOLVED METALS IN WATER (WATER)

Maxxam ID		GM8491	GM8492	GM8493		
Sampling Date		2013/05/27 08:00	2013/05/27 10:00	2013/05/27 12:00		
	UNITS	**COS-13-ELG**	**COS-13-AND**	**COS-13-BAB**	**RDL**	**QC Batch**
Dissolved Metals by ICPMS						
Dissolved Aluminum (Al)	ug/L	79.6	17.8	45.7	3.0	6860505
Dissolved Antimony (Sb)	ug/L	<0.50	<0.50	1.04	0.50	6860505
Dissolved Arsenic (As)	ug/L	8.18	3.00	6.04	0.10	6860505
Dissolved Barium (Ba)	ug/L	10.8	14.4	10.3	1.0	6860505
Dissolved Beryllium (Be)	ug/L	<0.10	<0.10	<0.10	0.10	6860505
Dissolved Bismuth (Bi)	ug/L	<1.0	<1.0	<1.0	1.0	6860505
Dissolved Boron (B)	ug/L	<50	<50	<50	50	6860505
Dissolved Cadmium (Cd)	ug/L	<0.010	<0.010	0.014	0.010	6860505
Dissolved Chromium (Cr)	ug/L	4.7	1.2	3.1	1.0	6860505
Dissolved Cobalt (Co)	ug/L	<0.50	<0.50	<0.50	0.50	6860505
Dissolved Copper (Cu)	ug/L	3.84	2.66	14.2	0.20	6860505
Dissolved Iron (Fe)	ug/L	270	319	97.7	5.0	6860505
Dissolved Lead (Pb)	ug/L	<0.20	<0.20	0.41	0.20	6860505
Dissolved Lithium (Li)	ug/L	<5.0	<5.0	<5.0	5.0	6860505
Dissolved Manganese (Mn)	ug/L	10.9	9.7	10.3	1.0	6860505
Dissolved Molybdenum (Mo)	ug/L	<1.0	<1.0	<1.0	1.0	6860505
Dissolved Nickel (Ni)	ug/L	<1.0	<1.0	<1.0	1.0	6860505
Dissolved Selenium (Se)	ug/L	<0.10	<0.10	<0.10	0.10	6860505
Dissolved Silicon (Si)	ug/L	3370	3790	1570	100	6860505
Dissolved Silver (Ag)	ug/L	<0.020	<0.020	<0.020	0.020	6860505
Dissolved Strontium (Sr)	ug/L	68.6	106	43.6	1.0	6860505
Dissolved Thallium (Tl)	ug/L	<0.050	<0.050	<0.050	0.050	6860505
Dissolved Tin (Sn)	ug/L	<5.0	<5.0	<5.0	5.0	6860505
Dissolved Titanium (Ti)	ug/L	<5.0	<5.0	<5.0	5.0	6860505
Dissolved Uranium (U)	ug/L	<0.10	<0.10	<0.10	0.10	6860505
Dissolved Vanadium (V)	ug/L	<5.0	<5.0	<5.0	5.0	6860505
Dissolved Zinc (Zn)	ug/L	<5.0	<5.0	32.3	5.0	6860505
Dissolved Zirconium (Zr)	ug/L	<0.50	<0.50	<0.50	0.50	6860505
Dissolved Calcium (Ca)	mg/L	10.2	15.9	7.17	0.050	6856703
Dissolved Magnesium (Mg)	mg/L	2.25	3.77	1.26	0.050	6856703
Dissolved Potassium (K)	mg/L	1.14	1.18	0.799	0.050	6856703
Dissolved Sodium (Na)	mg/L	5.93	9.36	5.20	0.050	6856703
Dissolved Sulphur (S)	mg/L	<3.0	<3.0	<3.0	3.0	6856703

RDL = Reportable Detection Limit

Maxxam Job #: B343148
Report Date: 2013/06/05

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

Package 1	8.7°C
Package 2	7.3°C

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

Maxxam Job #: B343148
Report Date: 2013/06/05

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6857298	Total Organic Carbon (C)	2013/05/30	98	80 - 120	107	80 - 120	<0.50	mg/L	3.7	20
6857301	O-TERPHENYL (sur.)	2013/05/30	103	60 - 130	98	60 - 130	98	%		
6857301	Total Extractables C10 to C30	2013/05/30	97	50 - 130	116	50 - 130	<0.20	mg/L	NC	40
6857833	Chemical Oxygen Demand	2013/05/31	NC	80 - 120	104	80 - 120	<10	mg/L	NC	20
6858450	Biochemical Oxygen Demand	2013/05/30			84	80 - 120	<6.0	mg/L	3.8	20
6859493	Nitrate plus Nitrite (N)	2013/05/30	103	80 - 120	107	80 - 120	<0.020	mg/L	NC	25
6859583	Nitrite (N)	2013/05/30	96	80 - 120	94	80 - 120	<0.0050	mg/L	NC	20
6860069	Orthophosphate (P)	2013/05/30	NC	80 - 120	92	80 - 120	<0.0050	mg/L	0.5	20
6860502	Dissolved Mercury (Hg)	2013/05/31	98	80 - 120	92	80 - 120	<0.010	ug/L	NC	20
6860505	Dissolved Aluminum (Al)	2013/05/31	109	80 - 120	105	80 - 120	<3.0	ug/L	NC	20
6860505	Dissolved Antimony (Sb)	2013/05/31	106	80 - 120	103	80 - 120	<0.50	ug/L	NC	20
6860505	Dissolved Arsenic (As)	2013/05/31	109	80 - 120	100	80 - 120	<0.10	ug/L	NC	20
6860505	Dissolved Barium (Ba)	2013/05/31	NC	80 - 120	101	80 - 120	<1.0	ug/L	2.2	20
6860505	Dissolved Beryllium (Be)	2013/05/31	101	80 - 120	92	80 - 120	<0.10	ug/L	NC	20
6860505	Dissolved Bismuth (Bi)	2013/05/31	93	80 - 120	104	80 - 120	<1.0	ug/L	NC	20
6860505	Dissolved Cadmium (Cd)	2013/05/31	108	80 - 120	102	80 - 120	<0.010	ug/L	1.5	20
6860505	Dissolved Chromium (Cr)	2013/05/31	99	80 - 120	99	80 - 120	<1.0	ug/L	NC	20
6860505	Dissolved Cobalt (Co)	2013/05/31	99	80 - 120	98	80 - 120	<0.50	ug/L	NC	20
6860505	Dissolved Copper (Cu)	2013/05/31	99	80 - 120	98	80 - 120	<0.20	ug/L	NC	20
6860505	Dissolved Iron (Fe)	2013/05/31	108	80 - 120	105	80 - 120	<5.0	ug/L	NC	20
6860505	Dissolved Lead (Pb)	2013/05/31	103	80 - 120	101	80 - 120	<0.20	ug/L	NC	20
6860505	Dissolved Lithium (Li)	2013/05/31	NC	80 - 120	95	80 - 120	<5.0	ug/L	NC	20
6860505	Dissolved Manganese (Mn)	2013/05/31	NC	80 - 120	99	80 - 120	<1.0	ug/L	1.5	20
6860505	Dissolved Molybdenum (Mo)	2013/05/31	NC	80 - 120	103	80 - 120	<1.0	ug/L	3.1	20
6860505	Dissolved Nickel (Ni)	2013/05/31	101	80 - 120	101	80 - 120	<1.0	ug/L	NC	20
6860505	Dissolved Selenium (Se)	2013/05/31	110	80 - 120	101	80 - 120	<0.10	ug/L	NC	20
6860505	Dissolved Silver (Ag)	2013/05/31	106	80 - 120	90	80 - 120	<0.020	ug/L	NC	20
6860505	Dissolved Strontium (Sr)	2013/05/31	NC	80 - 120	100	80 - 120	<1.0	ug/L	1.9	20
6860505	Dissolved Thallium (Tl)	2013/05/31	80	80 - 120	107	80 - 120	<0.050	ug/L	NC	20
6860505	Dissolved Tin (Sn)	2013/05/31	106	80 - 120	102	80 - 120	<5.0	ug/L	NC	20
6860505	Dissolved Titanium (Ti)	2013/05/31	101	80 - 120	100	80 - 120	<5.0	ug/L	NC	20
6860505	Dissolved Uranium (U)	2013/05/31	105	80 - 120	99	80 - 120	<0.10	ug/L	NC	20
6860505	Dissolved Vanadium (V)	2013/05/31	100	80 - 120	99	80 - 120	<5.0	ug/L	NC	20
6860505	Dissolved Zinc (Zn)	2013/05/31	NC	80 - 120	112	80 - 120	<5.0	ug/L	NC	20
6860505	Dissolved Boron (B)	2013/05/31					<50	ug/L	NC	20
6860505	Dissolved Silicon (Si)	2013/05/31					<100	ug/L	NC	20
6860505	Dissolved Zirconium (Zr)	2013/05/31					<0.50	ug/L	NC	20
6860706	Phenols	2013/05/31	109	80 - 120	104	80 - 120	<0.0010	mg/L	10.9	20
6860731	Dissolved Sulphate (SO4)	2013/05/30	NC	80 - 120	96	80 - 120	0.77, RDL=0.50	mg/L	6.0	20
6866170	O-TERPHENYL (sur.)	2013/06/04			93	50 - 130	94	%		

Maxxam Job #: B343148
Report Date: 2013/06/05

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Location: CITY OF SURREY
Sampler Initials: KM

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6866170	EPH (C10-C19)	2013/06/04			119	50 - 130	<0.20	mg/L	NC	30
6866170	EPH (C19-C32)	2013/06/04			118	50 - 130	<0.20	mg/L	NC	30

N/A = Not Applicable
RDL = Reportable Detection Limit
RPD = Relative Percent Difference
Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Maxxam

Maxxam Analytics International Corporation o/a Maxxam Analytics
4606 Canada Way, Burnaby, British Columbia Canada V5G 1K5 Tel (604) 734 7276 Toll-free (800) 665 8566 Fax (604) 030 0110 www.maxxam.ca

