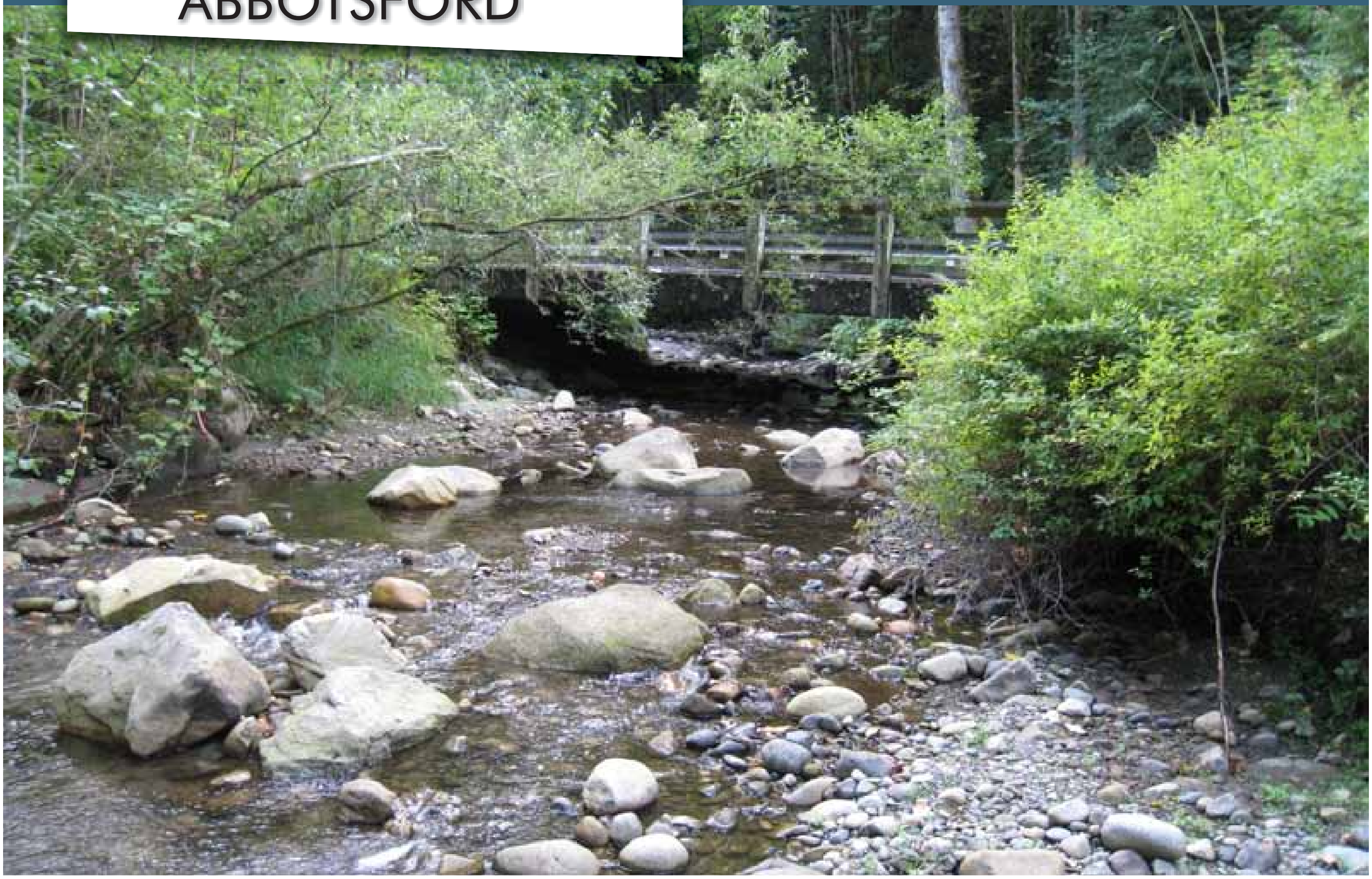

Final Report

Clayburn Creek Integrated Stormwater Management Plan - APPENDICES

May 2012

Submitted by:

KERR WOOD LEIDAL
consulting engineers

Appendix A

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A Watershed Overview

A.1 Understanding Stormwater Management

Introduction

This section outlines stormwater impacts associated with land development. Impacts caused by both large, infrequent storm events and small, frequent storm events are discussed, and the primary factors affecting stream health are also reviewed.

Understanding the Impacts of Land Development

Land development typically involves replacing pervious forested area with agricultural land followed with impervious pavement, concrete and building structures. Redevelopment typically involves replacing developed areas with higher density land use with a further increase in total impervious area (TIA). Increasing impervious area results in two types of impacts:

- **Stormwater Quantity Impacts:** Increased and faster responding peak flow rates during extreme rainfall-runoff events can cause flooding and erosion, and during typical rainfall events can trigger watercourse instability and deteriorate aquatic habitat. Baseflows during dry weather periods decrease and therefore reduce the fish support capacity of a watercourse.
- **Stormwater Quality Impacts:** Land development and building construction activities result in sedimentation of watercourses. It has been found that urbanization over 30% TIA also results in non-point source (NPS) pollution of receiving waters and poor stream water quality. Together, sediment and contaminants can significantly degrade the fisheries value of a creek system.

Stormwater Quantity Impacts

Stormwater quantity impacts can be segregated into two types, those associated with large infrequent storm/runoff events and those associated with smaller, more frequent ones, as follows:

Table A-1: Stormwater Quantity Impacts of Land Development

Storms	Return Period Event	Resulting Runoff	Potential Impacts of Development	Type of Assessment
Infrequently Occurring Large Storms	10-year to 100-year	Runoff results from both impervious and pervious areas for both the undeveloped and urbanized conditions, but a quicker, greater response occurs under the urbanized condition.	Flood and erosion damage	Hydrotechnical
Frequently Occurring Small Storms	Less than 2-year	Very little, if any, runoff is generated under natural forested conditions. Once land is urbanized, however, runoff results.	Stream corridor 'wear-and-tear' & deterioration of aquatic habitat	Environmental

AppendixA – Watershed Overview

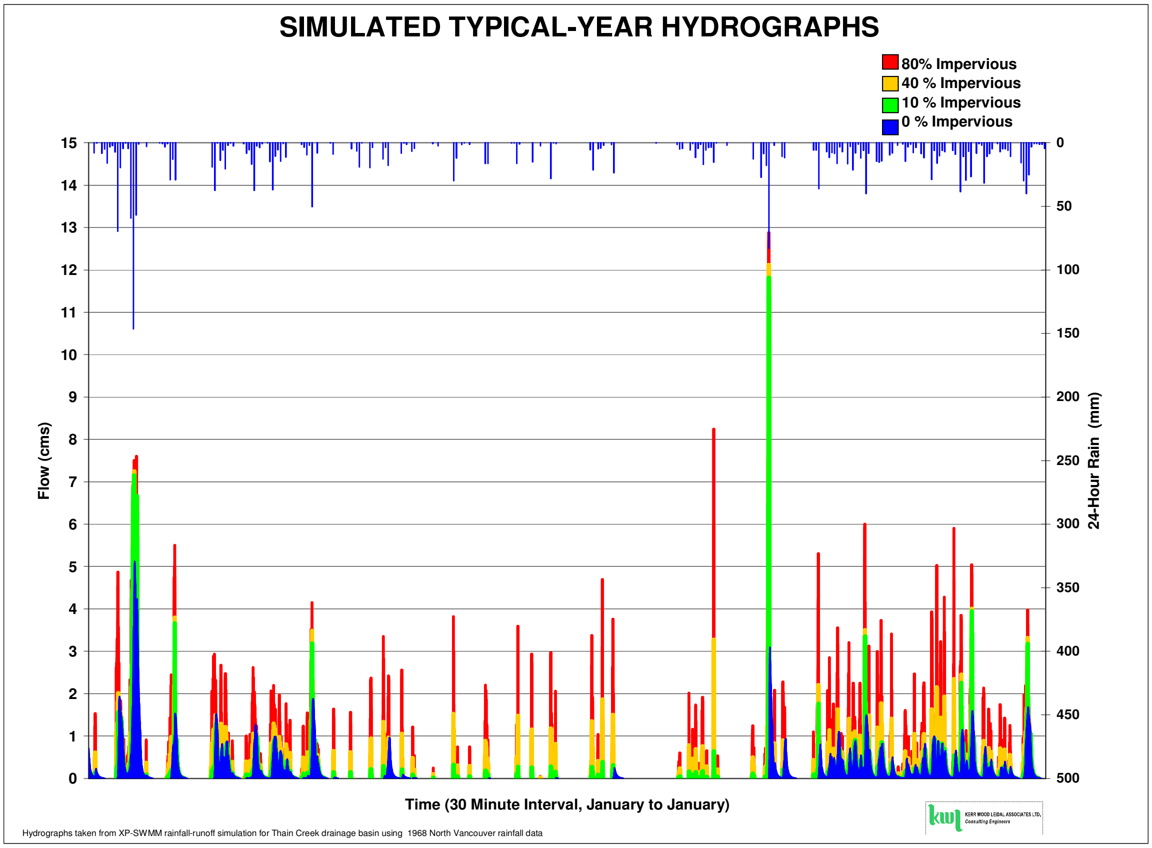

Figure A-1: Simulated Typical-Event Hydrograph for Levels of Imperviousness

Prior to land development, minor rainfall events do not yield surface runoff. However, because of increased impermeable area, surface runoff from these minor storms is produced after land development. This is clearly shown in the typical-year hydrograph for various levels of development (refer to following figure).

Research has shown that urban development, which typically increases impervious area and decreases riparian corridor, significantly impacts the abundance and diversity of fish populations and benthic macroinvertebrate communities. This is illustrated conceptually in Figure A-3.

The increased frequency of higher runoff rates and volumes causes watercourse wear and tear. The Mean Annual Flood (MAF) is a key parameter because watercourses tend to be in equilibrium under the MAF. The consequence of increasing the MAF is channel erosion until the channel widens or deepens to the point of establishing a new equilibrium. Erosion and sedimentation processes then progressively eliminate aquatic and riparian habitat.

510-057\500-Drawings\510057FigA-2_Impacts.CDR

STORMWATER IMPACTS OF INCREASING URBANIZATION

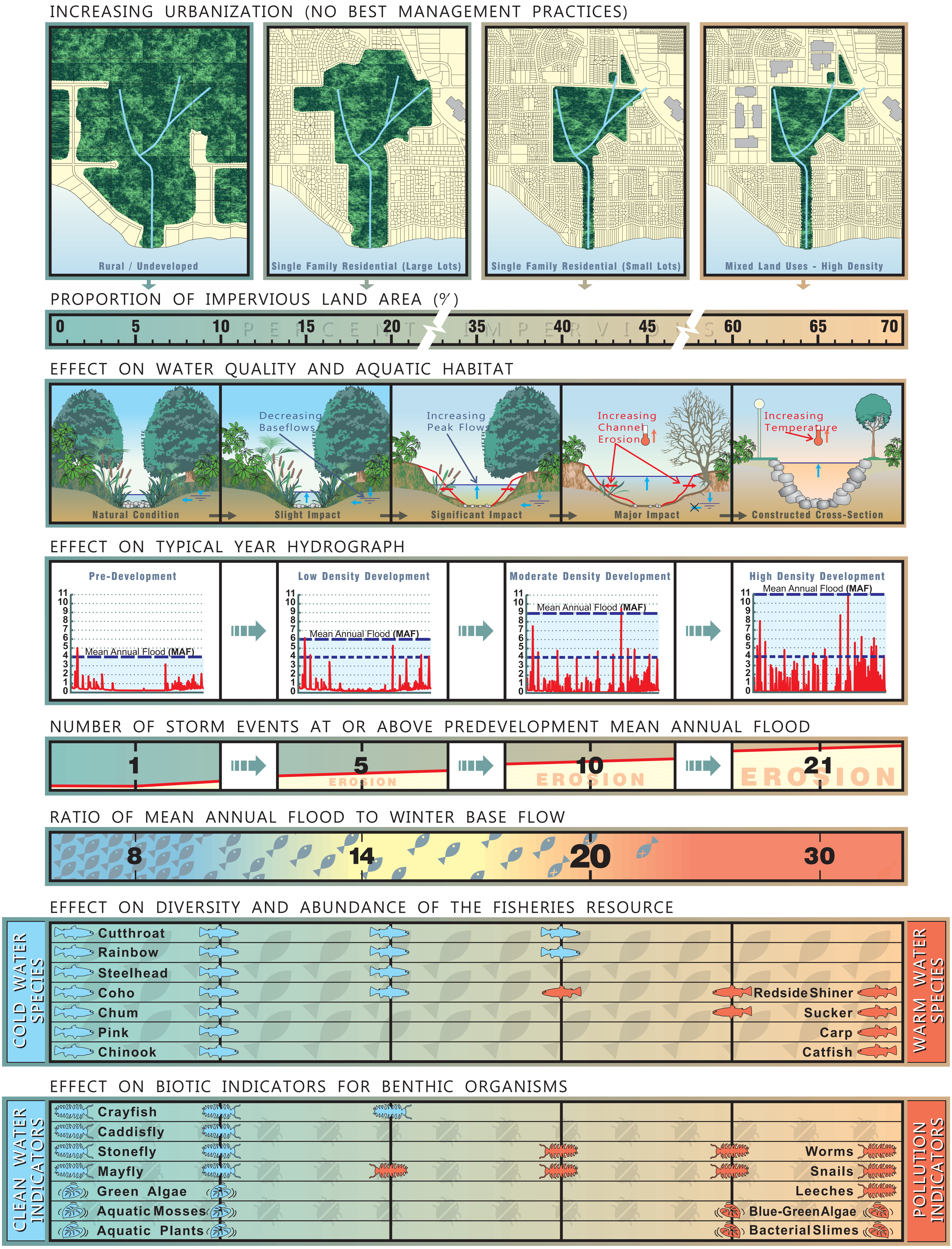

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Figure A-2

AppendixA – Watershed Overview

The reduction in groundwater infiltration and recharge results in lower baseflows, and hence higher ratios of peak flows to baseflows.

Primary Factors Limiting the Ecological Health of Urban Waterways

Recent research on urban streams indicates that four primary factors affect its ecological health. They are listed, in order of importance, as follows:

- changes in hydrology;
- disturbance to the riparian corridor;
- disturbances to fish habitat; and
- deterioration in water quality.

'Changes in hydrology' can be viewed as the paramount factor because it can impact the other factors. Increases in hydrology (flows and volumes and the frequency of their occurrence) accelerates natural rates of erosion and sedimentation, degrades or washes out aquatic and riparian habitat, and deteriorates water quality.

By the time pollutant loading is a significant water quality problem affecting fish survivability, the higher frequency of occurrence of increased flows resulting from land use densification have already degraded or disturbed the physical features associated with productive fish habitat.

Understanding the four limiting factors is key to developing guiding principles for an integrated approach to the environmental component of the ISMP. Address 'changes in hydrology' on a watershed basis, and there will be spin-off benefits in mitigating the other three factors.

Ecological Health Indicator/Performance Measure - Benthic Communities

During the past decade, environmental factors have become integral to stormwater management planning. It is now widely accepted that conventional stormwater management practices are ineffective in protecting aquatic habitat. Numerous problems include everything from the way cities are built, to the type of stormwater facilities built, and to the stormwater criteria used. Even today, many Best Management Practices (BMPs) and Low Impact Development (LID) methods are unproven, and the science behind them continues to evolve. LIDs methods encourage infiltration, evaporation, transpiration, and storage of rainfall on-site to minimize runoff. These methods are gaining popularity as a tool to help minimize the negative effects of stormwater. A measure, independent of the technology, methods, and criteria, is needed to determine whether the proposed stormwater management activities are achieving their objectives. The measure should also be reproducible in order to be defensible.

The biological integrity in a watershed can be measured in the form of the benthic macro-invertebrates community or streambed insects. Benthic macro-invertebrates occupy all watercourses, and their presence is independent of barriers and blockages, commercial and sport fishing quotas, and ocean survival of salmonids.

Appendix A – Watershed Overview

The Benthic Index of Biotic Integrity (B-IBI), developed by Karr (1996-1999), is a statistical rating system to measure benthic macro-inverterbrate communities. The index reflects Pacific Northwest conditions and has proven to be reproducible across most creek systems. More information on the index and how to use it can be found at http://www.salmonweb.org/salmonweb/ and within the report *Environmental Effects of Stormwater Discharges on Small Streams - Habitat and Benthic Assessment*, April 2000 available from the GVRD.

The index ranges from a score of 10, whichindicates the watershed health is in a“poor” condition, to a score of 50indicatingthe watershed health is “excellent”. Wild salmon are expected to be found in watersheds with high scores; while fewer fish species and lower salmonid densities are expected in watershed with scores below 25.

Land use changes, BMPs, and LID standards can be linked to the B-IBI scores or number and diversity of macroinvertebrates in a creek system. The index can also be used as a predictive planning tool.

Linking B-IBI Scores with a Watershed's Total Impervious Area

'Changes in hydrology' is directly linked to the concept of 'total' versus 'effective' impervious area.

- **Total Impervious Area (TIA):** Paved surfaces, building roofs and areas sealed from the underlying soils that are directly and indirectly connected to the local piped drainage system.
- **Effective Impervious Area (EIA):** Paved surfaces, building roofs and areas sealed from the underlying soils that are directly connected to the local piped drainage system. Thus, any part of the TIA that drains onto pervious ground is excluded from the measurement of EIA.

TIA is a physical measurement of impermeable surfaces typically taken from air photos, while EIA is determined through flow monitoring, and the hydrologic model calibration and verification process.

Figure A-2 is a graph showing a strong relationship between B-IBI scores and TIA. As TIA increases (watershed becomes more developed), B-IBI decreases (fewer and less diverse macroinvertebrate communities and therefore decreasing watershed health). Reducing TIA by applying the EIA concept based on the premise that impervious surfaces can be disconnected from the piped drainage system and the creek for frequently occurring events can have great environmental benefit. Implementing LIDs/BMPs that reduce EIA through the use of infiltration, attenuation, evaporation, and transpiration will reduce TIA, and increase the health of the watershed (and its B-IBI score).

AppendixA – Watershed Overview

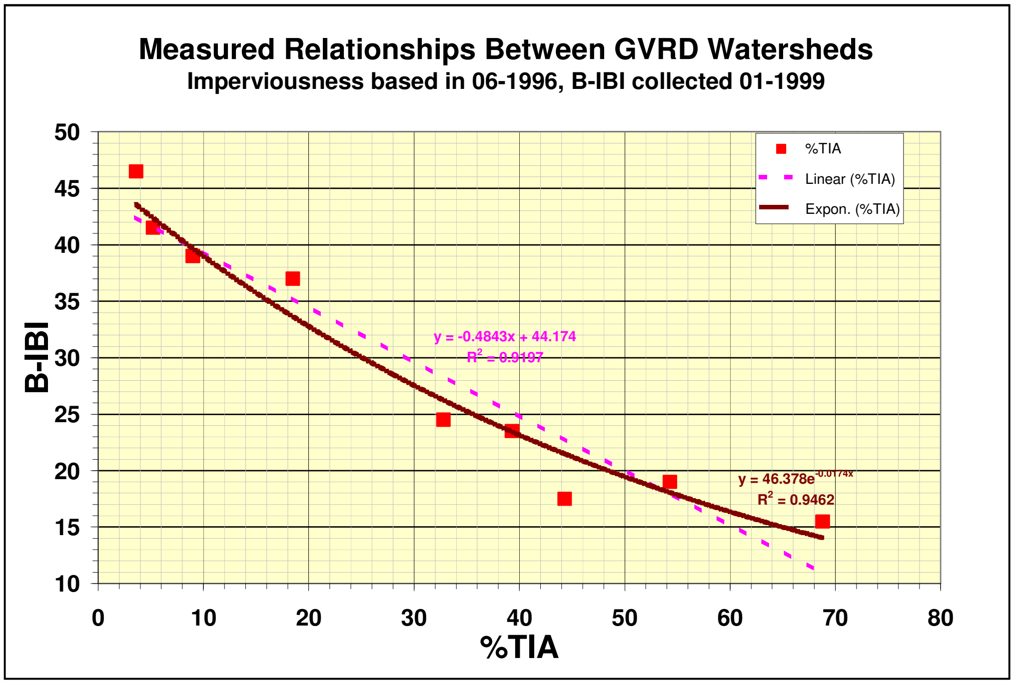

Figure A-3: Relationship between B-IBI Score and TIA

Summary of Findings

The key findings of this section are summarized as follows:

- Land development affects stormwater quantity and quality. With a TIA greater than 30%, increased peak flows and volumes for extreme events can cause flooding and erosion, and frequently occurring events can cause watercourse wear and tear resulting in erosion and deterioration of aquatic habitat. In addition, stream water quality is typically poor when the TIA is greater than 30%;
- The four primary factors affecting the ecological health of urban watercourses are, in order of importance: changes in hydrology, disturbances to riparian corridor, disturbances to fish habitat, and deterioration of water quality; and
- Benthic macroinvertebrate measurement is a biological indicator and performance measure of creek ecological health. It can be correlated with TIA and EIA.

Appendix A – Watershed Overview

A.2 City of Abbotsford Drainage Criteria

The *City of Abbotsford Consolidated Development Bylaw, 2006, Bylaw No. 1565-2006 Section No. 4 - Drainage Collection and Disposal* outlines the following guiding drainage criteria:

Infiltration Facilities

- Infiltration facilities can be used for rooftop runoff from single-family, multi-family, commercial, and industrial developments, where soil conditions are conducive to percolation, to reduce the need for downstream detention storage.
- Runoff from other areas of commercial, institutional, and multi-family developments may be permitted to infiltrate provided groundwater protection measures and strategies are provided to the satisfaction of the City Engineer.
- Infiltration systems for commercial, institutional, industrial, and multi-family developments are to be closed systems with no connection to the City drainage system.
- Volume reduction strategies such as rain gardens, vegetated swales, absorbent soils, and other innovative strategies are supported and encouraged by the City.

Detention Facilities

- Runoff from developments and subdivisions shall be controlled to prevent or mitigate flooding and environmental impacts
- Common controls include detention storage and/or infiltration systems for roof water
- The allowable release rate in the City is 5 L/s/ha of development. Storage is sized to detain runoff of flows in excess of the allowable rate
- If storage is calculated using the Modified Rational Method, a 1.5 safety factor is applied. Facilities are designed with overflow abilities for flow in excess of the 10-year event where the downstream drainage system can accommodate it, or for flows in excess of the 100-year where the downstream drainage system cannot accommodate the 10-year flow
- Facilities can include surface wet and/or dry ponds, surface parking lot storage, underground concrete tanks, linear detention ditches, and infiltration trenches

Culverts

- Roadway culverts and culverts located on natural watercourses shall convey the 200-year major flow
- Driveway culverts form part of the minor system and shall convey the 10-year minor flow
- Minimum diameter = 300 mm

Ditches

- Permanent open ditches are not accepted within the Urban Development Boundary of the City, but may be used in rural areas.

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Swales

- Swales are permitted in conjunction with lot grading, major flow paths, and roadside drainage

Minimum Basement Elevation (MBE)

- The MBE shall be 150 mm above the 100-year storm hydraulic grade line or above the centreline of a roadway designed to convey the 100-year flow.

A.3 Background Information

The available background reports are summarized in the following table.

Table A-2: Background Reports

Date	Report Title/Author
2010	Package from Concerned Citizens of Clayburn • Summary of Clayburn Creek Flood Incidents of ClayburnVillage • Clayburn Creek Watercourse Assessment: Development and Stream Management in an Urban Residential Area • Sections from 1991 Clayburn Creek Drainage Study
2008	Vicarro Ranch Community Detention Ponds- Assessment of Downstream Impacts, Hay & Company Consultants
2008	Clayburn Creek Flood Assessment 35265 Straiton Road, Hay & Company Consultants
2008	Clayburn Creek Watercourse Assessment: Development and Stream Management in an Urban Residential Area, Shawna M.T. Erickson (geography undergrad), Steven Marsh (instructor of Geography, U.C.F.V)
2007	Geomorphic Review of Proposed Gravel Removal Clayburn Creek, Golder Associates
2006	McKee Peak Environmental Reports, Terra Environmental & Madrone Environmental Services
2005	McKeePeak Planning Study, UMA Engineering
2005	Feasibility Evaluation of Stormwater Source Control Strategies for the Vicarro Ranch Development Area, CH2MHill
2005	City of AbbotsfordParks and Recreation Master Plan
2005	City of Abbotsford Official Community Plan
2005	Clayburn Creek Drainage Study, Associated Engineering
2003	FVRD, Electoral Area “H” Bylaw No. 584, 2003 – OCP for SumasMountain
2002	Stoney Creek Drainage Study, Dayton and Knight
2001	Matsqui Prairie Irrigation Review, Golder Associates
1996	Application for Environmental Review under Section 7 of the Water Act - Straiton Detention Pond, Urban Systems

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Date	Report Title/Author
1993	Matsqui Slough Drainage Study, UMA Engineering
1993	Straiton Stormwater Management Plan, Urban Systems
1991	Clayburn Creek Drainage Study, Dayton and Knight
1989	Willband Creek Drainage Study, UMA Engineering

A.4 GIS Layers of Existing Drainage System

The City keeps GIS databases (layers) for a wide variety of data; GIS layers for the drainage system were provided by the City. This included streams (channels), ditches, culverts, storm detention systems, storm sewers, and storm manholes.

Additional information for the channels was provided by several previous surveys of Stoney Creek and the Clayburn Creek lowlands. The Survey data provided by the City contained cross sections for the section of Stoney Creek north of Bateman Road, the channel east of Wright Street, the channel section between the confluences of Stoney Creek and Clayburn Creek and the property immediately east of Wright St. Bridge. Bridge profiles were provided for Stoney Creek and the lowlands of Clayburn Creek. The surveys also included information on some culverts, particularly the culverts located on Stoney Creek.

The City utilized several sources of culvert information. A GIS culvert layer contained the locations, inverts, sizes, and materials for some culverts. The layer did not contain all the culverts and was missing material, size and invert information. The City also provided hard copy information for 48 additional culverts including sizes and materials to supplement the GIS layer. As-builts from the City's WebMap application were used to determine sizes, materials, locations, and elevations for culverts that were missing information.

The storm drainage system consists of storm sewers, storm manholes and detention systems. The storm sewer GIS layer contained the length, size, material, inverts, upstream manhole name, and downstream manhole name. The layer was missing some sizes and materials, as well as both upstream and downstream elevations. The City filled in as much of the missing information as possible however pipes located at the upstream ends of sewer systems and service connections that still had missing data were removed. The manhole GIS Layer contained the rim elevations used for ground elevations in the model. The missing rim elevations were interpreted based on the digital elevation model (DEM) and two metre contours.

The detention systems GIS layer contained the area, location, type of facility, and as-built drawing number. The orifice diameter and elevations, overflow types and elevations, and structure elevations and volumes were obtained from as-builts on the City's WebMap application. As-builts not available on WebMap were obtained from the City in hard copy.

AppendixA – Watershed Overview

Existing Channel Modifications, Obstructions and Erosion

The GIS layers for the erosion, obstructions, and modification to channels were based on 2006 SHIM mapping provided by the City.

The erosion GIS layer contains the suspected sources of the erosion (bank, lack of riparian, landslide, livestock), the locations of erosion, the severity based on the area eroded, the exposure (i.e., eroded top soil, clay or till), the length, width, and height of the erosion, the slope, and comments or observations of the erosion and causes. Slope data was not always recorded, but creek gradients are shown on Figure A-3.

The obstructions GIS layer contains the type of obstruction, the location of the obstruction, whether the obstruction is a barrier in the stream, the length, width, and height of the obstruction, the slope, screen size, and comments or observations for eachobstruction. Slope was not always recorded, and the trash screen size is only included when the obstruction is ascreen in a detention pond.

The modification GIS layer contains the type of modification, the location of the modification, the type of material that modified the channel, the length, width and height of the modification, and comments on the nature of the modifications.

A.5 Drainage System Inventory

KWL undertook drainage inventory survey activities in June-August of 2009. The scope of work covered the portion of the Clayburn Creek watershed upstream of the Clayburn Road crossing immediately west of Bell Road. This watershed includes the following four major tributary catchments:

1. Clayburn Creek Main Stem;
2. Poignant Creek;
3. Diane Brook; and
4. Stoney Creek.

The purpose of the survey was to supplement the City of Abbotsford's existing geographic information system (GIS) database by locating, photographing and assessing the following features along each major tributary:

- hydraulic structures and stormwater outfalls;
- significant bank or channel erosion sites;
- significant gravel bars or sediment accumulation;
- beaver dams, log jams or other channel obstructions; and
- existing bank protection works or other channel modifications.

Appendix A – Watershed Overview

Given the extensive information already compiled by the City of Abbotsford on the less accessible reaches of the creek relating to erosion sites, channel obstructions and modifications, priority for KWL's field work program was assigned to collect information relating to hydraulic structures at or near major road crossings. From these road accessible points, short stream traverses were carried out at select locations.

Channel cross section dimensions, bank and substrate material, and channel slopes were also measured along each creek at locations representing typical local conditions.

The terms left and right in this report refer to the left and right side of the creek channel when looking downstream.

Equipment

Features and observations were positioned and recorded using a Trimble ProXT mapping grade GPS receiver together with a Trimble TSCE data collector operating Trimble Terrasync Professional field software.

A TruPulse 200B laser rangefinder with clinometer was used for length, height and slope measurements.

All inventory features were photographed at 1600 x 1200 pixel resolution using a Canon A710 digital camera. Photographs were cross referenced to the GPS position and other observations within the field data collection software.

Coordinate System

The coordinate system used for this survey is Universal Transverse Mercator (UTM) Zone 10 North, North American Datum of 1983.Raw GPS positions were differentially corrected against reference data measured at base stations in Chilliwack, Vancouver, and Bellingham. Final corrected GPS positions, field observations, and photo numbers for each inventory feature were exported in ESRI shape file format, using Trimble GPS Pathfinder Office software.Typical estimated accuracies for final corrected GPS positions are summarized below:

0-15cm	-
15-30cm	-
30-50cm	-
0.5-1m	30.4 %
1-2m	59.9 %
2-5m	8.3 %
>5m	1.3 %

AppendixA – Watershed Overview

Data Structure

The photographs and GPS positions associated with each feature were combined with additional field observations and measurements to produce a fully cross referenced database. The data collection structure used for this project is summarized below:

Culvert Inlet

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

Culvert Outlet and Storm Water Outfall

Diameter	(mm)
Material	(CMP, concrete, PVC, etc.)
Condition	(good, fair, damaged)
Headwall	(type)
Headwall Condition	(good, fair, damaged)
Energy Dissipation	(type)
Outlet Drop	(from invert of culvert down to creek bed)
Sediment Depth	(from invert of culvert up to creek bed)
Comment	(additional notes or comments)
Photo Numbers	

Bridge

Length	(along direction of flow)
Span	(across channel)
Height	(from creek bed up to bottom chord of bridge)
Thickness	(from bottom chord of bridge up to deck)
Comment 1	(additional notes or comments)
Comment 2	(additional notes or comments)
Photo Numbers	

Erosion

Location	(left bank, mid-channel, right bank))
Severity	(low, moderate, high)
Consequence	(low, moderate, high)
Length	(along direction of flow)
Depth	(height of eroding bank, or depth of eroded channel)
Comment	(additional notes or comments)
Photo Numbers	

Appendix A – Watershed Overview

Deposition

Location	(left bank, mid-channel, right bank)
Length	(along direction of flow)
Width	(across channel)
Comment	(additional notes or comments)
Photo Numbers	

Bank Protection

Type	(riprap, wall, gabions, etc.)
Location	(left bank, mid-channel, right bank)
Length	(along direction of flow)
Height	(vertically from creek bed to top of bank protection)
Comment	(additional notes or comments)
Photo Numbers	

Channel Obstruction

Cause	(natural, anthropogenic)
Stability	(unstable, stable, fixed)
Type	(logjam, beaver dam, concrete weir, etc.)
Drop	(change in creek bed elevation from upstrm. to dnstrm. side of obstruction)
Comment	(additional notes or comments)
Photo Numbers	

Cross Section

L. Bank Height	(vertically from creek bed to top of bank)
L. Bank Slope	(ratio, xH:1V)
R. Bank Height	(vertically from creek bed to top of bank)
R. Bank Slope	(ratio, xH:1V)
Bed Width	(toe of bank to toe of bank across channel bed)
Water Depth	(creek bed in thalweg to water surface at time of survey)
Upstrm. Slope	(along direction of flow upstream of section location, in percent)
Dnstrm. Slope	(along direction of flow upstream of section location, in percent)
Bed Material	(sand, gravel, cobbles, bedrock, clay, etc.)
Bank Material	(sandy loam, gravel loam, glacial till, bedrock, etc.)
Comment	(additional notes or comments)
Photo Numbers	

Wildlife

Species	
Comment 1	(additional notes or comments)
Comment 2	(additional notes or comments)
Photo Numbers	

Confluence

Bank	(bank on mainstem stream from which tributary stream enters)
Comment	(additional notes or comments)
Photo Numbers	

AppendixA – Watershed Overview

Work Program

Orthophotos, previously collected survey data and GIS data showing storm water collection systems, outfalls, streams and road crossing locations was provided by the City and used as background information to plan and carry out field investigations.

Road crossings apparent from the orthophoto for which no hydraulic structure data had yet been collected were the main focus of KWL's field work program. Many of these crossings occurred in the upper reaches of South Clayburn, North Clayburn, and Stoney Creeks.

Culverts, storm inlets, outfalls and bridges at each road crossing were positioned by GPS, photographed, measured, and assessed for condition, sedimentation, overflow height, and other information. These are summarized in Figure A-3.

From these road accessible points, short stream traverses were carried out at select locations upstream and downstream to investigate stream conditions away from the local influence of the hydraulic structures. Any significant erosion sites, gravel bars or other significant sediment accumulation, channel modifications and obstructions that were observed were positioned by GPS, assessed, and photographed.

Stream cross section dimensions, bank and substrate material, and channel slope were also measured along each creek at locations representing typical channel conditions,. These observations were positioned by differential GPS and recorded as cross section features.

A.6 Land Use Assessment

Background

As part of the Clayburn Creek ISMP investigations, HB Lanarc's role was to advise the project team on land use and development potential within the watershed in a manner that is consistent with the City's watershed and environmental goals. In late 2009/early 2010 with sustainable development principles in mind, HB Lanarc layered data provided by the project team to identify candidate sites, which would inform the kinds of development that would be in the best long term interests of the City of Abbotsford. Of primary concern was that future land developments not exacerbate flooding problems presently occurring in the lower watershed.

Constraints Based Planning

The Official Community Plan indicates land use for the watershed within the Urban Development Boundary as primarily Urban Residential, followed by Suburban Residential, with some small designations of City Residential, Industrial-Business, and Institutional. There are relatively large tracts of Resource/Conservation lands that correspond to watercourse and unique topographical features. The undeveloped areas not listed as Resource/Conservation is generally assigned as Urban Residential, which covers a broad spectrum of potential housing forms. Using a process that layered a series of site constraints, a pattern of candidate residential development sites emerged with the goal to minimize ecological impacts within the watershed.

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There are many watercourses, both permanent and ephemeral, throughout the watershed that will be protected under federal and provincial regulation. There are also ecological sensitivities, including the possible presence of blue- and red-listed species. Also, geotechnical conditions in some areas close to Clayburn Creek is a constraint to infiltration due to risk of seepage and erosion on incised channel banks. The study attempted to map some of the salient factors from available data, to help illustrate a method to identify the sites best suited for development and to anticipate the appropriate forms these developments might take. Our investigation also considered the relationship of residential development to the downtown core, travel patterns and potential transit service to these areas.

The criteria for potential development sites included:

1. Avoid watercourses (permanent and non-permanent) and riparian setbacks;
2. Develop at elevations less than 300m;
3. Avoid steep slopes > 35%;
4. Consider relationship to existing and proposed trails, parks and open space;
5. Avoid areas of soil instability and negative consequences of infiltration within those zones;
6. Identify Urban Development Boundary and Area H;
7. Aspect: give development preference to gentle slopes within 15 degrees east or west of south; and
8. Locate development parcels within a five minute walking distance to potential frequent transit loop.

This process of development candidate site identification was preliminary, and was used to illustrate a system of identifying development potential based on selection criteria. The criteria were not exhaustive, nor were they vetted by the City. For example, the ecological sensitive area study was not complete at the time of our study so the constraints that might result from that study were not included, except for the locations of watercourses and related riparian setbacks. The findings of the ecological study will have an impact on the selection of development candidate sites.

Even though the process was only preliminary, it does have value in it. The diagrams quickly reveal that when constraints are plotted there remains limited pockets suitable for development. Applying a planning process like this will identify the areas, with proper development guidelines, that may be developed with the least impact on the integrity of the natural areas.

Using criteria of gentle slopes with land oriented within 15 degrees either east or west of south as desirable dwelling locations, other candidate sites were revealed just outside of the Urban Development Boundary (UDB). This criterion also revealed significant environmentally sensitive areas remaining inside the UDB that would not be appropriate development sites. This prompted the question about whether the municipality should pursue adjusting the boundary based on a detailed geomorphologic and development rationale. Although a planning process and Council approvals would be needed, and the public and stakeholders must be properly engaged, the benefits might well be worth the effort in order to satisfy development demands while protecting significant natural and sensitive areas.

Balancing On-Site Stormwater Source Controls with Demand for Housing

The requirement for installing adequate source controls on residential development can sometimes compete with the municipality's desire to provide more intensive residential development. For example, strictly for stormwater management, it may be desirable to allow dwelling types that most closely resemble pre-development conditions, which may be five-acre single-family lots, in order to capitalize on the absorptive qualities of large areas of pervious surfaces. On the other hand, this type of development results in urban sprawl, potentially cumulatively decreased ecological diversity and habitat,

AppendixA – Watershed Overview

and increased dependency on the private automobile. More typical single family development on standard lots and streets have typically higher TIA's with property owner resistance to integrating and maintaining adequate sources controls on private property, resulting in the need for community scaled public stormwater management facilities that require significant capital, opportunity and maintenance costs.

In order to reduce carbon emissions, we considered a series of development candidate sites that would be developed at cumulative densities (including existing developed areas) that would trigger frequent transit service to the downtown core. A 22 km loop was plotted that represents a 16 minute transit trip from the furthest extent, at an average of 40km/hr. This frequent transit route has the benefit of serving existing residential areas as well as future developments within a five minute walk of the transit route.

Our analysis also considered the potential view sheds and visual impacts of clear cutting and retaining structures required for development on the south side of McKee Peak. This provided some understanding of the scale of earthwork and vegetation removal required for steep slope development.

Don Crockett, with HB Lanarc, presented a graphics package and led a discussion with planning staff at the City[1]. The graphic package and KMZ Google Earth files were submitted to planning staff in digital form for information.

In conclusion, it is recommended that:

That future land planning uses a comprehensive constraints-based approach to identify candidate development sites in order to protect key environmental features.

1. Development sites should incorporate higher residential density (aggregate) developments sufficient to justify a frequent bus transit loop to the City centre and reduce dependency on the private automobile. Furthermore, future land planning must consider and integrate existing and future alternative transportation modes and corridors.
2. Future development sites must incorporate adequate on-site, local or regional source controls.
3. The City should investigate the potential of adjusting the Urban Development Boundary and Area H to capture some of the more desirable development sites while protecting key environmental features not suitable for development within the UDB. The adjustment could be net zero to the area of the UDB.
4. As some of the candidate development parcels are highly visible from the adjacent communities, the City should either prepare or demand a visual impact study of proposed developments by the potential developer.
5. As the impact to vegetation, soils, and stormwater management for development on steep slopes is profound, the City should prepare a Steep Slopes Design Guidelines for those candidate sites that exceed 20% slope and establish a maximum limit on elevation for development parcels.

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[1] Abbotsford planning staff in attendance: Margaret-Ann Thornton, Director of Planning, Carl Johannsen, Manager of Community Planning, Ron Hintsche, Manager of Development Planning, and Wayne Gordon, Senior Planner. Date of meeting was March 30, 2010.