CHAIN OF CUSTODY RECORD

Page 1 of 1

INVOICE INFORMATION:		REPORT INFORMATION (if differs from invoice):		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name:	#11343 WORLEYPARSONS CANADA SERVICE	Company Name:		Quotation #:	B11130	MAXXAM JOB #:	BOTTLE ORDER #:
Contact Name:	Kurt Merrifield	Contact Name:		P.O. #:		B343148	400354
Address:	Suite 600 -4321 Still Creek Dr BURNABY BC V5C 6S7	Address:		Project #:	307076-04854	CHAIN OF CUSTODY #:	PROJECT MANAGER:
Phone:	(604)298-1616 Fax: (604)298-1625	Phone:	Fax:	Project Name:	City of Surrey	C#403354-01-01	Nahrita Sahni
Email:	kurt.merrifield@worleyparsons.com	Email:		Site #:			
				Sampled By:	KM		

REGULATORY CRITERIA: CAN.TradeAR@worleyparsons.com
- [ ] CSR
- [x] CCME
- [x] BC Water Quality
- [ ] Other _____

SPECIAL INSTRUCTIONS

TURNAROUND TIME (TAT) REQUIRED:

PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS

Regular (Standard) TAT:
(will be applied if Rush TAT is not specified)
Standard TAT = 5 working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.
[x]

Job Specific Rush TAT (if applies to entire submission)
1 Day [ ] 2 Day [ ] 3 Day [ ] Date Required: _____
Rush Confirmation Number: _____ (Call lab for #)

SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

ANALYSIS REQUESTED (Please be specific):

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Metals Field Filtered ? (Y / N)	Dissolved Metals FILTER & PRESERVE IN LAB	EPH / TEH	TOC / COD (H2SO4)	Phenols (4-AAP) (H2SO4)	Nitrate + Nitrite (N)	Nitrate (as N)	Nitrite	Sulphate	Orthophosphate	BOD / CARBONACEOUS	# of Bottles	Comments
1	GM 8491	COS-13-ELG	MAY 27, 2013	8:00	WATER	N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	6	
2	GM 8492	COS-13-AND	"	10:00	"	N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	"	
3	GM 8493	COS-13-BAB	"	12:00	"	N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	6	
4																		
5																		
6																		
7																		
8																		
9																		
10																		

B343148

*RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time:	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time:	# Jars Used and Not Submitted	Laboratory Use Only
Kurt Merrifield/KURT MERRIFIELD	13/05/29	14:00	Mike Laurel/Mike Laurel	2013/05/29	14:00		Time Sensitive [ ] Temperature (°C) on Receipt: 9.7, 10.1, 9.5, 8 Custody Seal Intact: N/A [ ] Yes [ ] No

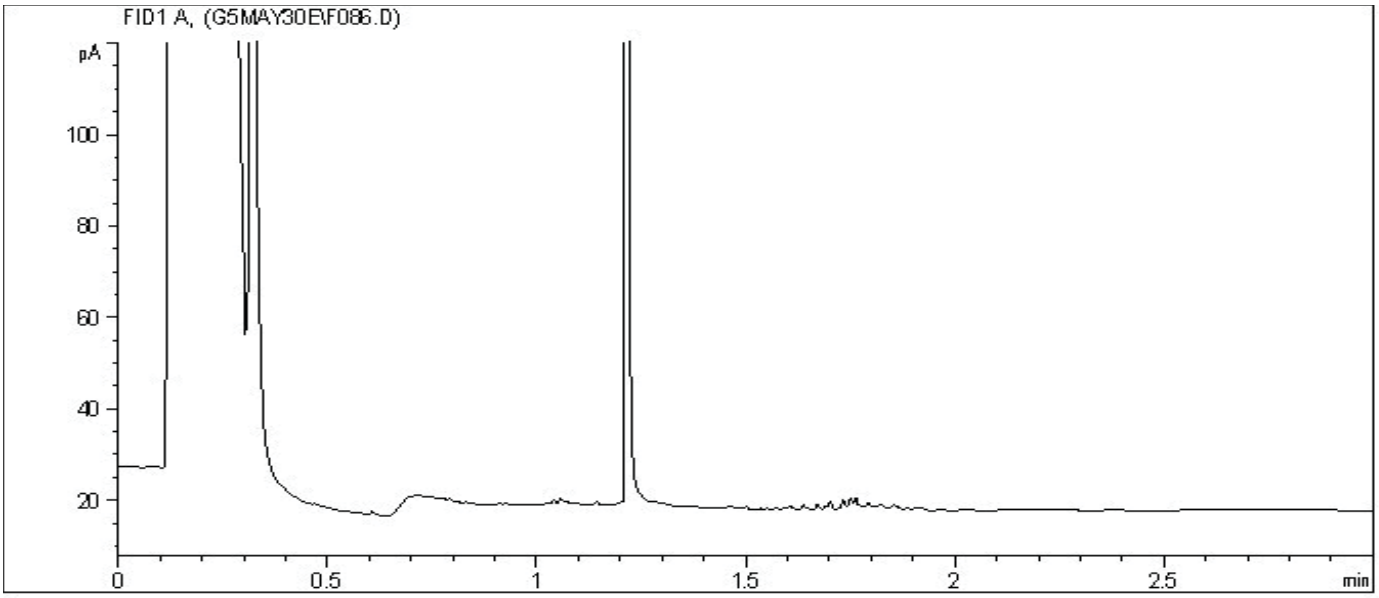
* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

White: Maxxam Yellow: Client

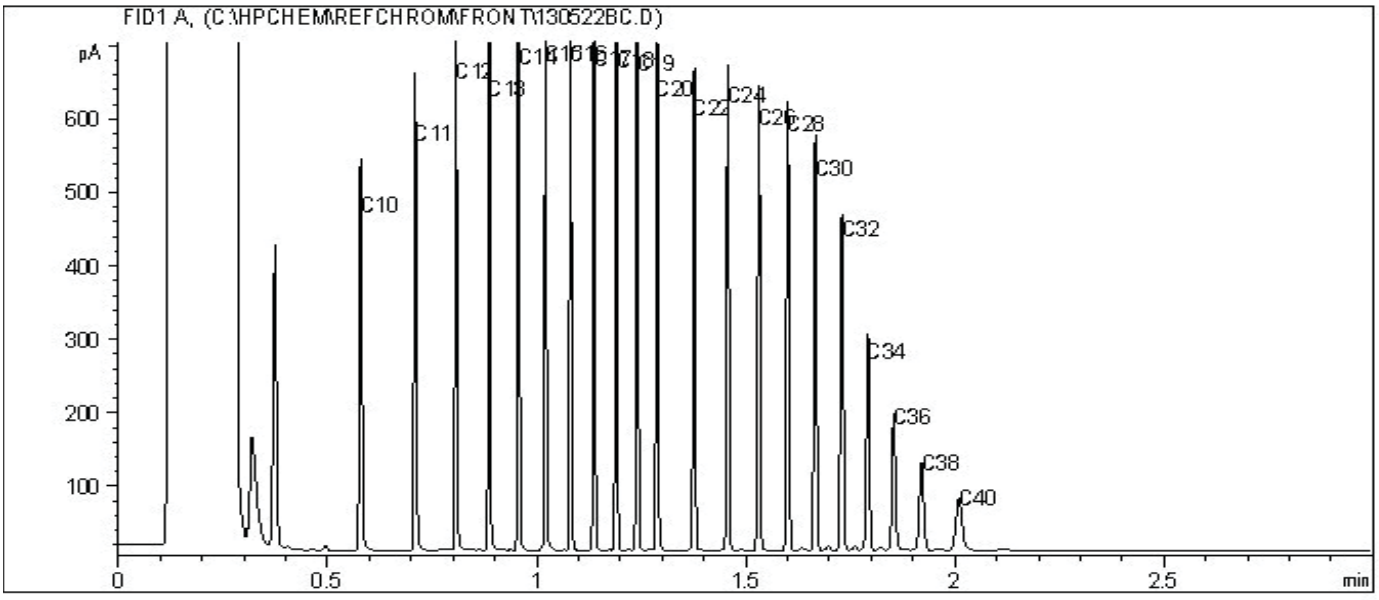
Report Date: 2013/06/05
Maxxam Job #: B343148
Maxxam Sample: GM8491

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Reference: CITY OF SURREY
Client ID: COS-13-ELG

Hydrocarbons (C10-C30) in Water - GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



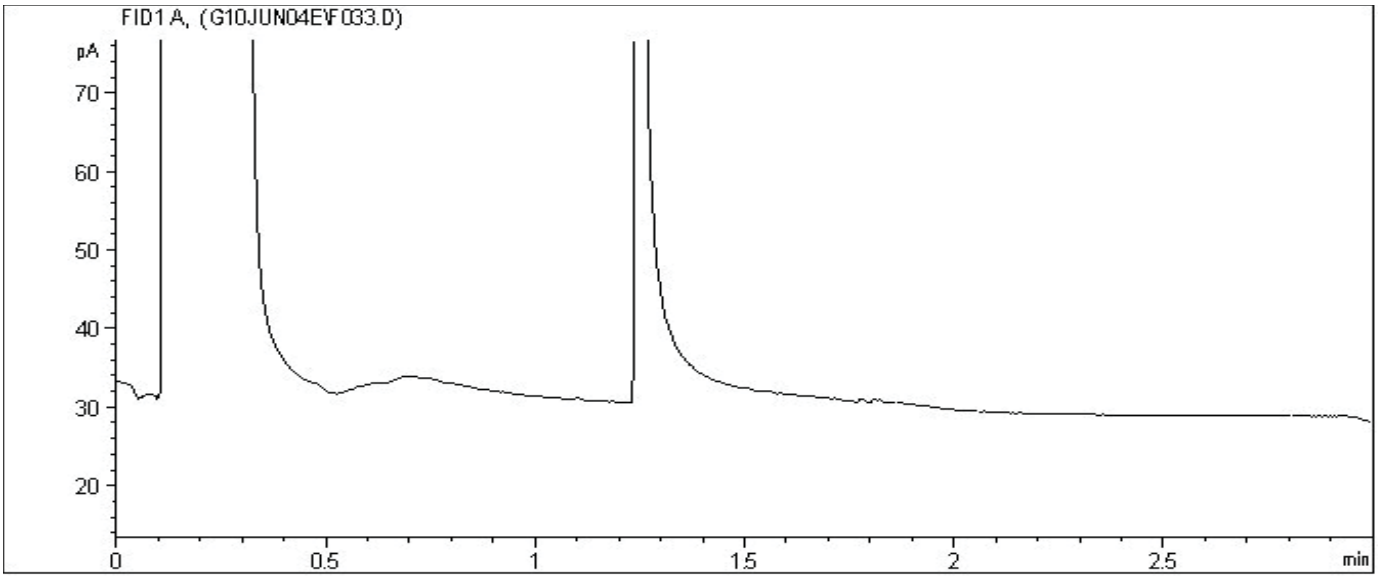
TYPICAL PRODUCT CARBON NUMBER RANGES

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

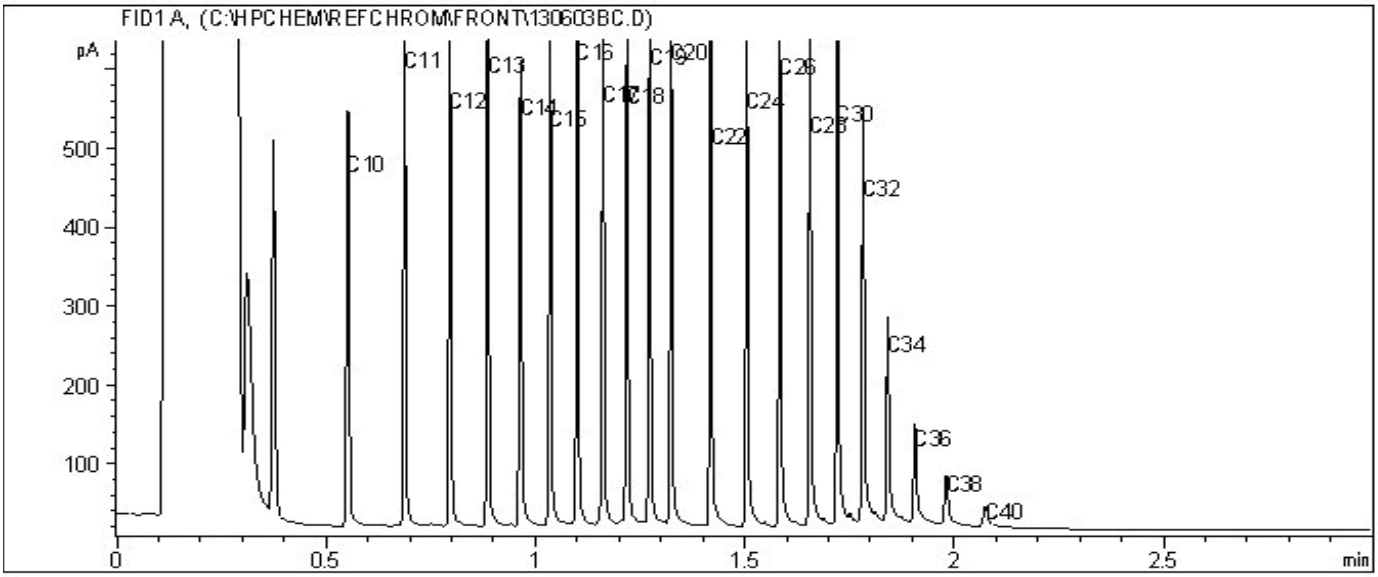
Report Date: 2013/06/05
Maxxam Job #: B343148
Maxxam Sample: GM8491

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Reference: CITY OF SURREY
Client ID: COS-13-ELG

Extrac. Petroleum HC in Water by GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

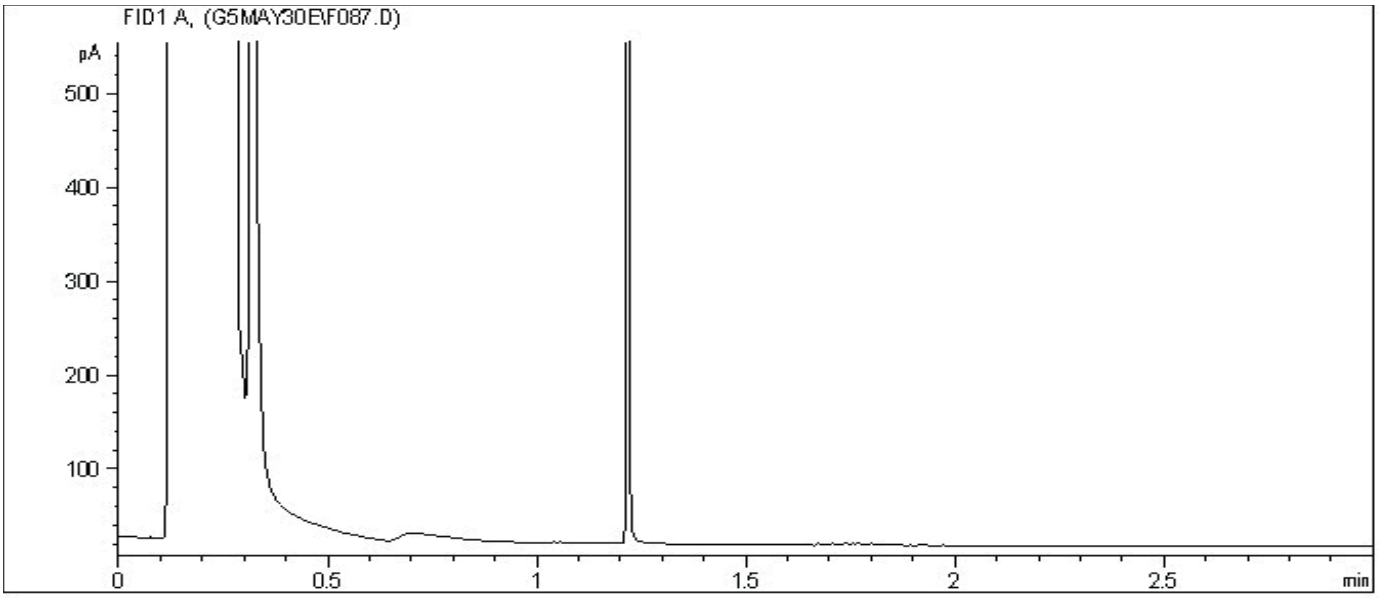
Gasoline:	C4 - C12		Diesel:	C8 - C22	
Varsol:	C8 - C12		Lubricating Oils:	C20 - C40	

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

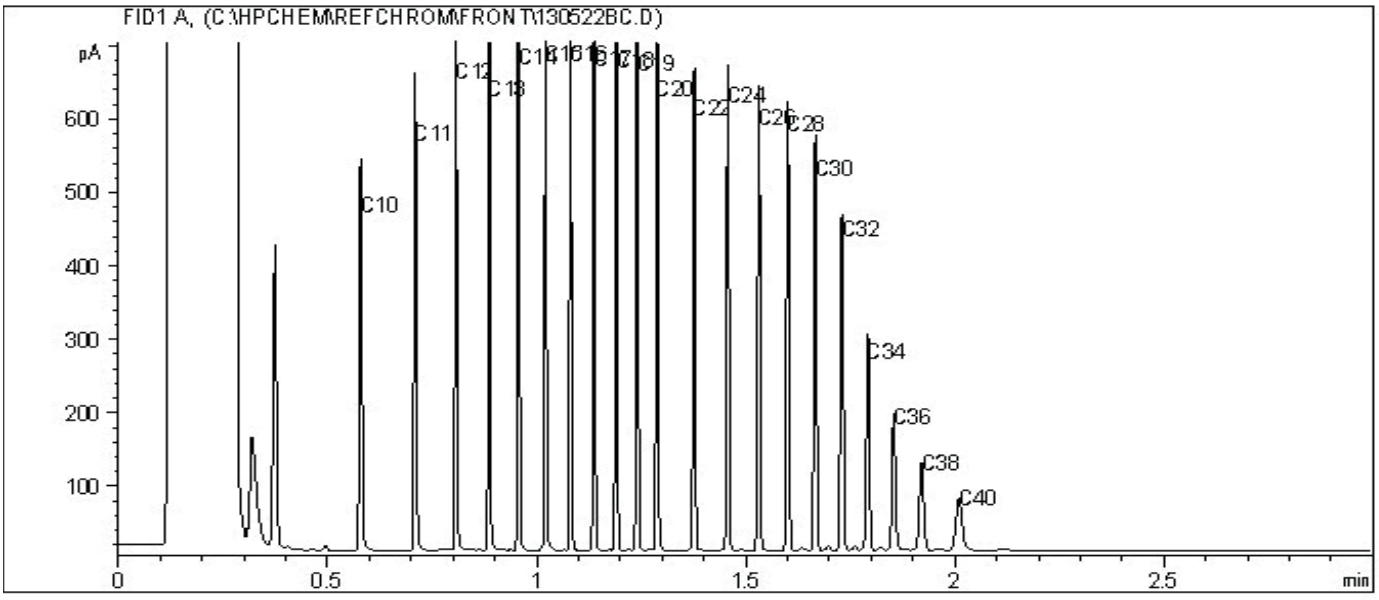
Report Date: 2013/06/05
Maxxam Job #: B343148
Maxxam Sample: GM8492

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Reference: CITY OF SURREY
Client ID: COS-13-AND

Hydrocarbons (C10-C30) in Water - GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