Appendix B

Hydrogeological and Geotechnical Assessment

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GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS

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Our file: 2993

March 2, 2010

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V5C 6G9

Attention: Crystal Campbell, P.Eng.

Dear Madam:

Re: Hydrogeological and Geotechnical Assessment for Development of Integrated Stormwater Management Plan, Clayburn Creek Watershed, Abbotsford, B.C.

Piteau Associates Engineering Ltd. (Piteau) was retained by Kerr Wood Leidal Associates Ltd. (KWL) to conduct a hydrogeological and geotechnical assessment of the Clayburn Creek Watershed (the Watershed) in Abbotsford, B.C. This assessment was designed to provide information to assist with the development of an Integrated Stormwater Management Plan (ISMP) for this area.

This assessment was conducted with the knowledge that, in many areas of British Columbia, ground infiltration of stormwater runoff has yielded a number of benefits, including reduction of peak flows and enhancement of summer low flows in local streams, and filtering out of contaminants and suspended sediments prior to discharge to streams.

OBJECTIVES AND SCOPE OF WORK

The objectives of the hydrogeological component of this assessment were to:

- Characterize the groundwater flow regime within the Watershed, including estimation of infiltration rates and creek baseflows; and
- Identify potential groundwater infiltration enhancement areas.

To meet these objectives, the following tasks were carried out:

- A desktop review of:
    - Maps of topography, surficial geology, shallow soils, surface water drainage, and current and future land use;
    - Pertinent consultant reports;
    - Water well logs for wells registered with the B.C. Ministry of Environment[1];

[1] Available via the MOE's on-line Water Resource Atlas: http://www.env.gov.bc.ca/wsd/data_searches/wrbc/

- Development of a conceptual groundwater flow model for the Watershed using the above sources of information and local meteorological and stream gauging data; and
- Visits to the site to:
  - Ground-truth soil types and pertinent hydrogeological features (e.g., springs),
  - Identify potential areas for enhanced groundwater infiltration works, and
  - Conduct percolation tests at select locations to quantify infiltration rates.

The objectives of the geotechnical component of this assessment were to:

- Identify areas of geotechnical instability within riparian areas; and
- Outline geotechnical constraints and mitigation measures for proposed infiltration enhancement works, where applicable.

GEOGRAPHICAL SETTING, TOPOGRAPHY, AND LAND USE

The Clayburn Creek Watershed is located west of the Abbotsford-Mission Highway (Highway 11) and north of the TransCanada Highway (Highway 1). It drains a large portion of Sumas Mountain and culminates near the original site of Clayburn Village. The Watershed covers an irregular shaped, 22 square kilometre area that stretches obliquely to the northeast and is roughly 7.5 km long and 3 km wide (Fig. 1).

From the flat floodplain of Matsqui Prairie at the western tip of the Watershed, the terrain ascends from west to east in semi-circular benches. For the purposes of this report, the Lowland Area is defined as that portion of the Watershed which extends to the crest of the uppermost bench (approx. 100 m-asl), located roughly 300m east of Clayburn Road. The Upland Area is defined as all higher ground northwest of this line. This area comprises a raised basin that is enclosed by several peaks (400 to 500 m-asl) to the north, east, and south.

The Upland Area is relatively undeveloped, with the exception of a golf course, a single-family residential development (referred to as the Auguston subdivision), a small industrial zone, a quarry, and various rural residences. The Lowland Area is intensely developed for single and multi-family residential use, with the exception of agricultural lands in the northwest portion.

Various measures for infiltrating stormwater have been implemented across the Lowland Area. These include approximately 1,500 m^2 of infiltration trenches and other small infiltration systems, and approximately 16,000 m^2 of unlined settling ponds. A playing field on Old Clayburn Road provides an additional 6,000 m^2 of surface area for infiltration. To our knowledge, fewer source control measures exist in the Upland Area, with the exception of small seepage tanks on individual lots in the Auguston subdivision.

CLIMATE

The Abbotsford Airport climate station is located approximately 10 km south west of the Watershed at an elevation of 60 m-asl. Monthly and daily precipitation records for this station are available from 1953 onward. Based on the normalized record for the period 1971 to 2000, the station receives about 1,573mm of precipitation annually. The highest monthly average occurs in November (241mm), and the lowest in August (49mm). The average annual temperature is 10.0°C, and minimum and maximum average monthly temperatures are 2.6 and 17.7°C in January and August, respectively.

Local precipitation data was also available for the period of September 2007 to September 2009 from a climate station at Ledgeview Golf Course (supplemented with data from Abbotsford City Hall, as needed). As illustrated on Fig. 2, total precipitation in 2008 (1,118mm) was lower than the normalized record, and ranged from 28mm in July to 230mm in November.

SURFACE DRAINAGE

The Upland Area is dissected by Clayburn and Poignant creeks and numerous smaller tributaries. In many places, particularly in the “seat” of the basin, the tributaries are sourced from small wetlands and boggy areas. Creek flows are generally to the southwest along moderately incised channels to deeply incised ravines. Downcutting is particularly severe for the reaches of creeks extending 1.5 km upstream and 1 km downstream of the confluence of Clayburn and Poignant creeks. In these areas, the ravine walls crest up to 75m above the creeks.

The Lowland Area is drained by Stoney Creek, whose headwaters are located on the flanks of McKee Peak and a lesser peak to the southwest. Several tributaries feed into a large marshy area which in turn decants into Stoney Creek at Wells Gray Avenue. Downstream of this point, the creek channel is relatively shallow except where it crosses topographic benches. In Palfry Park between Laburnum Road and Prior Avenue, it has eroded a relatively steep ravine. In the floodplain area, Stoney Creek picks up drainage from Nicholas Brook and associated drainage ditches before merging with Clayburn Creek.

The average annual flow measured at the Clayburn Creek hydrometric station (Fig. 1) in 2008 was 450 L/s. No flow data is available for Stoney Creek at this time; however, based on the relative size of its catchment basin, average annual flows on the order of 150 L/s are anticipated.

SURFICIAL GEOLOGY

The regional surficial geology map indicates that the Watershed is bounded by pre-Tertiary to Tertiary bedrock on the north, south, and east sides of the Upland Area (T and PT on Fig. 1). These rocks are volcanic, granitic, or sedimentary in origin, and are blanketed in most places by 1 to 5m of glacial, colluvial, and eolian sediments.

The “seat” of this basin was likely occupied by a large ice mass during the last major glaciation some 10,000 year ago. This event generated a variety of glacial sediments, including lodgement and minor flow till (Sf), and glaciofluvial channel, deltaic, and floodplain sands and gravels (Sa, Sj). The till unit is comprised primarily of a poorly sorted, compact to very compact sandy silt with substantial amounts of clay (Photo 1), and is up to 10m thick. The sand and gravel units contain some silt and clay lenses and are up to 40m thick (Photos 2, 3). Collectively, these sediments are referred to as Sumas Drift.

In many places, Sumas Drift sediments are underlain by glaciomarine silts and clays belonging to the Fort Langley Formation (FLc). These sediments are exposed in the deeply incised channels of Clayburn Creek, and consist mainly of silty clay and clay loam.

Salish and Fraser River Sediments were deposited within the last 8,000 years, and are still in the process of formation. Salish Sediments within the Watershed consist of colluvial sands deposited by mass wasting processes (SAm), and stream channel and overbank deposits (SAh and SAj). Predominant soil textures and thicknesses are as follows: sand and silt up to 4m thick (SAm), silty clay and fine sand up to 8m thick (SAh), and sand and gravel up to 10m thick (SAj). The sand and gravel deposits are located near the intersections of Straiton and Clayburn roads and the intersections of McKee and Upper Sumas Mountain roads. The sand and silt deposits are distributed across the northwest portion of the Lowland Area, and are interrupted in places by an up to 10m thick sequence of Fraser River Sediments (Fd) comprised of silt and clay.

SHALLOW SOILS

A variety of shallow soils have accumulated above the bedrock and surficial sediments described in the previous section. The most common soil types are the Ryder and Lonzo Creek soils (RD and LZ on Fig. 1). These cover the majority of the Upland Area, and are comprised of silt, silty loam, and sandy loam. Although the soils themselves are classed as moderate to well draining, infiltration is limited by the low permeability of the underlying till unit and frequent perched water table conditions.

The second most prevalent soil types are the Marble Hill and Abbotsford soils (MH and AD). These cover a large part of the Lowland Area, where drainage is facilitated by underlying coarse textured glacial outwash deposits.

Small areas of well drained colluvial soils blanket the local peaks. These include the Cannel and Poignant soils (CE and PT), which are described in many places as gravelly loam. The capacity of these soils to accept stormwater runoff would be limited by the depth to bedrock, which ranges from 0.1 to 1.0m.

An S-shaped accumulation of Sardis soils (SD) borders the lower reaches of Clayburn Creek near the intersection of Clayburn Road and Straiton Road. These comprise moderately well drained sands and gravels of undocumented thickness.

Soils in the low-lying floodplain area, including the Elk (EK), Hazelwood (HD), Glen Valley (GV), and Niven (NN) soils, are classified as having poor to very poor drainage owing to their high fines content (silt and clay) and high water table conditions. Here and elsewhere throughout the study area are small pockets of Calkins (CN) soils, which have similar drainage limitations.

WATER TABLE CONDITIONS

Hydrogeological sections depicting borehole lithologies and water table conditions in key areas are presented on Figs. 3 and 4. Copies of well logs for all wells included on the sections, and for select wells in other areas, are included with Appendix A.

Water well records for wells located in the northwest portion of the Lowland Area (Well Tag Nos. 6702, 56834, and 94127) indicate water table depths of less than 3m below grade. Flooding was observed on cultivated lands in this area during the November 2009 site reconnaissance (Photo 4).

Eight water wells and one spring are captured on Section A-A', which transects the Sumas Drift sands and gravels in the Lowland Area. Corresponding well logs indicate up to 43m of sand and gravel comprising a substantial unconfined aquifer. The water table is up to 25m below surface on the southwest half of the section, and eventually surfaces at the base of a hillslope on the north half of the section.

Nine water wells and two springs are captured on Section B-B,' which transects the Sumas Drift till formation along Dawson Road. Several wells are dug wells less than 3m deep, and collect water from saturated soils (Photo 5). Abundant spring-fed boggy areas and marshes are also indicative of their saturated condition. This is not surprising given that the section crosses a topographic depression where depths to bedrock are relatively shallow (< 15m).

North of Section B-B,' the surficial geology is mapped as pre-tertiary Volcanic and Granitic rock (Fig. 1). Most of the wells in this area are bedrock wells targeting water-bearing fracture sets at depths of 40m or more. Many are reported to yield modest flows of less than 1.3 L/s, suggesting that interconnecting fracture sets do not comprise substantial bedrock aquifers.

GROUNDWATER FLOW CONCEPTUAL MODEL

A conceptual model of groundwater flow within the Watershed was formulated using our knowledge of soil and sediment types and local climatic and hydrometric data. This model is illustrated on Fig. 5.

To obtain estimates of natural infiltration rates across the Watershed, raw discharge measured at the Clayburn Creek hydrometric station were compared to local total precipitation amounts. In 2008, the region received 1,118mm of precipitation, which is equivalent to 35.5 L/s/km^2. Low flows measured at the Clayburn Creek station in July were on the order of 40 L/s (Fig. 2). Since most of the flow at this time of year originates as groundwater, this offers an order of magnitude estimate of groundwater recharge within the catchment area. When divided by the approximate catchment area for Clayburn Creek (75% of the total area of the Watershed, or 16.6 km^2), a baseflow flux of 2.4 L/s/km^2 is obtained. This is equivalent to about 76 mm/year, or 6.8% of total precipitation.

Groundwater recharge rates will vary within the catchment depending on slope, degree of development, and the permeability and compaction of surface soils. In the Upland Area, most precipitation is expected to runoff into shallow drainage channels and wetland areas. Between 5 and 10% of rainfall is expected to saturate near surface soils and eventually report to Clayburn or Poignant creeks. In the adjacent Lowland Area, the sand and gravel aquifer is likely to receive between 30 and 50% of incident precipitation, depending on the density of development. However, recharge is expected to decrease again to between 5 and 10% in the lower lying floodplain owing to high water table conditions.

Groundwater contributions to surface flow (i.e., baseflows) are also expected to vary within the Watershed. Headwater reaches draining bedrock and low permeability soils, or that are perched (i.e. creek invert above the water table) are interpreted to receive negligible baseflows. These are indicated by the non-highlighted sections of creeks on Fig. 5. Stoney Creek is interpreted to be perched upstream of Laburnum Rd., based on groundwater level data obtained from nearby wells.

As watercourses progress downstream and enter more developed channels that intercept the water table, baseflows are expected to increase. Baseflow contributions for those reaches highlighted in purple (Fig. 5), are estimated to be between 2 and 3 L/s/km^2 (63 to 95 mm/year). Baseflow contributions to the lower reaches of Clayburn and Stoney Creeks (highlighted in pink on Fig. 5) cannot be back-analyzed from available gauging data. These reaches are underlain by permeable sands and gravels (Sa, SAj, SAw), which are interpreted to allow for a higher infiltration rate and a large quantity of groundwater storage. Here, baseflow contributions are estimated to range from 5 to 6 L/s/km^2 (158 to 190 mm/year), based on flow gauging data for the hydrogeologically similar Anderson Creek watershed in Langley, B.C[2].

FIELD INVESTIGATION

PERCOLATION TESTING PROGRAM AND RESULTS

Percolation tests were conducted at five locations within the Watershed, as indicated on Fig. 1. Readily accessible sites on municipal (park) lands were selected in each of the major surficial sediment types: the Sumas Drift till (Locations 1 and 2), the Sumas Drift and Salish sand and gravel (Locations 3 and 4), and the Salish sand and silt (Location 5). No percolation tests were conducted in areas mapped as Sandstone or Granitic or Volcanic rock, as thin soil/sediment

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[2] From archived hydrometric data available at: http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm?cname=WEBfrmMeanReport_e.cfm

horizons and the impermeable nature of bedrock make infiltration enhancement less practical (Photo 7). Ground conditions at or near Locations 1 through 5 are depicted in Photos 8, 1, 9, 2, and 10, respectively

Percolation tests were conducted on November 26, 2009 in accordance with the methodology described in the BC Ministry of Health Sewerage System Regulation (BC MOH, 2007). Each test involved excavating a two foot deep, one foot square test hole and filling it with water twice. After this pre-soak step, the hole was refilled to six inches from the bottom multiple times and the time for the water level to drop one inch was recorded. The test was concluded after consecutive trials did not vary by more than two minutes per inch. The final (slowest) percolation time was taken to be the most representative value of the suite.

The percolation times measured at the five test locations are tabulated in Table I. A correction factor of 0.33 has been applied to correct for flow across the side walls of the hole, and to facilitate comparison to infiltration rates measured elsewhere using a double ring infiltrometer. The corrected infiltration rate measured in the till unit at Location 1 was 2.7 mm/hr. This is comparable to values obtained for the same unit on the west end of the Auguston subdivision (0.1 to 5 mm/hr, Levelton, 2008). The second result measured in the till at Location 2 (22 mm/hr) is considered to be more representative of the better-drained overlying loamy soils.

Corrected percolations times measured in the sand and gravel unit at Locations 3 and 4 varied from 53 to 117 mm/hr. These are considerably slower than those anticipated for outwash sand and gravel (Tables opposite Fig. 1), probably due to the presence of loamy soils near ground surface. The percolation time measured in the silt and sand unit at Location 5 was 21 mm/hr, which is considered reasonable.

Infiltration rates listed on the table opposite Fig. 1 can be used for watershed flow monitoring. The listed short-term rates can be considered constant for the soils derived from coarse-grained sediments situated in well drained areas. However, long-term rates may be about 50% of the short-term rates in some areas due to layering in the shallow soil profile. Sustained infiltration rates in areas underlain by fine grained sediments or bedrock (Sam, SAh, Sf, Flc, Fd, T, PT) would be about 25% to 30% of the rates listed in the table.

CHARACTERIZATION OF GEOTECHNICAL HAZARDS

Slopes in the study area ranged from flat to steep. While flat to gentle slopes were noted throughout much of the study area, steep slopes are associated with the well incised portions (i.e., ravines) of Poignant and Clayburn creeks and to a much lesser extent the lower-central portion of Stoney Creek (Fig. 1). Steep slopes were also noted in the northern and southernmost portions of the Watershed, where terrain climbs steeply to the drainage divide, and locally throughout the Watershed. Where steep slopes are associated with the Clayburn and Poignant creek ravines, numerous natural instabilities, generally consisting of small, localized slumps or debris slides, were noted (Photos 11 and 12). Stream bank erosion was also noted at numerous locations along Poignant and Clayburn creeks, along the portion of Stoney Creek downstream of Old Clayburn Road, and along smaller tributary streams. A drawing called, “Erosions and Obstructions”, dated May 2009, showing the results of an audit of stream channel erosion within the Watershed was provided by KWL for our review. This figure is included in Appendix B and identifies the locations and sizes of sites of active erosion and/or instability along the stream channels in the Watershed.

With the exception of the portion of Stoney Creek downstream of Old Clayburn Road, and Clayburn Creek downstream of the junction of Straiton and Old Clayburn roads, riparian vegetation was relatively dense. Riparian vegetation was generally comprised of Red Alder, Maple, Cottonwood, Cedar, and Hemlock trees with an understory of salmonberry, ferns, devils club and blackberry. These species are indicative of moist to wet soil regimes in the riparian areas and on the slopes of the ravines. This is consistent with observations of seepage at several locations on the ravine slopes.

Stoney Creek below Old Clayburn Road was accessible via Palfry Park, McKee Park and Bateman Park. In this portion of the channel the riparian vegetation was limited and numerous eroded stream bank sections were noted (Photo 2). Vegetation reduces bank erosion and loss of soil from overbank areas. The lack of riparian vegetation along this portion of Stoney Creek has likely contributed to the observed significant erosion of unconsolidated sediments exposed in the banks. Higher peak flows during storm events, associated with upstream residential development, may have exacerbated this erosion.

Erosion of the banks of both Poignant and Clayburn creeks was visible from Straiton Road (Photo 13) and from the trail that follows the north side of Clayburn Creek between Straiton Road and McKee Road. This erosion is a natural result of the meandering of the stream channels. The dense, high clay content nature of the glaciomarine Fort Langley Formation and the till of the Sumas Drift deposit that are exposed in these areas make them erosion resistant. However, as the flow of water slowly erodes and undercuts the slope in these areas, the slopes spall blocks of soil that are more easily eroded due to the increased surface area exposed to mechanical weathering processes (Photo 11).

While a detailed assessment of the potential for instability of all lands within the study area was beyond the scope of our study, oversteep fills were noted pushed out onto moderate to steep ravine slopes. Failure of unstable fills or natural slopes into stream channels can result in an increased risk of debris torrent initiation due to debris loading.

Geotechnical hazards noted within the Watershed included active stream bank erosion along Poignant, Clayburn and Stoney creeks and their tributaries and active instability of steep ravine slopes along Poignant and Clayburn creeks. No evidence of large scale, deep-seated instability was noted during the field reconnaissance.

DISCUSSION REGARDING INFILTRATION ENHANCEMENT WORKS

POTENTIAL AREAS FOR INFILTRATION ENHANCEMENT

Shallow infiltration systems could be designed to infiltrate water into the majority of Lowland Area soils and sediments, as indicated by the yellow region identified as Area A on Fig. 6. This area is covered by well-drained Marble Hill and Abbotsford soils which in turn overlie permeable sands and gravels. Areas where the water table is more than 5m below surface offer substantial storage capacity for stormwater infiltration, so long as it is controlled to prevent excessive water table mounding and ground seepage in other areas.

The potential for ground infiltration of stormwater is more limited in the orange regions identified as Areas B and C (Fig. 6):

- Area B experiences high water table conditions and/or is blanketed by moderate to poorly drained loamy soils and sediments having high silt and clay contents. As this area is located near the outlet of the Watershed, source control measures are of less value and emphasis should be placed on engineering works that store upgradient runoff and prevent flooding during the wetter times of year.
- The high density of watercourses in Area C makes it a less attractive area for ground infiltration, despite the fact that it rests atop relatively well-drained soils and sediments. Furthermore, bedrock is suspected to be encountered at relatively shallow depths throughout this area.

Large-scale infiltration of stormwater is not recommended in the red region (Area D), which covers the majority of the Upland Area. This is due to the poor infiltration capacities of the till and relatively shallow depths to bedrock. Extensive ponding and high water table conditions on the north side of the Auguston subdivision indicate that these surficial materials are already saturated during the wetter months of the year. Unlike the Lowland Area, there is no substantial aquifer in this region to accept high volumes of infiltrated water. However, small-scale (individual lot) shallow infiltration works could be implemented in Area D in areas where the more permeable soil horizon above the till or bedrock is of adequate thickness. As evidenced by the percolation test result at Location 3, the soil horizon may offer acceptable infiltration capacity for this purpose.

Routing of stormwater to Area E, located east of the Auguston subdivision, may be an option for nearby developments in Area D. Local water well records (Well Tag Nos. 36145, 67529, 6670, 6686) indicate that Area E is underlain by an up to 5m thickness of medium-textured soils and Salish sands and gravels which are relatively unsaturated (water table approximately 5m deep). However, shallow bedrock in the northwestern portion of this area, and poorly drained terrain (marshy areas) to the southeast may limit infiltration opportunities.

GEOTECHNICAL CONSIDERATIONS FOR INFILTRATION ENHANCEMENT

General

There are many possible designs for the collection of stormwater runoff and discharge to the subsurface. The merits of each method would have to be evaluated relative to the nature and depths of the permeable soils and groundwater table, and the nature of the development being undertaken.

Tests should be conducted on each property to identify its capacity to infiltrate water and infiltration systems should be located within a given property where the greatest infiltration capacity is encountered. Subsurface soils should be investigated for each development with respect to natural infiltration capacity so that proper designs can be prepared. A wider distribution of smaller infiltration systems will help reduce the likelihood of water table mounding, which could have negative impacts with respect to slope stability or water ingress into basements/foundations. Infiltration system designs should consider the potential for down-slope negative impacts.

Forests, with their organic soils, root systems, and shade are good environments for the storage of precipitation for slow release to the subsurface. Forests have some of the lowest runoff coefficients of any land use type. The development of open space linkages and tree preservation corridors occupy a negligible proportion of land, but contribute significantly to recharge. As such, preservation of trees and forest soils should be promoted within individual developments. In addition, the preservation of topsoils, natural soil horizons and natural vegetation on development sites should be encouraged to the greatest extent possible.

Ravine areas immediately adjacent to creeks may have seepage occurring from upper, more permeable horizons, from exposed interbeds, and/or seepage near the stream channel itself. Ravines and riparian areas immediately adjacent to creeks and wetlands should be preserved to allow for the natural discharge of water. To this end, it is recommended that development, including infiltration works, bordering ravines be limited to areas above the top of the inner ravine. The top of the inner ravine is defined as the point where the sidewall slope breaks to less than 50% (Fig. 7). Riparian vegetation should not be removed from the Riparian Management areas or inner ravine slopes. It is important to note that development of lands adjacent to the streams within the Watershed may be subject to the regulations of the Department of Fisheries and Oceans (i.e., Federal Fisheries Act), the Ministry of Environment of B.C. (Environmental Management Act), and the local Municipal Act.

A schematic of proposed general setback zones is illustrated on Fig. 7. Zones 1 to 3 pertain to the implementation of infiltration works and Zones 4 and 5 pertain to land development other than infiltration works. Five setback zones have been identified. Zone 1 includes inner ravine slopes and should not be developed and no infiltration works should be constructed in these areas. Zone 2 represents the terrain above the inner ravine slopes (i.e., flatter than 50%), but inside a setback defined by a 4H:1V (i.e., 25%) slope angle from the toe of stream channel or ravine slopes. No infiltration works should be constructed within this zone without detailed site investigations and designs by a qualified geotechnical engineer (i.e., a professional engineer registered in B.C.). Zone 3 represents the terrain outside Zones 1 and 2 and construction of infiltration structures in this area is considered unlikely to negatively impact geotechnical stability or down-slope resources and infrastructure. A detailed hydrogeological assessment and design is recommended for all infiltration structures constructed in this zone.

As a preliminary planning guideline, setbacks for land development/construction purposes, excluding infiltration works, should be established utilizing a setback criteria of 2H:1V (i.e., 50%) from the toe of stream channel or ravine slopes. Detailed site investigations by a qualified geotechnical engineer are recommended prior to approval of any development and/or construction within the proposed setback zone, excluding inner ravine slopes which should not be developed. This area is identified as Zone 4 on Fig. 7. It is considered unlikely that development outside the setback zone would negatively impact geotechnical stability. However, in keeping with good practice, it is recommended that designs for development of lands within this area, identified as Zone 5 on Fig. 7, should be reviewed and approved by a qualified geotechnical engineer to ensure that negative impacts to geotechnical stability or down-slope resources and infrastructure will not occur as a result of any proposed development.

Where possible, storm drains should be designed in such a manner as to minimize the amount of drainage delivered to Stoney, Clayburn and Poignant creeks and/or their tributaries.

Area specific recommendations are provided in the following and refer to the five areas of potential stormwater infiltration (Areas A through E) described above and illustrated on Fig. 6.

Area A

Infiltration enhancement in Area A should not significantly exacerbate observed instability along Stoney Creek and Clayburn Creek if properly designed and located. As noted above, for planning purposes, offsets for construction of infiltration enhancement works should be established utilizing a setback criteria of 4H:1V (i.e., 25%) from the toe of stream channel or ravine slopes (Fig. 7). One notable exception to this is in the vicinity of Straiton Road in the northern portion of Area A. Due to the possible presence of fine-grained (silt and clay) layers in the subsurface in the northern portion of Area A, a setback of 200m from the crest of the steep slope above Straiton Road to the southwest is recommended. The extent of this setback is illustrated on Fig. 6. No infiltration structures should be placed within these setbacks without detailed site investigations and designs by a qualified geotechnical engineer.

No infiltration structures should be placed within 100m of the inner ravine slope of Stoney Creek without detailed site investigations and designs by a qualified geotechnical engineer. Inner ravine slopes should not be developed or considered for siting of infiltration works (Fig. 7).

Areas B and C

As noted above, Areas B and C offer more limited opportunities for collection of stormwater runoff for discharge to the subsurface.

Area D

As noted above, small-scale infiltration works are considered feasible in the portions of Area D where permeable soil horizons are of sufficient thickness above the till or bedrock contact. In the west-central portion of this area steep ravine slopes rise from Poignant and Clayburn creeks. Observed active instability on these slopes suggest they are metastable and increased infiltration near the crest could exacerbate observed instability.

As noted above and as illustrated on Fig. 7, for planning purposes, setbacks for purposes of siting infiltration works should be established utilizing a setback criteria of 4H:1V (i.e., 25%) from the toe of stream channel or ravine slopes. No infiltration works should be constructed within this zone without detailed site investigations and designs by a qualified geotechnical engineer. In addition, infiltration structures should not be placed within 250m of the inner ravine slopes of Poignant and Clayburn creeks and their tributaries in the west-central portion of Area D, without detailed site investigations and designs by a qualified geotechnical engineer. Inner ravine slopes should not be developed or considered for siting of infiltration works.

Area E

If properly designed and located, construction of infiltration enhancement works in Area E should not negatively impact geotechnical stability. Again, siting of infiltration structures should not be done without detailed site investigations and designs by a qualified geotechnical engineer.

CONCLUSIONS AND RECOMMENDATIONS

1. The upper portion of the Clayburn Creek watershed is underlain primarily by rock, till and glaciomarine sediments. The summer baseflow derived from this area is approximately 40 L/s, equivalent to a unit flux of 2.4 L/s/km^2, or an average annual recharge of 76 mm/year. A higher unit baseflow, estimated to be between 5 and 6 L/s/km^2 (158 to 189 mm/year) would be derived from the lower portions of the watershed that are underlain by permeable sands and gravels.

2. The soils and sediments underlying a large part of the Lowland Area (Area A) are relatively permeable and offer good potential for infiltration of stormwater. However, it is not recommended that enhanced infiltration measures be implemented where the water table is near surface (Area B), or where there is already a high density of surface water (Area C).

3. There are no deep aquifers and limited opportunities for stormwater infiltration in the Upland Area (Area D). Small, shallow infiltration works may be successful in areas where there are substantial accumulations of relatively well drained soils. This should be determined on a site-by-site basis with additional infiltration testing and water table monitoring. There is greater potential to infiltrate stormwater in Area E, owing to the relatively unsaturated, more permeable sediments and deeper water table.

4. In general, offsets for implementation of infiltration enhancement works should utilize a setback of 4H:1V (25%) from the toe of stream channel or ravine slopes. No infiltration structures should be constructed within this zone without detailed investigations and design by a qualified geotechnical engineer. Other setback requirements defined for specific areas include:

    - A 200m setback to the southwest of the crest of slope above Straiton Road in Area A;
    - A 100m setback from the inner ravine slope of Stoney Creek in Area A; and
    - A 250m setback from the inner ravine slopes of Poignant and Clayburn creeks and their tributaries in Area D.

5. Offsets for land development (building construction) without infiltration works should utilize a setback of 2H:1V (50%) from the toe of stream channel or ravine slopes. No development or infiltration works should be allowed on inner ravine slopes (sidewall slopes >50%).

6. Possible source control measures that could be implemented to minimize stormwater runoff and/or augment groundwater recharge include perforated storm pipes in shallow trenches, seepage basins, soak-away pits, infiltration chambers, absorbent landscapes, rain gardens, vegetated swales, and pervious paving. It is generally preferred to have a wide distribution of infiltration systems introducing water into different areas and material types, rather than a few concentrated areas discharging into one material type. This will reduce the potential for water table mounding, and in some areas, the potential for slope instability.

7. Systems that collect and store stormwater runoff for eventual infiltration to ground should have a number of considerations, such as adequate storage volume and a clarification system to eliminate sediments and floating detritus that could cause clogging. Infiltration systems should be designed to have sufficient storage to release the required volumes, but after that capacity is reached, it should be bypassed and discharged to the storm sewer system. Where possible, storm drains should be designed in such a manner as to minimize the amount of drainage delivered to Stoney, Clayburn and Poignant creeks and/or their tributaries.

8. More detailed hydrogeological assessments should be carried out by a qualified professional in those areas where ground infiltration measures are being considered. These would typically involve digging test pits or trenches and installing standpipe piezometer tubes for water table monitoring over at least a six month period. If possible, surface water monitoring in select drainage channels near the study area should also be conducted, where applicable.

9. Hydrometric station(s) should be set up on Stoney Creek to provide data to accurately determine seasonal flow fluctuations and baseflow.

LIMITATIONS

This report was prepared for the exclusive use of Kerr Wood Leidal Associates Ltd. and their client, the City of Abbotsford, and is intended to provide a preliminary assessment of stormwater infiltration capacity of soils at the site. Infiltration rates were estimated based on limited data and testing results, and soil conditions observed during site reconnaissance. As such, they are expected to vary from area to area, and hence, must be used for preliminary planning purposes only. Site specific tests will be required before detailed designs of stormwater infiltration systems are finalized.

The investigation has been conducted using a standard of care consistent with that expected of scientific and engineering professionals undertaking similar work under similar conditions in B.C. No warranty is expressed or implied. Any use, interpretation, or reliance on this information by any third party, is at the sole risk of that party, and Piteau accepts no liability for such unauthorized use.

CLOSURE

We trust that this is sufficient for your present purposes

Yours very truly,

PITEAU ASSOCIATES ENGINEERING LTD.

Mar 2 2010

Kathy C. Tixier, P.Eng.
Sr. Hydrogeologist

March 2/2010

James D. Hogarth, P.Eng.
Sr. Geotechnical Engineer

Andy Holmes, P.Eng.
Principal

KT/JDH/ATH/slc

Att.

REFERENCES

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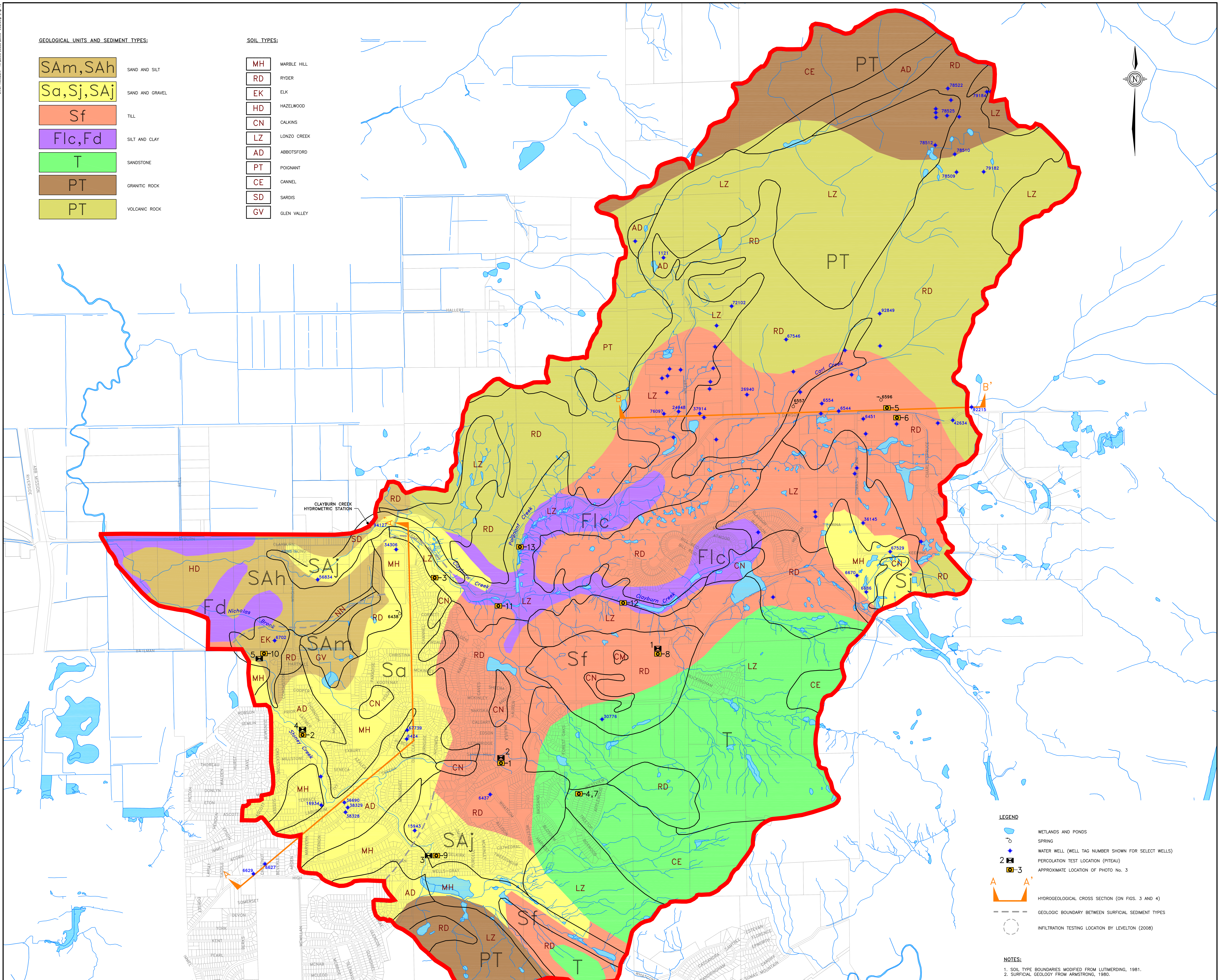
TABLE

TABLE I
SUMMARY OF PERCOLATION TEST RESULTS

Location Number	Easting[1]	Northing[1]	Elevation (m-asl)[1]	Location Description	Surficial Sediment Type	Test Hole Lithology	Test	Measured Percolation Rate		Corrected Percolation Rate[3] (mm/hr)
								(min/inch)	(mm/hr)	
1	10556601	5436073	163	Empty lot in new subdivision, east side of Golf Course	Till	0-20 cm: Light grey silty clay, some cobbles, moist 20-50 cm: Red-brown sandy silt, some clay, organic matter, moist	1	3:10:00	8.0	2.7
2	10555439	5435291	128	McKinley Park	Till	0-50 cm: Light brown, silty clay, some cobbles, organic matter, loosely compacted, moist	1 2 3 Representative Result[2]	0:20:00 0:21:00 0:23:00 **0:23:00**	66	22
3	10554959	5434607	66	McKee Creek Park	Sand and Gravel	0-50 cm: Brown, fine-grained silty sand and cobbles (>8 cm), organic matter, moist	1 2 3 4 5 Representative Result[2]	0:03:50 0:05:50 0:07:30 0:09:00 0:09:30 **0:09:30**	160	53
4	10553947	5435503	30	Stoney Creek Park	Sand and Gravel	0-10 cm: Dark brown, fine to medium grained silty sand, organic matter, moist 10-50 cm: Brown, medium to coarse sand and gravel, organic matter, moist	1 2 3 4 5 6 Representative Result[2]	0:01:36 0:02:25 0:03:05 0:03:50 0:04:20 0:04:20 **0:04:20**	352	117
5	10553684	5435935	5	Bateman Park	Sand and Silt	0-50 cm: Brown-black, fine to medium grained silty sand, some gravel, organic matter, moist	1 2 Representative Result[2]	0:22:20 0:24:30 **0:24:30**	62	21

Notes:
1. Measured using hand-held GPS device
2. The slowest percolation rate taken is considered the most representative value
3. Factor of 0.33 applied to corrected for infiltration across side walls of test pits for comparison to double ring infiltrometer results

FIGURES



NOTES:

1. SOIL TYPE BOUNDARIES MODIFIED FROM LUTIMERDING, 1981.
2. SURFICIAL GEOLOGY FROM ARMSTRONG, 1980.

KERR WOOD LEIDAL ASSOCIATES LTD. CITY OF ABBOTSFORD	PITEAU ASSOCIATES GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS VANCOUVER LIMA		
HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENTS FOR DEVELOPMENT OF ISMP, CLAYBURN CREEK WATERSHED ABBOTSFORD, B.C.	AREA MAP SHOWING SURFICIAL MATERIALS AND TESTING LOCATIONS	BY: KT/lf APPROVED:	DATE: DEC. 09 FIG: 1

SHALLOW SOIL TYPES IN CLAYBURN CREEK WATERSHED

(Table to accompany Fig. 1)

Soil Series[2] (In order of general occurrence)	Map Symbol[4]	Soil: Description	Soil: Drainage	Soil: Texture[1]	Underlying Sediments	Soil Depth Min (m)	Soil Depth Max (m)	Infiltration Rating[5]	Infiltration rate[6,7] Short-term (mm/hr)	Infiltration rate[6,7] Long-term (mm/hr)
Ryder	RD	Medium-textured eolian deposits	moderate to well	SiL to SL	Moderately coarse textured glacial till	0.50	-	2	15-30	4-9
Lonzo Creek	LZ	Medium-textured eolian deposits	moderate to well prone to perched water tables during heavy rain	Si	Moderately coarse textured glacial till	0.20	0.50	2	5-10	2-3
Marble Hill	MH	Medium-textured eolian deposits	well	SiL to SL	Gravelly glacial outwash	0.50	-	1	30-50	8-15
Abbotsford	AD	Medium -textured eolian deposits	well to rapid	SiL to SL	Gravelly glacial outwash	0.20	0.50	1	30-50	8-15
Cannel	CE	Moderately coarse textured glacial till or colluvium	well to rapid	SL to GSL	Bedrock	0.10	0.50	1	30-50	8-15
Elk	EK	Medium to moderately coarse textured alluvial deposit	poor prone to flooding	SiL to GSL	-	-	-	3	15-50	4-15
Hazelwood	HD	Fine to moderately fine textured floodplain deposits	poor high water table	SiC	Sand	1.00	-	3	<5	2
Poignant	PT	medium to moderately coarse textured eolian deposits and colluvium	well	GSiL to GSL	Bedrock	1.00	-	1	30-50	8-15
Sardis	SD	Coarse to moderately coarse textured local stream deposits	moderately well	GSL	-	-	-	1	50	13
Glen Valley	GV	Partially-decomposed organic material	very poor high water table	O	-	1.60	-	4	<5	2
Niven	NN	Moderately-textured floodplain deposits over organic material	poor to very poor high water table	SiCL to SiL	Organic material	0.30	0.80	4	5-15	2-5
Calkins	CN	Medium-textured eolian deposits	poor prone to perched water table	SiL to SCL	Glacial outwash or glacial till	0.20	0.80	4	15-30	4-9