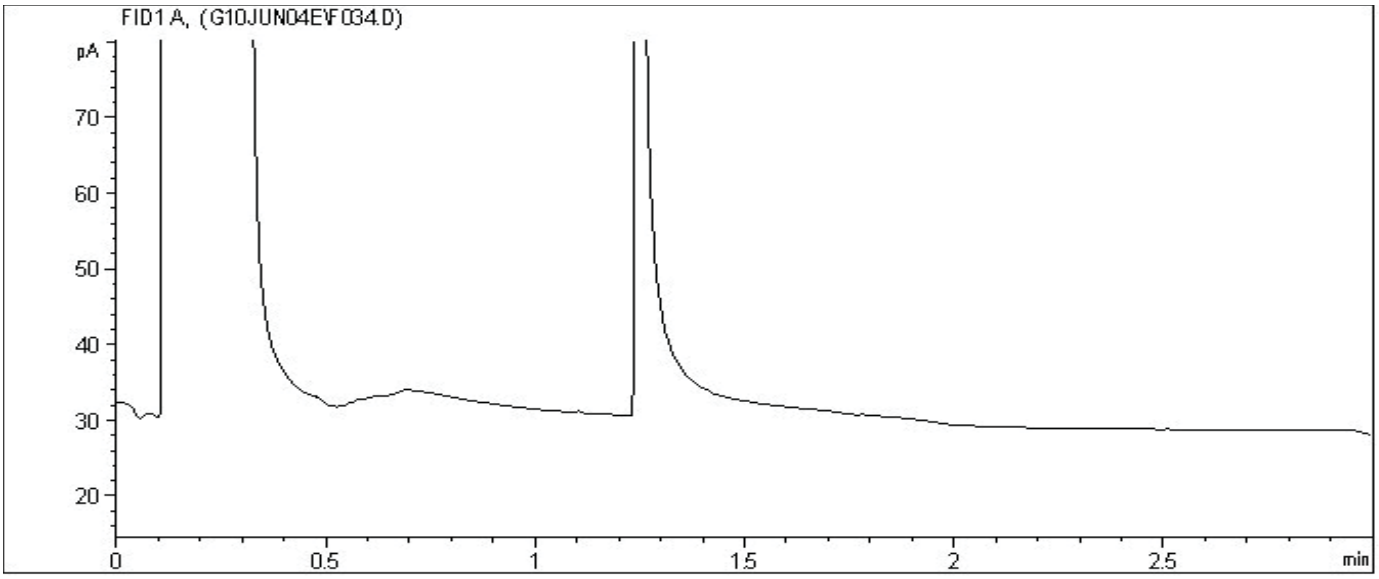
TYPICAL PRODUCT CARBON NUMBER RANGES

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

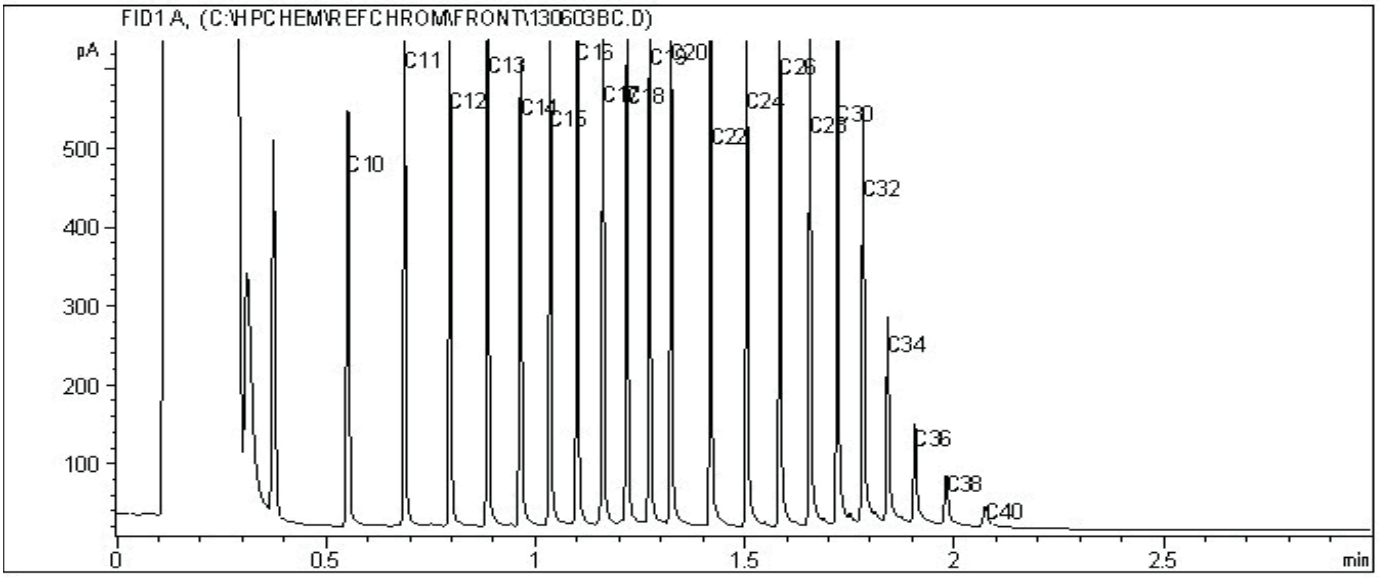
Report Date: 2013/06/05
Maxxam Job #: B343148
Maxxam Sample: GM8492

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Reference: CITY OF SURREY
Client ID: COS-13-AND

Extrac. Petroleum HC in Water by GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

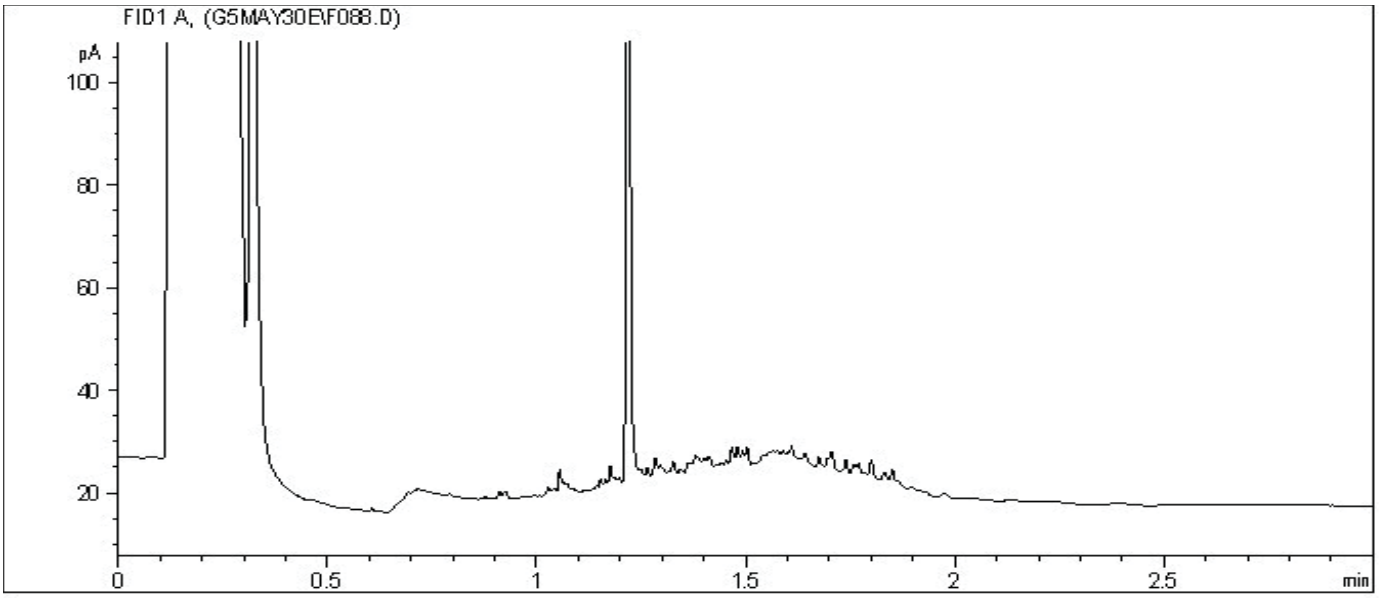
Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

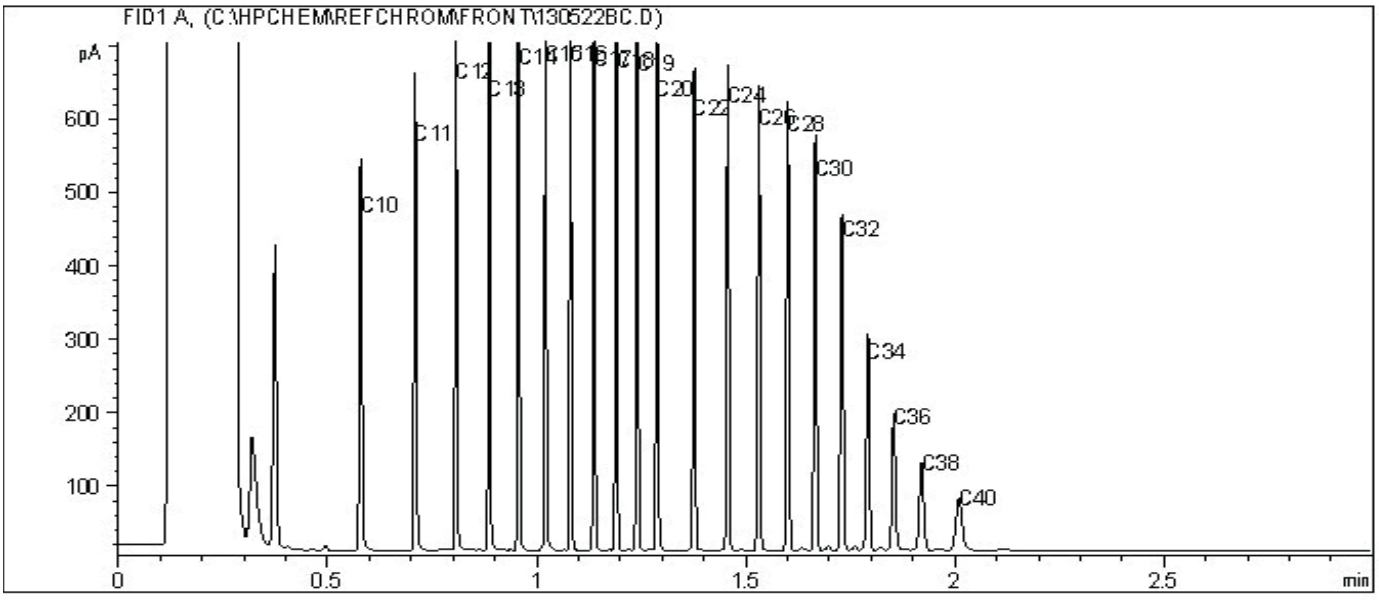
Report Date: 2013/06/05
Maxxam Job #: B343148
Maxxam Sample: GM8493

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Reference: CITY OF SURREY
Client ID: COS-13-BAB

Hydrocarbons (C10-C30) in Water - GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