SURFICIAL GEOLOGY UNITS IN CLAYBURN CREEK WATERSHED

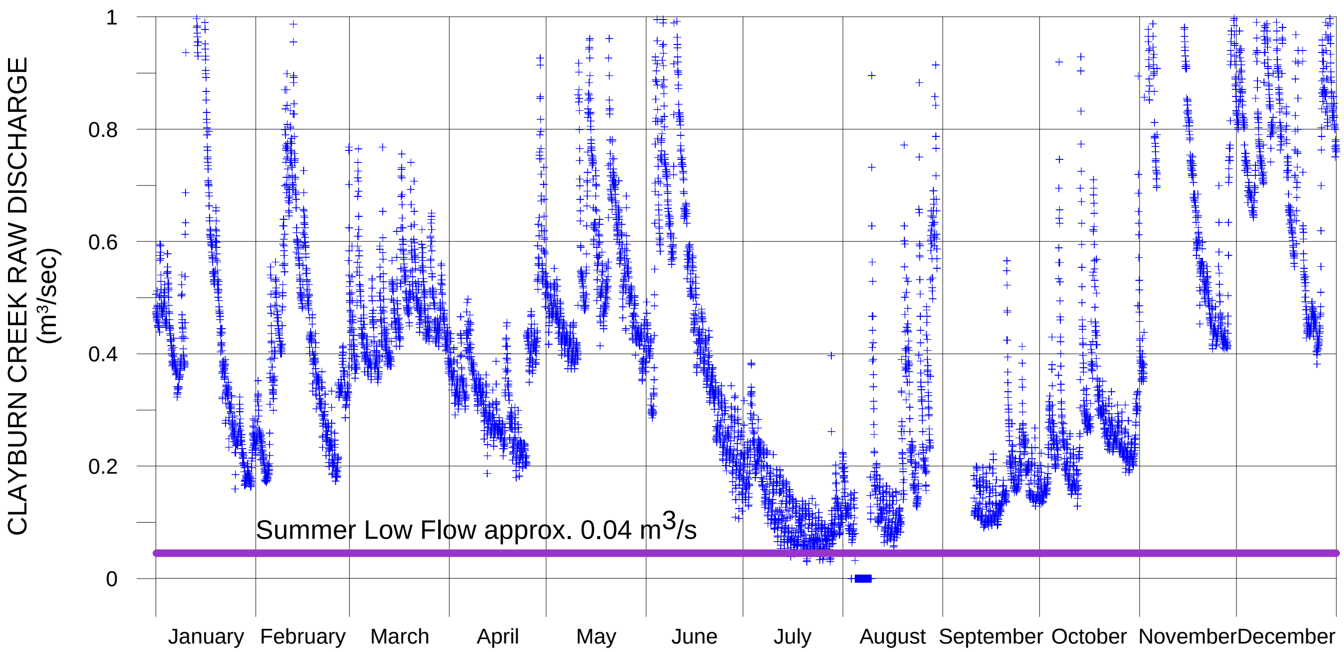
(Table to accompany Fig. 1)

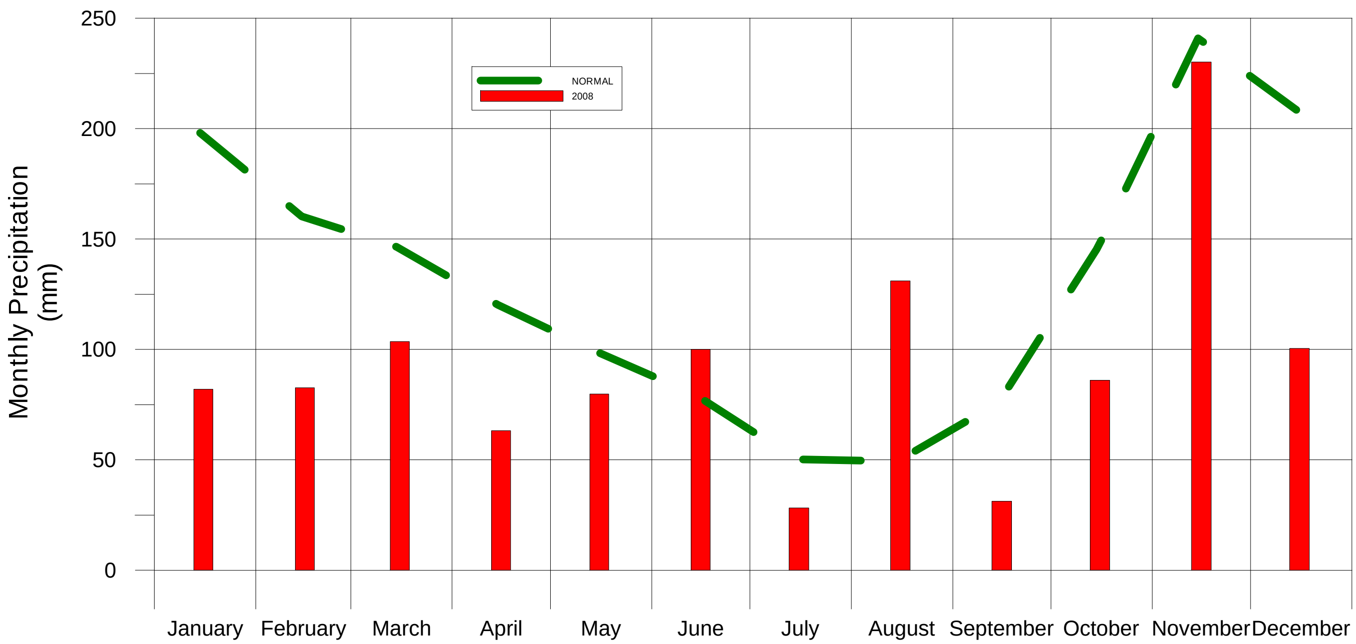
Unit Name[3] (in order of age)	Map Symbol[4]	Description	Age	Thickness	Group	Infiltration Rating[5]	Infiltration Rate[6,7] Short-term (mm/hr)	Infiltration Rate[6,7] Long-term (mm/hr)
Sand and Silt	SAm	Slopewash (colluvial) sand	Post-glacial	up to 4m	Salish Sediments	2	200-300	15-50
	SAh	Stream channel fill sand and sandy/clayey loam	Post-glacial	up to 8m	Salish Sediments	2	15-50	5-15
Sand and Gravel	Sa	Recessional glaciofluvial channel and floodplain sand and gravel deposits	Pleistocene	up to 40m normally 5 to 25m	Sumas Drift	1	300-500	150-250
	Sj	Advance glaciofluvial channel, deltaic, and floodplain sand and gravel deposits	Pleistocene	up to 40m	Sumas Drift	1	300-500	150-250
	SAj	Mountain stream and channel deposits	Post-glacial	up to 10m	Salish Sediments	1	200-400	100-200
Till	Sf	Sandy till and substratified drift	Pleistocene	2 to 10m	Sumas Drift	3	5-10	2-3
Silt and Clay	Flc	Glaciomarine stony silt to loamy clay	Pleistocene	8 to 100m	Fort Langley	3	<5	2
	Fd	Clayey silt and silty clay	Post-glacial	up to 10m	Fraser River Sediments	3	<5	2
Sandstone	T	Bedrock mantled by 1 to 5m of glacial drift and eolian sediments	Tertiary	-	Bedrock		n/a	n/a
Granitic and Volcanic Rock	PT	Bedrock mantled by 1 to 5m of glacial, colluvial, and eolian sediments	Pre-Tertiary	-	Bedrock		n/a	n/a

Notes:

1. Textures: C =clay; G = gravel, Si =silt; S =sand; O=organics; LS = loamy sand; SiC = silty clay, SL = sandy loam; SiCL = silty clay loam, SiL = silt loam, GSL = gravelly sandy loam, GSiL=gravelly silt loam, SCL = silty clay loam
2. Based on Luttmerding, 1981.
3. Based on Armstrong, 1980.
4. See distribution of soils on Fig. 1 in map pocket opposite.
5. The lowest infiltration rating number has the highest potential for sustained infiltration.
6. Representative infiltration rate from percolation test results and reported values for similar soils / sediments elsewhere.
7. Infiltration rates represent short-term infiltration rates. Long-term infiltration rates may be slower by 70-75% in soils derived from fine-grained sediments. Long-term infiltration rates in coarse-grained soils are estimated to be about 50% of the short-term rates due to potential layering in the shallow soil profile.

H:/PROJECT/2993/Discharge&Precip.grf





Notes:

1. Raw Discharge Data obtained from Clayburn Creek Hydrometric Station (Fig. 1)
2. 2008 climate data (histogram) obtained from climate station at Ledgeview Golf Course
3. Climate normals (dotted line) for Abbotsford Airport climate station

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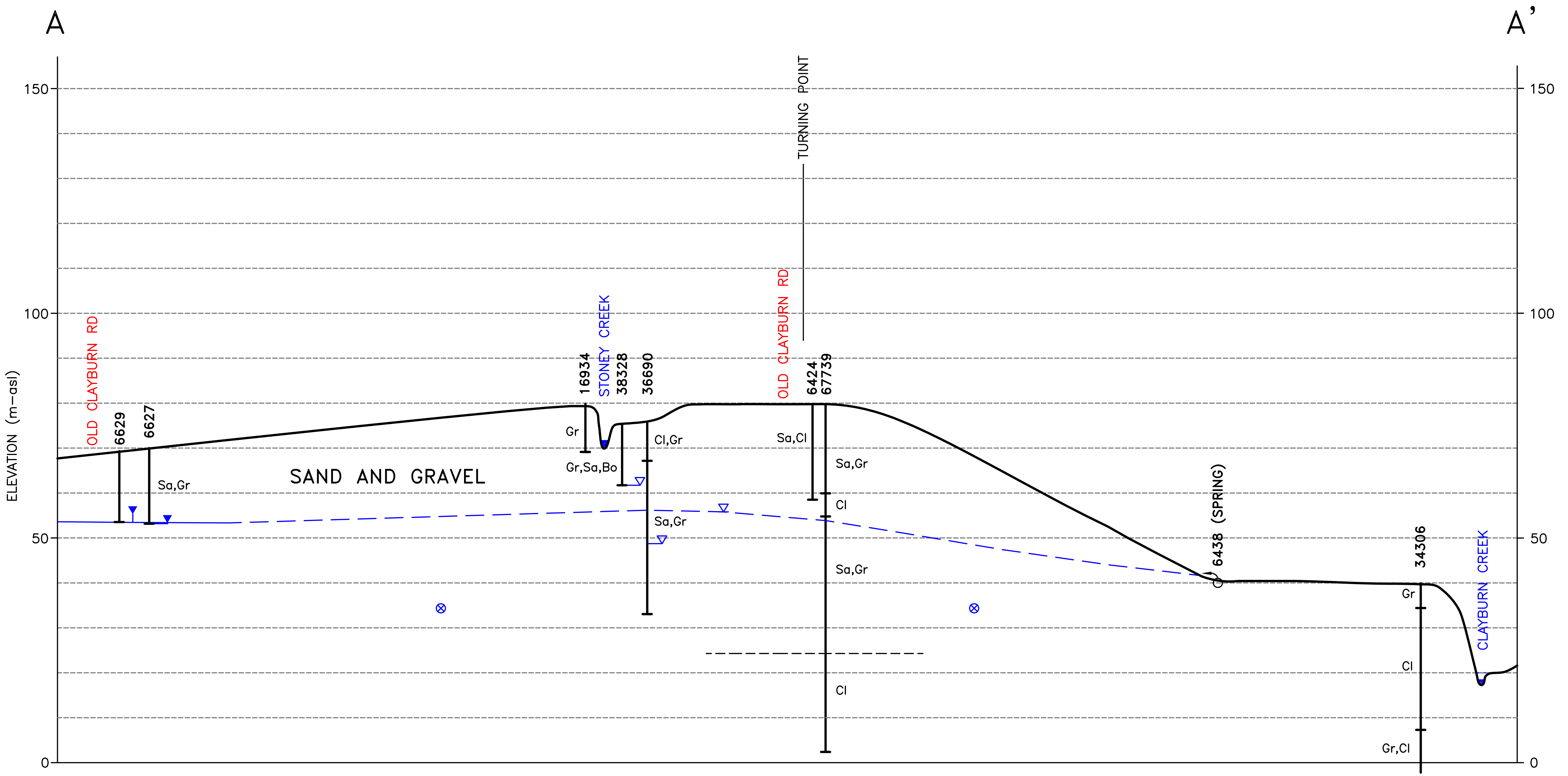
HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENTS FOR DEVELOPMENT OF ISMP CLAYBURN CREEK WATERSHED ABBOTSFORD, B.C.

2008 CLAYBURN CREEK DISCHARGE AND LOCAL PRECIPITATION AMOUNTS

BY: MAK
DATE: DEC 09
APPROVED:
FIG: 2

DWG. NUMBER: K:\2993\Cadd\2993-001.dwg (Fig 3)



LEGEND

Bo	BOULDERS		SPRING
Gr	GRAVEL		MEASURED GROUNDWATER ELEVATION
Sa	SAND		INFERRED GROUNDWATER ELEVATION
Si	SILT		INFERRED DIRECTION OF GROUNDWATER FLOW (INTO PAGE)
Ti	TILL		
Br	BEDROCK		
Cl	CLAY		

NOTES:

1. WELLS IDENTIFIED BY BC MOE WELL TAG NO.'S
2. SEE FIG. 1 FOR SECTION LOCATIONS

0 100 200 300 400 500m

SCALE 1:10000

VERTICAL SCALE 10x EXAGGERATED

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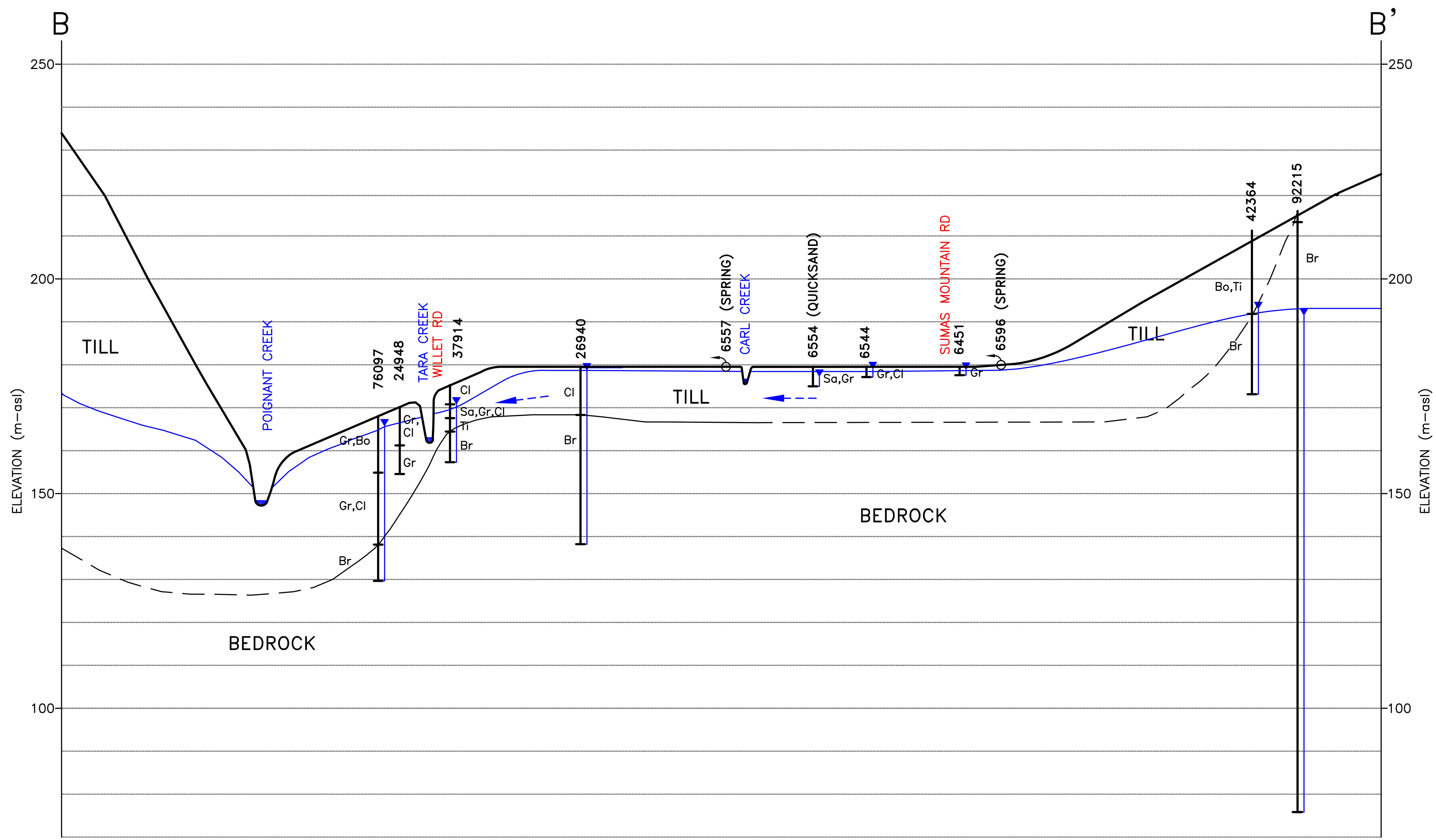
CROSS-SECTION A-A'

BY:	DATE:
MK/sl	NOV. 09
APPROVED:	FIG: 3

DWG. NUMBER: K:\2993\Cadd\2993-001.dwg (Fig 4)



LEGEND

Bo	BOULDERS
Gr	GRAVEL
Sa	SAND
Si	SILT
Ti	TILL
Br	BEDROCK
Cl	CLAY

SPRING

MEASURED GROUNDWATER ELEVATION

INFERRED GROUNDWATER ELEVATION

INFERRED DIRECTION OF FLOW IN SHALLOW SOILS

NOTES:

1. WELLS IDENTIFIED BY BC MOE WELL TAG NO.'S
2. SEE FIG. 1 FOR SECTION LOCATIONS

0 100 200 300 400 500m

SCALE 1:10000

VERTICAL SCALE 10x EXAGGERATED

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CROSS-SECTION B-B'

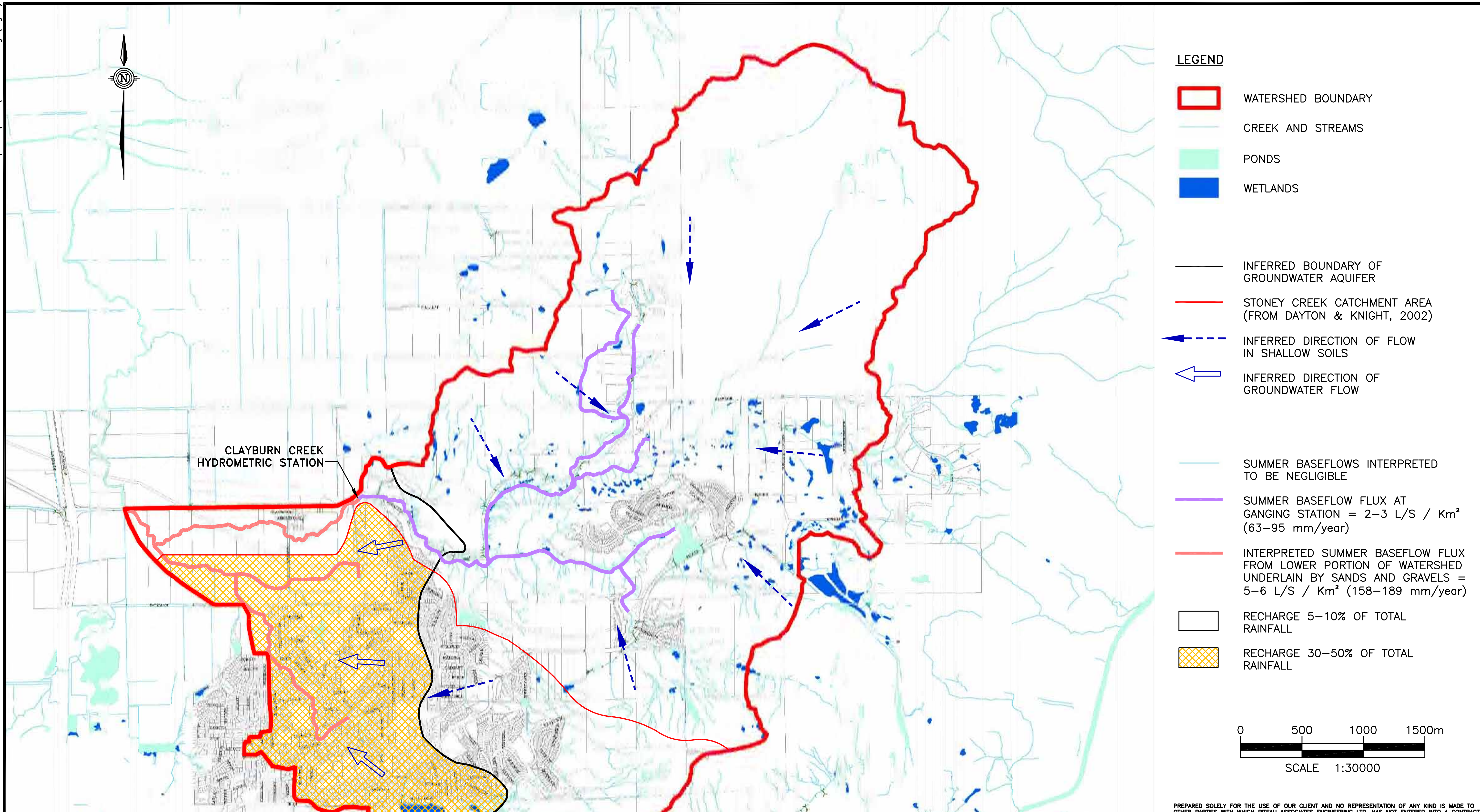
BY: MK/sl

DATE: NOV. 09

APPROVED:

FIG: 4

DWG. NUMBER: K:\2993\Cadd\2993-003.dwg (Fig 5)



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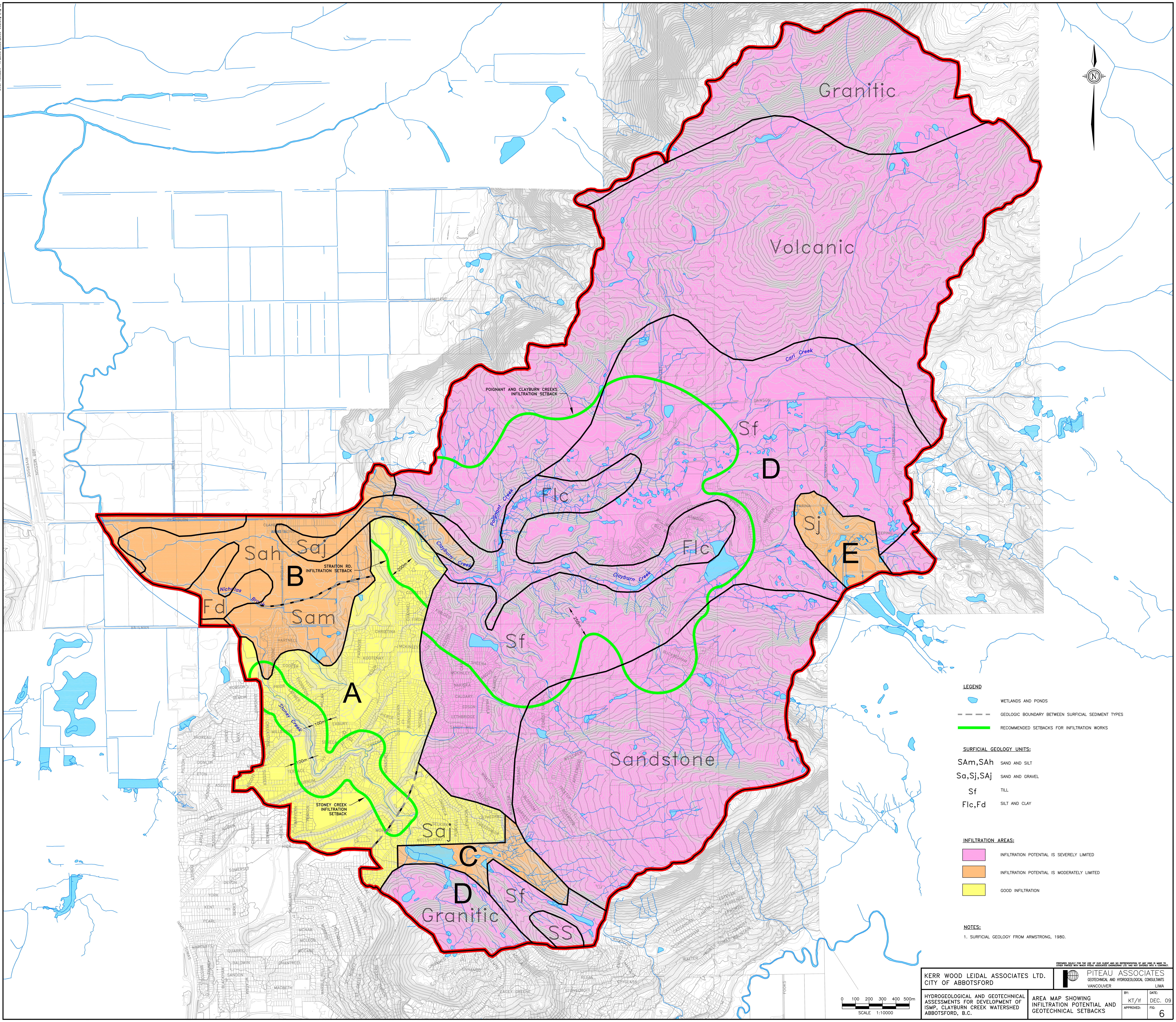
HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENTS FOR DEVELOPMENT OF ISMP, CLAYBURN CREEK WATERSHED ABBOTSFORD, B.C.

CONCEPTUAL HYDROGEOLOGIC MODEL

BY:	DATE:
KT/lf	DEC. 09
APPROVED:	FIG: 5


Granitic
Volcanic
Sf
D
Flc
Flc
Sj
E
Carl Creek
Poignant Creek
Clayburn Creek
Clayburn Creek
POIGNANT AND CLAYBURN CREEKS INFILTRATION SETBACK
Sah
Saj
B
STRAITON RD. INFILTRATION SETBACK
Fd
Sam
Nicholas Brook
A
Stoney Creek
STONEY CREEK INFILTRATION SETBACK
100m
200m
250m
Sf
Sandstone
Saj
C
D
Sf
Granitic
SS
LEGEND
WETLANDS AND PONDS
GEOLOGIC BOUNDARY BETWEEN SURFICIAL SEDIMENT TYPES
RECOMMENDED SETBACKS FOR INFILTRATION WORKS
SURFICIAL GEOLOGY UNITS:
SAm,SAh SAND AND SILT
Sa,Sj,SAj SAND AND GRAVEL
Sf TILL
Flc,Fd SILT AND CLAY
INFILTRATION AREAS:
INFILTRATION POTENTIAL IS SEVERELY LIMITED
INFILTRATION POTENTIAL IS MODERATELY LIMITED
GOOD INFILTRATION
NOTES:
1. SURFICIAL GEOLOGY FROM ARMSTRONG, 1980.
0 100 200 300 400 500m
SCALE 1:10000
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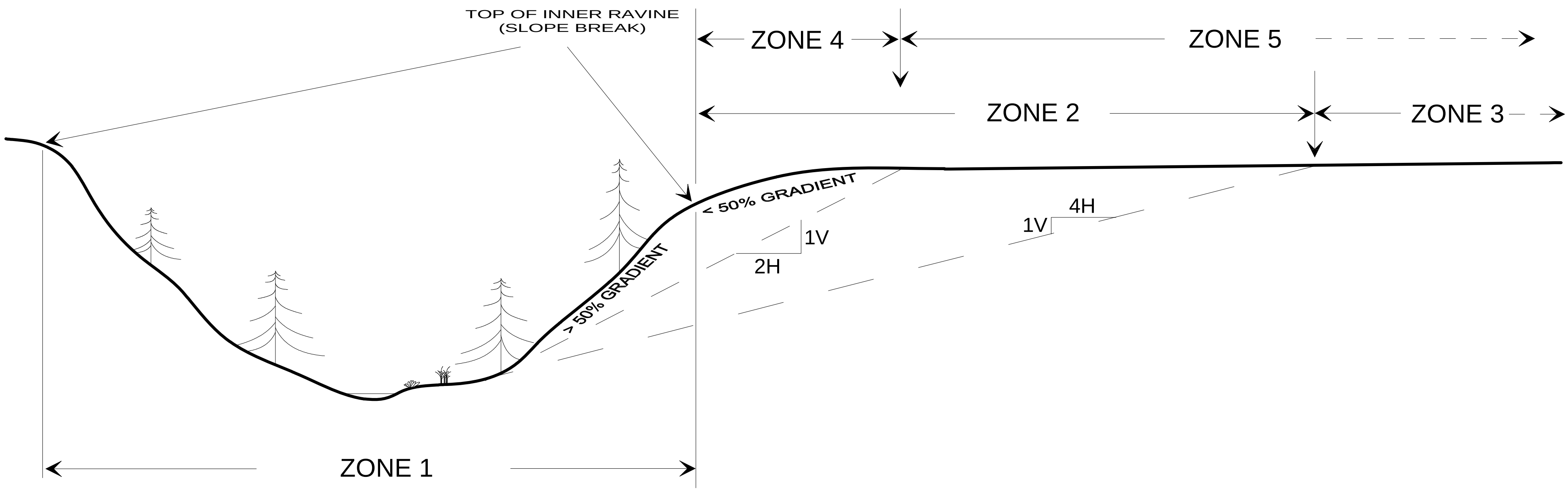
VANCOUVER LIMA
HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENTS FOR DEVELOPMENT OF ISMP, CLAYBURN CREEK WATERSHED ABBOTSFORD, B.C.
AREA MAP SHOWING INFILTRATION POTENTIAL AND GEOTECHNICAL SETBACKS
BY: KT/lf
DATE: DEC. 09
APPROVED:
FIG: 6



ZONE 1: INNER RAVINE AREA
DO NOT DEVELOP.
NO INFILTRATION
RECOMMENDED.

ZONE 2: INFILTRATION COULD NEGATIVELY IMPACT GEOTECHNICAL STABILITY. NO INFILTRATION STRUCTURES SHOULD BE CONSTRUCTED IN THIS AREA WITHOUT DETAILED SITE INVESTIGATIONS AND DESIGNS BY A QUALIFIED GEOTECHNICAL ENGINEER.

ZONE 3: INFILTRATION UNLIKELY TO NEGATIVELY IMPACT GEOTECHNICAL STABILITY. DETAILED SITE INVESTIGATIONS AND DESIGNS BY A QUALIFIED GEOTECHNICAL ENGINEER NOT CONSIDERED NECESSARY. DETAILED HYDROGEOLOGICAL ASSESSMENT AND DESIGN REQUIRED.

ZONE 4: LAND DEVELOPMENT COULD NEGATIVELY IMPACT GEOTECHNICAL STABILITY. DETAILED SITE INVESTIGATIONS AND DESIGNS BY A QUALIFIED GEOTECHNICAL ENGINEER RECOMMENDED.

ZONE 5: LAND DEVELOPMENT UNLIKELY TO NEGATIVELY IMPACT GEOTECHNICAL STABILITY. REVIEW OF DETAILED DESIGNS BY A QUALIFIED GEOTECHNICAL ENGINEER ARE RECOMMENDED.

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SCHEMATIC OF DEVELOPMENT AND INFILTRATION ZONES

BY:	DATE:
JDH	DEC 09
APPROVED:	FIG: 7

PHOTOS

Photo 1.
Saturated till exposure on creek embankment in McKinley Park.

Photo 2.
Silty sand and gravel on Stoney Creek channel bank.

FILE: P:/Photos/2993/Nov-2009-Report_Photos

Photo 3.
Sand and gravel profile on ravine bank in Straiton Park.

Photo 4.
Looking northwest towards Matsqui Slough floodplain from Westview Boulevard. High water table conditions in Lowland Area evidenced by surface ponding in distance.

Photo 5.
Saturated clayey till at Dawson Road and Charlie Spruce Place.

Photo 6.
Spring near Charlie Spruce Place.

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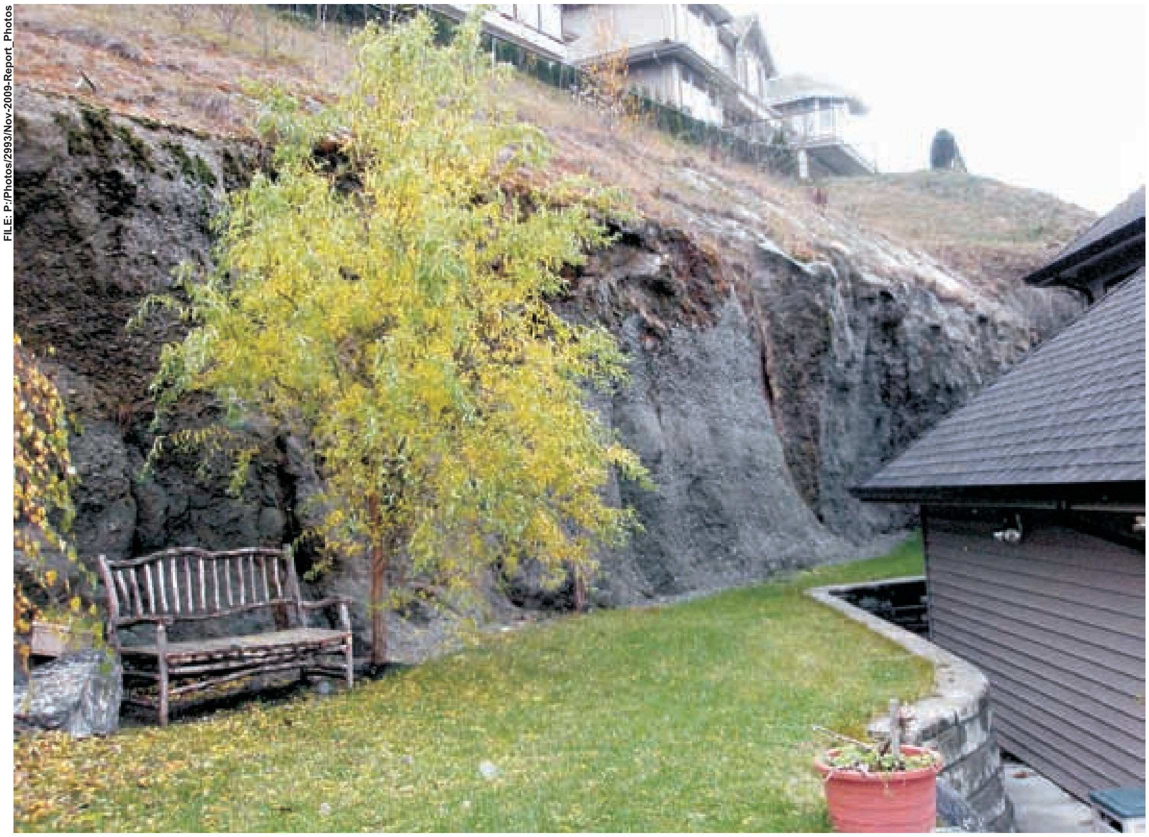

Photo 7.
Sandstone face with minimal overburden on Westview Blvd.

Photo 8.
Soak-away pit at north end of cul-de-sac adjacent to the east of Golf Course.

Photo 9.
Percolation test set-up at McKee trial (Location 3).

Photo 10.
Percolation test set-up at north end of Bateman Park (Location 5).

Photo 11.
Clayburn Creek eroding toe of slope. Note blocks of fine-grained till or glaciomarine silt and clay spalling off scarp.

Photo 12.
View of recent debris slide on lower ravine slope immediately above Clayburn Creek.

Photo 13.
View from Straiton Road of erosion of toe of ravine slope along Poignant Creek.

APPENDIX A

BC MOE WATER WELL LOGS

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 1121

Owner: BOB MATHEWS

Address: 5311 WILLET ST.

Area: ABBOTTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009444 Well: 25

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well:
Status of Well: New
Well Use: Water Supply System
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 36.0 inches
Casing drive shoe:
Well Depth: 30 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1901-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 9 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID: E218010
Water Chemistry Info Flag: Y
Field Chemistry Info Flag:
Site Info (SEAM): Y

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:
CAMP MCLANLIN WELL NO LONGER IN USE. USING 092G009444 - 24

LITHOLOGY INFORMATION:

- Return to Main
- Return to Search Options

Report 1 - Detailed Well Record

Well Tag Number: 6424 Owner: V PORT Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: 16 Section: 26 Range: Indian Reserve: Meridian: Block: Quarter: NE Island: BCGS Number (NAD 27): 092G009423 Well: 4 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Dug Diameter: 30.0 inches Casing drive shoe: Well Depth: 70 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950-01-01 00:00:00.0 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From   0 to   0 Ft.   Glacial clay and sand

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6437

Owner: BRYAN WIERS

Address: MCKEE RD.

Area: MATSQUI

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 16 Section: 25 Range:
Indian Reserve: Meridian: Block:
Quarter: SW
Island:
BCGS Number (NAD 27): 092G009423 Well: 2

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 82 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 68 feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Valley Water Services
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	1	Ft.	Top soil
From	1	to	64	Ft.	Sandstone
From	64	to	68	Ft.	Hard blue clay and sand
From	68	to	79	Ft.	Sandstone
From	79	to	82	Ft.	Black hard stone with white granite

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6438

Owner: CLAYBURN VILLAGE

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 16 Section: 25 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009441 Well: 2

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Unknown Constru
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 0 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft): 0 feet
Thickness (in):
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
0	0	0	null	null

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Spring

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6451

Owner: D MATHERS

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 19 Section: 32 Range:
Indian Reserve: Meridian: Block:
Quarter: NW
Island:
BCGS Number (NAD 27): 092G009444 Well: 8

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 6 feet 1.83
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 2 feet 0.61

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Gravel

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6544

Owner: A MATHERS

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 19 Section: 31 Range:
Indian Reserve: Meridian: Block:
Quarter: NE
Island:
BCGS Number (NAD 27): 092G009444 Well: 2

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 8 feet 2.4m
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 2 feet 0.6m

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Gravel with clay further down

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6554

Owner: H CATLIN

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 20 Section: 6 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): 092G009444 Well: 3

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 15 feet 457
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 15 feet 457

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Quicksand and gravel

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6557

Owner: D MATHER

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 20 Section: 6 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): 092G009444 Well: 4

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Other
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 0 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 10 (Driller's Estimate) Gallons per Hour (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Aquifer - spring

- Return to Main
- Return to Search Options
- Return to Search Criteria

Information Disclaimer
The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6596 Owner: SCHOOL Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: 20 Section: 5 Range: Indian Reserve: Meridian: Block: Quarter: SW Island: BCGS Number (NAD 27): 092G009444 Well: 1 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Other Diameter: 0.0 inches Casing drive shoe: Well Depth: 0 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950 01 01 00:00:00.0 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 20 (Driller's Estimate) Gallons per Hour (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Aquifer spring

- Return to Main
- Return to Search Options
- Return to Search Criteria

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6627 Owner: G HAWLEY Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: 16 Section: 26 Range: Indian Reserve: Meridian: Block: Quarter: SW Island: BCGS Number (NAD 27): 092G009412 Well: 4 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Dug Diameter: 0.0 inches Casing drive shoe: Well Depth: 55 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950-01-01 00:00:00.0 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 54 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Glacial, gravel and sand

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6629 Owner: P E SPIRLING Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: 16 Section: 26 Range: Indian Reserve: Meridian: Block: Quarter: SW Island: BCGS Number (NAD 27): 092G009412 Well: 3 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Dug Diameter: 0.0 inches Casing drive shoe: Well Depth: 52 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950-01-01 00:00:00.0 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 46 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Glacial
From 0 to 0 Ft. Note on card: "Log there but unreadable"

- Return to Main
- Return to Search Options

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6670

Owner: G MATHERS SR

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 19 Section: 31 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): 092G009442 Well: 1

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 21 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 15 feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 15 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
INSUFFICIENT IN DRY SUMMER

LITHOLOGY INFORMATION:

From	0 to	8 Ft.	Loam
From	8 to	15 Ft.	Gravel
From	15 to	21 Ft.	Sandrock

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6686

Owner: J A EQAUCAN

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 19 Section: 32 Range:
Indian Reserve: Meridian: Block:
Quarter: SW
Island:
BCGS Number (NAD 27): 092G009442 Well: 2

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 16 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
INSUFFICIENT IN DRY SUMMER

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Glacial

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6702

Owner: A ALLEN

Address:

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 16 Section: 26 Range:
Indian Reserve: Meridian: Block:
Quarter: NW
Island:
BCGS Number (NAD 27): 092G009414 Well: 1

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method: Dug
Diameter: 30.0 inches
Casing drive shoe:
Well Depth: 14 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1950-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 6 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
THERE WAS A DRILLED WELL ON THIS FARM BUT IT WAS A DRY HOLE.