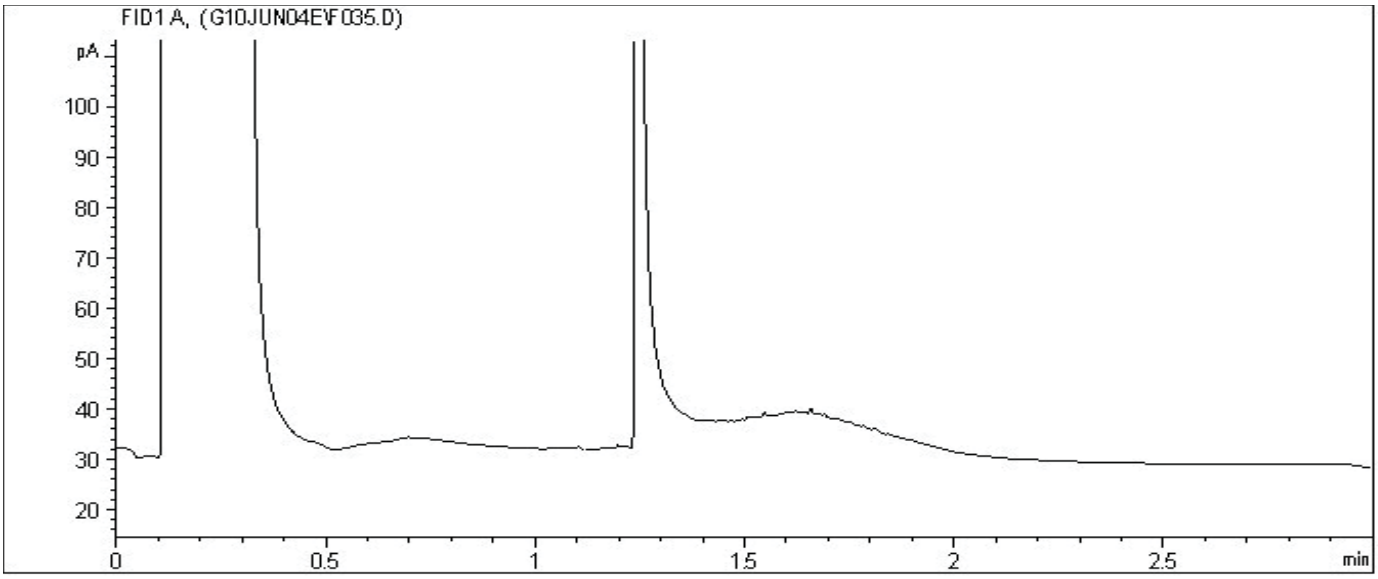
TYPICAL PRODUCT CARBON NUMBER RANGES

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

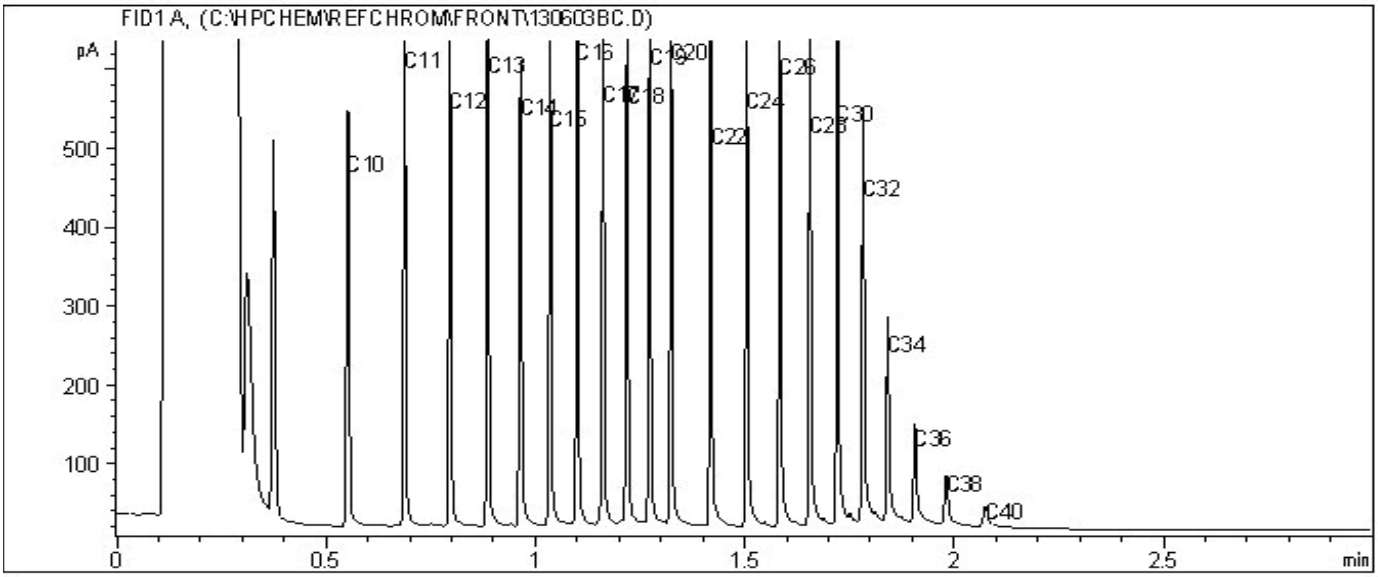
Report Date: 2013/06/05
Maxxam Job #: B343148
Maxxam Sample: GM8493

WORLEYPARSONS CANADA SERVICES LTD
Client Project #: 307076-04854
Site Reference: CITY OF SURREY
Client ID: COS-13-BAB

Extrac. Petroleum HC in Water by GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Appendix 3 Stakeholder Responses

From: Uhrich, Ted
Sent: August-22-13 1:09 PM
To: Gentles, Jake (Vancouver)
Cc: Scott, Margaret (Vancouver); Merry, Doug; Hislop, David
Subject: RE: Stakeholder Engagment for Integrated Stormwater Management Plan

Jake,

Thank you for forwarding these questions.

1. What are your areas of concern relating to the health of the watersheds (e.g., erosion/sedimentation issues, riparian health, etc.)? Please rank your concerns based on the order they should be addressed, from highest to lowest.
    a. The City has a large amount of parkland in these watersheds. As the stewards of the parkland, the Parks Division is concerned about the health of the watersheds. While the water quality and fish health are important to us, we also share that consideration with Engineering Drainage and Environment. We also share their concerns about bank erosion and sedimentation both for their impacts to the environment but also because they may lead to degradation of Park assets or create dangerous situations for park users. All that being said, probably our greatest concern and management challenge is the health of the riparian forested areas associated with these watersheds. Considerable resources go into invasive species removal, tree protection and rehabilitation of damaged ecosystems. It is in our best interest to ensure that riparian forested areas are healthy, free of invasives and are progressing in their succession to a mature forest. While public access is a priority for the Parks Division, we realize that in riparian areas public access has to be limited as it may compromise forest health as well as riparian and in-stream habitat. Specific to these watersheds, our greatest concerns in order are: adequate setbacks for all watercourses; protection of these setback areas as parkland so they are protected for perpetuity by the City who are the best stewards of these areas; management of root rot pockets in Sunnyside Acres Urban Forest that could lead to wider scale deforestation if left unmanaged; and adequate funding to manage existing parkland riparian areas for the reasons mentioned above.
2. Does your organization currently have any specific objectives intended to improve the health of the watersheds?
    a. The Parks Division shares the same corporate objectives as the Engineering Department in the improvement of the health of watersheds. Specific initiatives of the Parks Division in these watersheds are: management program of root rot in Sunnyside Acres Urban Forest; stewardship initiatives and partnering through the Nature Matters program including invasive plant removals and planting days; ongoing operational funding for managing riparian forested areas including invasive plan removal, planting and hazard tree management; and planned parkland acquisition in some areas of the watersheds.
3. Is your organization willing to support the City of Surrey Engineering department to develop and/or implement policies and projects that will improve the health of the watersheds? If so, what type of support are you willing to offer (i.e., monitoring, stream clean-up, application/enforcement of policies)?
    a. See above.

There are some specific issues I would like to draw your attention to as the ISMP is developed:

- The root rot issue identified above may have serious implications for Elgin and Anderson Creeks. More information is available if needed.
- The Sunnyside Lawn Cemetery is intended to expand and will lead to a reduction in forested areas in the Barbara Creek watershed.
- Realignment of Anderson Creek south of 32nd Ave is currently being investigated and more info is available if needed.
- The prevalence of RH-G and RA-G zoning in the Elgin and Anderson watersheds has greatly improved watershed health by enabling enhanced parkland dedication of 15-50% as opposed to the standard 5%.
- There is an area on the map you provided that is between Anderson and Barbara Creek watersheds north of 32nd Ave. Some consideration of the storm water management in this area should be addressed in the study.

I have CC'd Doug Merry, Parks Planning Analyst on this email. You can direct future correspondence to Doug who can provide further Parks input on this ISMP.

Thanks,

Ted

From: Gentles, Jake (Vancouver)
Sent: August-15-13 3:44 PM
To: Uhrich, Ted
Cc: Scott, Margaret (Vancouver)
Subject: Stakeholder Engagment for Integrated Stormwater Management Plan

Hello Mr. Uhrich,

I am a member of the consultant team engaged by the City of Surrey's Engineering department (Dave Hislop and Carrie Baron) to prepare an Integrated Stormwater Management Plan (ISMP) for the Elgin, Barbara, and Anderson Creek watersheds. These watersheds are located south of the Nicomekl River on either side of the Highway 99 corridor (see attached). The goal of the ISMP is to integrate stormwater management with land use planning to facilitate development while protecting the environment. As part of the ISMP, we are developing a Vision for the watershed which will incorporate the community's values and opinions. The Vision will be used to identify and prioritize creek enhancement projects and will serve to guide environmentally responsible land development.

A public kiosk session was held on June 22, 2013 to discuss watershed health issues with residents and to collect the following:

- Opinions on the perceived health of the watershed;
- Ideas on how the health can be improved;
- Preferred options for wet weather green infrastructure; and
- Level of interest in becoming involved in watershed health activities (e.g., volunteering, rain barrel programs, etc.).

An online survey was also available over a two month period which allowed residents who could not attend the public kiosk to contribute to the Vision.

As we move forward with developing the Vision, we would like to gain a better understanding of the concerns of the watersheds' key stakeholders, including the City's internal departments. Given your influence over parks and planning activities within the watersheds we would appreciate you taking the time to respond to the following questions:

1. What are your areas of concern relating to the health of the watersheds (e.g., erosion/sedimentation issues, riparian health, etc.)? Please rank your concerns based on the order they should be addressed, from highest to lowest.
2. Does your organization currently have any specific objectives intended to improve the health of the watersheds?
3. Is your organization willing to support the City of Surrey Engineering department to develop and/or implement policies and projects that will improve the health of the watersheds? If so, what type of support are you willing to offer (i.e., monitoring, stream clean-up, application/enforcement of policies)?