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Glacial blue clay and silt

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6696 Owner: ROSS & YOUNG Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: Lot: Township: 16 Section: 26 Range: Indian Reserve: Meridian: Block: Quarter: SE Island: BCGS Number (NAD 27): 092G009414 Well: 2 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 140 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1950-01-01 00:00:00.0 Driller: Unknown Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 0 Ft. Glacial

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 15493

Owner: S W COLLINS

Address: 35253 MCKEE RD.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 15119 Lot:
Township: 16 Section: 25 Range:
Indian Reserve: Meridian: Block:
Quarter: SW
Island:
BCGS Number (NAD 27): 092G009423 Well: 1

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 8.0 inches
Casing drive shoe:
Well Depth: 143 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 77 feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1958-01-01 00:00:00.0

Driller: G. & G. Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
DRY HOLE

LITHOLOGY INFORMATION:

From	0 to	33 Ft.	Fine sand
From	33 to	77 Ft.	Dry gravel
From	77 to	85 Ft.	Bedrock (sandstone?)
From	85 to	100 Ft.	Fractured granite?
From	100 to	143 Ft.	Sandstone?

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 16934 Owner: TEN OAKES FARMS LTD Address: Area: WELL LOCATION: NEW WESTMINSTER Land District District Lot: Plan: 23887 Lot: C Township: 16 Section: 26 Range: Indian Reserve: Meridian: Block: Quarter: SE Island: BCGS Number (NAD 27): 092G009414 Well: 6 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 8.0 inches Casing drive shoe: Well Depth: 35 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1961-01-01 00:00:00.0 Driller: G. & G. Well Drilling Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 300 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0 to	6 Ft.	Gravel and boulders
From	6 to	12 Ft.	Sand
From	12 to	19 Ft.	Coarse gravel
From	19 to	30 Ft.	Very coarse gravel
From	30 to	33.5 Ft.	Gravel
From	33.5 to	34.5 Ft.	Clay
From	34.5 to	35 Ft.	Sand

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 24948

Owner: J C MACKENZIE

Address: 4963 WILLET RD.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 36423 Lot:
Township: 20 Section: 6 Range:
Indian Reserve: Meridian: Block:
Quarter: SW
Island:
BCGS Number (NAD 27): 092G009444 Well: 9

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 51 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1971-06-08 00:00:00.0

Driller: Hi-Land Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
DRY - ALL CASING PULLED

LITHOLOGY INFORMATION:

From	0	to	4	Ft.	Loam
From	4	to	29	Ft.	Clay and gravel - hardpan
From	29	to	41	Ft.	Dry gravel
From	41	to	51	Ft.	Hardpan
From	51	to	0	Ft.	Bedrock

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 26940

Owner: HUESTIS INVESTMENT

Address: DAWSON RD.

Area: STRATTON

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: 20 Section: 6 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009444 Well: 17

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Unknown Constru
Diameter: 8.0 inches
Casing drive shoe:
Well Depth: 135 feet 41.1
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 39 feet 11.9
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1972-09-12 00:00:00.0

Driller: A. & H. Construction
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 20 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 2 feet 0.61

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag: Y
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	2	Ft.	Soil
From	2	to	9	Ft.	Clay
From	9	to	39	Ft.	Till
From	39	to	103	Ft.	Shale
From	0	to	0	Ft.	Bail test well at 4 gpm with 80ft. of DD
From	0	to	0	Ft.	Static 6 ft.
From	103	to	135	Ft.	Shale
From	0	to	0	Ft.	Bail test well at 16 gpm with a 59ft.
From	0	to	0	Ft.	of drawdown. Static 1'6"

- Return to Main
- Return to Search Options
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Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 30776

Owner: J.WATERS/LINLEY?

Address: 35864 MCKEE RD.

Area: MATSQUI

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 43936 Lot: 25
Township: 16 Section: 25 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): 092G009423 Well: 5

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Abandoned
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 800 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 23 feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1974-07-15 00:00:00.0

Driller: A. & H. Construction
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate) DRY HOLE
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
DRY HOLE - ABANDONED

LITHOLOGY INFORMATION:
From 0 to 23 Ft. Clay
From 23 to 800 Ft. Shale and sandstone

- Return to Main
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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 34306

Owner: ROY JACOBSON

Address: 4355 OLD CLAYBURN RD.

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 40079 Lot: 7
Township: 16 Section: 35 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): 092G009441 Well: 1

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 138 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1976-02-06 00:00:00.0

Driller: Hi-Land Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 6 (Driller's Estimate) Gallons per Hour (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 110 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
SOME IRON IN WATER

LITHOLOGY INFORMATION:

From	0 to	3 Ft.	Loam
From	3 to	18 Ft.	Gravel
From	18 to	34 Ft.	Clay
From	34 to	36 Ft.	Dirty sand
From	36 to	107 Ft.	Clay
From	107 to	134 Ft.	Gravel, clay, hardpan
From	134 to	136 Ft.	Gravel
From	136 to	138 Ft.	Dirty sand

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 36145

Owner: DENNIS PRATHER

Address: 4390 SUMAS MOUNTAIN RD.

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 16829 Lot: 8
Township: 19 Section: 32 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009442 Well: 5

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 49 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 10 feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1976-12-13 00:00:00.0

Driller: Linder's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 10 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 1? feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
SOME IRON IN WATER. ROCK WELL DATA OPEN BORE HOLE 33. DIAM 6" FROM 6' TO 49'.

LITHOLOGY INFORMATION:

From	0 to	10 Ft.	Sand and gravel		
From	10 to	40 Ft.	Shale		
From	40 to	49 Ft.	W.B. shale		

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 36690

Owner: MCKINNEY LABORATORIE

Address:

Area: MATSQUI

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 23887 Lot: C
Township: 16 Section: 26 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009414 Well: 10

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 140 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1977-02-14 00:00:00.0

Driller: Nor-West Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	32	Ft.	Sandy brown clay and gravel (compact)
From	32	to	42	Ft.	Fine brown sand and gravel (compact)
From	42	to	53	Ft.	Coarse brown sand with some gravel
From	0	to	0	Ft.	(loose)
From	53	to	80	Ft.	Coarse sand and fine gravel
From	80	to	92	Ft.	Coarse brown sand with some gravel
From	92	to	105	Ft.	Coarse dry gravel (loose)
From	105	to	111	Ft.	Coarse sand and gravel (loose)
From	111	to	115	Ft.	Fine brown sand and gravel (loose)
From	115	to	140	Ft.	Wet brown sand, with coarse gravel

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 37914

Owner: PERCY SIEMANS

Address: 4818 WILLET RD.

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 12389 Lot: A
Township: 20 Section: 6 Range:
Indian Reserve: Meridian: Block:
Quarter: SW
Island:
BCGS Number (NAD 27): 092G009444 Well: 22

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 59 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 33 feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1977-08-15 00:00:00.0

Driller: Valley Water Services
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: .5 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 15 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
YIELD .5 GPM @ 56'

LITHOLOGY INFORMATION:

From	0 to	1 Ft.	Top soil
From	1 to	7 Ft.	Hardpan
From	7 to	15 Ft.	Sandy brown clay
From	15 to	19 Ft.	Sand and gravel - clay binder
From	19 to	25 Ft.	Clay and gravel lenses with some water
From	0 to	0 Ft.	seams
From	25 to	33 Ft.	Flat till
From	33 to	59 Ft.	Bedrock
From	0 to	0 Ft.	Yield .5 gpm @ 56'

- Return to Main
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Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 38328

Owner: MCKINNEY LABORATORIE

Address:

Area: MATSQUI

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 41509 Lot: 108
Township: 16 Section: 26 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009414 Well: 9

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 45 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1977-10-02 00:00:00.0

Driller: Nor-West Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 5 Ft. Coarse brown sand and gravel
From 5 to 10 Ft. Coarse sand and gravel
From 10 to 20 Ft. Coarse brown sand, gravel and boulders
From 20 to 35 Ft. Coarse sand and gravel
From 35 to 40 Ft. Coarse sand, with some gravel
From 40 to 45 Ft. Wet sand and gravel

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 38329

Owner: MCKINNEY LABORATORIE

Address:

Area: MATSQUI

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 41509 Lot: 108
Township: 16 Section: 26 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009414 Well: 8

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 45 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1977-10-02 00:00:00.0

Driller: Nor-West Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0 to	5 Ft.	Compact silty brown sand with some
From	0 to	0 Ft.	gravel
From	5 to	10 Ft.	Coarse gravel and sand
From	10 to	15 Ft.	Coarse gravel sand, and boulders
From	15 to	20 Ft.	Fine brown sand, with some gravel
From	20 to	25 Ft.	Coarse sand, some gravel (compact)
From	25 to	35 Ft.	Fine silty brown sand (with lenses of
From	0 to	0 Ft.	clay)
From	35 to	45 Ft.	Brown sand and gravel (compact)

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 42364

Owner: SCOTT MCKAY

Address: 37138 DAWSON RD.

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 57303 Lot: 18
Township: 19 Section: 32 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G010333 Well: 2

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 125 feet 38.1
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: 65 feet 19.8
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1979-05-21 00:00:00.0

Driller: Jay Dee Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 1 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 60 feet 18.3

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
OWNERS HAVE SUBDIVIDED LOT AND DRILLED ANOTHER WELL FOR WHICH THERE IS NO RECORD

LITHOLOGY INFORMATION:

From	0 to	8 Ft.	Brown till
From	8 to	18 Ft.	Till and boulders
From	18 to	27 Ft.	Grey till
From	27 to	60 Ft.	Grey boulders and bedrock
From	60 to	65 Ft.	Fault
From	65 to	125 Ft.	Bedrock
From	0 to	0 Ft.	Fracture at 116'

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 56834 Owner: HOMESTEAD NURSERIES Address: 4262 WRIGHT ST. Area: MATSQUI WELL LOCATION: NEW WESTMINSTER Land District District Lot: 204 Plan: 33210C Lot: Township: 16 Section: 35 Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 092G009432 Well: 2 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Irrigation Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 8.0 inches Casing drive shoe: Well Depth: 70 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1987 01 01 00:00:00.0 Driller: Field Drilling Contractors Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 150 (Driller's Estimate) U.S. Gallons per Minute Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 8 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	33	Ft.	Sandy clay
From	33	to	38	Ft.	Gravel sand W.B.
From	38	to	60	Ft.	Gravelly clay - W/wood
From	60	to	69	Ft.	Gravel sand - W.B.
From	69	to	115	Ft.	Sandy clay

- Return to Main
- Return to Search Options
- Return to Search Criteria

Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 67529

Owner: JAMIESON H R

Address: 36124 KEEPING RD

Area: SUMAS MTN

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: TWP Section: 32 Range:
Indian Reserve: Meridian: Block:
Quarter: SE
Island:
BCGS Number (NAD 27): Well: 0

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use:
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 515 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag: N
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date:

Driller: M. S. A. Water Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 30 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
CASING

LITHOLOGY INFORMATION:
From 3 to 515 Ft. BEDROCK
From 0 to 3 Ft. OVERBURDEN

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 67546

Owner: DONAE ENTERPRISES IN

Address: 5024 MATHERS WAY

Area: ABBOTSFORD

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009444 Well:

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use:
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 0.0 inches
Casing drive shoe:
Well Depth: 405 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993 04 14 00:00:00.0

Driller: Field Drilling Contractors
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 11 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 35 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:
CASING 4.5 TO 24.0.

LITHOLOGY INFORMATION:

From	0	to	10	Ft.	SAND & CLAY
From	10	to	24	Ft.	HARDPAN
From	24	to	70	Ft.	GREY SOFT GRANITE
From	70	to	71	Ft.	DAMP
From	71	to	135	Ft.	GREY SOFT GRANITE
From	381	to	405	Ft.	GREY GRANITE
From	183	to	185	Ft.	GREY SOFT GRANITE
From	185	to	235	Ft.	BLACK & GREY MIX GRANITE WET
From	265	to	375	Ft.	GREY GRANITE
From	375	to	380	Ft.	BLACK GRANITE
From	380	to	381	Ft.	SANDY COLOR MORE WATER
From	135	to	183	Ft.	BLACK SHALE

- Return to Main
- Return to Search Options
- Return to Search Criteria

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 67739

Owner: OSCAR DAYTON

Address: 3715 OLD CLAYBURN RD

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot:
Township: TWP Section: 26 Range:
Indian Reserve: Meridian: Block:
Quarter: NE
Island:
BCGS Number (NAD 27): 092G009423 Well: 3

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use:
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 7.0 inches
Casing drive shoe:
Well Depth: 254 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date:

Driller:
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
CASING

LITHOLOGY INFORMATION:

From	0 to	67	Ft.	SAND GRAVEL
From	67 to	82	Ft.	BLUE CLAY
From	82 to	83	Ft.	SAND
From	83 to	90	Ft.	CLAY
From	90 to	183	Ft.	FINE SAND GRAVEL
From	0 to	0	Ft.	DEVELOPED
From	192 to	233	Ft.	FINE SAND
From	233 to	254	Ft.	F SAND CLAY LENSES
From	0 to	0	Ft.	HOLE WAS DRILLED AS A TEST HOLE FOR A PR
From	0 to	0	Ft.	TRAILER PARK-WELL NEVER USED AND PROPERT
From	183 to	192	Ft.	CLAY

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 72102

Owner: MORELLI STEVE MR

Address: 5176 WILLET ROAD

Area: MATSQUI

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 61513 Lot: 20
Township: 20 Section: 6 Range:
Indian Reserve: Meridian: Block:
Quarter: SW
Island:
BCGS Number (NAD 27): 092G009444 Well: 32

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use:
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 275 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-10-01 00:00:00.0

Driller: Nor-West Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 8 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
CASING 2.2 TO 22.0.

LITHOLOGY INFORMATION:

From	24	to	94	Ft.	HARD GREEN GRANITE SOME
From	0	to	0	Ft.	BROKEN ROCK
From	94	to	145	Ft.	SOFT GREEN GRANITE WITH
From	0	to	0	Ft.	LAYERS OF SANDSTONE
From	145	to	240	Ft.	HARD GREEN GRANITE SOME
From	0	to	0	Ft.	FRACTURES
From	240	to	265	Ft.	HARD GREEN & PURPLE
From	0	to	0	Ft.	GRANITE SOME QUARTZ &
From	0	to	0	Ft.	FRACTURES
From	265	to	275	Ft.	Error in Lithology Ent
From	0	to	0	Ft.	LAYERS OF SANDSTONE
From	0	to	0	Ft.	1/2 GPM AT 260-280 FEET
From	0	to	0	Ft.	1/2 GPM AT 280-300 FEET
From	0	to	0	Ft.	1/2 GPM AT 300-320 FEET
From	0	to	0	Ft.	1/2 GPM AT 320-340 FEET
From	0	to	0	Ft.	6 GPM AT 380-400 FEET
From	0	to	4	Ft.	SANDY TOP SOIL
From	4	to	17	Ft.	SILTY SAND GRAVEL &
From	0	to	0	Ft.	BOULDERS
From	17	to	22	Ft.	STONEY BROWN HARD PAN
From	0	to	0	Ft.	SOME BOULDERS
From	22	to	24	Ft.	WET SILTY GRAVEL ?
From	0	to	0	Ft.	FRACTURES

- Return to Main
- Return to Search Options

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 76097

Owner: JOHN GLAZENA

Address: 32483 KING RD

Area: ABBOTSFORD BC

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009444 Well: 27

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use:
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe: 38.4
Well Depth: 126 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: Y

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1992-03-30 00:00:00.0

Driller: A. & H. Construction
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 30 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 8 feet 2.44

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
null	null		60
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
HERITAGE VALLEY SUMAS MT ABBOT

LITHOLOGY INFORMATION:

From	0	to	5	Ft.	TOP SOIL FILL
From	5	to	30	Ft.	GRAVEL TILL BOULDERS
From	30	to	45	Ft.	GRAVEL H2O APP
From	45	to	55	Ft.	CLAY
From	55	to	70	Ft.	SAND GRAVEL LITTLE H2O APP 10 GPM
From	70	to	98	Ft.	CLAY
From	98	to	106	Ft.	GRAVEL H2O 15 GPM APP
From	106	to	126	Ft.	BED ROCK CLAY TILL
From	126	to		Ft.	BEDROCK FINE CLAY

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- Return to Search Options
- Return to Search Criteria

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 78509

Owner: GEN CON DEVELOPMENT

Address: 37178 WHELAN ROAD

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 6799 Lot: 2
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 2

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-08-19 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
SUMAS MT SUBDIVISION HAMMER DIED FROM BACK PRESSURE

LITHOLOGY INFORMATION:

From	0	to	8	Ft.	BROWN SILTY SAND COBBLES
From	8	to	22	Ft.	SILTY GRAVEL
From	22	to	187	Ft.	BROWNISH GRANITE
From	187	to	194	Ft.	SOFT BROWN GRANITE
From	194	to	280	Ft.	GREY GRANITE 1/2 GPM
From	280	to	332	Ft.	GREY GRANITE WHITE QUARTZ LAYERS
From	332	to	336	Ft.	FRACTURED GRANITE 25+ GPM

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 78510

Owner: GEN CON DEVELOPMENTS

Address:

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 6799 Lot: 3
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 3

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: 243 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-07-21 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 18 (Driller's Estimate) U.S. Gallons per Minute
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 22 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
SUMAS MT SUBDIVISION 18 GPM

LITHOLOGY INFORMATION:
From 0 to 32 Ft. BRWON SAND SILT COBBLES
From 32 to 61 Ft. GREY TILL
From 61 to 66 Ft. BROWN SAND VERY SILTY LITTLE WATER
From 66 to 79 Ft. GREY TILL
From 79 to 234 Ft. GREY GRANITE
From 234 to 243 Ft. FRACTURE GRANITE WB

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 78512

Owner: GEN CON DEVELOPMENTS

Address: 37069 WHELAN ROAD

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 6799 Lot: 4
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 4

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-07-23 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
SUMAS MT SUBDIVISION 140 FRACTURE WB 173 FRACTURE WB 187 FRACTURE WB

LITHOLOGY INFORMATION:
From 0 to 204 Ft. GRANITE

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 78522

Owner: GEN CON CONTRACTING

Address: 5947 SUMAS MOUNTIAN ROAD

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 6799 Lot: 8
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 8

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-09-10 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0 to	16 Ft.	BROWN SILTY SAND & COBB LES
From	16 to	19 Ft.	BROWN SILTY SAND WET
From	19 to	28 Ft.	BROWN CLAY & SAND
From	28 to	171 Ft.	GREYISH GREEN GRANITE
From	171 to	176 Ft.	SALT & PEPPER GRANITE
From	176 to	187 Ft.	GREY GRANITE
From	187 to	196 Ft.	FRACTURED GRANITE WB
From	196 to	202 Ft.	GREY GRANTIE

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 78525

Owner: ROY & CAROL GEN-CON

Address: 37134 LIAMEL ROAD

Area: ABBOTSFORD

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 6799 Lot: 5
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 5

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1993-09-21 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
SUMAS MTN SUBDIVISION

LITHOLOGY INFORMATION:
From 0 to 145 Ft. GREY GRANITE
From 145 to 165 Ft. BLACK GRANITE
From 165 to 230 Ft. BROWN GRANTIE 1/2 GPM
From 230 to 280 Ft. SALT & PEPPER GRANITE 1 GPM

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 79182

Owner: CORRINE WRIGHT

Address: CARMEN ROAD

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 45083 Lot: C
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 19

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: 150 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1999-09-01 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 5 (Driller's Estimate) U.S. Gallons per Minute
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 45 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 9 Ft. GRAVEL SAND BROWN CLAY
From 9 to 18 Ft. GRAVEL
From 18 to 32 Ft. GREY CLAY GRAVEL
From 32 to 141 Ft. 132 LITTLE WATER 1 GPM DARK GREEN ROCK
From 141 to 145 Ft. BIEGE ROCK WB
From 145 to 150 Ft. GREEN ROCK

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 79184

Owner: CORRINE WRIGHT

Address: 37277 LIAMEL ROAD

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: LMP 15008 Lot: 1
Township: 20 Section: 8 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G020111 Well: 12

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe:
Well Depth: 228 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1999-09-09 00:00:00.0

Driller: Perry's Well Drilling
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level:

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
0	0		0
0	0		0

Casing from	to feet	Diameter	Material	Drive Shoe
null	null	0	null	null

GENERAL REMARKS:
EXISTING HOME

LITHOLOGY INFORMATION:
From   0 to   11 Ft.   SAND & GRAVEL
From   11 to   159 Ft.   MED GREEN COLOUR ROCK
From   159 to   182 Ft.   BIEGE COLOUR
From   182 to   191 Ft.   PINK COLOUR WB
From   191 to   206 Ft.   DARK GREEN
From   206 to   208 Ft.   PINK WB
From   208 to   228 Ft.   LIGHT GREEN ROCK

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 92215

Owner: LIDDELL

Address: 37189 DAWSON ROAD

Area: ABBOTSFORD

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G010333 Well: 5

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: Y Y
Well Depth: 458 feet 140m
Elevation: feet (ASL)
Final Casing Stick Up: 24 inches
Well Cap Type:
Bedrock Depth: Feet
Lithology Info Flag: Y
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2007-04-10 00:00:00.0

Driller: A. & H. Drilling Ltd.
Well Identification Plate Number: 21887
Plate Attached By: WILLIAM RICHARD
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 1 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 80 feet 24m

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: Y
Material: Bentonite clay
Method:
Depth (ft): 15 feet
Thickness (in): 2 inches
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
0	15	6	Steel	Y
0	15	10	Steel	Y

GENERAL REMARKS:
RIG #3. 6" CASING SHOE.

LITHOLOGY INFORMATION:

From	0 to	6 Ft.	topsoil	
From	6 to	48 Ft.	grey granite	
From	48 to	52 Ft.	BLACK & WHITE	granite
From	52 to	67 Ft.	GREEN & GREY	fractured rock
From	67 to	138 Ft.	BLACK & WHITE	granite
From	138 to	176 Ft.	GREEN & GREY	granite
From	176 to	218 Ft.	GREY & WHITE	granite
From	218 to	271 Ft.	GREY, WHITE & GREEN	granite
From	271 to	296 Ft.	GREY & WHITE	granite
From	296 to	362 Ft.	GREEN & WHITE	granite
From	362 to	458 Ft.	GREY, BLACK & WHITE	granite

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BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 92849

Owner: PEBBLE

Address: 5035 UPPER SUMAS MTN ROAD

Area: ABBOTSFORD

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009444 Well: 28

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: N
Well Depth: feet 280
Elevation: feet (ASL)
Final Casing Stick Up: 36 inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2006-06-07 00:00:00.0

Driller: Nor-West Drilling
Well Identification Plate Number: 16224
Plate Attached By: T OSTER
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 1.25 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 34 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
0	19	6	null	N

GENERAL REMARKS:
RIG NO: AR#1.

LITHOLOGY INFORMATION:

From	0	to	2	Ft.	fill	
From	2	to	4	Ft.	soil	
From	4	to	13	Ft.	HARDPAN & COBBLES	
From	13	to	17	Ft.	BROKEN ROCK	
From	17	to	90	Ft.	SHALE WITH LAYERS OF BROWN SHALE	green
From	90	to	105	Ft.	SHALE WITH QUARTZ LENSES	green fractured
From	105	to	130	Ft.	LAYERS OF BROWN SHALE	green shale
From	130	to	210	Ft.	GREYISH GREEN WITH LIGHT GREEN LAYERS	granite
From	210	to	250	Ft.	LAYERS OF BROWN SHALE	green shale
From	250	to	280	Ft.	SANDSTONE WITH QUARTZ LENSES	brown

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 94127

Owner: ISHERWOOD

Address: 35003 CLAYBURN ROAD

Area: ABBOTSFORD

WELL LOCATION:
Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G009432 Well: 3

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: inches
Casing drive shoe: N Y
Well Depth: 57 feet
Elevation: feet (ASL)
Final Casing Stick Up: 36 inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: Y
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2006-09-12 00:00:00.0

Driller: A. & H. Drilling Ltd.
Well Identification Plate Number: 15047
Plate Attached By: WILLIAM RICHARD
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 50 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 8 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: N
Material:
Method:
Depth (ft):
Thickness (in):
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size
48	56.5		40
56.5	57		null

Casing from	to feet	Diameter	Material	Drive Shoe
0	48	6	Steel	Y
0	10	10	Steel	N

GENERAL REMARKS:
DRILLED TO 61 FEET AND PULLED BACK TO 57 FEET

LITHOLOGY INFORMATION:
From 0 to 6 Ft. DIRT
From 6 to 59 Ft. WATER BEARING gravel
From 59 to 61 Ft. silt

- Return to Main
- Return to Search Options
- Return to Search Criteria

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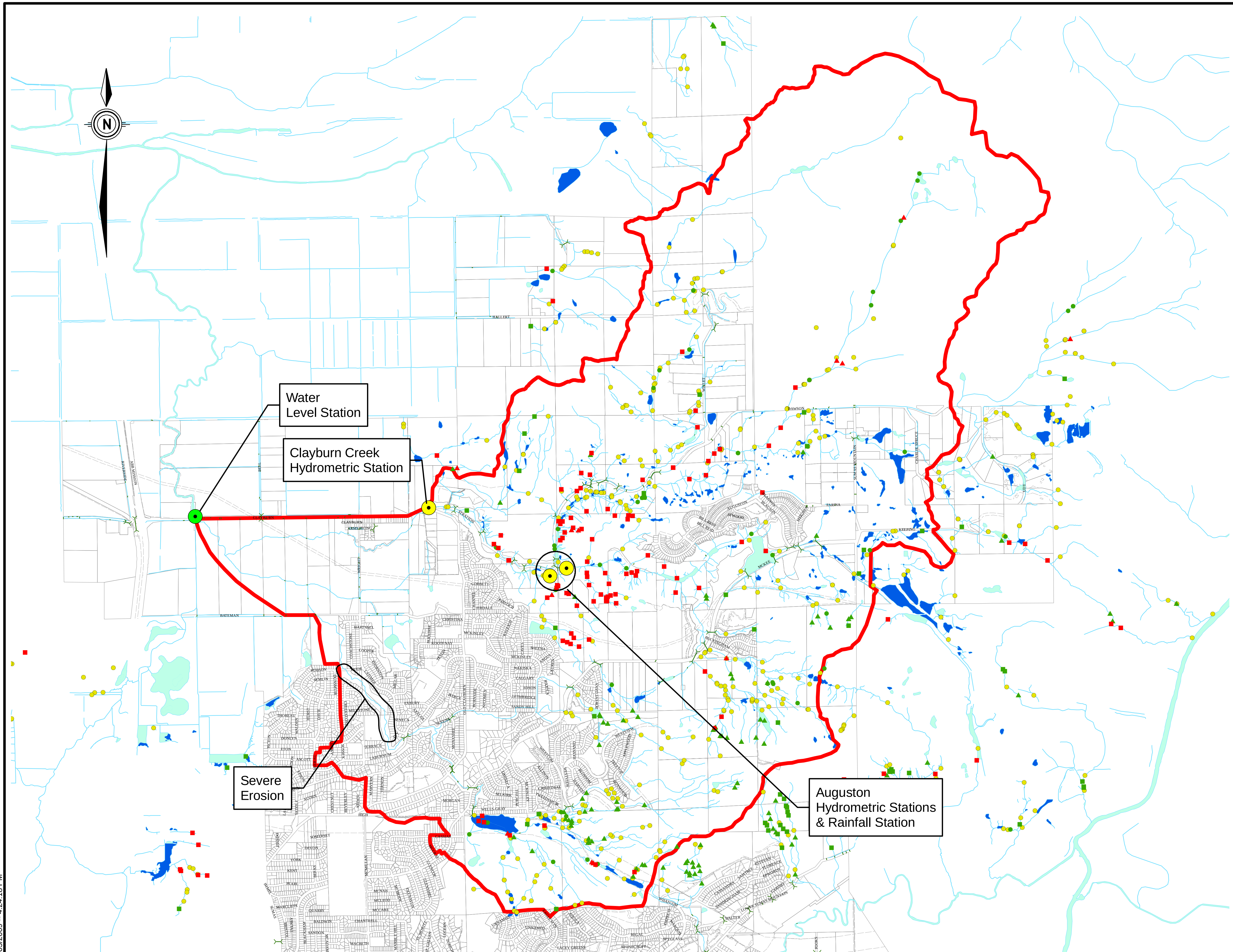
APPENDIX B

EROSION AND OBSTRUCTIONS FIGURE



City of Abbotsford
Clayburn Creek
ISMP

Legend

- Watershed Boundary
- Creeks and Streams
- Detention System

Wetlands

TYPE

- PONDS
- WETLANDS
- Modifications

Erosion

Severity

- <5m sq
- 5-10m sq
- >10m sq

Obstructions

Barrier

- Potential
- Yes
- unknown

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

500 0 500
Scale in Metres 1:30,000

Project No.	Date
510-057	May 2009

Erosion and Obstuctions

Map Document: (O:\0500-0599\510-057\430-GIS\Mxd-Rp\510057Fig2.mxd)
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KERR WOOD LEIDAL
consulting engineers

Appendix C

Environmental Assessment

Appendix C – Environmental Inventory and Assessment

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Appendix C – Environmental Inventory and Assessment

C Environmental Inventory and Assessment

C.1 Introduction

An environmental inventory was undertaken to summarize watershed conditions and trends. This included collection and collation of information on water and sediment quality, benthic invertebrate communities, aquatic species and habitats, vegetation and land cover patterns, and wildlife use and terrestrial habitat.

C.2 Water Quality

The term water quality refers to the chemical, physical and biological conditions of water and the degree to which it is impaired or degraded by natural or anthropogenic factors. Good water quality in streams is vital to the protection of ecosystem functioning and aquatic life, such as fish, as well as human uses for drinking water and recreation, and aesthetics. Comparisons to BC Approved Water Quality Guidelines (BC AWQGs) and the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) is recommended to assess whether current stormwater management is adequately protecting these values.

Since 1997, B.C. Ministry of Environment (MOE) has conducted extensive monitoring within the hillside portion of the ISMP study area, particularly in Straiton Bowl, due to concerns over water quality impacts from increasing levels of development. Since 2008, additional sampling has been conducted in cooperation with the City of Abbotsford. Sampling has included:

- Discrete (grab) sampling for total suspended solids (TSS), turbidity, fecal coliform and *E. coli* bacteria, nutrients, and total and dissolved metals during both baseflow (low flow) and storm event (high flow) conditions (over 250 samples taken at 18 sites from 2008–2010)
- In-situ monitoring of general water quality parameters (e.g., dissolved oxygen, specific conductivity) taken with grab samples under low and high flow conditions
- Continuous monitoring of general water quality parameters (temperature, specific conductivity, pH, turbidity) at five locations in the study area (3 on Clayburn Creek, 1 on Stoney Creek, 1 on Poignant Creek)
- Continuous temperature monitoring at various sites throughout the watershed

As part of the inventory work conducted for the ISMP, in-situ measurements of general water quality parameters (water temperature, dissolved oxygen, specific conductivity, pH, turbidity, and oxygen reduction potential (ORP)) were undertaken on September 22 and 23, 2009 (40 sites in total; additional eight sites visited but found to be dry at time of sampling). Sampling sites are illustrated in Figure 3-1.

- General water quality parameter sampling results:
  - Water temperature: range = 10.06–16.53ºC, mean = 13.30ºC
  - Dissolved oxygen: range = 4.99–10.10 mg/L, mean = 8.48 mg/L
  - Specific conductivity: range = 48–322 µS/cm, mean = 151 µS/cm
  - pH: range = 5.80–8.08, mean = 7.37
  - Turbidity: range = 17.7–396.7 NTU; mean = 183.9 NTU
  - Oxygen reduction potential (ORP): range = 0.0–136.2, mean = 7.3

Appendix C – Environmental Inventory and Assessment

Based on the results of both the MOE and ISMP sampling, several priority water quality issues have been identified in the Clayburn Creek Watershed:

- **Turbidity and suspended sediment within Clayburn Creek:** Sedimentation within the middle and upper portions of Clayburn Creek (upstream of the confluence with Poignant Creek) is a major water quality concern. Sedimentation is occurring in the ravine section of the watershed adjacent to new development but also upstream of new development (D. Sutherland, pers. comm.). Sedimentation has been detected in elevated levels of turbidity (storm event grab sampling) and frequent high turbidity events (continuous monitoring). As well, the level of sediment movement and deposition has made it difficult to run continuous monitoring probes (probes become buried). It is unclear whether sedimentation may represent historic land use impacts (forestry, power line rights-of-way, etc.), impacts of recent development, or a combination of both factors. Potential sources of sediment within the Clayburn Creek watershed needs more detailed examination. An important finding of the recent MOE sampling (2008-2010) of the outfalls from new development is that catchments within new development (e.g., Auguston neighbourhood) that have BMPs in place (either surface detention ponds or underground detention tanks) performed better than catchment with no BMPs in place (D. Sutherland, pers. comm.). Problems with sedimentation have not been detected in the other subwatersheds.
- **Bacteriological contamination in Diane Brook and Stoney Creek:** Sampling from 1997-2001 found elevated levels of fecal coliform in lower Poignant Creek. The most likely sources this watershed are hobby farms and failing septic fields in the Straiton community in the upper reaches of Diane Brook. Sampling from 1997-2001 and 2009 also found high levels of fecal coliform in Stoney Creek downstream of the utility right-of-way (Vicarro Ranch) where cows are pastured. Currently this area has no fencing to exclude the cows from the creek. Development proposals for this area are in process.
- **Elevated levels of metals, oil, and grease from residential areas in Stoney Creek:** The highest levels of metals contamination in the study area have been found in Stoney Creek (Quilty 2001). Higher levels of metals are usually associated with urbanizing and urbanized catchments.
- **Specific conductivity in developed upland areas:** Specific conductivity measurements show increasing seasonal impacts from road salting in developing areas of the watershed.

Stream temperatures do not appear to have been elevated significantly by land development in the watershed at present.

Link to Watershed Health

In the Clayburn Creek ISMP study area, good water quality is important to protecting aquatic life and ecosystems, as well as a clean irrigation water source. With the exception of sedimentation in Clayburn Creek, the magnitude and distribution of water quality problems in the study area is to be expected for the level, type, and distribution of development present. Options to improve water quality include addressing point sources of contamination, Best Management Practices (BMPs) and structural water quality treatment (swales, sources controls), In general, water quality impacts from point sources (fecal coliforms from livestock and septic fields) will be easier to address than contamination from non-point sources (metals in runoff from roads).

Appendix C – Environmental Inventory and Assessment

C.3 Sediment Quality

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

Sediment quality sampling was undertaken on September 23, 2009. Sediment samples were taken at ten sites (same as benthic sampling sites plus two lowland sites on the Clayburn mainstem) and tested for total metals. Where possible, each sample was a composite of surface and shallow sub-surface fine sediment collected from 10–15 sites from within the active stream channel. Sampling sites are illustrated in Figure 3-1.

MOE also conducted sediment sampling in the Straiton Bowl area from 1997–2001 (summarized in Quilty 2001).

From the ISMP sampling and a review of historical MOE data, several priority sediment quality issues were identified:

- **Elevated levels of metals in upper watershed sites:** Sampling results from 1997-2001 found that total manganese in sediments in upper Clayburn Creek (near McKee Road) exceeded Probable Effect Levels (PEL)[1]. Levels of total chromium, iron, manganese, and zinc were elevated in several tributaries. With the exception of manganese, concentrations were similar or slightly higher than mean regional values from other studies in Metro Vancouver and are considered to have a sublethal effect on receiving waters. Similar to previous sampling, sampling in 2009 found that manganese levels were high at the uppermost sampling sites in all four subwatersheds. However, while levels were above the lower guideline, they were below the guideline for most severe impacts. Some metals (copper, iron, zinc) were also higher in upper Clayburn Creek relative to other sampled sites, although not above guidelines. The widespread presence of elevated metals suggests that these values originate from natural sources, such as exposed bedrock.
- **Isolated metals contamination in lower watershed sites:** Metal levels in sediment sampled from lower watershed sites were generally lower than upper watershed sites, however, there were some exceptions. Arsenic levels were slightly above the ISQG in Stoney Creek (near Stoney Creek Park), and nickel levels were above the ISQG in the lower part of Poignant Creek (along Straiton Road) and at the Clayburn lowlands site. Elevated arsenic levels are likely natural while the nickel levels, particularly at the lowlands site on Clayburn Creek, may represent contamination from human sources.
- **High levels of metals, oil, and grease in Stoney Creek:** Sampling from 1997-2001 found levels of arsenic, chromium, copper, iron, manganese, nickel, and zinc exceeded water quality guidelines. High levels of oil and grease were also found in sediment samples. Higher levels of these contaminants are usually associated with urbanizing and urbanized catchments. Oil and grease testing on sediment samples was not conducted in 2009.

[1] Probable Effects Levels (PELs) are defined as "levels which, if exceeded, will cause severe effects on aquatic life" (Nagpal et al., 2006) and are provided with sediment quality guidelines for some metals. Exceedance of PELs represents more severe contamination than exceedance of sediment quality guidelines.

Appendix C – Environmental Inventory and Assessment

It should be noted that levels of metals in sediments were assessed only from a single sample at each site, and in some cases this level of sampling is insufficient for comparison to appropriate guidelines (i.e., mean value based on five samples in 30 days required). Further assessment is needed.

Full sediment quality sampling results can be found in Appendix 1, Tables C1-1 and C1-2.

Link to Watershed Health

Sediment quality is an indicator of the cumulative impacts of water pollution on watershed health. Similar to water quality, sediment quality results are as to be expected for the level and type, and distribution of development present. High levels of metals, oil, and grease in Stoney Creek are typical of developed catchments where streams receive substantial road runoff and support the water quality findings reported above. Further investigation of the sources of particularly high levels of certain metals at specific sites (e.g., manganese, arsenic) is needed to understand whether these are natural or human-caused.

C.4 Benthic Invertebrates

Benthic invertebrates (streambed insects) are useful indicators of stream condition and can be monitored over time to track changes in stream or watershed health. Benthic invertebrate community sampling provides an integrated measure of cumulative effects of watershed changes, such as urbanization, not consistently captured by water quality measurements. However, benthic sampling does not necessarily provide insight into the cause of changes to stream condition. Both multi-metric and multivariate methods are available to summarize benthic invertebrate community structure and composition to compare among watersheds or look for relationships with other watershed factors (e.g., water quality, impervious area, riparian forest integrity). B-IBI (Benthic Index of Biotic Integrity) is a common multi-metric method for summarizing benthic invertebrate data and has been used extensively to measure the condition of small streams in Metro Vancouver.

In collaboration with MOE, benthic invertebrate sampling was undertaken on September 3, 2009 and September 23, 2009 at eight stations in the Clayburn Creek watershed (one upper and one lower site in each of the four major subwatersheds). Each station consisted of a single composite sample of three Serber sampler placements (3 min substrate disturbance each) within the same or adjacent riffles in a 50 m reach. Sampling generally followed the field sampling protocol described in the GVRD Benthic Macroinvertebrate B-IBI Guide (EVS, 2003) (although one sample was taken at each site, rather than four samples within one 500 m sampling reach in a single stream). Organic detritus and inorganic sediment trapped in the net was transferred to plastic jars and preserved in a 10% formalin solution. Sample processing, subsampling, taxonomic identification, and B-IBI scoring (used as an index of watershed health) was completed by Rhithron Associates (Missoula, MT). Sampling sites are illustrated in Figure C-1 and detailed taxonomic methods are provided in Table C-2.

The B-IBI Index operates on a scale of 10 to 50, with 10 representing a degraded watershed and 50 representing a pristine, old growth watershed. Typically, undeveloped watersheds in the Lower Mainland score a maximum of 40 points (considered good condition).

Appendix C – Environmental Inventory and Assessment

B-IBI scores across the eight sampling sites ranged from a high of 38 in upper Diane Brook to a low of 26 in lower Poignant Creek (Table C-1)[2]. In general, scores were higher at the upstream sites versus the downstream sites in each watershed, reflecting the lower levels of development in the headwaters of each catchment. Five of the eight sites sampled had a B-IBI score of 34 or better. The overall mean B-IBI score for the ISMP study area was 32.8 (SD 3.8).

Across all four sites, mean taxa richness was 29.3 (SD 3.8, min 24, max 35). Variability across eight of the ten metrics that make up the total B-IBI score accounts for the variability observed in B-IBI scores between sites.

Full taxonomic data and individual B-IBI scores for the 2009 sampling are available in Appendix 2.

Previous benthic invertebrate sampling has also taken place in the Clayburn Creek watershed. As part of its overall watershed monitoring program, sampling of benthic invertebrates using the B-IBI methodology (Surber sampling and multi-metric analysis) has been undertaken by MOE in Clayburn Creek and several tributaries since 1997. Sampling has included:

- Composite samples (3 Surber placements per sample) were collected at ten sites on March 30, 1997 (ten sites). Nine sites were resampled on July 27, 1997.
- In 2000, to allow for additional statistical analysis, individual Surber samples (3 per site) were collected from five sites on September 6, 2000.

Individual Surber samples (ranging from 1-5 per site) were collected from five sites during the fall of 2001 (one site), 2002 (three sites), and 2006 (two sites).B-IBI values calculated by MOE also indicate that Clayburn Creek is in good biological condition, compared with other watersheds in the lower Fraser Valley (Table C-2). In fact, scores are generally higher than in the 2009 sampling, suggesting a decline in condition may have occurred. However, although the methods used were similar, B-IBI calculations used inconsistent methods or are not well-documented. As a result, reported scores require recalculation using standardized methods[3] and cannot be directly compared to the 2009 results. While standardization would help to assess trends in watershed health, this standardization was beyond the scope of the ISMP.

[2] Under the 10-metric B-IBI scoring system, for each metric, each sample is given a score from 1 to 5. Therefore, the minimum possible B-IBI score is 10 and the maximum score is 50 (Page et al., 2008).

[3] Because calculated B-IBI values are sensitive to sample type (single Surber placement vs. composite sample), sample size (subsampling to 400 organisms vs. no subsampling), taxonomic standards (variation in lowest practical taxonomic level), and life history traits (errors in previous life history information used for the lower Fraser Valley) used, careful attention is needed to ensure comparability across sites and years. Examples of inconsistencies evident in previous MOE B-IBI scoring include the use of non-subsampled data to calculate B-IBI scores (fully picked samples vs. subsample of ca. 400 organisms) and no clear life history trait reference. Datasets must be standardized to allow for comparisons between years and for assessment of trends in stream health.

Table C-1: 2009 Benthic Invertebrate Sampling Results

Creek	Clayburn Creek				Poignant Creek				Diane Brook				Stoney Creek			
Site	CLAY2 (downstream)		CLAY3 (upstream)		POIG1 (downstream)		POIG2 (upstream)		DIAN1 (downstream)		DIAN2 (upstream)		STON1 (downstream)		STON2 (upstream)	
Metric	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
Taxa richness	31	5	29	5	24	3	32	5	33	5	33	5	25	3	27	3
E richness	7	3	7	3	6	3	5	3	7	3	4	1	6	3	5	3
P richness	6	3	4	3	3	1	6	3	5	3	6	3	4	3	3	1
T richness	7	3	4	1	5	3	9	3	8	3	7	3	6	3	7	3
Intolerant taxa richness	1	1	1	1	0	1	1	1	1	1	3	3	1	1	1	1
Clinger richness	12	3	13	3	14	3	16	3	16	3	14	3	14	3	11	3
Long-lived richness	4	3	5	5	2	1	4	3	4	3	6	5	4	3	3	3
% tolerant	0.96	5	1.73	5	0.95	5	0.23	5	7.48	5	2.75	5	0.00	5	0.00	5
% predator	14.94	3	20.52	5	8.31	1	16.90	3	19.20	3	45.50	5	7.30	1	14.01	3
% dominance (3)	33.73	5	39.60	5	48.46	5	48.84	5	44.64	5	33.75	5	48.91	5	51.37	5
Sample BIBI Score		**34**		**36**		**26**		**34**		**34**		**38**		**30**		**30**
Mean BIBI by subwatershed	**35.0 (SD = 1.4)**				**30.0 (SD = 5.7)**				**36.0 (SD = 2.8)**				**30.0 (SD = 0.0)**			
Biological Condition[1]	**Fair**				**Fair**				**Fair**				**Fair**			
Overall BIBI	**32.8 (SD = 3.8) / Fair**															

Sampling Sites	UTM-E	UTM-N	Creek	Location Description
CLAY2	555618	5436398	Clayburn Ck	15 m u/s of confluence with Poignant Ck
CLAY3	557242	5436639	Clayburn Ck	d/s of McKee Rd off of trail below Auguston development (MOE benthic site)
POIG1	555557	5436549	Poignant Ck	30 m u/s of bridge access to Clayburn Ck Park in reach parallel to Straiton Rd, u/s of confluence with Poignant Ck
POIG2	558215	5439941	Poignant Ck	at footbridge down trail off Russel Rd cul-de-sac
DIAN1	556787	5437139	Diane Brook	u/s of confluence with Poignant Ck, off of Mathers Park near school (MOE benthic site)
DIAN2	558310	5439034	Diane Brook	at footbridge down trail from pullout at height of land on Upper Sumas Mtn Rd near Highland Quarry
STON1	553819	5435764	Stoney Ck	near intersection of Latimer St and Prior Ave, behind Stoney Creek Park
STON2	554944	5434576	Stoney Ck	u/s of McKee Rd, d/s of Wells Gray Ave, within McKee Trail Park

[1] Biological condition categories based on Morley (2000) (modified from Karr et al. 1996) and available at http://pugetsoundstreambenthos.org/About-BIBI.aspx

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Table C-2: Benthic Sampling Sites/MOE Monitoring Program Unstandardized B-IBI Scores, 1997–2006

Site	Calculated B-IBI values					
	1997	2000	2001	2002	2006	2009
Diane Brook, d/s of Dawson Rd (Straiton 1)	nc	40				
Diane Brook, u/s of confluence with Poignant Ck (Straiton 3)	nc	48				X
Poignant Ck, u/s of confluence with Clayburn Ck (Straiton 4)	nc	46			38.4*	X
Clayburn Ck, at Matsqui Flats near staff gauge (Straiton 5)	nc	46		nc		
Clayburn Ck, u/s of confluence with Poignant Ck (Straiton 6)	nc	46	33.5*	nc	40.5*	X

Source: B.C. Ministry of Environment
Notes: nc = data available but B-IBI not yet calculated; X = sampled in 2009 for ISMP; *denotes an average of multiple samples

Environment Canada also collected benthic invertebrate samples from 1998–2000 at several sites within Clayburn Creek as part of CABIN (Canadian Aquatic Biomonitoring Network) sampling of the Fraser River watershed. CABIN uses kicknet sampling and a multivariate data analysis method that compares invertebrate community composition to undisturbed reference conditions to assess the magnitude of deviation from reference condition (magnitude of stress). Habitat variables are used to select an appropriate reference group for comparison. Results from the Clayburn Creek sampling are shown in Table C-3. Results range from not stressed (Clayburn mainstem in 1999, downstream of confluence with Poignant Creek) to stressed (Clayburn Creek, downstream of Clayburn Rd). Because different methods were used, results of the CABIN sampling are also not directly comparable to the 2009 sampling and B-IBI values.

Table C-3: Benthic Sampling Sites/EC Sampling Results Using the CABIN Methodology, 1998–2000

Site/Year	Stream (Year)	Site Description	Site Type	Probability	Assessment Result (BEAST)	Exposure
CLB0198	Poignant Creek (98)	u/s of confluence with Clayburn Creek; u/s of bridge along road	Reference	-	-	-
CLB0298	Clayburn Creek (98)	Small trib. just u/s of confluence with Poignant Creek	Reference	-	-	-
CLB0398	Clayburn Creek (98)	d/s of confluence of Poignant & Clayburn cks	Test	43.3%	Possibly stressed	Residential/urban
CLB0399	Clayburn Creek (99)	d/s of confluence of Poignant & Clayburn cks	Test	43.4%	Not stressed	Residential/urban
CLB0300	Clayburn Creek (00)	d/s of confluence of Poignant & Clayburn cks	Test	55.1%	Possibly stressed	Residential/urban
CLB0498	Stoney Creek (98)	In Bateman Park	Test	49.2%	Possibly stressed	Residential/urban
CLB0598	Clayburn Creek (98)	d/s of Clayburn Rd; u/s of confluence with Willband Ck	Test	99.3%	Stressed	Agricultural

Sources: Sylvestre et al. 2005; Canadian Aquatic Biomonitoring Network (CABIN) online database
Note: Possible results = not stressed, possibly stressed, stressed, or severely stressed

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Link to Watershed Health

B-IBI is an overall indicator of watershed health, representing the cumulative impacts of upstream development on aquatic ecosystems (e.g., changes in flow regime, water quality, instream habitat). The sampling results indicate that the four subwatersheds are in fair condition based on their benthic invertebrate communities. Compared with many watersheds within Metro Vancouver, B-IBI scores are significantly higher in the Clayburn Creek system. However, scores are as expected based on the low levels of impervious area and high levels of riparian forest cover in many of the subwatersheds (see Watershed and Riparian Forest Cover Assessment section).

Scores for Stoney Creek sites (B-IBI = 30 at both sites) show that the biological condition of Stoney Creek is better than expected given the amount of urbanization in this subwatershed. Conditions can be better than expected due to a range of factors, such as successful mitigation of flow and water quality impacts (using source controls, detention ponds, filtration, etc.), significant baseflows from groundwater, or a relatively short time period since development.

C.5 Watershed and Riparian Forest Cover Assessment

Forest cover contributes to or regulates many important watershed processes, such as the movement and provision of water, sediment, nutrients, organic matter, and wood. Within watersheds, forests are important regulators of streamflow through rainfall interception, capture, and evapotranspiration. Forests within the riparian area, the interface zone between the water and land, also protect streams by providing cooling shade and stabilizing banks, as well as supplying food, nutrients, organic matter, and instream wood debris that are important components of aquatic ecosystems and fish habitat.

A desktop evaluation of watershed and riparian forest cover was undertaken to assess the amount and distribution of tree canopy cover within different regions of the study area and identify areas for potential riparian forest restoration. Forest cover was digitized on 2008 orthophotos. A standard 30 m buffer on either side of the stream centrelines (60 m total width) across all permanent streams was used to assess riparian forest integrity (RFI) across the study watersheds. Refer to Figure 3-2 for the locations of existing riparian corridors. Key findings of the analysis were:

Approximately 69.7% (1472.3 ha) of the Clayburn Creek ISMP study area is forested. The vast majority of this forest cover is in upland undeveloped portions of the study area. Only a small amount of forest cover remains in the agricultural lowland portion of the study area. In developed area, small amounts of forest cover can be found in public parks, street medians, and private yards.

Across the four subwatersheds which make up the study area, watershed forest cover ranged from 91.6% (Poignant Creek) to 42.9% (Stoney Creek) (Table C-4). The high forest cover in the Poignant Creek subwatershed reflects the relatively low levels of development in this subwatershed. The amount of forest cover in the Stoney Creek subwatershed is still higher than many developed lower Fraser Valley watersheds (often less than 10%).

Riparian forest cover showed a similar pattern to watershed forest cover, although riparian cover was higher than watershed forest cover as a whole in all four subwatersheds. RFI in the major subwatersheds ranges from 92.7% (Poignant Creek) to 55.7% (Stoney Creek) (Table C-4). The higher RFI values indicate that riparian areas were largely protected during development. Overall, RFI across the study area was 78.4%.

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Table C-4: Watershed Health Indicators – Watershed and Riparian Forest Cover

Subwatershed	Total Area (ha)	Watershed Forest Cover (ha)	Watershed Forest Cover (%)	Riparian Forest Cover (ha)	Riparian Forest Integrity (RFI) (%)
Clayburn Ck	657.2	438.0	73.5	108.0	83.1
Poignant Ck	503.5	455.8	91.6	49.5	92.7
Diane Brook	464.9	346.3	76.6	43.0	89.7
Stoney Ck	627.1	232.1	42.9	48.0	55.7
Total Study Area	2252.8	1472.3	69.7	248.5	78.4

Link to Watershed Health

Watershed forest cover plays an important role in maintaining natural watershed hydrology through rainfall interception, capture, and evapotranspiration. The moderate to high levels of forest cover among subwatersheds means that these hydrologic functions have been significantly impaired in some areas and not in others, but are still relatively intact watershed-wide.

Riparian forest cover protects streams by providing cooling shade, stabilizing banks, and supplying instream wood debris. While riparian forest integrity in the lowland portion of the watershed is typical of agricultural areas throughout Metro Vancouver, the riparian forest integrity in upland areas is higher than other similar Metro Vancouver watersheds and reflects the fact that much of the watershed is still undeveloped or that, where urban development has occurred in the watershed, it is relatively recent and was subject to riparian protection measures, such as Abbotsford's current Streamside Protection Bylaw,

C.6 Aquatic Species and Habitat Inventory

Fish Communities

Information on the fish species present in Clayburn Creek and its tributaries represent an accumulation of data from several sources, including the provincial Fisheries Information Summary System (FISS), observations made during watercourse mapping conducted for the City of Abbotsford, older government reports (fishery officer estimates, habitat surveys and assessments, etc.), fish salvage reports from recent instream works, and discussions with DFO staff and local Streamkeeper groups. No new fish sampling was undertaken as part of the ISMP.

- Six (and possibly seven) salmonid species, nine native non-salmonid species, and two introduced fish species are known from the ISMP study area (Table C-5 and Table C-6).
- Coho Salmon is the most abundant anadromous salmonid species in the watershed. Estimated historical returns range from 75-800 spawners (DFO, year unknown). The primary coho spawning reaches are in the middle transitional reaches of Clayburn and Stoney creeks, and in the lower reaches of Poignant Creek. The lower agricultural reaches of Clayburn and Stoney creeks represent additional rearing habitat for coho. Hatchery-raised coho releases occur annually in both Clayburn and Stoney creeks.

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Table C-5: Salmon and Trout Species (Mainstem & Study Area Tributaries Only)

Code	Common Name	Scientific Name	Source(s)	Status/comments	Historic Escapement Estimates[1]
CO	Coho salmon	*Oncorhynchus kisutch*	FISS, 2010	Wild pop'ns; regular hatchery releases in both Clayburn and Stoney creeks	75–800
CM	Chum salmon	*Oncorhynchus keta*	FISS, 2010	Wild pop'ns, spawn in lower reaches	20–90
PK	Pink salmon	*Oncorhynchus gorbuscha*	FISS, 2010	Wild pop'ns; odd years only; spawn in very lower reaches; uncertain if still present	50 (odd years only)
CH	Chinook salmon	*Oncorhynchus tshawytscha*	FISS, 2010	Unverified; may represent exchange of juveniles with Fraser River	-
SK / KO	Sockeye salmon/ Kokanee	*Oncorhynchus nerka*	FISS, 2010	Unverified, likely in error	-
ST / RB	Steelhead/ Rainbow trout[2,3]	*Oncorhynchus mykiss*	FISS, 2010	Anadromous and resident pop'ns; resident pop'ns stocked 1940-47	15–50
CT/ACT	Cutthroat trout/ Searun cutthroat trout[2]	*Oncorhynchus clarki*	FISS, 2010	Anadromous and resident pop;ns; hatchery production in past; stocked 1937-41; anadromous pop'ns stocked 1984-95	n/a; abundant resident populations

Abbreviations for sources: FISS = Fisheries Information Summary System
[1]from DFO (year unknown) and Schubert, 2008
[2]includes both anadromous (sea-run) and non-anadromous (resident) forms.
[3]Steelhead are an anadromous form of rainbow trout that migrate to sea and return to their home streams to spawn.

- Chum Salmon occur in the lower reaches of Clayburn Creek in limited numbers. Chum are likely limited to the lower gradient reaches of Clayburn Creek, below the confluence with Poignant Creek. Occasional Chum spawners are also seen in the lower reaches of Stoney Creek (Stoney Salmon Stalkers, pers. comm.).
- Pink Salmon were also known historically in the lower reaches of the Clayburn Creek watershed in odd years only (DFO, year unknown). It is not known whether this run still exists.

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Table C-6: Non-Salmonid Fish Species Records (Mainstem & Study Area Tributaries Only)

Code	Common Name	Scientific Name(s)	Source(s)	Status/comments
DV	Dolly Varden	*Salvelinus malma*	FISS, 2010	Unverified, likely rare
L	Lamprey (General)	*Lampetra* sp.	FISS, 2010	Likely wild, indigenous populations of this species
LMB	Largemouth Bass*	*Micropterus salmoides*	Nova Pacific, 2009	Trapped during fish salvage in lower reaches of Clayburn Creek in 2009
CSU	Largescale Sucker	*Catostomus macrocheilus*	Nova Pacific, 2009	Trapped during fish salvage in lower reaches of Clayburn Creek in 2009
NSC	Northern Pikeminnow (formerly N. Squawfish)	*Ptychocheilus oregonensis*	Nova Pacific, 2009	Trapped during fish salvage in lower reaches of Clayburn Creek in 2009
PCC	Peamouth Chub	*Mylocheilus caurinus*	Nova Pacific, 2009	Trapped during fish salvage in lower reaches of Clayburn Creek in 2009
CAS	Prickly Sculpin	*Cottus asper*	FISS, 2010	Wild, indigenous
PMB	Pumpkinseed*	*Lepomis gibbosus*	FISS 2010; Nova Pacific, 2009	Trapped during fish salvage in Stoney Creek in 2002; in lower reaches of Clayburn Creek in 2009
RSC	Redside Shiner	*Richardsonius balteatus*	FISS, 2010	
CC	Sculpin (General)	*Cottus sp.*	FISS, 2010	
CRA	Signal Crayfish	*Pacifastacus leniusculus*	Nova Pacific, 2008	Trapped during fish salvages in Clayburn and Stoney creeks in 2008
SB	Stickleback (General)	*Gasterosteus* sp.	FISS, 2010	Wild, indigenous
ST	Sturgeon (general)	*Acipenser* sp.	FISS, 2010	Unverified; record is likely from Matsqui Slough below the study area and represents exchange with the Fraser River
TSB	Three-spine Stickleback	*Gasterosteus aculeatus*	FISS, 2010	Trapped during fish salvage in Stoney Creek in 2002

Abbreviations for sources: FISS = Fisheries Information Summary System (http://www.env.gov.bc.ca/fish/fiss/index.html)
*denotes an introduced (non-native) species.

- Records of both Chinook and Sockeye salmon exist for the watershed. These species do not reproduce in the study area. Records may represent rearing juveniles entering from the Fraser River (records may be from the lower reaches in the Matsqui Slough area), strays, or be mis-identifications of other species.

- Steelhead (anadromous) were present in Clayburn Creek historically and are thought to be still present in the watershed, although their returns are small. Rainbow Trout (resident) have also been reported in the watershed and the creek was regularly stocked in the 1940s. Rainbow Trout and Steelhead appear virtually identical as juveniles.

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- Resident Cutthroat Trout are abundant in permanently-flowing upper reaches of all the major tributaries. Small runs of searun Cutthroat Trout (anadromous) are known historically, and releases of searun Cutthroat Trout were done from 1984–1995 to enhance existing wild populations. The current status of this run is unknown and any run is likely to be small.

- Two non-native fish species, Pumpkinseed and Largemouth Bass, are known from the watershed. Pumpkinseed trapped in the lower agricultural reaches of Clayburn and Stoney creeks during fish salvages for instream works and Largemouth Bass was trapped in lowland agricultural reaches of Clayburn Creek. Largemouth Bass are a voracious predator and can have large impacts of native fish populations. They are very difficult to remove from a system once established.

- Other native fish species present are typical of low gradient streams in the lower Fraser Valley (Table C-6).

Instream Fish Habitat

Fish habitat characteristics (channel conditions, substrates, complexity, etc.) were assessed during field visits in September 2009, supplemented by additional site visits in January 2011. To understand the distribution of different habitat types, habitat conditions were assessed by reach and measured at representative reach points (data found in Appendix C3). Mapped reaches based on the assessment are shown in Figure C-4. Fish habitat was assessed across five major areas within the ISMP study area:

- **Lowland agricultural reaches (Study area boundary upstream to Old Clayburn Road (Clayburn Creek) and Bateman Road (Stoney Creek)):** The lower agricultural reaches of Clayburn and Stoney creeks offer some limited spawning habitat for chum, coho, and (possibly) pink salmon, as well as steelhead/rainbow trout and cutthroat trout. The large amount of poorly sorted sediments deposited as the creeks emerge from the west slope of Sumas Mountain limits spawning and historically led to frequent dredging. Lowland reaches would have historically been important rearing habitat for coho, however, the dredging as well as channelization and straightening has resulted in a lack of pool habitats and instream cover, reducing rearing capacity. Furthermore, streamside vegetation in these reaches is either lacking entirely or limited to a very narrow band of trees and shrubs.

- **Middle and upper reaches of Clayburn Creek (upstream of Old Clayburn Rd):** The middle reaches of Clayburn Creek are some of the most productive reaches of the watershed. These reaches are characterized by a moderate channel gradient, cobble/boulder substrates, large wood debris and boulders, and (with the exception of the presence of Straiton Rd) a wide riparian buffer. Coho, chum, steelhead/rainbow trout, and cutthroat trout spawning has been reported in the areas upstream of Clayburn Village (IRC, 1994). A ravine section of the creek, above the confluence with Poignant Creek and below the Auguston Development, is excellent spawning and rearing habitat for coho. Fish passage further upstream is restricted by a steeper section with several small falls (Schubert, 1982). Increased sedimentation within the ravine has degraded fish habitat in this area (A. Jonsson, pers. comm.; D. Sutherland, pers. comm.). Several eroding ravine slopes exist below the Ledgeview Golf Course. The headwaters of Clayburn Creek, upstream of McKee Rd, go dry in late summer.

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- **Middle and upper reaches of Stoney Creek (upstream of Bateman Rd):** Like Clayburn Creek, the transitional reaches of Stoney Creek were historically productive spawning and rearing habitat. These sections are characterized by a moderate channel gradient, gravel/cobble substrates, and moderate amounts of wood debris. Much of the channel runs through a wider, shallower ravine compared to Clayburn Creek. Although Stoney Creek is now more urbanized than the other subwatersheds, much of the riparian corridor remains intact. Several major erosion sites exist. Chum salmon spawn in the lower sections through Bateman Park and coho have been observed from this area up to the culvert under Wells Gray Ave. Spawning coho can move up into the Vicarro Ranch area (in the power line right-of-way), although spawning habitat is currently limited above this culvert and riparian habitat has been lost. Cutthroat trout are resident in and above the utility right-of-way on the north side of Eagle Mountain. A section of Stoney Creek goes dry in late summer in the vicinity of Laburnum Ave in some years.

- **Poignant Creek and its tributaries:** Poignant Creek is the least developed of the four subwatersheds but fish habitat use is limited by access. A natural cascading waterfall just upstream of the confluence with Diane Brook restricts anadromous fish passage further upstream. Coho salmon, cutthroat trout, and steelhead are present below the waterfall. Resident cutthroat trout are abundant in the upper reaches below the headwater reaches which go dry in summer. A small dam on the north arm of Poignant Creek, near Camp McLanlin (Girl Guide camp at the north end of Willett Road), is an obstruction to fish movement in this reach. A large portion of the riparian corridor of Poignant Creek and its tributaries remains intact.

- **Diane Brook and its tributaries:** The Diane Brook subwatershed contains the Straiton community as well as several large gravel pit operations. Due to a cascading waterfall immediately upstream of the confluence with Poignant Creek, the entire length of Diane Brook is not accessible to anadromous fish species. Resident cutthroat trout are abundant in the reach north of the Auguston Development and common in upper portions of the creek. They are also common in ditches in the rural areas along Dawson Road which feed into Diane Brook.

Representative photos of instream fish habitat (by reach) are found in Appendix C4. Due to limitations in the scope of the ISMP, habitat was only assessed in detail on the Clayburn Creek mainstem and its major tributaries (Stoney Creek, Poignant Creek, Diane Brook).

Fish Passage Barriers

For a watershed of its size and complexity, Clayburn Creek has a relatively small number of human-created fish passage barriers. This is a likely due to the fact that much of the development within the watershed is relatively recent. Also, some previously existing fish passage barriers have been addressed through recent upgrade projects. Only three structures are known to impede or prevent fish passage within the watershed at present (listed from downstream to upstream):

- **Matsqui Slough (Gladwin) Pump Station (Figure C-1):** Although not in the study area, the floodboxes and pump station provides fish access between the Fraser River and the Clayburn Creek system through the dyke. The station is composed of four identical floodboxes, each composed of a 2.1 m x 2.3 m box culvert (<1% gradient and greater than 20 m in length) with a side-mounted steel flapgate at the outlet end of the culvert (LGL Limited et al., 2009). When the floodgates are closed (irrigation period), combinations of seven different pumps can be used to move water through the dyke and into the Fraser River (KWL, 2010). A fish-friendly suction pump,

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installed in 1990, functions as the lead pump between April 15 to August 15 (main outgoing migration period for juvenile salmon). In 1999, the fish-friendly pump was estimated to have reduced the mortality of coho smolts passing through the pump station from 70% to 5% (Fraser River Action Plan, 1999). However, recent tests of fish passage were inconclusive and further evaluation was recommended (A. Thomson, pers. comm. in LGL Limited et al., 2009). Although fish-friendly pumps are an improvement over older-style pumps, these pumps can still result in higher than expected mortality for outgoing juveniles. Also, the frequency with which the flapgates are open to allow the passage of returning adults during the fall migration period is not known.

(a) Matsqui (Gladwin) Pump Station (upstream side)

(b) Dyke floodboxes and flapgates (downstream side)

(c) Example of cascading waterfalls creating natural barrier to fish passage on Poignant Creek

Figure C-1: **Photos of Known & Potential Barriers to Fish Passage**

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- **Small dam on north arm of Poignant Creek:** A small wooden dam on Poignant Creek upstream of Camp McLanlin (Girl Guide camp at the north end of Willett Road) limits movement of resident fish populations in the north arm of Poignant Creek.

- **Impoundment (Cattle Pond) on McKee Creek (Stoney Creek) on Vicarro Ranch property:** A large impoundment installed to create a large pond for cattle limits movement of resident fish populations in the section of McKee Creek (Stoney Creek) in the powerline right-of-way portion of Vicarro Ranch (Enkon, 2009; Gebauer & Associates, 2009).

Partial and complete barriers to fish passage may also periodically occur as a result of debris jams, fallen logs, and root wads along the creek. Such barriers were not comprehensively inventoried or reviewed as part of the ISMP.

Several natural barriers also restrict anadromous fish passage into the upper sections of the watershed:

- **Steep grade section on Clayburn Creek, upstream of confluence with Poignant Creek:** Large boulders have created several large step waterfalls which likely represent the limit of upstream fish passage in the ravine section of Clayburn Creek. This is located approximately adjacent to the lower end of the Auguston Development.

- **Large falls on Poignant Creek just below confluence with Diane Brook (Figure C-1c):** A series of small and large waterfalls cascading over bedrock prevents any upstream fish passage into Diane Brook or Poignant Creek above this point.

- **Steep cascading section on McKee Creek (Stoney Creek) on Vicarro Ranch property:** A steep cascading section of McKee Creek limits the movement of resident fish populations in this area.

Also, as a result of efforts by the City of Abbotsford, local stewardship groups, and other agencies and organizations, two culverts which were previously identified fish passage barriers have undergone modifications to improve fish passage through them:

- **Culvert replacement on Stoney Creek at Bateman Road (completed in 2007) (Figure C-2a):** Aging twin culverts, which had been deemed a barrier to fish passage, particularly for juveniles, were replaced with a new fish passable culvert.

- **Culvert improvements on Stoney Creek at Wells Gray Avenue (completed in 2009) (Figure C-2b):** The existing culvert and flow control structures upstream of the culvert were modified to allow returning coho access to spawning habitat above Wells Gray Avenue

Fish Distribution

Based on information on fish species present in the watershed, instream habitat characteristics, flow regime, and known barriers to fish passage, fish presence in the watershed can be dividedinto several zones:

- Lowland fish communities which prefer larger lower-gradient streams, larger pools, and, in some cases, softer substrates are confined to Clayburn Creek downstream of the Clayburn Road bridge and Stoney Creek, downstream of Bateman Road.

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- Anadromous fish species (primarily coho) extend to the following areas on the major creeks:
  - Clayburn Creek: up to a steep gradient section at the downstream end of the Auguston Development (upstream of confluence with Poignant Creek)
  - Poignant Creek: up to a large falls below the confluence with Diane Brook
  - Stoney Creek: up to a large impoundment created a pond known as Cattle Pond on the Vicarro Ranch property

Smaller tributary streams below these restrictions may also support both anadromous species but limited information was available. There is no anadromous fish access to Diane Brook.

- Resident trout populations (mainly Cutthroat Trout, but also possibly Rainbow Trout due to past stocking) exist above areas accessible to anadromous species in all four subwatersheds. However, in most cases, the upstream extent of resident fish presence is poorly known.

The distributions of lowland, anadromous, and resident fish is shown in Figure C-7 and the likely distributions of different salmonid species is further summarized in Table C-7.

Table C-7: Distribution of Salmon and Trout Species

Species	Clayburn Creek	Poignant Creek	Diane Brook	Stoney Creek
Coho	X (below steep grade section at lower end of Auguston development only)	X (below falls only)		X (up to Cattle Pond on Vicarro Ranch property)
Chum	X (lower reaches only)			X (lower reaches only)
Pink	? (very lowest reaches only)			
Steelhead	X (below falls at lower end of Auguston development only)	X (below falls only)		
Searun (coastal) cutthroat trout (Anadromous)	X (below falls at lower end of Auguston development only)	X (below falls only)		?
Rainbow trout (Resident)	X	?	?	?
Cutthroat trout (Resident)	X	X	X	X

C.7 Watercourse Classification

Based on the above findings, a preliminary watercourse classification map was developed based on fish presence and flow regime (permanence) as per Abbotsford's Streamside Protection Bylaw (Figure C-3). The major source of reach-specific data was the Sensitive Habitat Inventory Methodology (SHIM) mapping completed for the Clayburn Creek watershed in 2010, supplemented by field reconnaissance and, in some cases, inference. Because detailed information is not available for some reaches, many streams have only been partially classified or have yet to be classified (shown as unclassified). The

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watercourse classification is meant to be used for general planning purposes only. All classifications require detailed assessment to confirm their status and the specific stream setbacks required during development (as per Abbotsford's Streamside Protection Bylaw).

C.8 Priority Fish and Aquatic Habitat Issues

Based on the review of fish habitat within the ISMP study area, the following priority issues have been identified for aquatic habitat in the Clayburn Creek watershed:

- **Mitigating flow impacts from future development:** Without mitigation measures, the impervious surfaces associated upland development (roofs, roads, driveways) increase the volume of runoff and speed with which rainfall reaches the stream channel, leading to higher volume and more erosive peak flows. Baseflows can also decline as less rainfall is being infiltrated. Both have large impacts on fish habitat quality. Measures such as source controls and infiltration are critical to mitigating these impacts.

- **Mitigating sedimentation effects on fish habitat in Clayburn Creek mainstem:** Incidental observations have identified increasing sedimentation as an ongoing concern, particularly in the ravine portion of the Clayburn Creek tributary, near the Ledgeview Golf Course. The natural conditions present in the Clayburn watershed (soil types, steep ravine slopes, etc.) make it particularly sensitive to erosion and sediment issues. Much of the sedimentation appears to originate from erosion points on several steep ravine slopes with fine (silt and clay) soils, but also from developed areas. Some erosion is likely natural but may have been exacerbated by past logging activity and changes in flows associated with the upstream forest cover and land use.

- **Protection of summer baseflows due to low summer water flows in some reaches:** Stoney Creek goes dry in August and September, and other streams in the watershed experience very low flow (e.g., upper portions of Poignant and Clayburn creeks). In several reaches, temperature and dissolved oxygen levels are beyond the range suitable for rearing salmonids. Low flow issues may be further exacerbated by water withdrawals for agricultural use. More work is needed to understand the sensitivity of streams in the Clayburn watershed, important recharge areas for existing flows that need adequate protection (such as wetlands), and the contributions of water withdrawals and ongoing urbanization to declining summer baseflows.

- **Increasing large wood is debris recruitment:** While our initial observations indicate that fish habitat quality is good in the portion of the watershed within the study area, large instream wood and other forms of cover is generally low. The addition of instream wood and boulder structures will be one strategy for enhancing or restoring fish habitat as part of the ISMP.

- **Riparian forest cover in lower watershed:** The riparian assessment indicated relatively high amounts of riparian forest cover in the Clayrburn watershed. However, riparian removal in some sections has resulted in bank instability and increased summer water temperatures. There are still a range of sites in which riparian restoration can be undertaken. This will be an important strategy for maintaining stream health as part of the ISMP.

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- **Lower watershed:** The most degraded fish and riparian habitat in the Clayburn watershed is located in the agricultural lowlands which are outside the ISMP study area. Integrating fish habitat planning with flood protection measures in this part of the watershed will be an important part of the ISMP and will help in improving rearing capacity in the overall watershed.

C.9 Previous Fish Habitat Enhancements and Compensation

Several fish habitat enhancement projects have been already undertaken in the watershed. Most of the projects have been jointly undertaken by the City of Abbotsford and local stewardship groups and organizations, with support for federal and provincial agencies. Some improvements have also occurred as compensation for development impacts elsewhere in the watershed. To date, most of the improvements have focused on upland sections of Stoney Creek, with very little work done in other watercourses.

(a) Upstream end of newly replaced culvert on Stoney Creek at Bateman Road

(b) Downstream end of culvert on Stoney Creek at Wells Gray Avenue

(c) Riparian planting - Stoney Creek in Bateman Park

(d) Riparian fencing in Bateman Park

Figure C-2: **Photos of Examples of Previous Fish Habitat Enhancements**

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Example projects include:

- **Culvert replacements and improvements on Stoney Creek (Figure C-2a and Figure C-2b):** Previously mentioned above, the culverts at Bateman Rd were replaced in 2007 and the culvert at Wells Gray Ave was modified in 2009 to improve fish passage in the middle reaches of Stoney Creek.
- **Older Instream Works on Stoney Creek:** In the early 1980s, bank stabilization, gravel introduction, pool creation, and the resolution of water withdrawal problems were all undertaken in the transitional reaches of Stoney Creek upstream of Bateman Park.
- **Riparian Plantings on Stoney Creek:** Work in the 1980's also included planting to restore streamside vegetation. More recently, native trees and shrubs have been planted to restore or widen the existing riparian corridor in Bateman Park. Fencing has been added to protect this vegetation and limit access to the creek (see Fig. C-2c and C-2d).
- **Fish Habitat Compensation Projects associated with Whatcom Road Connector (upper tributaries of Stoney Creek):** Compensation proposed included enlarging an inline pond (Dive Pond), improving fish access through adding step-pool structure to an existing tributary to Stoney Creek (Tributary CB-Main), constructing a new channel in an area subject to historical gravel infilling, and numerous riparian plantings (Gebauer & Associates, 2009).
- **Stream Cleanups and Community Outreach:** Numerous stream cleanups have been organized by local stewardship groups to remove garbage and other debris from the creeks and to educate local residents about stream stewardship.

Link to Watershed Health

Clayburn Creek is still a productive fish-producing watershed, with Coho salmon and steelhead populations that are regionally significant, although salmon populations have declined significantly from historical levels due to human impacts to habitat. Colonization by tolerant and predatory non-native fish species is both an indicator of and a concern to watershed health.

Instream fish habitat quality is good, particularly in the lower upland sections of the watershed, although sedimentation impacts, summer baseflows, and lack of large wood debris have all impacted habitat. Channelization, dredging, and riparian forest loss has impacted the amount and quality of rearing habitat in the lowland sections and diminished the productive capacity of the watershed.

For a watershed of its size and complexity, Clayburn Creek has a relatively small number of human-created fish passage barriers (2 full, 1 partial). Potential exists to improve access to some of these areas through removing or modifying barriers.

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C.9 Terrestrial Species and Habitats

In addition to fish, the Clayburn Creek watershed is home to many terrestrial wildlife species, including a high number of species at risk[4]. The watershed encompasses large areas of several sensitive or important habitat types, including mature forest (particularly second-growth deciduous forest), forested swamps, and unique habitats such as sandstone rock faces and dry bluffs. Regionally, Sumas Mountain, on which the Clayburn Creek watershed is a part of, is an important large reservoir for biodiversity in the lower Fraser Valley, and is similar in size and significance to Burns Bog.

Species at Risk

Species occurrence information available for the Clayburn Creek watershed shows that it is an area of regional significance for species at risk, based on the number of species present and number of occurrences for many species. It is likely that the largest populations of Mountain Beaver, *rufa* subspecies (*Aplodontia rufa rufa*) and Oregon Forestsnail (*Allogona townsendiana*) in the lower Fraser Valley are found within the watershed. Species at risk known to occur in the watershed include one fish; three amphibians, six birds, six mammals, three invertebrates, two vascular plant species, and one moss (see Table C-8).

These species are:

(a) currently listed under the federal Species at Risk Act (SARA)[5] and/or

(b) on the provincial red or blue lists with the BC Conservation Data Centre (BC CDC)[6].

For all but one of the rare species listed, sightings in the Clayburn Creek watershed have occurred recently (within last 20 years). For silver hair moss (*Fabronia pusilla*), recent survey work associated with their status assessment for listing has not located the species. It is possible that the species has been extirpated from the watershed. In addition, over 600 recent species at risk occurrences representing nine different species have been located since 2006 (R. Durand, pers. comm.).

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[4] "Species at risk" is a general term used to describe an extirpated, endangered, threatened species, or a species of special concern.
[5] The national status of species listed under Schedule 1 of SARA, the official list of wildlife species at risk in Canada, is initially assessed by an independent scientific panel, the Committee for the Status of Endangered Wildlife in Canada (COSEWIC). COSEWIC classifies assessed species according the following categories of risk of extinction:
Extinct (X) - A wildlife species that no longer exists.
Extirpated (XT) - A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E) - A wildlife species facing imminent extirpation or extinction.
Threatened (T) - A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC) - A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Data Deficient (DD) - A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Not At Risk (NAR) - A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
COSEWIC then recommends species classified as XT, E, T, or SC for official listing by the Minister on Schedule 1.
[6] In British Columbia, species and ecological communities are assigned to one of three lists by the BC Conservation Data Centre, based on their provincial Conservation Status Rank (as assessed using methodology and standards established by NatureServe). Red-listed species are Extirpated, Endangered, or Threatened in British Columbia. Blue-listed species are Vulnerable and Yellow-listed species are secure.