Unfortunately, our timelines to complete the ISMP are tight. If you would like your opinions to be reflected in the Vision for the watersheds, we request that you submit your responses to the aforementioned questions prior to August 23rd (next Friday). If there is a more appropriate person within your organization to contact, please let me know. Thank you in advance for your assistance.

Best Regards,

Jake Gentles, P.Eng.
Intermediate Water Resources Engineer
Water Business Unit
Infrastructure & Envrionment, WorleyParsons Canada

From: Jim Armstrong
Sent: August-20-13 8:20 PM
To: Gentles, Jake (Vancouver)
Cc: Nicomekl Enhancement Society
Subject: Nicomekl Enhancement Society

Jake,
Magnus has requested that I respond to your questions regarding the City of Surrey's Integrated Stormwater Management Plan (ISMP) for Elgin. Barbara and Anderson Creeks as I led Metro Vancouver's Regional Integrated Stormwater Management Plan in 2012 and now represent the Department of Fisheries and Oceans Canada Salmon Enhancement Habitat Advisory Board - South Fraser Area.

In regards to concerns within the watersheds, our concerns are as follows:

1. Riparian Area health - intense development is adversely affecting the overall health of all urban streams and the current streamside setbacks are not adequate to protect or enhance the overall stream health. stormwater management does not protect the fisheries habitat or provide adequate flows when required (i.e dry season) and does not control flows during flash flooding events.
2. Specific stream protection measures should be advanced to ensure that there is a managed riparian area within each watershed to provide nutrients for fisheries, reduce the overall heatsink during the summer months and control the discharge of pollutants to the streams. More measurable parameters are needed and increase frequency. All stream management should not be led by engineering staff as they treat it as "flood management" and not fisheries habitat.
3. Our organization will continue to support the efforts of the Environmental Engineering group under Carrie Baron to protect and enhance stream health. Her leadership has shown a great improvement of the overall management strategy that the City of Surrey had more than a decade ago.

If you have any further questions, please feel free to contact me.

Jim Armstrong, M.Sc., R.P.Bio

From: Roy Strang
Sent: August-16-13 2:01 PM
To: Gentles, Jake (Vancouver)
Subject: FW: I.S.W .

From: Roy Strang
Sent: August-16-13 12:01 PM
To: 'Jake Gentles'
Cc: 'Ron Meadley'; 'Al Schulze'
Subject: I.S.W ..

In response to your request for comment on watershed management in South Surrey I have these comments:-

1. Priority should be given to protection of vegetation in the catchment basins, especially in headwater areas, and protection of riparian vegetation so as to minimise stream-bank erosion and consequent deleterious effects on water quality. By protection here I mean avoidance of clearing or brush removal, tree preservation and, where necessary, re-planting with native plant species
2. The Anderson creek which flows through Sunnyside Acres Urban Forest (there are several 'Anderson Creeks' in the area) is ephemeral and its integrity has been compromised by culverting and piping between the Forest and the Nicomekl River so that it is not, at present, of significant fish bearing capacity.
3. I think I can speak for Sunnyside Acres Heritage Society when I affirm that we shall willingly co-operate with conservation water management activities within and adjacent to the Forest.

I hope these remarks are helpful and am ready to elaborate on them if necessary. R.M.Strang

Appendix 4 Implementation Plan Summary

INITIATIVE # 1 - RECONFIGURE HWY 99 CROSSING

Goals Achieved: Nos. 1 & 4

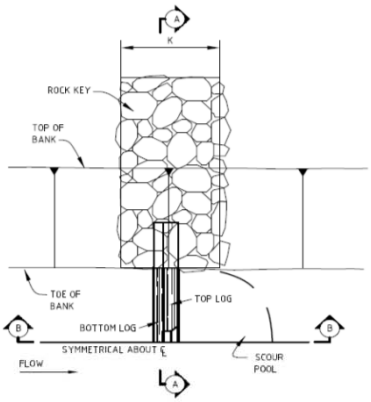
Est. Cost: $25,000 TO $35,000

Description: Install a bio-engineered log weir in order to route base flows to Barbara Creek

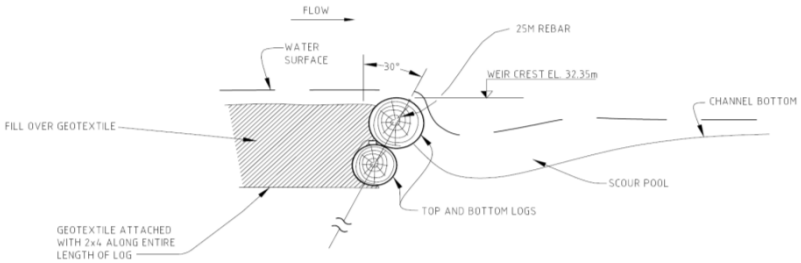
Barbara Creek - Northwest of 32 Ave Diversion and Hwy 99

Priority: High - Complete by Summer 2016

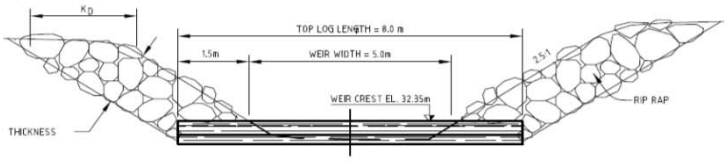
Log Weir Detail:



PLAN VIEW



SECTION Ⓑ



SECTION Ⓐ

(Drawings courtesy of NGSC)

Design Considerations:

- Water Act Approval may be required
- Confirmatory survey of the existing culvert inlets and channel cross section
- Accessibility for future maintenance
- Construction access
- Durability of materials used
- Soil conditions
- Selection of granular fill and geotextile materials

ELGIN, BARBARA, AND ANDERSON CREEKS
INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

WorleyParsons
resources & energy

DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	1	0

INITIATIVE # 2 - 152 STREET STORM SEWER (OPTION 1)

Goals Achieved: No. 4

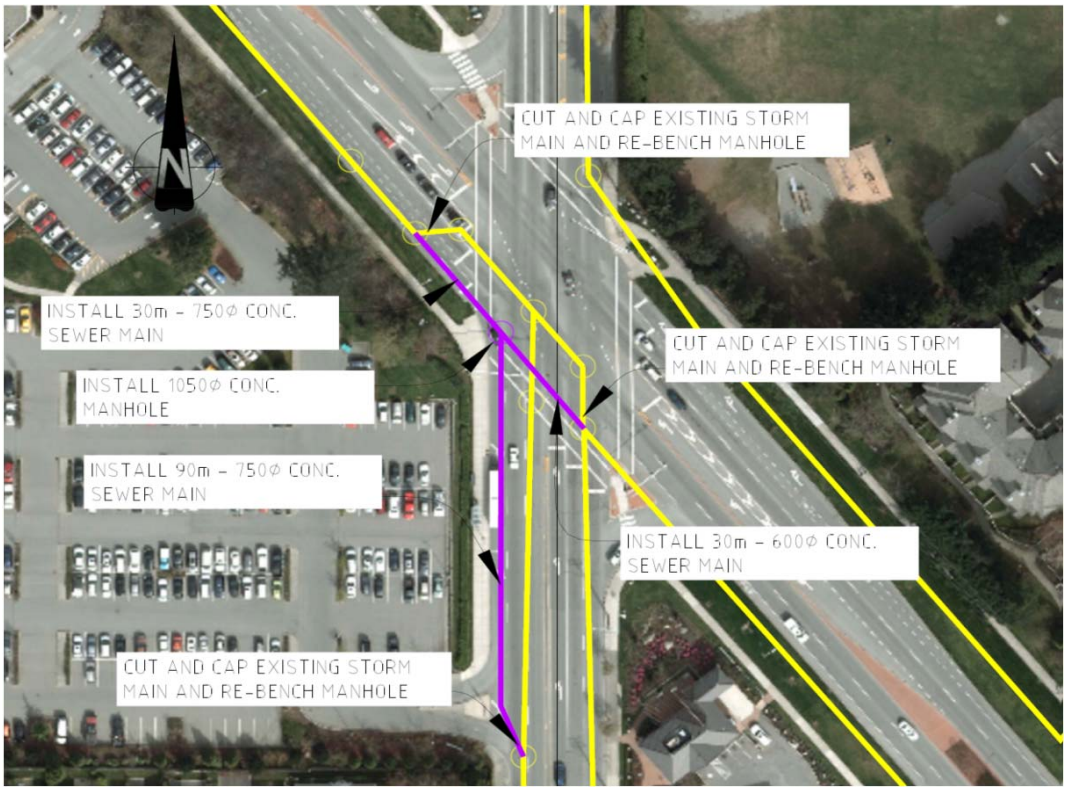
Est. Cost: $110,000 TO $120,000

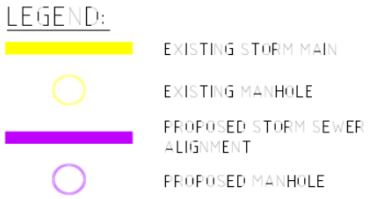
Description: Install 120 m of 750 mm dia. concrete storm main and reconfigure storm sewer at southwest corner of 152 Street and King George Boulevard to increase capacity and mitigate flooding

Priority: Moderate - Complete by 2018

Barbara Creek - 152 Street and King George Boulevard

Conceptual Sketch (Plan)





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DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
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INITIATIVE # 2 - 152 STREET STORM SEWER - OPTION 2

Goals Achieved: No. 4

Est. Cost: $10,000 to $12,000

Description: Replace four manhole frames and covers along 152 Street south of King George Boulevard with sealable manhole frames and covers to mitigate flooding

Priority: Moderate - Complete by 2018

Barbara Creek - 152 Street and King George Boulevard

Conceptual Sketch (Plan)

LEGEND:

EXISTING STORM MAIN

EXISTING MANHOLE

EXISTING MANHOLE W/
SEALABLE FRAME AND COVER

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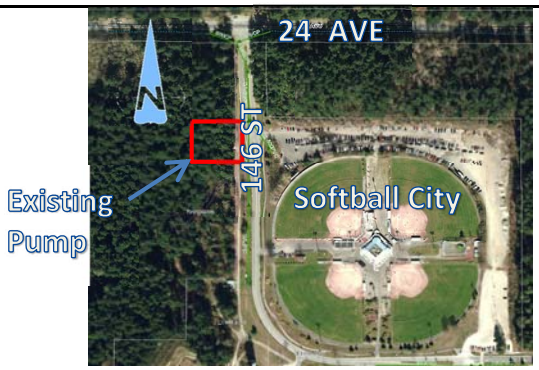
INITIATIVE # 3 - ELGIN CREEK GROUNDWATER PUMPING SYSTEM

Goals Achieved: No. 1 and No. 6

Est. Cost: $10,000 to $12,000

Description: Connect the Elgin Creek groundwater pumping system to the City's SCADA system to facilitate an assessment of the system's performance and to synchronize the system's operational cycle to the flow gauge at 32 Street

Priority: Moderate - Complete by 2018



Elgin Creek - 146 Street ROW South of 24 Avenue

Photos (Crescent Road):

Photo (32 Avenue Flow Gauge):

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INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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STRATEGY #1 - CONTROL AND MANAGE CHEMICAL USAGE AND DISPOSAL

Goals Achieved: No. 1 and 5

Est. Cost: NA

Description: Address the potential release of contaminants into the creeks in order to protect the health of aquatic habitat

Priority: Very High - Ongoing

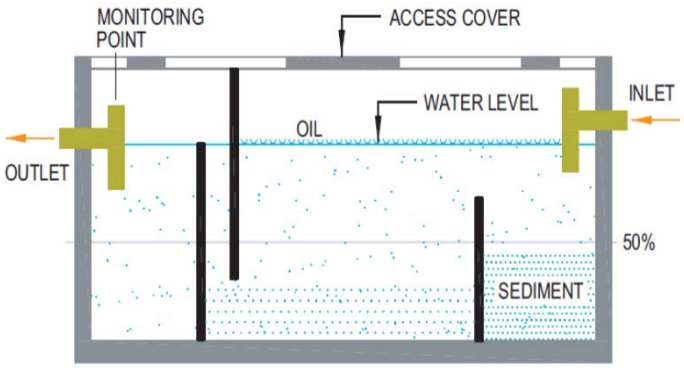
Actions Required:

- Identify industrial and commercial operators whose practices could result in the release of contaminants to the storm sewer
- Work with identified operators to develop and implement best practices
- Continue to require the installation of oil interceptors where there is the potential for the release of hydrocarbons (i.e., gas stations and parking lots)
- Monitor pesticide usage and enforce the Pesticide By-Law

Release of hydrocarbons to the Storm Sewer:

(Image Courtesy of City of Burnaby)

Typical Oil Water Interceptor:



(Image Courtesy of Capital Regional District)

Release of Contaminated Runoff to the Storm Sewer:

(Image Courtesy of Capital Regional District)

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INTEGRATED STORMWATER MANAGEMENT PLAN
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DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
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STRATEGY #2 - MANAGE NON-POINT SOURCE CONTAMINANTS

Goals Achieved: No. 1 and 5

Est. Cost: NA

Description: Address the potential release of contaminants into the creeks in order to protect the health of aquatic habitat. Non-point source contaminants can be related to the following categories: Roads and Boulevards, Municipal Utilites, Waste Management.

Priority: Very High - Review Current Practices by 2014

Actions Required:

- Review current operation and maintenance practices
- Consider whether current practices are consistent with BMPs
- Consider altering practices to match BMPs

Catch Basin Stencilling

(Image Courtesy of City of Surrey)

Catch basin protective device:

(Image Courtesy of BMP Supplies)

Best Management Practices:

- Regular street sweeping using dry clean methods
- Safe paint handling procedures
- Preventing construction materials and by-products from entering storm sewers during contruction or repair works
- Regular calibration of de-icing material spreaders
- Dry clean methods for cleaning sidewalks
- Regular removal of sediment and debris from catch basins and storm sewer mains
- Elimination of illegal / illicit discharge points
- Stencilling at catch basins to indicate connection to fish bearing creeks
- Regular inspection and cleaning of illegal dumping hot spots
- Installing litter receptacles in areas with large quantities of litter

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INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	6	0

STRATEGY #3 - IMPLEMENT BIOSWALES

Goals Achieved: No. 1, 3, 4, and 6

Est. Cost: $9 to $10 per m^2 served

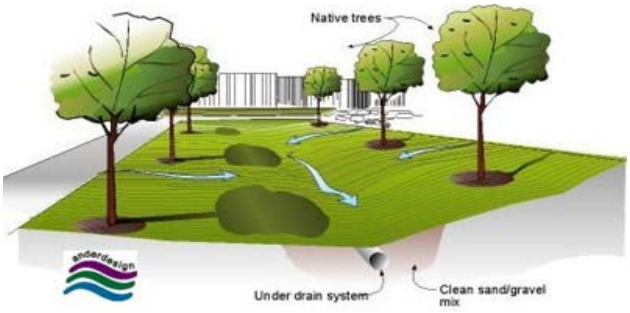
Description: Rain gardens facilitate bio-retention, infiltration, filtration, and attenuation of stormwater runoff and can be implemented to add aesthetic value in new developments, existing road corridors, private properties and large civic and commercial facilities

Priority: Moderate - Complete by 2018

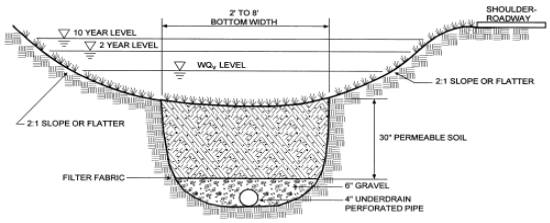
Actions Required:

- Assess location, context, soil conditions, and desired outcomes
- Assess potential for sub-surface contaminant sources
- If applicable, design and implement bioswale
- Maintain as required

Typical Cross Sections:



(Image Courtesy of Pierce County, WSU Extension)



(Graphic Courtesy of Maryland Stormwater Design Manual)

Photos:

(Photo Courtesy of City of Surrey Rosemary Heights NCP)

Design Considerations:

- Surface area treated
- Infiltration capacity of underlying soils
- Native and low maintenance planting materials
- Will bioswale include an underdrain?
- Will bioswale be used to remove contaminants?
- Are residents willing to maintain boulevard swales?

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INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	7	0

STRATEGY #3 - IMPLEMENT RAIN GARDENS

Goals Achieved: No. 1, 3, 4, and 6

Est. Cost: $20 to $27 per m^2 served

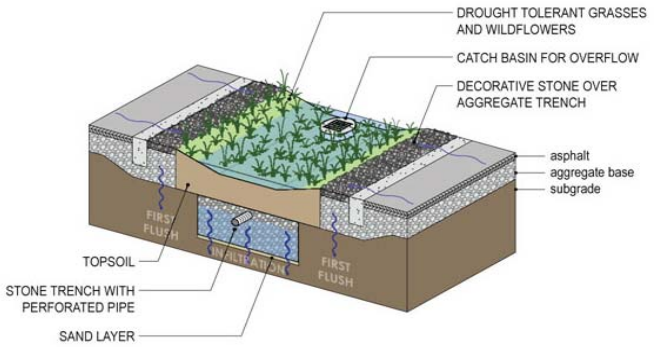
Description: Rain gardens facilitate bio-retention, infiltration, filtration, and attenuation of stormwater runoff and can be implemented in new developments, existing road corridors (as curb planters), parks, and adjacent to parking lots

Priority: Moderate - Complete by 2018

Actions Required:

- Assess location, context, soil conditions, and desired outcomes
- Assess potential for sub-surface contaminant sources
- If applicable, design and implement rain garden
- Maintain as required

Typical Cross Section:



(Graphic Courtesy of Sustainable Water Management Wiki)

Design Considerations:

- Surface area treated
- Infiltration capacity of underlying soils
- Native and low maintenance planting materials
- Aesthetics
- Will rain garden have an underdrain or lawnbasin?
- Anticipated foot traffic
- Maintenance requirements
- Height of groundwater table

Photos (South Surrey Recreation Centre Rain Garden):

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INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	8	0

STRATEGY #3 - IMPLEMENT PERMEABLE PAVEMENT

Goals Achieved: No. 1, 3, 4, and 6

Est. Cost: $100 to $120 per m^2 served

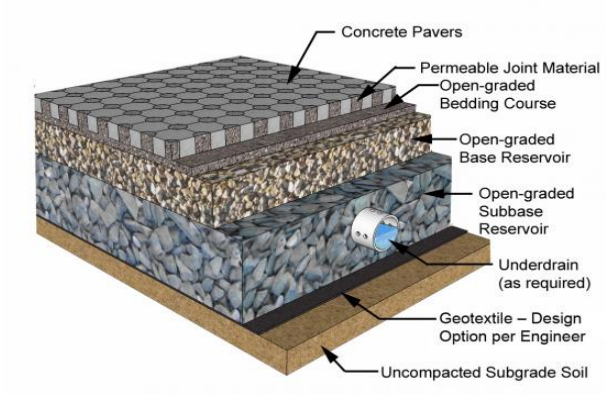
Description: Permeable pavement facilitates infiltration and filtration of stormwater runoff and can be implemented in parking lots

Priority: Moderate - Complete by 2018

Actions Required:

- Assess location, context, soil conditions, and desired outcomes
- Assess potential for sub-surface contaminant sources
- If applicable, design and implement permeable pavement
- Maintain as required

Typical Cross Section:



(Graphic Courtesy of Interlocking Concrete Pavement Institute)

Design Considerations:

- Anticipated vehicle loading
- Infiltration capacity of underlying soils
- Type of permeable paving material
- Aesthetics
- Potential Contaminants
- Longevity
- Maintenance requirements

Photo (Permeable Pavers at South Surrey Recreation Centre):

(Image Courtesy of City of Surrey)

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INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	9	0

STRATEGY #4 - RAISE PUBLIC AWARENESS OF RIPARIAN AREAS

Goals Achieved: No. 1 and 2

Est. Cost: NA

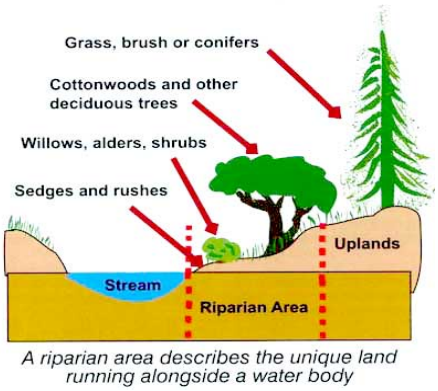
Description: Riparian areas are an important component of watershed health as they supply aquatic habitat with food and organic material and provide shade, cover, and habitat for aquatic species

Priority: High - Ongoing

Actions Required:

- Develop online or print material for the public
- Stress the importance of riparian areas and how they contribute to watershed health
- Inform the public of what they can do to protect riparian areas

Riparian area cross section:



A riparian area describes the unique land running alongside a water body

(Graphic Courtesy of the Manitoba Agriculture, Food and Rural Initiatives)

How the public can protect riparian areas:

- Avoid dumping refuse and green waste in riparian areas
- Do not create or use unauthorized trails through riparian areas
- Do not plant invasive species
- Notify Surrey of the locations of invasive species

Photo (Elgin Creek Riparian Area):

ELGIN, BARBARA, AND ANDERSON CREEKS
INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

WorleyParsons
resources & energy

DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	10	0

STRATEGY #5 - CONTROL AND MANAGE INVASIVE PLANTS

Goals Achieved: No. 1 and 2

Est. Cost: NA

Description: The presence of invasive plants can affect the biodiversity of riparian areas, adversely impacting watershed health.