Table C-8: Confirmed and Potential Species at Risk

Common Name	Scientific Name	Conservation Status				Status in Clayburn Creek Watershed	Reference(s)
		Global Rank	Prov Rank	COSEWIC	BC List		
Fish							
Cutthroat Trout, *clarkii* subspecies	*Oncorhynchus clarkii clarkii*	G4T4	S3S4	-	Blue	Confirmed present in most tributaries	R. Durand, pers. comm.
Amphibians and Reptiles							
Red-legged Frog	*Rana aurora*	G4	S3S4	SC (2004)	Blue	Present in forested swamps and ponds	R. Durand, pers. comm.
Western Toad	*Bufo boreas*	G4	S4	SC (2002)	-		
Rubber Boa	*Charina bottae*	G5	S4	SC (2003)	-	Historic record	BC CDC, 2009
Birds							
American Bittern	*Botaurus lentiginosus*	G4	S3B	-	Blue		
Great Blue Heron, *fannini* subspecies	*Ardea herodias fannini*	G5T4	S2S3B, S4N	SC (2008)	Blue	Confirmed present	Gebauer & Associates, 2009
Peregrine Falcon, *anatum* subspecies	*Falco peregrinus anatum*	G4T4	S2B	SC (2007)	Red		
Band-tailed Pigeon	*Patagioenas fasciata*	G4	S3S4B	SC (2008)	Blue		
Barn Owl	*Tyto alba*	G5	S3	SC (2001)	Blue	Confirmed present	Gebauer & Associates, 2009
Western Screech-Owl, *kennicottii* subspecies	*Megascops kennicottii kennicottii*	G5T4	S3	SC (2002)	Blue	Observed adjacent to and south of utility RoW on north side of Eagle Mountain	Golder, 2005
Mammals							
Pacific Water Shrew	*Sorex bendrii*	G4	S1S2	E (2006)	Red		
Trowbridge's Shrew	*Sorex trowbridgii*	G5	S3S4	-	Blue		
Townsend's Mole	*Scapanus townsendii*	G5	S1	E (2003)	Red	Recent observations of mole hills of this species	Gebauer & Associates, 2009
Townsend's Big-eared Bat	*Corynorhinus townsendii*	G4	S3	-	Blue		
Snowshoe Hare, *washingtonii* subspecies	*Lepus americanus washingtonii*	G5T3T5	S1	-	Red	Observed	Madrone, 2007
Mountain Beaver, *rufa* subspecies	*Aplodontia rufa rufa*	G5T4?	S3	SC (1999)	Blue	Several large colonies present	Madrone, 2007
Invertebrates							
Blue Dasher	*Pachydiplax longipennis*	G5	S3S4	-	Blue	Found in Dive Pond in utility RoW in upper Stoney Creek	Gebauer & Associates, 2009
Oregon Forestsnail	*Allogona townsendiana*	G3G4	S1S2	E (2002)	Red	Abundant in mature deciduous forest throughout	Madrone, 2007; R. Durand, pers. comm.
Pacific Sideband	*Monadenia fidelis*	G4G5	S3S4	-	Blue	Confirmed present	R. Durand, pers. comm.
Vascular Plants							
Phantom Orchid	*Cephalanthera austinae*	G4	S2	T (2000)	Red	One confirmed location NE of utility RoW in upper Stoney Creek	BC CDC, 2009
Pacific Waterleaf	*Hydrophyllum tenuipes*	G4G5	S2	-	Blue	Abundant in riparian areas throughout	BC CDC, 2009 Fraser Valley Conservancy
Mosses							
Silver Hair Moss	*Fabronia pusilla*	G4G5	SH	E (2002)	Red	Last observed in ; recent surveys have not found this species	BC CDC, 2009

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Table C-8 summarizes all terrestrial species at risk known from the Clayburn Creek watershed including their conservation status, current status within the watershed, and sources of records. In general, rare species occurrences are distributed widely throughout the watershed although wetlands, undisturbed riparian areas (e.g., ravines), and mature forests are important habitats for multiple species at risk (see Sensitive Ecosystem and Wildlife Habitat Mapping section). Occurrences, and especially multiple occurrences, of species at risk are a good indicator of sensitive habitats that require particular attention in planning. However, given the *ad hoc* nature of rare species surveys in the watershed to date, current records could also reflect imbalanced survey effort. The absence of records for a particular location does not necessarily indicate the absence of that species from that site.

Sensitive Ecosystem and Wildlife Habitat Mapping

Both Terrestrial Ecosystem Mapping (TEM) and Sensitive Ecosystem Mapping (SEI) have recently been completed for a large portion of Sumas Mountain, including the upland portions of the Clayburn Creek watershed (Durand, 2010). The mapping found a high proportion of the remaining natural land cover in the watershed was identified as either sensitive or other important ecosystems (OIE). A detailed breakdown of the types and amount of sensitive and other important ecosystem (OIE) documented in the ISMP study area is summarized in Table C-9. Because not all areas of the ISMP study area were mapped (lowlands and McKee Peak Planning Area excluded), it is likely that the amount of sensitive ecosystems within the study area would be higher if unmapped areas were included.

Table C-9: Types and Amounts of Sensitive and Other Important Ecosystems (OIE)

Ecosystem Type	SEI Code	Area (ha)	% Area of Watershed
Sensitive Ecosystems			
Mature Coniferous Forest	MF:co		
Mature Mixed Forest	MF:mx		
Mixed Woodland Forest	WD:mx		
Freshwater Pond	FW:pd		
Riparian Medium Bench Floodplain	RI:fm		
Riparian High Bench Floodplain	RI:fh		
Wetland Swamp	WN:sp		
Other Important Ecosystems			
Mature Broadleaf Forest	MF:bd		
Young Coniferous Forest	YF:co		
Young Mixed Forest	YF:mx		
Young Broadleaf Forest	YF:bd		
Total SE or OIE in Study Area			

Data provided from Durand, 2010.

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Pacific Water Shrew Habitat Suitability Modelling

Pacific Water Shrew, listed as Endangered under Canada's Species at Risk Act, is found only in Canada in the lower Fraser Valley. Most of its known occurrences are from intact, densely vegetated riparian forests of small tributaries and headwater streams. Because of its strong association with streams and riparian areas, documented occupancy of the Clayburn Creek system, and previous work on identifying suitable habitat, further assessment was conducted on this species to inform watershed planning. Existing habitat suitability models were used to assess the habitat suitability of streams and ecological communities within the Clayburn Creek watershed for Pacific Water Shrew (*Sorex bendirii*).

Separate habitat suitability models for this species that use habitat attributes collected as part of SHIM and TEM mapping (see Craig, 2006; Craig, 2007a; and Craig, 2007b for details). Both the SHIM-based and the TEM-based habitat suitability models were run on existing SHIM and TEM datasets for the City of Abbotsford. Both models rate habitat as either high, moderate, low, or nil. In addition to looking at the results of the individual models, results were also compared for part of the watershed because the two datasets covered different parts of the watershed. Habitat suitability analysis using SHIM data was completed by Dr. Vanessa Craig of Ecologic Research (see full report in Appendix C5). Results ofboth the SHIM and TEM models are shown in Figure 3-5.

In general, the results show that a large amount of potentially suitable Pacific Water Shrew habitat exists within the ISMP study area. From the TEM model, the highest rated habitat using the TEM data found in the watershed had Moderate suitability (no habitat was rated as High suitability) and was found in upper Clayburn Creek, mostly south of McKee Rd. Using the SHIM data which covers the watershed more comprehensively (data not available for Area H at time of analysis), habitat suitability was rated as High along a high proportion of small tributaries in all of the major subwatersheds, but particularly in the ravine sections of Clayburn and Poignant creeks and along the small tributaries of Stoney Creek on the north slope of Eagle Mountain.

At the time this assessment was conducted in fall 2009, SHIM mapping was not available for Area H and TEM mapping had not been completed for areas other than the McKee Peak Planning Area. As further TEM and SHIM data is now available for other areas of the watershed, further habitat suitability mapping could now be completed but has not been undertaken as part of the ISMP.

Priority Issues

The following priority issues were identified for terrestrial habitat in the Clayburn Creek watershed:

- **Protection of habitat for species at risk, particularly on private land:** Many of the occurrences of species at risk known in the watershed exist on private land with the potential of future development. Land use planning tools that can incorporate protection of habitat for species at risk should be a priority for use in this context. For example, opportunities may exist to widen or enhance required stream or geotechnical setbacks to encompass high-priority habitats for species at risk in exchange for higher densities in low-priority habitat areas.

- **Protection of habitat types with important hydrologic functions, such as wetlands and forests:** In addition to providing habitat for wildlife, some habitat types provide important ecological functions. Wetlands provide important hydrologic functions, such as purifying surface water and recharging groundwater. Mature forests reduce peak flows in stream by intercepting and transpiring a large amount of rainfall.

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- **Protection of large areas of undeveloped mature forest:** Large core areas of habitat are important for maintaining large populations of species that sustain adequate genetic diversity and reduce vulnerability of populations to local extirpation.

- **Maintenance of habitat connectivity to facilitate species movement:** Many wildlife species require corridors of natural vegetation to facilitate movement between larger habitat patches. Maintenance of a network of core areas and the connections between them is important to sustaining some wildlife populations, particularly birds and large mammals.

- **Invasive plants:** Invasive plants have a large impact of ecosystem health, competing for space and moisture with native species. High-impact invasive plants such as knotweed (*Fallopia* sp.), English ivy (*Hedera* sp.) and yellow lamium (*Lamium galeobdolon*) are present in the watershed although their abundance and distribution has not been documented. Species such as Himilayan blackberry (*Rubus armenicus*) are very common. Developing a control strategy for this species is a key component of protecting forest and riparian ecosystems in the study area.

Appendix C1

Table C1-1: In-situ Water Quality Parameter Sampling Data (September 2009).

ID	Catchment	Date	Time	UTM-E (NAD83)	UTM-N (NAD83)	Temp (^oC)	Cond (µS/cm)	SpCond (µS/cm)	DO (%)	DO (mg/l)	pH pH	Turbidity (NTU)	ORP ORP	Comments
1		22-Sep-09	9:33	554752	5434623	13.64	0.248	0.194	90.3	9.34	7.85	141.8	4.4	
2		22-Sep-09	9:45	554925	5434627	14.23	0.268	0.213	88.2	9.04	7.66	284.3	4	
3		22-Sep-09	10:24	555342	5434428	12.61	0.087	0.067	74.2	7.89	7.1	241.1	67.7	
4		22-Sep-09	10:24	555342	5434428	12.34	0.091	0.069	72.8	7.59	7.01	188.3	136.2	
5		22-Sep-09	10:25	555342	5434428	14.46	0.175	0.14	70.2	7.08	5.8	294.1	1.3	
6		22-Sep-09	10:44	555950	5434606	dry	dry	dry	dry	dry	dry	dry	dry	
7		22-Sep-09	10:57	556224	5435098	dry	dry	dry	dry	dry	dry	dry	dry	
8		22-Sep-09	11:08	555657	5435232	dry	dry	dry	dry	dry	dry	dry	dry	
9		22-Sep-09	11:10	555711	5435396	dry	dry	dry	dry	dry	dry	dry	dry	
10		22-Sep-09	11:14	555939	5435651	13.75	0.106	0.082	75.9	7.78	7.25	194.5	1.3	
11		22-Sep-09	11:21	556686	5435654	12.82	0.128	0.098	52.4	5.33	6.79	32.6	3.2	
12		22-Sep-09	11:29	556826	5435750	12.73	0.151	0.115	68.4	6.88	6.89	17.7	0.6	
13		22-Sep-09	11:37	556868	5435886	14.24	0.167	0.133	59.3	6.01	6.91	38.8	1.3	
14		22-Sep-09	11:49	556780	5435963	13.70	0.273	0.215	90.9	9.40	7.49	66.3	0.5	
15		22-Sep-09	12:33	557375	5436439	12.63	0.063	0.048	61.2	6.40	7.33	42.4	1.6	
16		22-Sep-09	12:42	557381	5436538	12.53	0.423	0.322	83.8	8.82	7.17	92.7	0.3	
17		22-Sep-09	12:52	557738	5436583	13.65	0.260	0.204	50.2	4.99	7.20	135.7	4.7	
18		22-Sep-09	13:02	557999	5437519	14.03	0.226	0.178	59.7	5.98	6.85	74.7	2.6	
19		22-Sep-09	13:06	558002	5438063	13.96	0.236	0.185	70.3	6.79	6.71	110.5	0.6	
20		22-Sep-09	13:16	558316	5439048	12.93	0.189	0.146	83.0	8.73	7.01	216.5	0.6	
21		22-Sep-09	13:23	558483	5439317	13.97	0.157	0.123	74.7	7.64	7.05	143.8	4.1	
22		22-Sep-09	13:33	558243	5439918	12.02	0.110	0.083	85.4	9.13	7.17	128.9	1.1	
23		22-Sep-09	13:51	557421	5437711	14.52	0.136	0.109	90.3	9.21	7.38	186.2	0.6	
24		22-Sep-09	14:03	556669	5438325	13.38	0.078	0.060	92.2	9.61	7.33	190.5	0.1	
25		22-Sep-09	14:15	555853	5437105	10.06	0.101	0.073	90.2	10.10	7.30	181.3	0.5	
26		22-Sep-09	14:25	555595	5436398	13.60	0.167	0.130	93.4	9.70	7.47	264.7	2.7	
27		22-Sep-09	14:30	555619	5436368	13.55	0.317	0.249	92.8	9.64	7.63	294.2	0.5	
28		22-Sep-09	14:34	555592	5436363	13.63	0.232	0.180	91.0	9.42	7.73	291.4	1.1	
29		22-Sep-09	14:58	555108	5436504	13.48	0.200	0.155	96.1	10.01	7.88	188.4	1.2	
30		22-Sep-09	14:58	555107	5436505	13.37	0.200	0.156	93.2	9.71	7.88	245.1	1.1	
31		22-Sep-09	15:06	554930	5436751	13.93	0.129	0.102	93.5	9.49	8.08	220.1	1.1	
32		22-Sep-09	15:13	554705	5436891	14.10	0.196	0.155	92.4	9.49	7.84	281.9	0.8	
33		22-Sep-09	15:21	554878	5434955	dry	dry	dry	dry	dry	dry	dry	dry	
34		22-Sep-09	15:24	554610	5435093	dry	dry	dry	dry	dry	dry	dry	dry	
35		22-Sep-09	15:30	554455	5435103	dry	dry	dry	dry	dry	dry	dry	dry	
36		23-Sep-09	9:13	554315	5435018	dry	dry	dry	dry	dry	dry	dry	dry	
37		23-Sep-09	9:22	554018	5435432	11.06	0.223	0.164	91.7	10.10	7.69	157.6	0.0	
38		23-Sep-09	10:20	554944	5434576	14.60	0.262	0.210	88.3	8.95	7.74	184.3	5.3	
39		23-Sep-09	10:52	553819	5435764	11.92	0.224	0.169	91.4	9.84	7.62	195.6	0.8	
40		23-Sep-09	11:03	553657	5435988	12.39	0.224	0.170	93.2	9.93	7.79	169.3	0.5	
41		23-Sep-09	11:17	553358	5436310	13.04	0.232	0.179	85.0	8.95	7.76	129.0	6.2	
42		23-Sep-09	11:19	553447	5436480	13.45	0.190	0.150	93.5	9.60	7.80	139.1	1.3	
43		23-Sep-09	11:24	552630	5436820	13.43	0.245	0.191	63.4	6.45	7.63	167.1	4.7	
44		23-Sep-09	11:45	552416	5437624	13.51	0.241	0.189	67.6	6.89	7.72	166.8	4.9	
45		23-Sep-09	12:06	553956	5436581	14.04	0.195	0.154	98.0	10.09	7.38	256.2	2.9	
46		23-Sep-09	12:28	554116	5436039	12.15	0.238	0.182	83.4	8.81	6.94	356.0	6.8	
47		23-Sep-09	12:31	553965	5436140	12.15	0.242	0.182	80.4	8.65	7.28	396.7	12.9	
48		23-Sep-09	13:42	556787	5437139	16.53	0.144	0.121	101.6	9.91	7.85	249.0	0.6	DIAN1
					mean	13.30	0.194	0.151	81.8	8.48	7.37	183.9	7.3	
					min	10.06	0.063	0.048	50.2	4.99	5.80	17.7	0.0	
					max	16.53	0.423	0.322	101.6	10.10	8.08	396.7	136.2	
					count	40	40	40	40	40	40	40	40	

Coordinates in UTM NAD83.

KERR WOOD LEIDAL
consulting engineers

Table C1-2: Metal Concentrations in Sediment Samples (September 2009)

Sample ID			CLAY-LOW (166)	CLAY1	CLAY2	CLAY3	POIG1	POIG2	DIAN1	DIAN2	STON1 (163)	STON2 (162)	BC Working Sediment Quality Guidelines - Freshwater (August 2006)		CCME Sediment Quality Guidelines - Freshwater (Update 2002)		Other Comparative Values		
Date Sampled			23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09	23-SEP-09							
Metals	Units	Detection Limits											ISGQ BC 2006	PEL BC 2006	ISGQ CCME 2002 (Aquatic Life)	PEL CCME 2002 (Aquatic Life)	Still Creek Subbasin 1995 (median)	Brunette River Subbasin 1995 (median)	Oh (2003) thesis Table 2-3
Aluminum (Al)	mg/kg	50	9250	10800	9760	14200	10200	7600	10400	11400	10100	11700							
Antimony (Sb)	mg/kg	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10							
Arsenic (As)	mg/kg	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	6.2	<5.0	5.9	17	5.9	17.0			
Barium (Ba)	mg/kg	1	46.7	44.2	48.5	122	49.4	50.9	48.5	65.4	42.5	53.9							
Beryllium (Be)	mg/kg	0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50							
Bismuth (Bi)	mg/kg	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20							
Cadmium (Cd)	mg/kg	0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.6	3.5	0.6	3.5	141	103	
Calcium (Ca)	mg/kg	50	4400	4630	3900	3640	4480	2030	3740	3400	3650	3660							
Chromium (Cr)	mg/kg	2	25.7	22.2	20.5	27.5	19.3	8.4	16.3	13.0	21.4	19.2	37.3	90	37.3	90.0			
Cobalt (Co)	mg/kg	2	5.8	5.6	6.3	8.7	6.2	4.4	5.9	6.4	5.7	6.3							18
Copper (Cu)	mg/kg	1	10.6	9.1	10.3	12.5	10.3	2.7	6.5	5.9	10.6	12.1	35.7	197	35.7	197.0	130	51	33-210
Iron (Fe)	mg/kg	50	17900	18100	16200	21000	16900	11400	15400	16900	16900	18000	21200	43766			2.10%	2.10%	4.00%
Lead (Pb)	mg/kg	30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	35	91	35.0	91.3	130	55	10-223
Lithium (Li)	mg/kg	2	6.8	7.7	7.2	11.5	7.4	5.9	8.1	6.9	7.9	8.4							
Magnesium (Mg)	mg/kg	50	5230	5960	4930	4940	5840	4080	5290	4610	4930	4990							
Manganese (Mn)	mg/kg	1	320	339	348	495	420	780	444	921	319	503	460	1100			576	807	
Molybdenum (Mo)	mg/kg	4	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0							
Nickel (Ni)	mg/kg	5	17.6	13.9	14.8	21.5	16.1	<5.0	10.2	9.1	15.2	14.5	16	75			17	12	32-340
Phosphorus (P)	mg/kg	50	416	442	363	282	367	231	364	310	318	347							
Potassium (K)	mg/kg	200	480	570	590	830	530	<200	400	410	460	500							
Selenium (Se)	mg/kg	2	<2.0	<2.0	<2.0	<2.0	<3.0	<3.0	<2.0	<2.0	<2.0	<2.0	2						
Silver (Ag)	mg/kg	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.5*						
Sodium (Na)	mg/kg	200	240	240	210	<200	250	<200	<200	<200	<200	<200							
Strontium (Sr)	mg/kg	0.5	22.3	20.5	22.2	34.9	24.0	13.2	14.9	18.9	19.8	23.4							
Thallium (Tl)	mg/kg	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50							
Tin (Sn)	mg/kg	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0							
Titanium (Ti)	mg/kg	1	778	679	629	454	754	364	695	642	732	564							
Vanadium (V)	mg/kg	2	49.8	44.2	40.0	41.5	39.2	17.4	34.1	31.1	46.9	40.6							
Zinc (Zn)	mg/kg	1	38.6	34.4	32.0	64.8	37.5	37.7	36.5	77.1	38.0	42.5	123	315	123.0	315.0	251	128	159-983

*Ontario sediment quality guideline

(highlighted) noticeably higher levels at site(s) compared with other sites in the study area

Sampling Sites	UTM-E	UTM-N	Creek	Location Description
CLAY-LOW (166)	553447	5436480	Clayburn Ck	At farm bridge downstream of sediment trap; approx. halfway between Wright St and confluence with Stoney Ck
CLAY1	554525	5436874	Clayburn Ck	5 m d/s of Old Clayburn Rd at staff gage
CLAY2	555618	5436398	Clayburn Ck	15 m u/s of confluence with Poignant Ck
CLAY3	557242	5436639	Clayburn Ck	d/s of McKee Rd off of trail below Auguston development (MOE benthic site)
POIG1	555557	5436549	Poignant Ck	30 m u/s of bridge access to Clayburn Ck Park in reach parallel to Straiton Rd, u/s of confluence with Poignant Ck
POIG2	558215	5439941	Poignant Ck	at footbridge down trail off Russel Rd cul-de-sac
DIAN1	556787	5437139	Diane Brook	u/s of confluence with Poignant Ck, off of Mathers Park near school (MOE benthic site)
DIAN2	558310	5439034	Diane Brook	at footbridge down trail from pullout at height of land on Upper Sumas Mtn Rd near Highland Quarry
STON1 (163)	553819	5435764	Stoney Ck	near intersection of Latimer St and Prior Ave, behind Stoney Creek Park
STON2 (162)	554944	5434576	Stoney Ck	u/s of McKee Rd, d/s of Wells Gray Ave, within McKee Trail Park

Coordinates in NAD83.

Analysis of biological samples:
Technical summary of methods and quality assurance procedures
Prepared for Raincoast Applied Ecology
Patrick Lilley, Project Manager
October 15, 2009

by
W. Bollman, Chief Biologist
Rhithron Associates, Inc.
Missoula, Montana

METHODS

Sample processing

Eight macroinvertebrate samples from the City of Abbotsford were delivered to Rhithron's laboratory facility in Missoula, Montana on July 6, 2009. All samples arrived in good condition. An inventory document containing sample identification information was provided by the Raincoast Applied Ecology (RAE) Project Manager. Upon arrival, samples were unpacked and examined, and checked against the RAE inventory. An inventory spreadsheet was created and sent to the RAE Project Manager. This spreadsheet included project code and internal laboratory identification numbers and was verified by the RAE Project Manager prior to upload into the Rhithron database.

Standard sorting protocols were applied to achieve representative subsamples of a minimum of 400 organisms. Caton sub-sampling devices (Caton 1991), divided into 30 grids, each approximately 5 cm by 6 cm were used. Each individual sample was thoroughly mixed in its jar(s), poured out and evenly spread into the Caton tray, and individual grids were randomly selected. The contents of each grid were examined under stereoscopic microscopes using 10x-30x magnification. All aquatic invertebrates from each selected grid were sorted from the substrate, and placed in 95% ethanol for subsequent identification. Grid selection, examination, and sorting continued until at least 400 organisms were sorted. All unsorted sample fractions were retained and stored at the Rhithron laboratory.

Organisms were individually examined by certified taxonomists, using 10x – 80x stereoscopic dissecting scopes (Leica S8E and S6E) and identified to target taxonomic levels consistent with Washington LPTL (Plotnikoff and White 1996) protocols and data generated for previous RAE projects, using appropriate published taxonomic references and keys. Identification, counts, life stages, and information about the condition of specimens were recorded on bench sheets. To obtain accuracy in richness measures, organisms that could not be identified to the target level specified in MPCA protocols were designated as "not unique" if other specimens from the same group could be taken to target levels. Organisms designated as "unique" were those that could be definitively distinguished from other organisms in the sample. Identified organisms were preserved in 95% ethanol in labeled vials, and archived at the Rhithron laboratory.

Representatives of each identified taxon were placed in labeled vials. Each reference specimen was internally verified by three Rhithron taxonomists. Specimens added to the collection and their verifications were continuously tracked on a reference collection form.

Quality control procedures

Quality control procedures for initial sample processing and subsampling involved checking sorting efficiency. These checks were conducted on 100% of the samples by independent observers who microscopically re-examined 20% of sorted substrate from each sample. All organisms that were missed were counted and this number was added to the total number obtained in the original sort. Sorting efficiency was evaluated by applying the following calculation:

$$SE = \frac{n_1}{n_{1+2}} \times 100$$

where: SE is the sorting efficiency, expressed as a percentage, n_1 is the total number of specimens in the first sort, and n_{1+2} is the total number of specimens in the first and second sorts combined.

Quality control procedures for taxonomic determinations of invertebrates involved checking accuracy, precision and enumeration. Nine samples were randomly selected and all organisms re-identified and counted by an independent taxonomist. Taxa lists and enumerations were compared by calculating a Bray-Curtis similarity statistic (Bray and Curtis 1957) for each selected sample. Routinely, discrepancies between the original identifications and the QC identifications are discussed among the taxonomists, and necessary rectifications to the data are made. Discrepancies that cannot be rectified by discussions are routinely sent out to taxonomic specialists for identification. However, taxonomic certainty for identifications in this project was high and no external verifications were necessary.

Six taxonomists independently reviewed the reference collection to verify consistency of identifications.

Data analysis

Taxa lists and counts for each sample were constructed. Metric calculations and scoring for the B-IBI for Puget Sound Lowlands streams (Karr and Chu 1999) were performed using Rhithron's customized database software. A sites-by-taxa and sites-by-metrics data matrix was compiled in Microsoft Excel XP.

RESULTS

Quality Control Procedures

Results of quality control procedures for subsampling and taxonomy are given in Table 1. Sorting efficiency averaged 98.14% for macroinvertebrate samples, taxonomic precision for identification and enumeration averaged 97.86% for the randomly selected macroinvertebrate QA samples, and data entry efficiency averaged 100% for the project. These similarity statistics fall within acceptable industry criteria (Stribling et al. 2003).

Data analysis

Taxa lists and counts and metric summary pages for each sample are given in the Appendix. Electronic spreadsheets containing macroinvertebrate identifications and metric values and scores were provided to the RAE Project Manager via email. The complete verified reference collection was also delivered to the RAE Project Manager.

Table 1. *Results of internal quality control procedures for subsampling and taxonomy.* City of Abbotsford, Fall 2009.

RAI Sample ID	Station name	Client ID	Sorting efficiency	Bray-Curtis similarity for taxonomy and enumeration
RAE09CS2059	Clayburn Creek - downstream	CLAY2	97.65%	
RAE09CS2060	Clayburn Creek - upstream	CLAY3	98.69%	
RAE09CS2061	Poignant Creek - downstream	POIG1	96.54%	96.16%
RAE09CS2062	Poignant Creek - upstream	POIG2	98.84%	
RAE09CS2063	Diane Brook - downstream	DIAN1	100.00%	
RAE09CS2064	Diane Brook - upstream	DIAN2	98.80%	
RAE09CS2065	Stoney Creek - downstream	STON1	98.87%	
RAE09CS2066	Stoney Creek - upstream	STON2	94.80%	97.64%

REFERENCES

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Plotnikoff, R.W. and J. S. White. 1996. Taxonomic Laboratory Protocol for Stream Macroinvertebrates Collected by the Washington State Department of Ecology. Washington State Department of Ecology, Environmental Assessment Publication No. 96-323.

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APPENDIX

Taxa lists and metric summaries

City of Abbotsford

Fall 2009

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2059

RAI No.: RAE09CS2059 | Sta. Name: Clayburn Creek - downstream
Client ID: CLAY2
Date Coll.: 9/23/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Acari	3	0.72%	Yes	Unknown		5	PR
Oligochaeta	2	0.48%	Yes	Unknown		10	CG
Ephemeroptera							
Ameletidae							
Ameletus sp.	4	0.96%	Yes	Larva		0	CG
Baetidae							
Baetis tricaudatus	23	5.54%	Yes	Larva		4	CG
Ephemerellidae							
Ephemerella sp.	34	8.19%	Yes	Larva	Early Instar	1.5	SC
Heptageniidae							
Cinygmula sp.	21	5.06%	Yes	Larva		0	SC
Epeorus sp.	1	0.24%	Yes	Larva	Early Instar	2	CG
Heptageniidae	22	5.30%	No	Larva	Early Instar	4	SC
Rhithrogena sp.	34	8.19%	Yes	Larva		0	CG
Leptophlebiidae							
Paraleptophlebia sp.	24	5.78%	Yes	Larva		1	CG
Plecoptera							
Capniidae							
Capniidae	3	0.72%	Yes	Larva		1	SH
Chloroperlidae							
Sweltsa sp.	13	3.13%	Yes	Larva		0	PR
Nemouridae							
Zapada cinctipes	23	5.54%	Yes	Larva		3	SH
Perlidae							
Hesperoperla pacifica	2	0.48%	Yes	Larva		1	PR
Perlodidae							
Perlodidae	9	2.17%	Yes	Larva	Early Instar	2	PR
Skwala sp.	7	1.69%	Yes	Larva		3	PR
Trichoptera							
Brachycentridae							
Micrasema sp.	9	2.17%	Yes	Larva		1	SH
Glossosomatidae							
Glossosoma sp.	7	1.69%	Yes	Larva		0	SC
Glossosomatidae	1	0.24%	No	Pupa		0	SC
Hydropsychidae							
Hydropsyche sp.	52	12.53%	Yes	Larva		5	CF
Lepidostomatidae							
Lepidostoma sp.	4	0.96%	Yes	Larva		1	SH
Limnephilidae							
Limnephilidae	1	0.24%	Yes	Pupa		3	SH
Rhyacophilidae							
Rhyacophila Brunnea Gr.	1	0.24%	Yes	Larva		2	PR
Rhyacophila narvae	9	2.17%	Yes	Larva		0	PR

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2059

RAI No.: RAE09CS2059
Sta. Name: Clayburn Creek - downstream
Client ID: CLAY2
Date Coll.: 9/23/2009
No. Jars: 1
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Coleoptera							
Elmidae							
Elmidae	12	2.89%	No	Larva	Early Instar	4	CG
Heterlimnius sp.	52	12.53%	No	Larva		3	CG
Heterlimnius sp.	2	0.48%	Yes	Adult		3	CG
Narpus concolor	2	0.48%	Yes	Larva		2	CG
Zaitzevia sp.	4	0.96%	Yes	Larva		5	CG
Diptera							
Ceratopogonidae							
Ceratopogoninae	2	0.48%	Yes	Larva		6	PR
Tipulidae							
Dicranota sp.	9	2.17%	Yes	Larva		3	PR
Hexatoma sp.	5	1.20%	Yes	Larva		2	PR
Limnophila sp.	1	0.24%	Yes	Larva		3	PR
Rhabdomastix sp.	1	0.24%	Yes	Larva		1	PR
Chironomidae							
Chironomidae							
Chironomidae	16	3.86%	Yes	Larva		10	CG
Sample Count	415						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2060

RAI No.:	RAE09CS2060			Sta. Name:	Clayburn Creek - upstream
Client ID:	CLAY3				
Date Coll.:	9/23/2009	No. Jars:	1	STORET ID:	

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Cyclopoida	1	0.29%	Yes	Unknown		8	CF
Oligochaeta	26	7.51%	Yes	Unknown		10	CG
Planariidae							
Polycelis coronata	10	2.89%	Yes	Unknown		1	OM
Sphaeriidae							
Sphaeriidae	1	0.29%	Yes	Unknown		8	CF
Ephemeroptera							
Ameletidae							
Ameletus sp.	2	0.58%	Yes	Larva		0	CG
Baetidae							
Baetis tricaudatus	1	0.29%	Yes	Larva		4	CG
Diphetor hageni	2	0.58%	Yes	Larva		5	CG
Heptageniidae							
Cinygmula sp.	10	2.89%	Yes	Larva		0	SC
Ironodes sp.	19	5.49%	Yes	Larva		0	SC
Rhithrogena sp.	7	2.02%	Yes	Larva		0	CG
Leptophlebiidae							
Leptophlebiidae	4	1.16%	No	Larva	Damaged	2	CG
Paraleptophlebia sp.	38	10.98%	Yes	Larva		1	CG
Plecoptera							
Chloroperlidae							
Sweltsa sp.	37	10.69%	Yes	Larva		0	PR
Nemouridae							
Nemouridae	3	0.87%	No	Larva	Damaged	2	SH
Zapada cinctipes	51	14.74%	Yes	Larva		3	SH
Perlidae							
Calineuria californica	12	3.47%	Yes	Larva		2	PR
Pteronarcyidae							
Pteronarcys princeps	11	3.18%	Yes	Larva		0	SH
Trichoptera							
Brachycentridae							
Micrasema sp.	1	0.29%	Yes	Larva		1	SH
Glossosomatidae							
Glossosoma sp.	3	0.87%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsyche sp.	48	13.87%	Yes	Larva		5	CF
Rhyacophilidae							
Rhyacophila Betteni Gr.	8	2.31%	Yes	Larva		0	PR
Coleoptera							
Elmidae							
Heterlimnius sp.	1	0.29%	Yes	Larva		3	CG
Lara sp.	1	0.29%	Yes	Larva		1	SH
Zaitzevia sp.	6	1.73%	Yes	Larva		5	CG

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2060

RAI No.: RAE09CS2060
Sta. Name: Clayburn Creek - upstream
Client ID: CLAY3
Date Coll.: 9/23/2009
No. Jars: 1
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Dixidae							
Dixa sp.	12	3.47%	Yes	Larva		1	CG
Psychodidae							
Pericoma sp.	1	0.29%	Yes	Larva		4	CG
Simuliidae							
Simulium sp.	1	0.29%	Yes	Larva		6	CF
Tipulidae							
Hexatoma sp.	7	2.02%	Yes	Larva		2	PR
Limnophila sp.	2	0.58%	Yes	Larva		3	PR
Pedicia sp.	5	1.45%	Yes	Larva		6	PR
Chironomidae							
Chironomidae							
Chironomidae	15	4.34%	Yes	Larva		10	CG
Sample Count	346						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2061

RAI No.: RAE09CS2061 | Sta. Name: Poignant Creek - downstream
Client ID: POIG1
Date Coll.: 9/3/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Acari	1	0.24%	Yes	Unknown		5	PR
Ephemeroptera							
Baetidae							
Baetis tricaudatus	52	12.35%	Yes	Larva		4	CG
Ephemerellidae							
Ephemerella sp.	1	0.24%	Yes	Larva	Early Instar	1.5	SC
Heptageniidae							
Cinygmula sp.	10	2.38%	Yes	Larva		0	SC
Heptageniidae	31	7.36%	No	Larva	Early Instar	4	SC
Ironodes sp.	3	0.71%	Yes	Larva		0	SC
Rhithrogena sp.	78	18.53%	Yes	Larva		0	CG
Leptophlebiidae							
Leptophlebiidae	1	0.24%	Yes	Larva	Damaged	2	CG
Plecoptera							
Chloroperlidae							
Sweltsa sp.	11	2.61%	Yes	Larva		0	PR
Nemouridae							
Zapada cinctipes	17	4.04%	Yes	Larva		3	SH
Perlodidae							
Perlodidae	2	0.48%	Yes	Larva	Early Instar	2	PR
Trichoptera							
Glossosomatidae							
Glossosoma sp.	14	3.33%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsyche sp.	74	17.58%	Yes	Larva		5	CF
Rhyacophilidae							
Rhyacophila sp.	3	0.71%	No	Pupa		1	PR
Rhyacophila sp.	2	0.48%	Yes	Larva	Early Instar	1	PR
Rhyacophila Brunnea Gr.	4	0.95%	Yes	Larva		2	PR
Rhyacophila narvae	7	1.66%	Yes	Larva		0	PR
Coleoptera							
Elmidae							
Heterlimnius sp.	3	0.71%	Yes	Adult		3	CG
Heterlimnius sp.	32	7.60%	No	Larva		3	CG
Zaitzevia sp.	3	0.71%	No	Larva		5	CG
Zaitzevia sp.	1	0.24%	Yes	Adult		5	CG

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2061

RAI No.: RAE09CS2061
Sta. Name: Poignant Creek - downstream
Client ID: POIG1
Date Coll.: 9/3/2009
No. Jars: 1
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Ceratopogonidae							
Ceratopogoninae	2	0.48%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	2	0.48%	Yes	Larva		1	CG
Simuliidae							
Simulium sp.	15	3.56%	Yes	Larva		6	CF
Tipulidae							
Antocha sp.	2	0.48%	Yes	Larva		3	CG
Dicranota sp.	2	0.48%	Yes	Larva		3	PR
Hexatoma sp.	1	0.24%	Yes	Larva		2	PR
Chironomidae							
Chironomidae							
Chironomidae	45	10.69%	Yes	Larva		10	CG
Chironomidae	2	0.48%	No	Pupa		10	CG
Sample Count	421						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2062

RAI No.:	RAE09CS2062			Sta. Name:	Poignant Creek - upstream
Client ID:	POIG2				
Date Coll.:	9/23/2009	No. Jars:	1	STORET ID:	

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Acari	8	1.85%	Yes	Unknown		5	PR
Nematoda	1	0.23%	Yes	Unknown		5	PA
Oligochaeta	32	7.41%	Yes	Unknown		10	CG
Planariidae							
Polycelis coronata	3	0.69%	Yes	Unknown		1	OM
Sphaeriidae							
Sphaeriidae	4	0.93%	Yes	Unknown		8	CF
Ephemeroptera							
Baetidae							
Baetis tricaudatus	2	0.46%	Yes	Larva		4	CG
Ephemerellidae							
Ephemerella sp.	1	0.23%	Yes	Larva	Early Instar	1.5	SC
Heptageniidae							
Cinygmula sp.	17	3.94%	Yes	Larva		0	SC
Ironodes sp.	12	2.78%	Yes	Larva		0	SC
Leptophlebiidae							
Paraleptophlebia sp.	83	19.21%	Yes	Larva		1	CG
Plecoptera							
Chloroperlidae							
Sweltsa sp.	8	1.85%	Yes	Larva		0	PR
Leuctridae							
Leuctridae	25	5.79%	Yes	Larva	Early Instar	0	SH
Nemouridae							
Zapada cinctipes	58	13.43%	Yes	Larva		3	SH
Perlidae							
Calineuria californica	2	0.46%	Yes	Larva		2	PR
Perlidae	3	0.69%	No	Larva	Early Instar	2	PR
Perlodidae							
Skwala sp.	2	0.46%	Yes	Larva		3	PR
Pteronarcyidae							
Pteronarcys sp.	1	0.23%	Yes	Larva	Early Instar	2	SH