Priority: High - Ongoing

Actions Required:

- Continue to raise public awareness of invasive plant issues
- Consider implementing best management practices, including the detection, containment, and suppression related practices listed below

Current Brochure:

(Image Courtesy of City of Surrey)

Best Management Practices:

- Develop or adopt a list of invasive plant species
- Raise Public Awareness
- Inspect riparian areas
- Control site disturbance near riparian areas
- Encourage responsible residential gardening

ELGIN, BARBARA, AND ANDERSON CREEKS
INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

WorleyParsons
resources & energy

DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	11	0

STRATEGY #6 - REVIEW CAPITAL AND DEVELOPMENT PROJECTS

Goals Achieved: No. 1, 2, 3, 4, and 6	Actions Required:
Est. Cost: NA	• Assess whether capital and development projects could accommodate WWGI at conceptual and application stages • Assess whether projects could coincide with creek improvements works • Determine whether development applications are compliant with leave strip and lot coverage requirements
Description: Review upcoming capital and development projects for opportunities to implement infrastructure that will contribute watershed health and for compliance with runoff related regulations and requirements	
Priority: High - Ongoing	

STRATEGY #7 - PROTECT THE SUNNYSIDE ACRES URBAN FOREST

Goals Achieved: No. 7	Actions Required:
Est. Cost: NA	• Decommission unauthorized trails • Install no dumping of waste signs around the Forest perimeter • Educate the public on the Forest's ecological importance • Create a containment belt around trees afflicted with root rot
Description: Continue to manage the Forest to maintain its health and enable residents to access it in a responsible and sustainable manner	
Priority: High - Ongoing	

Photo of Tree Afflicted with Root Rot:

(Images courtesy of sunnysideacres.ca)

ELGIN, BARBARA, AND ANDERSON CREEKS
INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	12	0

LONG RANGE OPPORTUNITY #1 - BANK STABILIZATION

Goals Achieved: No. 1 and 3

Est. Cost: Varies

Description: Identify creek sites with unstable bank materials with a high potential for causing damage to existing structures or degradation of aquatic habitat and prioritize their remediation

Priority: High - Monitor every two years or as required

Actions Required:

- Monitor the creeks for signs of bank instabilities
- Assess known bank instabilities using a prioritization system
- Implement bank stabilization infrastructure

Bank Instability Prioritization System Example

Criteria	Description	Range (Score)
Consequence	The potential for damage to existing structures if the bank instability worsens	• High: Residences (60) • Medium: Secondary Structures (30) • Low: No Structures (0)
Probability	The probability, based on visual assessment, that the bank instability will worsen over the next two years	• High (10) • Medium (5) • Low (0)
Visual Change	Whether a visual change was noted from the previous ravine assessment or a new location	• Yes (10) • No (0)
Predicted Peak Velocity	The peak flow velocities results for the 2-, 5-, and 100- year storm events predicted by the Model (scored out of 20)	• 2-Year < 1.0 m/s (0) • 2-Year > 1.0 m/s (4) • 5-Year > 1.5 m/s (6) • 100-Year > 2.0 m/s (10)

Prioritization Categories

Very High	>80	This site should be reviewed by a qualified Geotechnical Engineer and, if required, should be remediated as a priority
High	60 to 79	This site should be reviewed by a qualified Geotechnical Engineer and, if required, should be remediated within the next one to two years
Moderate	30 to 59	This site should continue to be monitored and should be considered for remediation if work occurs nearby
Low	<30	This site should be revisited during the next ravine assessment, no other action is required

ELGIN, BARBARA, AND ANDERSON CREEKS
INTEGRATED STORMWATER MANAGEMENT PLAN
IMPLEMENTATION PLAN

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DATE:	ORIGINATOR:	REVIEWER:	WORLEYPARSONS APPROVER:	PROJECT NUMBER:	FIGURE:	REV:
May 1, 2014	J. GENTLES	A. TIMMIS	A. TIMMIS	307076-04854	13	0

LONG RANGE OPPORTUNITY #2 - FIRST FLUSH CAPTURE

Goals Achieved: No. 1 and 5

Est. Cost: NA

Description: Determine whether capturing first flush runoff from the industrial/commercial portion of the Barbara Creek catchment can would provide benefit by reducing the contaminant loading to Barbara Creek

Priority: Low - Baseline conditions and during first flush storms

Actions Required:

- Establish a sampling station at the storm sewer outfall to Barbara Creek at the 32 Ave Diversion
- Monitor discharge to quantify the first flush effect
- Determine whether capturing first flush flows could improve downstream aquatic habitat conditions

LONG RANGE OPPORTUNITY #3 - FLOOD PROTECTION

Goals Achieved: No. 4

Est. Cost: NA

Description: Determine whether flood control infrastructure is required to protect low lying properties adjacent to the Nicomekl River as a result of predicted peak water levels

Priority: Low

Actions Required:

- Review projected sea level rise reports and predicted peak water levels in the Nicomekl River as they become available
- Compare the predicted water levels to the existing dyke elevations

Appendix 5 Sample Reporting Sheets

MONITORING AND ADAPTIVE MANAGEMENT REPORT COVER SHEET

Municipality: City of Surrey

Name of Watershed or Drainage Area: Barbara Creek

ISMP Status: Ongoing

Size (ha): 261

General Classification: Higher Gradient

Monitoring Location(s): No. 1 Instream No. 2 Pipe No. 3 NA

GPS Coordinates of Monitoring Location(s) and nearest Intersection (attach map):

Location No. 1 - 514328E, 5434965N, Elev. = 6.5 m; 36 Avenue and 152 Street

Location No. 2 - 514117E, 5434971N, Elev. = 24 m; 36 Avenue and 150 Street

Degree and Age of Development:

Recent densification with single family urban and multiple family lots.

Land Use Composition:

Zoning Category	%	Zoning Category	%	Zoning Category	%	Useage	%
Single Family Residential	17	Commercial	10	Agricultural / Golf Course / Cemetery	10	Roadways	20
Multiple Residential	24	Industrial	4	Institutional	5	Greenspace	10

Temperature and Precipitation Averages:

Summer: Moderate / Dry

Winter: Cool / Wet

Riparian Area Protection: Individual reviews per DFO Land Development Guidelines

Notes:

MONITORING RESULTS REPORT SHEET

WATER QUALITY MONITORING RESULTS

Wet Season

Indicator	2013 Average	Current Average	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Temperature (°C)	NA	6.0	6				
Dissolved Oxygen (mg/L)	NA	11.0	11				
pH	NA	5.0	5				
Conductivity (µS/cm)	NA	50.0	50				
Turbidity (NTU)	NA	30.0	30				
E.coli	NA	76.00	76	76			
Fecal Coliforms	NA	447.21	2000	100			
Nitrate (as Nitrogen, mg/L)	NA	2	2				
Total Iron (µg/L)	NA	6000	6000				
Total Cadmium (µg/L)	NA	0.01	0.01				
Total Copper (µg/L)	NA	2	2				
Total Lead (µg/L)	NA	4	4				
Total Zinc (µg/L)	NA	41	41				

Dry Season

Indicator	2013 Average	Current Average	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Temperature (°C)	12.2	14.1	14.1				
Dissolved Oxygen (mg/L)	9.3	9.6	9.6				
pH	7.75	7.6	7.61				
Conductivity (µS/cm)	70	110.0	110				
Turbidity (NTU)	1.81	2.5	2.5				
E.coli	NA	76.00	76	76			
Fecal Coliforms	NA	447.21	2000	100			
Nitrate (as Nitrogen, mg/L)	0.319	0.319	0.319				
Total Iron (µg/L)	NA	900	900				
Total Cadmium (µg/L)	NA	0.1	0.1				
Total Copper (µg/L)	NA	2	2				
Total Lead (µg/L)	NA	4	4				
Total Zinc (µg/L)	NA	41	41				

FLOW MONITORING RESULTS

Parameter	2013 Value	Current Value	Trend - Stable (S), Decreasing (D), or Increasing (I)	Target
MAD (L/s)	NA			
T_{qmean}	NA			S or I
Low Pulse Count	NA			S or D
Low Pulse Duration (Days)	NA			S or I
Summer Baseflow (L/s)	NA			S
Winter Baseflow (L/s)	NA			S or I
High Pulse Count	NA			S or D
High Pulse Duration (Days)	NA			S or I

BIOMONITORING RESULTS

Parameter	2013 Value	Current Value	Trend - Stable (S), Decreasing (D), or Increasing (I)	Target
B-IBI Score	22			S or I
Total Taxa Richness	19			S or I

Notes

DATE:	CATCHMENT:	SIZE:	GENERAL CLASSIFICATION:
May 1, 2014	Elgin Creek	261 ha	Higher Gradient
MONITORING LOCATION:			

CITY OF SURREY
the future lives here.

Figure 1