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2062

RAI No.: RAE09CS2062 | Sta. Name: Poignant Creek - upstream
Client ID: POIG2
Date Coll.: 9/23/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Trichoptera							
Brachycentridae							
Micrasema sp.	6	1.39%	Yes	Larva		1	SH
Glossosomatidae							
Glossosoma sp.	5	1.16%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsyche sp.	6	1.39%	Yes	Larva		5	CF
Lepidostomatidae							
Lepidostoma sp.	5	1.16%	Yes	Larva		1	SH
Philopotamidae							
Wormaldia sp.	22	5.09%	Yes	Larva		0	CF
Rhyacophilidae							
Rhyacophila Betteni Gr.	5	1.16%	Yes	Larva		0	PR
Rhyacophila blarina	24	5.56%	Yes	Larva		1	PR
Rhyacophila Brunnea Gr.	1	0.23%	Yes	Larva		2	PR
Rhyacophila narvae	16	3.70%	Yes	Larva		0	PR
Coleoptera							
Elmidae							
Heterlimnius sp.	4	0.93%	Yes	Larva		3	CG
Zaitzevia sp.	1	0.23%	Yes	Larva		5	CG
Diptera							
Ceratopogonidae							
Ceratopogoninae	2	0.46%	Yes	Larva		6	PR
Simuliidae							
Simulium sp.	1	0.23%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	1	0.23%	Yes	Larva		3	PR
Hexatoma sp.	1	0.23%	Yes	Larva		2	PR
Chironomidae							
Chironomidae							
Chironomidae	67	15.51%	Yes	Larva		10	CG
Chironomidae	3	0.69%	No	Pupa		10	CG
Sample Count	432						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2063

RAI No.: RAE09CS2063 **Sta. Name:** Diane Brook - downstream
Client ID: DIAN1
Date Coll.: 9/3/2009 **No. Jars:** 1 **STORET ID:**

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Acari	8	2.00%	Yes	Unknown		5	PR
Nematoda	1	0.25%	Yes	Unknown		5	PA
Oligochaeta	9	2.24%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	9	2.24%	Yes	Larva		4	CG
Diphetor hageni	10	2.49%	Yes	Larva		5	CG
Ephemerellidae							
Ephemerella sp.	6	1.50%	Yes	Larva	Early Instar	1.5	SC
Heptageniidae							
Cinygmula sp.	87	21.70%	Yes	Larva		0	SC
Heptageniidae	41	10.22%	No	Larva	Early Instar	4	SC
Ironodes sp.	1	0.25%	Yes	Larva		0	SC
Rhithrogena sp.	3	0.75%	Yes	Larva		0	CG
Leptophlebiidae							
Leptophlebiidae	10	2.49%	Yes	Larva	Early Instar	2	CG
Plecoptera							
Capniidae							
Capniidae	1	0.25%	Yes	Larva		1	SH
Chloroperlidae							
Sweltsa sp.	18	4.49%	Yes	Larva		0	PR
Nemouridae							
Zapada sp.	18	4.49%	Yes	Larva	Damaged	2	SH
Perlidae							
Calineuria californica	3	0.75%	Yes	Larva		2	PR
Perlodidae							
Perlodidae	2	0.50%	No	Larva	Early Instar	2	PR
Skwala sp.	1	0.25%	Yes	Larva		3	PR
Trichoptera							
Brachycentridae							
Micrasema sp.	2	0.50%	Yes	Larva		1	SH
Glossosomatidae							
Glossosoma sp.	7	1.75%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsyche sp.	11	2.74%	Yes	Larva		5	CF
Philopotamidae							
Philopotamidae	1	0.25%	Yes	Larva	Early Instar	3	CF
Rhyacophilidae							
Rhyacophila Betteni Gr.	1	0.25%	Yes	Larva		0	PR
Rhyacophila blarina	3	0.75%	Yes	Larva		1	PR
Rhyacophila narvae	25	6.23%	Yes	Larva		0	PR
Uenoidae							
Uenoidae	1	0.25%	Yes	Pupa		0	SC

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2063

RAI No.: RAE09CS2063 | Sta. Name: Diane Brook - downstream
Client ID: DIAN1
Date Coll.: 9/3/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Coleoptera							
Elmidae							
Heterlimnius sp.	20	4.99%	No	Larva		3	CG
Heterlimnius sp.	1	0.25%	Yes	Adult		3	CG
Zaitzevia sp.	8	2.00%	Yes	Adult		5	CG
Zaitzevia sp.	22	5.49%	No	Larva		5	CG
Hydraenidae							
Hydraena sp.	1	0.25%	Yes	Adult		5	PR
Diptera							
Ceratopogonidae							
Ceratopogoninae	2	0.50%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	1	0.25%	Yes	Larva		1	CG
Empididae							
Oreogeton sp.	1	0.25%	Yes	Larva		4	PR
Simuliidae							
Simulium sp.	3	0.75%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	6	1.50%	Yes	Larva		3	PR
Hexatoma sp.	6	1.50%	Yes	Larva		2	PR
Chironomidae							
Chironomidae							
Chironomidae	50	12.47%	Yes	Larva		10	CG
Chironomidae	1	0.25%	No	Pupa		10	CG
Sample Count	401						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2064

RAI No.: RAE09CS2064 Sta. Name: Diane Brook - upstream
Client ID: DIAN2
Date Coll.: 9/23/2009 No. Jars: 1 STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Acari	6	1.50%	Yes	Unknown		5	PR
Oligochaeta	11	2.75%	Yes	Unknown		10	CG
Ostracoda	1	0.25%	Yes	Unknown		8	CG
Sphaeriidae							
Sphaeriidae	25	6.25%	Yes	Unknown		8	CF
Ephemeroptera							
Baetidae							
Diphetor hageni	1	0.25%	Yes	Larva		5	CG
Heptageniidae							
Cinygmula sp.	19	4.75%	Yes	Larva		0	SC
Heptageniidae	15	3.75%	No	Larva	Early Instar	4	SC
Ironodes sp.	13	3.25%	Yes	Larva		0	SC
Leptophlebiidae							
Leptophlebiidae	11	2.75%	Yes	Larva	Early Instar	2	CG
Plecoptera							
Chloroperlidae							
Suwallia sp.	29	7.25%	Yes	Larva		1	PR
Leuctridae							
Leuctridae	1	0.25%	Yes	Larva	Early Instar	0	SH
Nemouridae							
Zapada sp.	35	8.75%	Yes	Larva	Early Instar	2	SH
Perlidae							
Calineuria californica	18	4.50%	Yes	Larva		2	PR
Hesperoperla pacifica	1	0.25%	Yes	Larva		1	PR
Perlodidae							
Perlodidae	2	0.50%	Yes	Larva	Early Instar	2	PR
Trichoptera							
Glossosomatidae							
Glossosoma sp.	10	2.50%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsyche sp.	19	4.75%	Yes	Larva		5	CF
Lepidostomatidae							
Lepidostoma sp.	6	1.50%	Yes	Larva		1	SH
Philopotamidae							
Philopotamidae	1	0.25%	Yes	Larva	Early Instar	3	CF
Rhyacophilidae							
Rhyacophila sp.	4	1.00%	No	Larva	Early Instar	1	PR
Rhyacophila Betteni Gr.	1	0.25%	Yes	Larva		0	PR
Rhyacophila blarina	71	17.75%	Yes	Larva		1	PR
Rhyacophila narvae	10	2.50%	Yes	Larva		0	PR

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2064

RAI No.: RAE09CS2064 | Sta. Name: Diane Brook - upstream
Client ID: DIAN2
Date Coll.: 9/23/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Coleoptera							
Dytiscidae							
Oreodytes sp.	1	0.25%	Yes	Adult		5	PR
Elmidae							
Heterlimnius sp.	5	1.25%	Yes	Larva		3	CG
Lara sp.	2	0.50%	Yes	Larva		1	SH
Zaitzevia sp.	11	2.75%	Yes	Larva		5	CG
Diptera							
Ceratopogonidae							
Ceratopogoninae	15	3.75%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	1	0.25%	Yes	Larva		1	CG
Empididae							
Oreogeton sp.	2	0.50%	Yes	Larva		4	PR
Pelecorhynchidae							
Glutops sp.	1	0.25%	Yes	Larva		1	PR
Simuliidae							
Simulium sp.	2	0.50%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	6	1.50%	Yes	Larva		3	PR
Hexatoma sp.	15	3.75%	Yes	Larva		2	PR
Chironomidae							
Chironomidae							
Chironomidae	29	7.25%	Yes	Larva		10	CG
Sample Count	400						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2065

RAI No.: RAE09CS2065 | Sta. Name: Stoney Creek - downstream
Client ID: STON1
Date Coll.: 9/23/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Oligochaeta	11	2.68%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	63	15.33%	Yes	Larva		4	CG
Baetis tricaudatus	8	1.95%	Yes	Larva		4	CG
Heptageniidae							
Cinygmula sp.	34	8.27%	Yes	Larva		0	SC
Ironodes sp.	33	8.03%	Yes	Larva		0	SC
Rhithrogena sp.	6	1.46%	Yes	Larva		0	CG
Leptophlebiidae							
Leptophlebiidae	76	18.49%	Yes	Larva	Early Instar	2	CG
Plecoptera							
Nemouridae							
Zapada cinctipes	41	9.98%	Yes	Larva		3	SH
Zapada Oregonensis Gr.	3	0.73%	Yes	Larva		2	SH
Perlodidae							
Perlodidae	1	0.24%	Yes	Larva	Early Instar	2	PR
Skwala sp.	7	1.70%	Yes	Larva		3	PR
Trichoptera							
Glossosomatidae							
Glossosoma sp.	31	7.54%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsychidae	8	1.95%	No	Larva	Early Instar	4	CF
Parapsyche almota	1	0.24%	Yes	Larva		3	PR
Limnephilidae							
Ecclisomyia sp.	1	0.24%	Yes	Larva		4	CG
Rhyacophilidae							
Rhyacophila sp.	3	0.73%	No	Larva	Early Instar	1	PR
Rhyacophila Betteni Gr.	3	0.73%	Yes	Larva		0	PR
Rhyacophila blarina	4	0.97%	Yes	Larva		1	PR
Rhyacophila narvae	3	0.73%	Yes	Larva		0	PR
Coleoptera							
Elmidae							
Heterlimnius sp.	3	0.73%	Yes	Larva		3	CG
Lara sp.	2	0.49%	Yes	Larva		1	SH
Narpus concolor	5	1.22%	Yes	Larva		2	CG
Diptera							
Empididae							
Empididae	3	0.73%	Yes	Larva	Early Instar	6	PR
Simuliidae							
Simulium sp.	2	0.49%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	3	0.73%	Yes	Larva		3	PR
Limnophila sp.	2	0.49%	Yes	Larva		3	PR

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2065

RAI No.: RAE09CS2065 Sta. Name: Stoney Creek - downstream
Client ID: STON1
Date Coll.: 9/23/2009 No. Jars: 1 STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Chironomidae							
Chironomidae							
Chironomidae	5	1.22%	No	Pupa		10	CG
Chironomidae	49	11.92%	Yes	Larva		10	CG
Sample Count	411						

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2066

RAI No.: RAE09CS2066 Sta. Name: Stoney Creek - upstream
Client ID: STON2
Date Coll.: 9/3/2009 No. Jars: 1 STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Non-Insect							
Acari	12	3.30%	Yes	Unknown		5	PR
Nematoda	1	0.27%	Yes	Unknown		5	PA
Oligochaeta	57	15.66%	Yes	Unknown		10	CG
Crangonyctidae							
Crangonyx sp.	6	1.65%	Yes	Unknown		6	CG
Sphaeriidae							
Sphaeriidae	1	0.27%	Yes	Unknown		8	CF
Ephemeroptera							
Baetidae							
Baetis tricaudatus	6	1.65%	Yes	Larva		4	CG
Heptageniidae							
Cinygma sp.	10	2.75%	Yes	Larva		0	SC
Cinygmula sp.	1	0.27%	Yes	Larva		0	SC
Ironodes sp.	3	0.82%	Yes	Larva		0	SC
Leptophlebiidae							
Paraleptophlebia sp.	65	17.86%	Yes	Larva		1	CG
Plecoptera							
Plecoptera	4	1.10%	No	Larva	Early Instar	11	PR
Nemouridae							
Malenka sp.	16	4.40%	Yes	Larva		1	SH
Zapada cinctipes	65	17.86%	Yes	Larva		3	SH
Perlodidae							
Skwala sp.	9	2.47%	Yes	Larva		3	PR
Trichoptera							
Glossosomatidae							
Glossosoma sp.	23	6.32%	Yes	Larva		0	SC
Hydropsychidae							
Hydropsychidae	1	0.27%	No	Pupa		4	CF
Parapsyche almota	7	1.92%	Yes	Larva		3	PR
Lepidostomatidae							
Lepidostoma sp.	1	0.27%	Yes	Pupa		1	SH
Philopotamidae							
Wormaldia sp.	4	1.10%	Yes	Larva		0	CF
Rhyacophilidae							
Rhyacophila sp.	2	0.55%	No	Pupa		1	PR
Rhyacophila Betteni Gr.	1	0.27%	Yes	Larva		0	PR
Rhyacophila Brunnea Gr.	3	0.82%	Yes	Larva		2	PR
Rhyacophila narvae	3	0.82%	Yes	Larva		0	PR
Coleoptera							
Elmidae							
Elmidae	1	0.27%	Yes	Larva	Damaged	4	CG
Hydrophilidae							
Hydrophilidae	1	0.27%	Yes	Larva		5	PR

Taxa Listing

Project ID: RAE09CS2
RAI No.: RAE09CS2066

RAI No.: RAE09CS2066 | Sta. Name: Stoney Creek - upstream
Client ID: STON2
Date Coll.: 9/3/2009 | No. Jars: 1 | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Simuliidae							
Simulium sp.	2	0.55%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	7	1.92%	Yes	Larva		3	PR
Hexatoma sp.	1	0.27%	Yes	Larva		2	PR
Limnophila sp.	1	0.27%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Chironomidae	49	13.46%	Yes	Larva		10	CG
Chironomidae	1	0.27%	No	Pupa		10	CG
Sample Count	364						

Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2059
Sta. Name: Clayburn Creek - downstream
Client ID: CLAY2
STORET ID:
Coll. Date: 9/23/2009

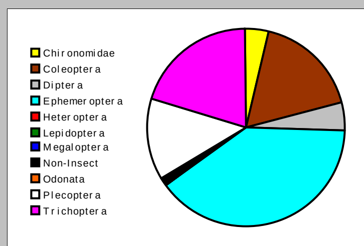
Abundance Measures

Sample Count: 415
Sample Abundance: 830.00 50.00% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	2	5	1.20%
Odonata			
Ephemeroptera	7	163	39.28%
Plecoptera	6	57	13.73%
Heteroptera			
Megaloptera			
Trichoptera	7	84	20.24%
Lepidoptera			
Coleoptera	3	72	17.35%
Diptera	5	18	4.34%
Chironomidae	1	16	3.86%

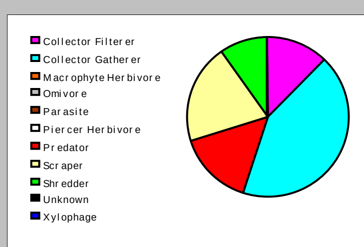


Dominant Taxa

Category	A	PRA
Heterlimnius	54	13.01%
Hydropsyche	52	12.53%
Rhithrogena	34	8.19%
Ephemerella	34	8.19%
Paraleptophlebia	24	5.78%
Zapada cinctipes	23	5.54%
Baetis tricaudatus	23	5.54%
Heptageniidae	22	5.30%
Cinygmula	21	5.06%
Chironomidae	16	3.86%
Sweltsa	13	3.13%
Elmidae	12	2.89%
Perlodidae	9	2.17%
Micrasema	9	2.17%
Dicranota	9	2.17%

Functional Composition

Category	R	A	PRA
Predator	12	62	14.94%
Parasite			
Collector Gatherer	10	176	42.41%
Collector Filterer	1	52	12.53%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	3	85	20.48%
Shredder	5	40	9.64%
Omivore			
Unknown			

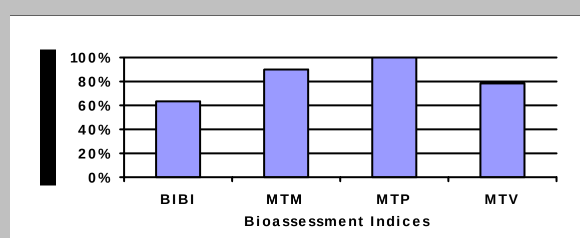


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	31	3	3		3
Non-Insect Percent	1.20%				
E Richness	7	3		3	
P Richness	6	3		3	
T Richness	7	3		3	
EPT Richness	20		3		3
EPT Percent	73.25%		3		3
Oligochaeta+Hirudinea Percent	0.48%				
Baetidae/Ephemeroptera	0.141				
Hydropsychidae/Trichoptera	0.619				
Dominance					
Dominant Taxon Percent	13.01%		3		3
Dominant Taxa (2) Percent	25.54%				
Dominant Taxa (3) Percent	33.73%	5			
Dominant Taxa (10) Percent	73.01%				
Diversity					
Shannon H (loge)	2.891				
Shannon H (log2)	4.170		3		
Margalef D	5.179				
Simpson D	0.072				
Evenness	0.052				
Function					
Predator Richness	12		3		
Predator Percent	14.94%	3			
Filterer Richness	1				
Filterer Percent	12.53%			1	
Collector Percent	54.94%		3		3
Scraper+Shredder Percent	30.12%		3		1
Scraper/Filterer	1.635				
Scraper/Scraper+Filterer	0.620				
Habit					
Burrower Richness	6				
Burrower Percent	8.19%				
Swimmer Richness	3				
Swimmer Percent	12.29%				
Clinger Richness	13	3			
Clinger Percent	65.54%				
Characteristics					
Cold Stenotherm Richness	0				
Cold Stenotherm Percent	0.00%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	4				
Air Breather Percent	3.86%				
Voltinism					
Univoltine Richness	24				
Semivoltine Richness	4	3			
Multivoltine Percent	10.12%		3		
Tolerance					
Sediment Tolerant Richness	4				
Sediment Tolerant Percent	4.10%				
Sediment Sensitive Richness	1				
Sediment Sensitive Percent	1.69%				
Metals Tolerance Index	2.815				
Pollution Sensitive Richness	1	1		1	
Pollution Tolerant Percent	0.96%	5		3	
Hilsenhoff Biotic Index	2.723		3		3
Intolerant Percent	44.34%				
Supertolerant Percent	4.34%				
CTQa	51.233				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	32	64.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	30	100.00%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	14	77.78%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	19	90.48%	None



Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2060
Sta. Name: Clayburn Creek - upstream
Client ID: CLAY3
STORET ID:
Coll. Date: 9/23/2009

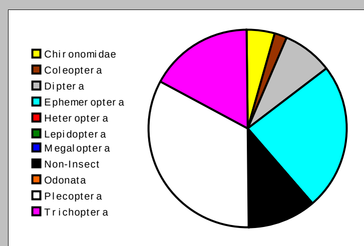
Abundance Measures

Sample Count: 346
Sample Abundance: 346.00 100.00% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	4	38	10.98%
Odonata			
Ephemeroptera	7	83	23.99%
Plecoptera	4	114	32.95%
Heteroptera			
Megaloptera			
Trichoptera	4	60	17.34%
Lepidoptera			
Coleoptera	3	8	2.31%
Diptera	6	28	8.09%
Chironomidae	1	15	4.34%

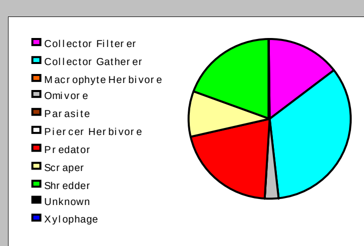


Dominant Taxa

Category	A	PRA
Zapada cinctipes	51	14.74%
Hydropsyche	48	13.87%
Paraleptophlebia	38	10.98%
Sweltsa	37	10.69%
Oligochaeta	26	7.51%
Ironodes	19	5.49%
Chironomidae	15	4.34%
Dixa	12	3.47%
Calineuria californica	12	3.47%
Pteronarcys princeps	11	3.18%
Polycelis coronata	10	2.89%
Cinygmula	10	2.89%
Rhyacophila Betteni Gr.	8	2.31%
Rhithrogena	7	2.02%
Hexatoma	7	2.02%

Functional Composition

Category	R	A	PRA
Predator	6	71	20.52%
Parasite			
Collector Gatherer	11	115	33.24%
Collector Filterer	4	51	14.74%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	3	32	9.25%
Shredder	4	67	19.36%
Omnivore	1	10	2.89%
Unknown			

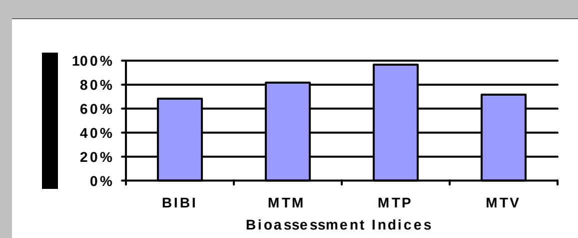


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	29	3	3		3
Non-Insect Percent	10.98%				
E Richness	7	3		3	
P Richness	4	3		3	
T Richness	4	1		2	
EPT Richness	15		3		1
EPT Percent	74.28%		3		3
Oligochaeta+Hirudinea Percent	7.51%				
Baetidae/Ephemeroptera	0.036				
Hydropsychidae/Trichoptera	0.800				
Dominance					
Dominant Taxon Percent	14.74%		3		3
Dominant Taxa (2) Percent	28.61%				
Dominant Taxa (3) Percent	39.60%	5			
Dominant Taxa (10) Percent	77.75%				
Diversity					
Shannon H (loge)	2.753				
Shannon H (log2)	3.972		3		
Margalef D	4.806				
Simpson D	0.083				
Evenness	0.057				
Function					
Predator Richness	6		3		
Predator Percent	20.52%	5			
Filterer Richness	4				
Filterer Percent	14.74%			1	
Collector Percent	47.98%		3		3
Scraper+Shredder Percent	28.61%		2		1
Scraper/Filterer	0.627				
Scraper/Scraper+Filterer	0.386				
Habit					
Burrower Richness	5				
Burrower Percent	8.67%				
Swimmer Richness	5				
Swimmer Percent	15.90%				
Clinger Richness	13	3			
Clinger Percent	36.99%				
Characteristics					
Cold Stenotherm Richness	1				
Cold Stenotherm Percent	3.18%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	4				
Air Breather Percent	4.34%				
Voltinism					
Univoltine Richness	19				
Semivoltine Richness	5	5			
Multivoltine Percent	8.09%		3		
Tolerance					
Sediment Tolerant Richness	4				
Sediment Tolerant Percent	11.56%				
Sediment Sensitive Richness	1				
Sediment Sensitive Percent	0.87%				
Metals Tolerance Index	2.505				
Pollution Sensitive Richness	1	1		1	
Pollution Tolerant Percent	1.73%	5		3	
Hilsenhoff Biotic Index	2.965		3		3
Intolerant Percent	53.47%				
Supertolerant Percent	12.43%				
CTQa	57.920				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	34	68.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	29	96.67%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	13	72.22%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	17	80.95%	Slight



Tuesday, April 13, 2010

Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2061
Sta. Name: Poignant Creek - downstream
Client ID: POIG1
STORET ID:
Coll. Date: 9/3/2009

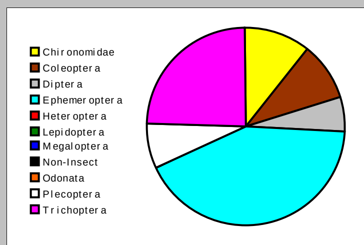
Abundance Measures

Sample Count: 421
Sample Abundance: 902.14 46.67% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	1	1	0.24%
Odonata			
Ephemeroptera	6	176	41.81%
Plecoptera	3	30	7.13%
Heteroptera			
Megaloptera			
Trichoptera	5	104	24.70%
Lepidoptera			
Coleoptera	2	39	9.26%
Diptera	6	24	5.70%
Chironomidae	1	47	11.16%

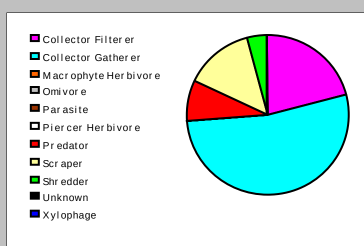


Dominant Taxa

Category	A	PRA
Rhithrogena	78	18.53%
Hydropsyche	74	17.58%
Baetis tricaudatus	52	12.35%
Chironomidae	47	11.16%
Heterlimnius	35	8.31%
Heptageniidae	31	7.36%
Zapada cinctipes	17	4.04%
Simulium	15	3.56%
Glossosoma	14	3.33%
Sweltsa	11	2.61%
Cinygmula	10	2.38%
Rhyacophila narvae	7	1.66%
Rhyacophila	5	1.19%
Zaitzevia	4	0.95%
Rhyacophila Brunnea Gr.	4	0.95%

Functional Composition

Category	R	A	PRA
Predator	9	35	8.31%
Parasite			
Collector Gatherer	8	221	52.49%
Collector Filterer	2	89	21.14%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	4	59	14.01%
Shredder	1	17	4.04%
Omivore			
Unknown			

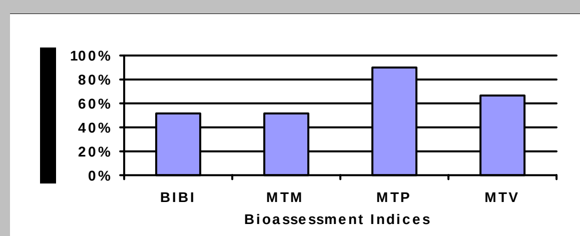


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	24	3	2		2
Non-Insect Percent	0.24%				
E Richness	6	3		3	
P Richness	3	1		2	
T Richness	5	3		3	
EPT Richness	14		3		0
EPT Percent	73.63%		3		3
Oligochaeta+Hirudinea Percent					
Baetidae/Ephemeroptera	0.295				
Hydropsychidae/Trichoptera	0.712				
Dominance					
Dominant Taxon Percent	18.53%		3		3
Dominant Taxa (2) Percent	36.10%				
Dominant Taxa (3) Percent	48.46%	5			
Dominant Taxa (10) Percent	88.84%				
Diversity					
Shannon H (loge)	2.303				
Shannon H (log2)	3.322		3		
Margalef D	3.926				
Simpson D	0.139				
Evenness	0.078				
Function					
Predator Richness	9		3		
Predator Percent	8.31%	1			
Filterer Richness	2				
Filterer Percent	21.14%			1	
Collector Percent	73.63%		2		1
Scraper+Shredder Percent	18.05%		2		0
Scraper/Filterer	0.663				
Scraper/Scraper+Filterer	0.399				
Habit					
Burrower Richness	4				
Burrower Percent	12.35%				
Swimmer Richness	2				
Swimmer Percent	12.83%				
Clinger Richness	14	3			
Clinger Percent	67.70%				
Characteristics					
Cold Stenotherm Richness	0				
Cold Stenotherm Percent	0.00%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	3				
Air Breather Percent	1.19%				
Voltinism					
Univoltine Richness	19				
Semivoltine Richness	2	1			
Multivoltine Percent	23.75%		3		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	1.19%				
Sediment Sensitive Richness	1				
Sediment Sensitive Percent	3.33%				
Metals Tolerance Index	3.471				
Pollution Sensitive Richness	0	1		0	
Pollution Tolerant Percent	0.95%	5		3	
Hilsenhoff Biotic Index	3.543		3		2
Intolerant Percent	33.02%				
Supertolerant Percent	11.16%				
CTQa	56.696				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	26	52.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	27	90.00%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	12	66.67%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	11	52.38%	Moderate



Metrics Report

Project ID:	RAE09CS2
RAI No.:	RAE09CS2062
Sta. Name:	Poignant Creek - upstream
Client ID:	POIG2
STORET ID:	
Coll. Date:	9/23/2009

Abundance Measures

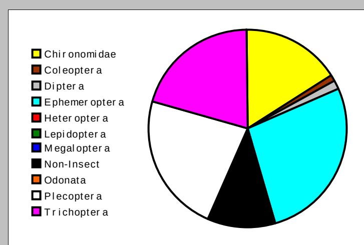
Sample Count:	432	
Sample Abundance:	2,592.00	16.67% of sample used

Coll. Procedure:

Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	5	48	11.11%
Odonata			
Ephemeroptera	5	115	26.62%
Plecoptera	6	99	22.92%
Heteroptera			
Megaloptera			
Trichoptera	9	90	20.83%
Lepidoptera			
Coleoptera	2	5	1.16%
Diptera	4	5	1.16%
Chironomidae	1	70	16.20%

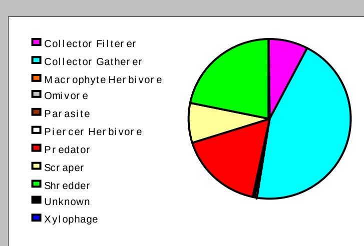


Dominant Taxa

Category	A	PRA
Paraleptophlebia	83	19.21%
Chironomidae	70	16.20%
Zapada cinctipes	58	13.43%
Oligochaeta	32	7.41%
Leuctridae	25	5.79%
Rhyacophila blarina	24	5.56%
Wormaldia	22	5.09%
Cinygmula	17	3.94%
Rhyacophila narvae	16	3.70%
Ironodes	12	2.78%
Sweltsa	8	1.85%
Acari	8	1.85%
Micrasema	6	1.39%
Hydropsyche	6	1.39%
Glossosoma	5	1.16%

Functional Composition

Category	R	A	PRA
Predator	11	73	16.90%
Parasite	1	1	0.23%
Collector Gatherer	6	192	44.44%
Collector Filterer	4	33	7.64%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	4	35	8.10%
Shredder	5	95	21.99%
Omivore	1	3	0.69%
Unknown			

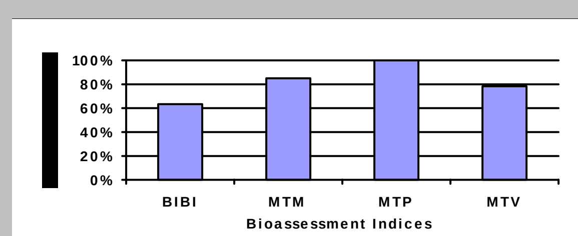


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	32	3	3		3
Non-Insect Percent	11.11%				
E Richness	5	3		2	
P Richness	6	3		3	
T Richness	9	3		3	
EPT Richness	20		3		3
EPT Percent	70.37%		3		3
Oligochaeta+Hirudinea Percent	7.41%				
Baetidae/Ephemeroptera	0.017				
Hydropsychidae/Trichoptera	0.067				
Dominance					
Dominant Taxon Percent	19.21%		3		3
Dominant Taxa (2) Percent	35.42%				
Dominant Taxa (3) Percent	48.84%	5			
Dominant Taxa (10) Percent	83.10%				
Diversity					
Shannon H (loge)	2.672				
Shannon H (log2)	3.855		3		
Margalef D	5.120				
Simpson D	0.100				
Evenness	0.060				
Function					
Predator Richness	11		3		
Predator Percent	16.90%	3			
Filterer Richness	4				
Filterer Percent	7.64%			2	
Collector Percent	52.08%		3		3
Scraper+Shredder Percent	30.09%		3		1
Scraper/Filterer	1.061				
Scraper/Scraper+Filterer	0.515				
Habit					
Burrower Richness	4				
Burrower Percent	17.13%				
Swimmer Richness	2				
Swimmer Percent	19.68%				
Clinger Richness	16	3			
Clinger Percent	28.70%				
Characteristics					
Cold Stenotherm Richness	1				
Cold Stenotherm Percent	5.79%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	2				
Air Breather Percent	0.46%				
Voltinism					
Univoltine Richness	23				
Semivoltine Richness	4	3			
Multivoltine Percent	19.44%		3		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	7.87%				
Sediment Sensitive Richness	2				
Sediment Sensitive Percent	6.25%				
Metals Tolerance Index	1.650				
Pollution Sensitive Richness	1	1		1	
Pollution Tolerant Percent	0.23%	5		3	
Hilsenhoff Biotic Index	3.453		3		2
Intolerant Percent	55.56%				
Supertolerant Percent	24.54%				
CTQa	52.767				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	32	64.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	30	100.00%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	14	77.78%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	18	85.71%	None



Tuesday, April 13, 2010

Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2063
Sta. Name: Diane Brook - downstream
Client ID: DIAN1
STORET ID:
Coll. Date: 9/3/2009

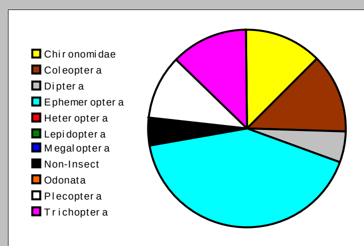
Abundance Measures

Sample Count: 401
Sample Abundance: 1,850.77 21.67% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	3	18	4.49%
Odonata			
Ephemeroptera	7	167	41.65%
Plecoptera	5	43	10.72%
Heteroptera			
Megaloptera			
Trichoptera	8	51	12.72%
Lepidoptera			
Coleoptera	3	52	12.97%
Diptera	6	19	4.74%
Chironomidae	1	51	12.72%

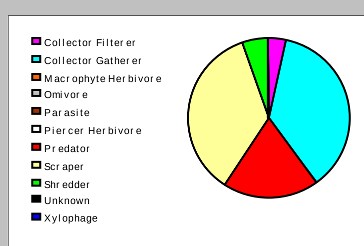


Dominant Taxa

Category	A	PRA
Cinygmula	87	21.70%
Chironomidae	51	12.72%
Heptageniidae	41	10.22%
Zaitzevia	30	7.48%
Rhyacophila narvae	25	6.23%
Heterlimnius	21	5.24%
Zapada	18	4.49%
Sweltsa	18	4.49%
Hydropsyche	11	2.74%
Leptophlebiidae	10	2.49%
Diphetor hageni	10	2.49%
Oligochaeta	9	2.24%
Baetis tricaudatus	9	2.24%
Acari	8	2.00%
Glossosoma	7	1.75%

Functional Composition

Category	R	A	PRA
Predator	12	77	19.20%
Parasite	1	1	0.25%
Collector Gatherer	9	144	35.91%
Collector Filterer	3	15	3.74%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	5	143	35.66%
Shredder	3	21	5.24%
Omivore			
Unknown			

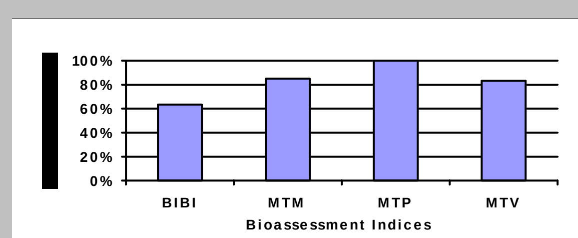


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	33	3	3		3
Non-Insect Percent	4.49%				
E Richness	7	3		3	
P Richness	5	3		3	
T Richness	8	3		3	
EPT Richness	20		3		3
EPT Percent	65.09%		3		2
Oligochaeta+Hirudinea Percent	2.24%				
Baetidae/Ephemeroptera	0.114				
Hydropsychidae/Trichoptera	0.216				
Dominance					
Dominant Taxon Percent	21.70%		3		3
Dominant Taxa (2) Percent	34.41%				
Dominant Taxa (3) Percent	44.64%	5			
Dominant Taxa (10) Percent	77.81%				
Diversity					
Shannon H (loge)	2.655				
Shannon H (log2)	3.830		3		
Margalef D	5.563				
Simpson D	0.120				
Evenness	0.060				
Function					
Predator Richness	12		3		
Predator Percent	19.20%	3			
Filterer Richness	3				
Filterer Percent	3.74%			3	
Collector Percent	39.65%		3		3
Scraper+Shredder Percent	40.90%		3		2
Scraper/Filterer	9.533				
Scraper/Scraper+Filterer	0.905				
Habit					
Burrower Richness	5				
Burrower Percent	16.46%				
Swimmer Richness	3				
Swimmer Percent	4.99%				
Clinger Richness	16	3			
Clinger Percent	61.85%				
Characteristics					
Cold Stenotherm Richness	1				
Cold Stenotherm Percent	0.25%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	2				
Air Breather Percent	2.99%				
Voltinism					
Univoltine Richness	24				
Semivoltine Richness	4	3			
Multivoltine Percent	19.70%		3		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	5.24%				
Sediment Sensitive Richness	1				
Sediment Sensitive Percent	1.75%				
Metals Tolerance Index	1.679				
Pollution Sensitive Richness	1	1		1	
Pollution Tolerant Percent	7.48%	5		2	
Hilsenhoff Biotic Index	3.292		3		2
Intolerant Percent	48.63%				
Supertolerant Percent	14.96%				
CTQa	59.069				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	32	64.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	30	100.00%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	15	83.33%	None
MTM	Montana DEQ Mountains (Bukantis 1998)	18	85.71%	None



Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2064
Sta. Name: Diane Brook - upstream
Client ID: DIAN2
STORET ID:
Coll. Date: 9/23/2009

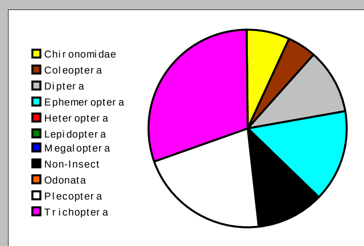
Abundance Measures

Sample Count: 400
Sample Abundance: 750.00 53.33% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	4	43	10.75%
Odonata			
Ephemeroptera	4	59	14.75%
Plecoptera	6	86	21.50%
Heteroptera			
Megaloptera			
Trichoptera	7	122	30.50%
Lepidoptera			
Coleoptera	4	19	4.75%
Diptera	7	42	10.50%
Chironomidae	1	29	7.25%

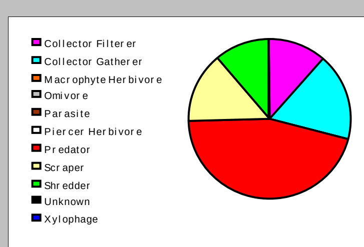


Dominant Taxa

Category	A	PRA
Rhyacophila blarina	71	17.75%
Zapada	35	8.75%
Suwallia	29	7.25%
Chironomidae	29	7.25%
Sphaeriidae	25	6.25%
Hydropsyche	19	4.75%
Cinygmula	19	4.75%
Calineuria californica	18	4.50%
Hexatoma	15	3.75%
Heptageniidae	15	3.75%
Ceratopogoninae	15	3.75%
Ironodes	13	3.25%
Zaitzevia	11	2.75%
Oligochaeta	11	2.75%
Leptophlebiidae	11	2.75%

Functional Composition

Category	R	A	PRA
Predator	14	182	45.50%
Parasite			
Collector Gatherer	8	70	17.50%
Collector Filterer	4	47	11.75%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	3	57	14.25%
Shredder	4	44	11.00%
Omivore			
Unknown			

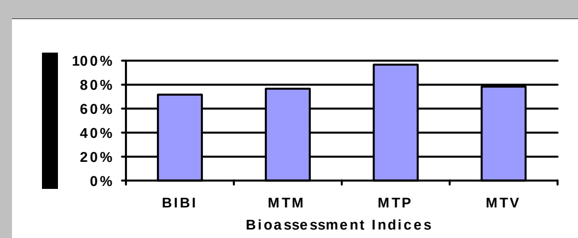


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	33	3	3		3
Non-Insect Percent	10.75%				
E Richness	4	1		2	
P Richness	6	3		3	
T Richness	7	3		3	
EPT Richness	17		3		2
EPT Percent	66.75%		3		2
Oligochaeta+Hirudinea Percent	2.75%				
Baetidae/Ephemeroptera	0.017				
Hydropsychidae/Trichoptera	0.156				
Dominance					
Dominant Taxon Percent	17.75%		3		3
Dominant Taxa (2) Percent	26.50%				
Dominant Taxa (3) Percent	33.75%	5			
Dominant Taxa (10) Percent	68.75%				
Diversity					
Shannon H (loge)	2.918				
Shannon H (log2)	4.210		3		
Margalef D	5.385				
Simpson D	0.073				
Evenness	0.050				
Function					
Predator Richness	14		3		
Predator Percent	45.50%	5			
Filterer Richness	4				
Filterer Percent	11.75%			1	
Collector Percent	29.25%		3		3
Scraper+Shredder Percent	25.25%		2		1
Scraper/Filterer	1.213				
Scraper/Scraper+Filterer	0.548				
Habit					
Burrower Richness	6				
Burrower Percent	17.00%				
Swimmer Richness	3				
Swimmer Percent	0.75%				
Clinger Richness	14	3			
Clinger Percent	50.75%				
Characteristics					
Cold Stenotherm Richness	3				
Cold Stenotherm Percent	1.00%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	3				
Air Breather Percent	5.50%				
Voltinism					
Univoltine Richness	23				
Semivoltine Richness	6	5			
Multivoltine Percent	9.25%		3		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	8.00%				
Sediment Sensitive Richness	1				
Sediment Sensitive Percent	2.50%				
Metals Tolerance Index	2.589				
Pollution Sensitive Richness	3	3		2	
Pollution Tolerant Percent	2.75%	5		3	
Hilsenhoff Biotic Index	3.203		3		2
Intolerant Percent	62.50%				
Supertolerant Percent	16.50%				
CTQa	62.444				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	36	72.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	29	96.67%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	14	77.78%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	16	76.19%	Slight



Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2065
Sta. Name: Stoney Creek - downstream
Client ID: STON1
STORET ID:
Coll. Date: 9/23/2009

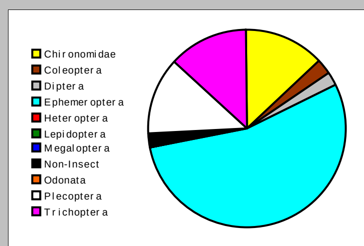
Abundance Measures

Sample Count: 411
Sample Abundance: 493.20 83.33% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	1	11	2.68%
Odonata			
Ephemeroptera	6	220	53.53%
Plecoptera	4	52	12.65%
Heteroptera			
Megaloptera			
Trichoptera	6	54	13.14%
Lepidoptera			
Coleoptera	3	10	2.43%
Diptera	4	10	2.43%
Chironomidae	1	54	13.14%

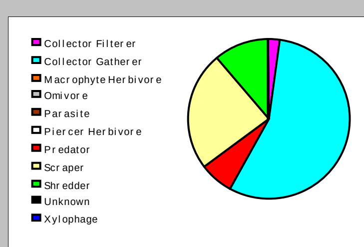


Dominant Taxa

Category	A	PRA
Leptophlebiidae	76	18.49%
Baetis tricaudatus	71	17.27%
Chironomidae	54	13.14%
Zapada cinctipes	41	9.98%
Cinygmula	34	8.27%
Ironodes	33	8.03%
Glossosoma	31	7.54%
Oligochaeta	11	2.68%
Hydropsychidae	8	1.95%
Skwala	7	1.70%
Rhithrogena	6	1.46%
Narpus concolor	5	1.22%
Rhyacophila blarina	4	0.97%
Zapada Oregonensis Gr.	3	0.73%
Rhyacophila Betteni Gr.	3	0.73%

Functional Composition

Category	R	A	PRA
Predator	9	30	7.30%
Parasite			
Collector Gatherer	9	227	55.23%
Collector Filterer	1	10	2.43%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	3	98	23.84%
Shredder	3	46	11.19%
Omivore			
Unknown			

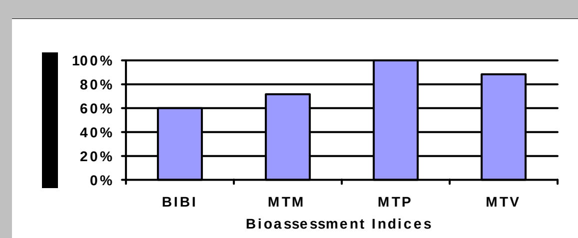


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	25	3	3		2
Non-Insect Percent	2.68%				
E Richness	6	3		3	
P Richness	4	3		3	
T Richness	6	3		3	
EPT Richness	16		3		1
EPT Percent	79.32%		3		3
Oligochaeta+Hirudinea Percent	2.68%				
Baetidae/Ephemeroptera	0.323				
Hydropsychidae/Trichoptera	0.167				
Dominance					
Dominant Taxon Percent	18.49%		3		3
Dominant Taxa (2) Percent	35.77%				
Dominant Taxa (3) Percent	48.91%	5			
Dominant Taxa (10) Percent	89.05%				
Diversity					
Shannon H (loge)	2.423				
Shannon H (log2)	3.495		3		
Margalef D	4.736				
Simpson D	0.109				
Evenness	0.089				
Function					
Predator Richness	9		3		
Predator Percent	7.30%	1			
Filterer Richness	1				
Filterer Percent	2.43%			3	
Collector Percent	57.66%		3		3
Scraper+Shredder Percent	35.04%		3		1
Scraper/Filterer	9.800				
Scraper/Scraper+Filterer	0.907				
Habit					
Burrower Richness	3				
Burrower Percent	14.36%				
Swimmer Richness	2				
Swimmer Percent	17.27%				
Clinger Richness	14	3			
Clinger Percent	34.06%				
Characteristics					
Cold Stenotherm Richness	1				
Cold Stenotherm Percent	0.24%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	2				
Air Breather Percent	1.22%				
Voltinism					
Univoltine Richness	18				
Semivoltine Richness	4	3			
Multivoltine Percent	30.41%		3		
Tolerance					
Sediment Tolerant Richness	3				
Sediment Tolerant Percent	3.89%				
Sediment Sensitive Richness	1				
Sediment Sensitive Percent	7.54%				
Metals Tolerance Index	2.544				
Pollution Sensitive Richness	1	1		1	
Pollution Tolerant Percent	0.00%	5		3	
Hilsenhoff Biotic Index	3.285		3		2
Intolerant Percent	49.64%				
Supertolerant Percent	15.82%				
CTQa	49.773				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	30	60.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	30	100.00%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	16	88.89%	None
MTM	Montana DEQ Mountains (Bukantis 1998)	15	71.43%	Slight



Tuesday, April 13, 2010

Metrics Report

Project ID: RAE09CS2
RAI No.: RAE09CS2066
Sta. Name: Stoney Creek - upstream
Client ID: STON2
STORET ID:
Coll. Date: 9/3/2009

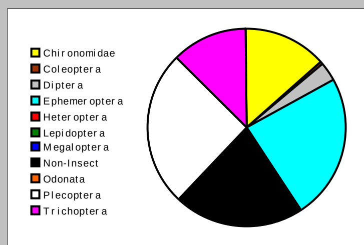
Abundance Measures

Sample Count: 364
Sample Abundance: 364.00 100.00% of sample used

Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Non-Insect	5	77	21.15%
Odonata			
Ephemeroptera	5	85	23.35%
Plecoptera	3	94	25.82%
Heteroptera			
Megaloptera			
Trichoptera	7	45	12.36%
Lepidoptera			
Coleoptera	2	2	0.55%
Diptera	4	11	3.02%
Chironomidae	1	50	13.74%

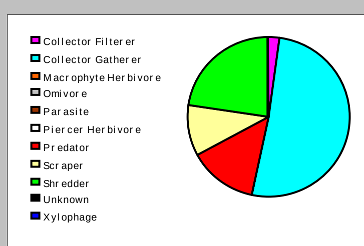


Dominant Taxa

Category	A	PRA
Zapada cinctipes	65	17.86%
Paraleptophlebia	65	17.86%
Oligochaeta	57	15.66%
Chironomidae	50	13.74%
Glossosoma	23	6.32%
Malenka	16	4.40%
Acari	12	3.30%
Cinygma	10	2.75%
Skwala	9	2.47%
Parapsyche almota	7	1.92%
Dicranota	7	1.92%
Crangonyx	6	1.65%
Baetis tricaudatus	6	1.65%
Wormaldia	4	1.10%
Plecoptera	4	1.10%

Functional Composition

Category	R	A	PRA
Predator	10	51	14.01%
Parasite	1	1	0.27%
Collector Gatherer	6	185	50.82%
Collector Filterer	3	8	2.20%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	4	37	10.16%
Shredder	3	82	22.53%
Omivore			
Unknown			

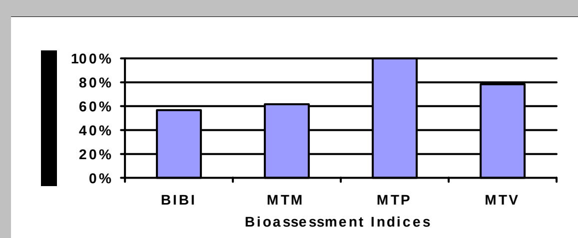


Metric Values and Scores

Metric	Value	BIBI	MTP	MTV	MTM
Composition					
Taxa Richness	27	3	3		2
Non-Insect Percent	21.15%				
E Richness	5	3		2	
P Richness	3	1		2	
T Richness	7	3		3	
EPT Richness	15		3		1
EPT Percent	61.54%		3		2
Oligochaeta+Hirudinea Percent	15.66%				
Baetidae/Ephemeroptera	0.071				
Hydropsychidae/Trichoptera	0.178				
Dominance					
Dominant Taxon Percent	17.86%		3		3
Dominant Taxa (2) Percent	35.71%				
Dominant Taxa (3) Percent	51.37%	3			
Dominant Taxa (10) Percent	86.26%				
Diversity					
Shannon H (loge)	2.452				
Shannon H (log2)	3.538		3		
Margalef D	4.426				
Simpson D	0.119				
Evenness	0.070				
Function					
Predator Richness	10		3		
Predator Percent	14.01%	3			
Filterer Richness	3				
Filterer Percent	2.20%			3	
Collector Percent	53.02%		3		3
Scraper+Shredder Percent	32.69%		3		1
Scraper/Filterer	4.625				
Scraper/Scraper+Filterer	0.822				
Habit					
Burrower Richness	4				
Burrower Percent	16.21%				
Swimmer Richness	2				
Swimmer Percent	19.51%				
Clinger Richness	11	3			
Clinger Percent	16.76%				
Characteristics					
Cold Stenotherm Richness	1				
Cold Stenotherm Percent	2.75%				
Hemoglobin Bearer Richness					
Hemoglobin Bearer Percent					
Air Breather Richness	4				
Air Breather Percent	2.75%				
Voltinism					
Univoltine Richness	20				
Semivoltine Richness	3	3			
Multivoltine Percent	18.96%		3		
Tolerance					
Sediment Tolerant Richness	4				
Sediment Tolerant Percent	18.13%				
Sediment Sensitive Richness	2				
Sediment Sensitive Percent	7.42%				
Metals Tolerance Index	2.203				
Pollution Sensitive Richness	1	1		1	
Pollution Tolerant Percent	0.00%	5		3	
Hilsenhoff Biotic Index	4.408		3		1
Intolerant Percent	36.54%				
Supertolerant Percent	29.67%				
CTQa	51.375				

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	28	56.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	30	100.00%	None
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	14	77.78%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	13	61.90%	Slight



Appendix C3. Reach Summary Data.

Table C3-1. Summary of Channel and Substrate Characteristics, Complexity, and Erosion in the Clayburn Creek watershed.

Reach	Length (m)	Bankfull Width (m)	Wetted Width (m)	% Boulder	% Cobble	% Large Gravel	% Small Gravel	% Fines	LWD per 100 m	Erosion*
Clayburn R1	1566	4.6	1.3	0	0	10	60	30	0	Minor
Clayburn R2	949	5.9	3.1	0	10	60	20	10	0	Minor
Clayburn R3	1447	11.1	3.1	35	45	10	7.5	2.5	2	Localized
Clayburn R4	481	8.9	2.6	0	20	50	25	5	0	Moderate
Clayburn R5	728	2.6	2.5	2.5	5	40	40	12.5	n/a	Major
Clayburn R6	997	3.4	0.8	10	25	40	20	5	10	Localized
Clayburn R7	692	1.5	1.1	0	0	0	40	60	1	Minor
Stoney R1	1091	8.3	2.0	0	0	5	45	50	0	Minor
Stoney R2	805	8.2	2.9	0	20	50	25	5	7	Minor
Stoney R3	1386	7.3	0.0	5	30	40	20	5	0	Moderate
Stoney R4	733	7.4	0.8	10	35	35	15	5	2	Localized
Stoney R5	818	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Minor
Stoney R6	918	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Minor
Nicholas R1	1399	1.5	1.2	0	0	15	45	40	0	Minor
Poignant R1	1342	8.1	3.8	30	30	25	10	5	4	Minor
Poignant R2	3053	3.9	2.4	5	40	30	23	5	0	Localized
Poignant R3	1358	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Minor
Poignant R4	1113	3.7	1.4	20	30	30	15	5	6	Minor
Diane R1	1775	13.5	3.2	5	15	25	35	20	10+	Localized
Diane R2	624	3.1	2.2	0	25	50	20	5	0	Minor
Diane R3	1813	2.4	1.3	5	10	45	30	10	9	Minor

* note that the erosion rating is related to fish habitat concerns and is not as detailed as Section X-X.

Table C3-2. Summary of Channel and Riparian Characteristics and Fish Habitat Values in the Clayburn Creek watershed.

Reach	% culverted	% channelized	% Riparian Forest Integrity (RFI)	Fish Presence	Fish Community	Salmonid Species (see codes in text)	Habitat Quality
Clayburn R1	1% (16 m)	42% (650 m)	18.1	Present	Lowland	CM, ST, CO, CT, PK?, CH?	Spawning – Nil Rearing – Moderate
Clayburn R2	4% (42 m)	50% (476 m)	35.9	Present	Lowland	CM, ST, CO, CT, PK?	Spawning – Moderate Rearing – Moderate
Clayburn R3	0%	0%	84.0	Present	Anadromous	CM, ST, CO, CT	Spawning – High Rearing – High

Table C3-2 (cont'd). Summary of Channel and Riparian Characteristics and Fish Habitat Values in the Clayburn Creek watershed.

Reach	% culverted	% channelized	% Riparian Forest Integrity (RFI)	Fish Presence	Fish Community	Salmonid Species (see codes in text)	Habitat Quality
Clayburn R4	0%	0%	100.0	Present	Anadromous	CO, CT, ST?	Spawning – High Rearing – High
Clayburn R5	0%	0%	100.0	Present	Resident / Anadromous (potential)	CT, CO?	Spawning – Moderate Rearing – Moderate
Clayburn R6	0%	0%	98.8	Present	Resident	CT	Spawning – Moderate Rearing – Moderate
Clayburn R7	12% (82 m)	17% (116 m)	79.2	Potential	Resident (potential)	CT?	Spawning – Moderate Rearing – Moderate
Stoney R1	4% (42 m)	62% (667 m)	0.6	Present	Lowland	CM, CO, CT	Spawning – Nil Rearing – Moderate
Stoney R2	0%	0%	67.9	Present	Anadromous	CM, CO, CT	Spawning – Moderate Rearing – Moderate
Stoney R3	2% (32 m)	0%	82.9	Present	Anadromous	CO, CT	Spawning – High Rearing – Low (goes dry)
Stoney R4	21% (152 m)	23% (170 m)	56.5	Present	Anadromous	CO, CT	Spawning – High Rearing – Moderate
Stoney R5	0%	7% (57 m)	14.4	Present	Anadromous	CO, CT	Spawning – Low Rearing – Moderate
Stoney R6	0%	16% (149 m)	36.6	Potential	Resident (potential)	CT?	Spawning – Low Rearing – Moderate
Nicholas R1	3% (40 m)	71% (1000 m)	42.0	Unknown	Unknown	Unknown	Spawning – Low Rearing – Moderate
Poignant R1	0%	0%	91.4	Present	Anadromous	ST, CO, CT	Spawning – High Rearing – High
Poignant R2	0%	3% (81 m)	84.0	Present	Resident	CT	Spawning – Moderate Rearing – Moderate
Poignant R3	0%	0%	97.8	Present	Resident	CT	Spawning – Moderate Rearing – Moderate
Poignant R4	0%	0%	100.0	Unknown	Unknown	Unknown	Spawning – Moderate Rearing – Moderate
Diane R1	0%	0%	100.0	Present	Resident	CT	Spawning – High Rearing – High
Diane R2	76% (474 m)	2% (12 m)	74.9	Unknown	Unknown	Unknown	Spawning – Moderate Rearing – Moderate
Diane R3	3% (61 m)	0.5% (9 m)	98.5	Unknown	Unknown	Unknown	Spawning – Moderate Rearing – Moderate

Appendix C4. Representative Channel Photos.

Figure C4-1. Photos of Representative Channel Conditions in Clayburn Creek ISMP Study Area.

Clayburn R1

Clayburn R2

Clayburn R3

Clayburn R4

Clayburn R5

Clayburn R6

Clayburn R7

Stoney R1

Stoney R2

Stoney R3

Stoney R4

Stoney R5

Figure C4-2. Photos of Representative Channel Conditions in Clayburn Creek ISMP Study Area**.**

NO PHOTO

Stoney R6

Nicholas R1

Poignant R1

NO PHOTO

Poignant R2

NO PHOTO

Poignant R3

Poignant R4

Diane R1

NO PHOTO

Diane R2

Diane R3

Analysis of SHIM data for the City of Abbotsford

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1 February 2010

EcoLogic
RESEARCH

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Introduction

As part of the development of an Integrated Stormwater Management Plan, Raincoast Applied Ecology was interested in identifying habitat suitability of the streams in the City of Abbotsford for Pacific Water Shrew (*Sorex bendirii*). Raincoast Applied Ecology requested that I run the SHIM data collected along streams in the City of Abbotsford through a Bayesian Belief Network, that I designed in 2006 (Craig 2006). The network assigns a rating of High, Moderate, Low, or Nil suitability to stream segments based on their stream and upland habitat characteristics.

SHIM habitat suitability model

Variables used for SHIM habitat suitability modeling included:

- Primary stream class (choices were: channelized, culvert, ditch, modified, natural, other);
- Stream gradient (measured in degrees);
- Bankfull width (measured in m);
- Bankfull depth (measured in m);
- Riparian class of the dominant vegetation on the left bank (choices were: row crops, broadleaf forest, bryophytes, coniferous forest, planted tree farm, disturbed wetland, dug out pond, exposed soil, flood plain, herbs and grasses, high impervious, medium impervious, low impervious, mixed forest, natural wetland, rock, and shrubs);
- Riparian class of the dominant vegetation on the right bank (same as for left above);
- Qualifier for riparian class on the left bank (choices were: agriculture, natural, urban residential, recreation, disturbed, and unknown);
- Qualifier for riparian class on the right bank (same as for left above);
- Structural stage of the dominant riparian vegetation on the left bank (choices were: low shrubs <2m, tall shrubs >2m, sapling >10m, young forest, mature forest, old forest);
- Structural stage of the dominant riparian vegetation on the right bank (same as for left above);
- Density of shrubs in the left bank riparian zone (choices were: <5%, 5-33%, 34-66%, 67-100%);
- Density of shrubs in the right bank riparian zone (same as for left above).

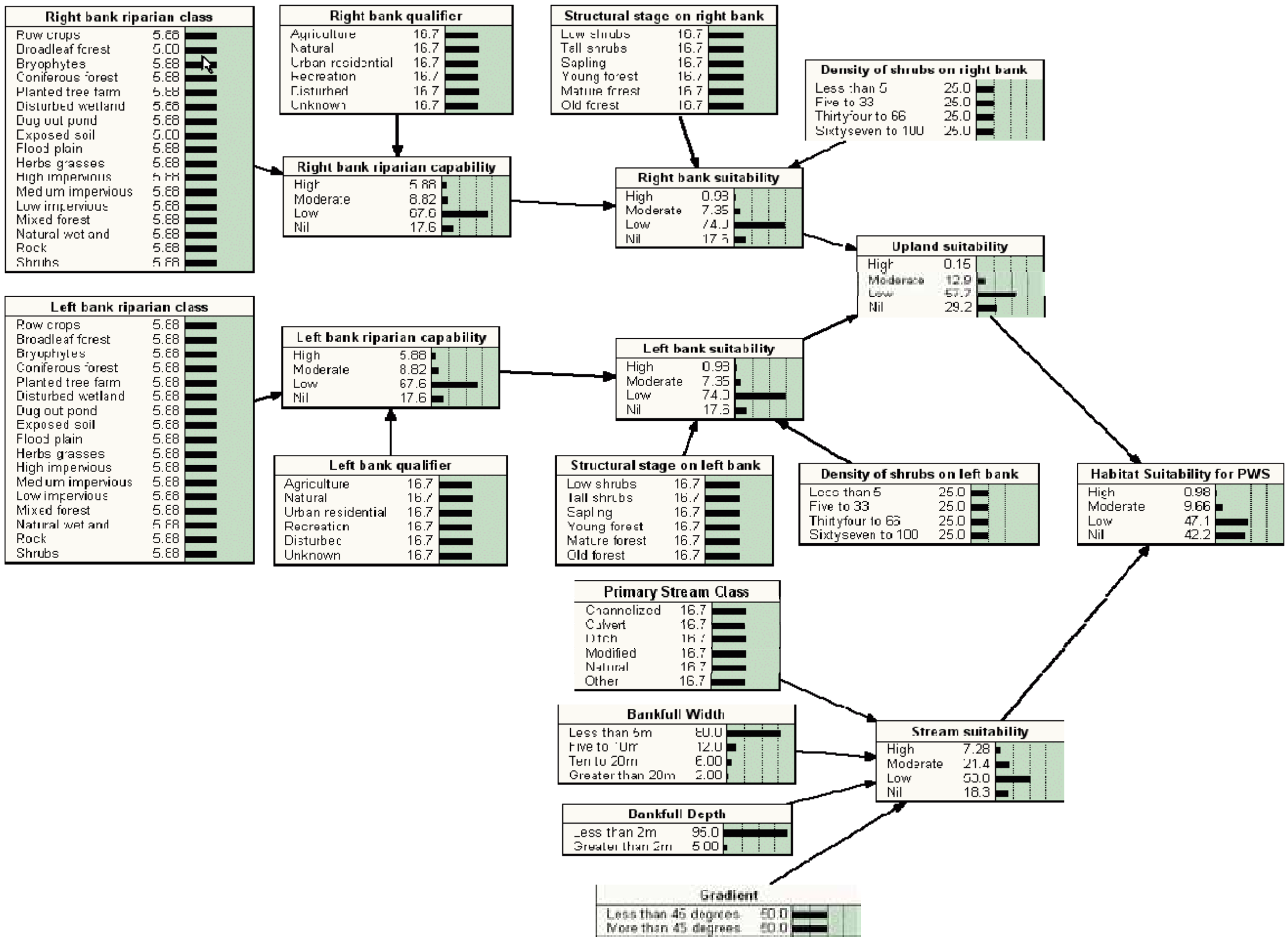

Figure 1. Full Bayesian Belief Network for rating the suitability of habitat for Pacific water shrew based on SHIM data.

- The Bayesian Belief Network (BBN; Figure 1) consists of 3 submodels:

  - Stream characteristics submodel (Figure 2), which uses the primary stream class, bankfull width, bankfull depth, and gradient to classify the suitability of the watercourse.
  - Upland characteristics submodel (Figure 3), which uses the dominant riparian class with the land use qualifier (left and right banks), the structural stage of the dominant vegetation (left and right), and the density of shrubs present (left and right) to classify the suitability of the upland habitat.

    For this submodel, there were 3 steps:
    a. the overall <u>habitat capability</u> of the dominant riparian class was ranked, which provides a maximum suitability of the class;
    b. the habitat suitability of the right and left bank was rated separately; and
    c. an overall habitat suitability rating was applied based on the combination of right and left bank suitability.

  - An overall habitat suitability submodel (Figure 4) which combines stream suitability and upland suitability to provide an overall suitability classification for the habitat.

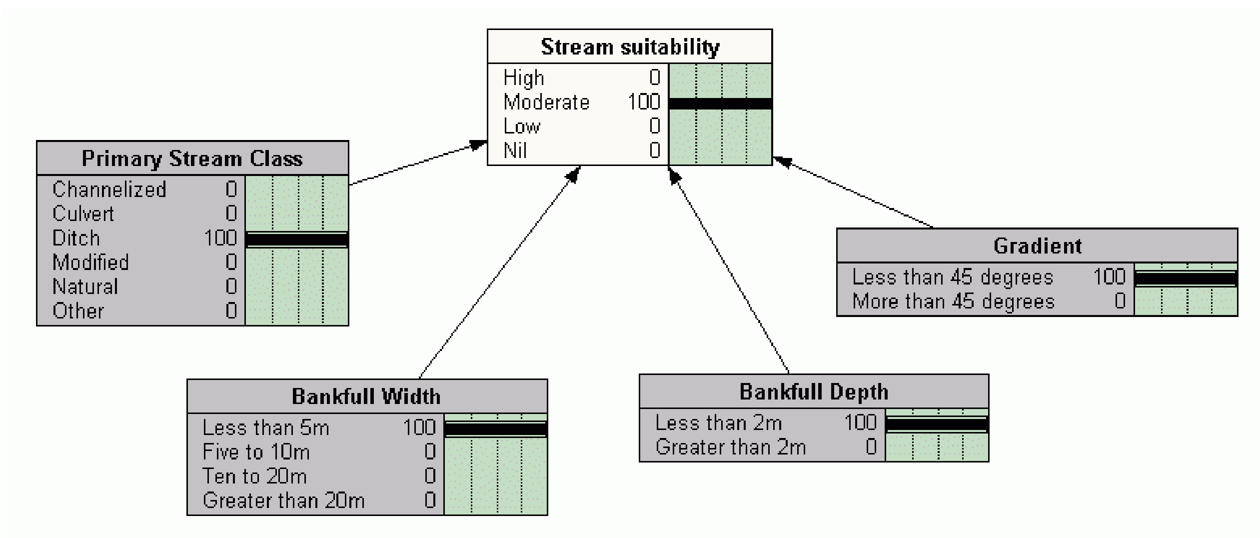

Figure 2. Stream suitability submodel.

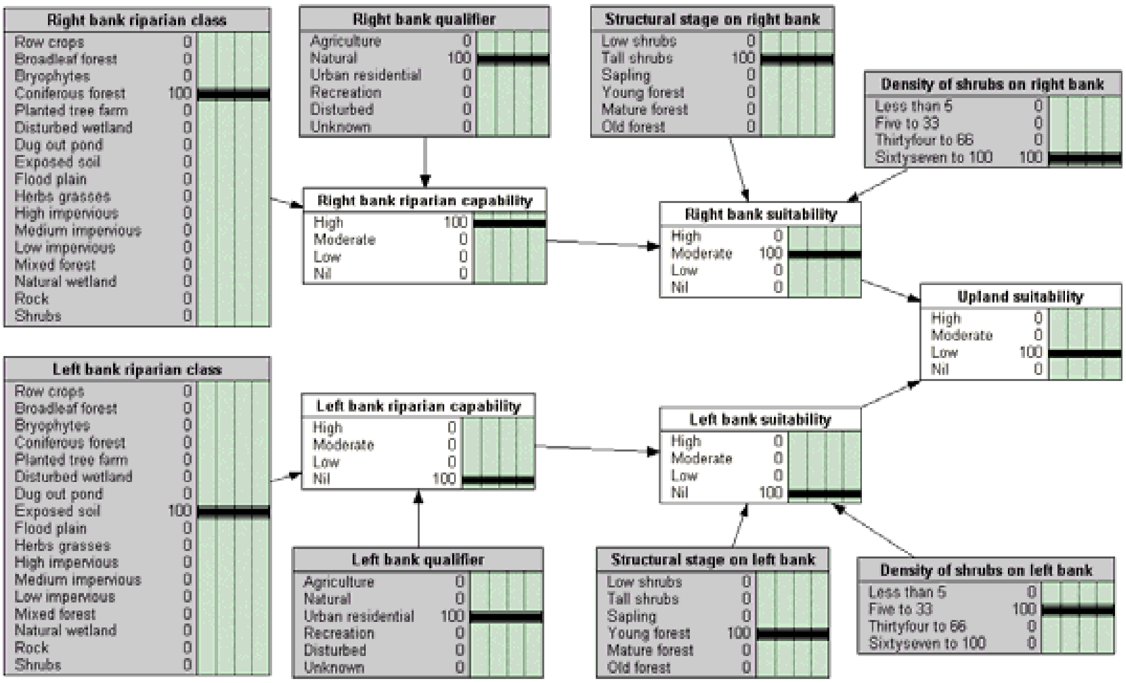

Figure 3. Upland suitability submodel. Right and left bank capability is calculated first. Suitability of habitat on the left and right banks is calculated separately, then combined to generate an overall suitability index for the site.

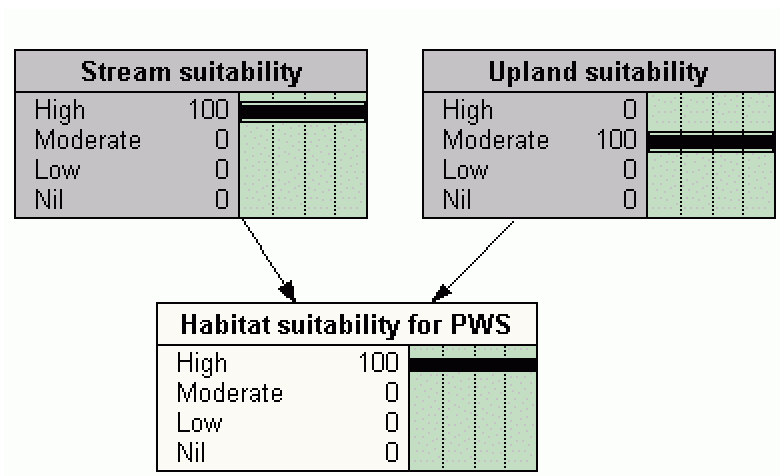

Figure 4. The overall habitat suitability submodel. Combines the ratings for stream and upland habitat to generate an overall suitability index.

Data Issues

There were 173 lines of data with data errors identified in the dataset. Some occurred where Riparian classes were assigned that were anomalous (not eligible categories according to the SHIM guidelines), such as Christmas tree farms, or Non-intens agriculture. In others, shrub cover was recorded as being in the 0-33% cover class; however, that class is not an option (options in SHIM are <5% and 5-33%). All identified data errors were corrected to match the required formatting of the model. Changes were documented in the excel file ‘Changes to Abbotsford SHIM data’.

Abbotsford SHIM data were run through the BBN model using the variables identified above, with the changes to the data mentioned above. Many data lines had missing data, which decreased the certainty of the stream suitability rating. In particular, many data lines were missing information about the type of stream surveyed (variable Primary, in column ‘S’ in the Abbotsford SHIM data). I noticed that there was additional information about the Primary stream class in column ‘CO’ titled Primary_1. I combined these 2 columns to create a modified Primary data field, and reran the data through the model. This created 2 output data sets provided in excel format: Abbotsford_SHIM + output for RAE, and Abbotsford_SHIM with modified PRIMARY + output for RAE. The file with the modified Primary data column would provide better suitability ratings for those cases where the Primary stream data was missing in column ‘S’.

Model Output

The output from the model is the probability that the stream segment suitability is High, Moderate, Low or Nil. Model output was provided for each of the submodels as well as the overall habitat suitability model. Output columns include habitat: Probability that the upland suitability is high/moderate/low/nil; probability that the stream suitability is high/moderate/low/nil; and probability that the overall habitat suitability is higher/moderate/low/nil. I added a column that provides the overall habitat suitability rating and its confidence.

Model output was provided for the Abbotsford SHIM data using the dataset where primary stream class information was provided by column ‘S’ only, and where primary stream class information was provided by columns ‘S’ and ‘CO’ combined. Where data for all of the variables in the model is present, the model is set up so that the conditional probability output is 100% certainty. However, in many instances, data for at least one of the variables included in the model were not collected; in those cases the habitat suitability probability is split between two or more outcomes. For overall rating purposes, stream segment suitability was ranked according to the suitability class that had the <u>highest</u> probability, and assigned a confidence class (either ≥75% or 50-74% (called ≥50%). For example, if a data case had a probability of 55% that it was Moderate suitability, and 45% that it was Low suitability, it was assigned a Moderate suitability rating, with a confidence class of ≥50%. Where habitat suitability probabilities were tied between two suitability classes, the data case was assigned to the highest class. For example if a data case had a probability of 50% that it was Moderate and 50% that it was Low, then it was assigned a Moderate suitability rating, with a confidence class ≥50%. Lower confidence ratings occurred when data were missing. In the Notes column I noted where the data segment was for a ditch, or where there were tied suitability probabilities.

The suitability rating is the relative current suitability of the site. The highest suitability rating (High) is reserved for those sites that meet the benchmark of optimal habitat set for the species. This does not indicate that only High suitability habitat is suitable for Pacific water shrew. Habitat rated as Moderate suitability is also considered very suitable for

Pacific water shrew. Habitats rated Low indicate that the site is currently not the most suitable for the shrew, or indicates uncertainty in the rating, but it does not indicate that the Pacific water shrew will not occur in those habitats. As such, Low ratings require more careful interpretation. In many cases, sites will be rated Low because it reflects uncertainty due to missing data (see for example, case (IDnum) 87). In addition, sites in ditch habitat are rated as a maximum suitability of Low because it is not a natural habitat; however, Pacific water shrews have been captured often in these habitats as part of Environmental Assessment and/or mitigation efforts. We currently do not know if Pacific water shrew uses ditch habitat as living habitat, or as corridor habitat; however, we do know that Pacific water shrews will use this habitat where the surrounding upland habitat is suitable (for example, where there is heavy shrub cover along the ditch edge). For an example of this, compare cases 1 and 12. In case 1, the ditch is rated Low because, although the right bank is unsuitable (exposed soil, little cover), the left bank is forested with heavy shrub cover. In case 12, the ditch is rated as Nil because both left and right bank are unsuitable. Note also that in some cases, although a site is currently rated as Low suitability, the site could become more suitable if it was rehabilitated, or if succession was permitted to occur (ie. shrubs and/or forest permitted to grow).

Appendix D

Hydrologic and Hydraulic Modelling

Appendix D – Hydrologic and Hydraulic Modelling

Contents

Figures

Tables

Appendix D – Hydrologic and Hydraulic Modelling

D Hydrologic and Hydraulic Modelling

D.1 Introduction

This Appendix outlines the development of the detailed hydrologic and hydraulic model of the Clayburn Creek Drainage Basin. The section includes:

- description of the detailed hydrologic and hydraulic model development using the City GIS data base
- calibration and verification of the hydrologic model to ensure accurate predictions of watershed rainfall-runoff response

The completed hydrologic/hydraulic model was used to assess the drainage system under different design event conditions. The results of these analyses are presented in Appendix E.

D.2 Rainfall and Flow Monitoring Data Collection

KWL collected flow data from a gauge installed on the downstream side of the bridge at Clayburn Road and Straiton Road. The station was installed in June 2007 and continues to operate. The Rainfall data was collected from the Ledgeview rain gauge, the Abbotsford Municipal Hall rain gauge and the Marshall Site 2 rain gauge.

Table D-1 summarizes monitoring data collected at nearby monitoring sites and the monitoring period for each. The locations of the stations are shown on Figure D-1.

Table D-1: Flow and Rainfall Monitoring Site Summary

Monitoring Station	Location	Active Period
Clayburn Creek Flow Station	Clayburn Creek D/S Intersection of Clayburn Road, Old Clayburn Road and Straiton Road	Jun. 2007 to present
Auguston Rainfall & Flow Station (Envirowest)		Not available
Ledgeview Golf Course Rainfall Station	SE Corner of the Golf Course, off McKee Road	Aug. 2008 to present
Marshall Rainfall Station (Marshall 2)	Tributary 10 U/S of Hwy 11 (near McClary Ave.)	Apr. 2003 to present
City Hall Rainfall Station	Abbotsford City Hall	Sept. 2007 to present

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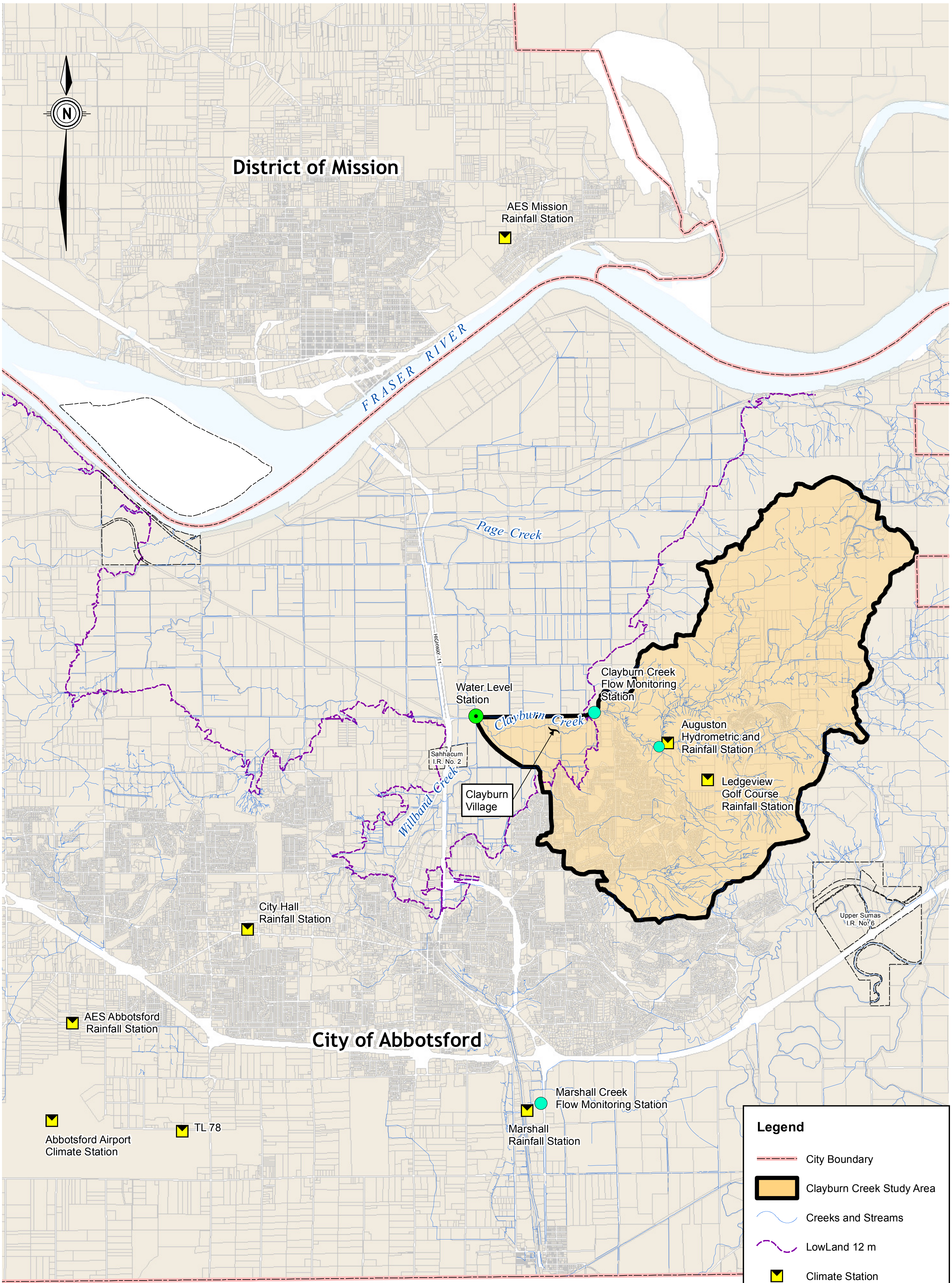

Reference: This information is not warranted as to its accuracy by Kerr Wood Leidal Associates. This information is provided for illustrative purposes only.
Topographic information provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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consulting engineers

City of Abbotsford
Clayburn Creek ISMP

Project No.	Date
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Climate and Flow Monitoring Station Locations

Figure D-1

Appendix D – Hydrologic and Hydraulic Modelling

Clayburn Creek Flow Monitoring

The Clayburn Creek flow monitoring station was originally established between 1990 and 1991 and updated in 2001, but had not been operating for the few years prior to the installation of the new station on June 14, 2007. The new staff gauge was installed on the east wall of the outlet of the culvert.

Water level is measured using an Ultrasonic Level Sensor and recorded in a Data Logger. The data is transmitted via cellular telemetry to the FlowWorks server which can be accessed by logging into www.flowworks.com. The water levels are converted to flow using the stage-discharge relationship shown on Figure D-2.

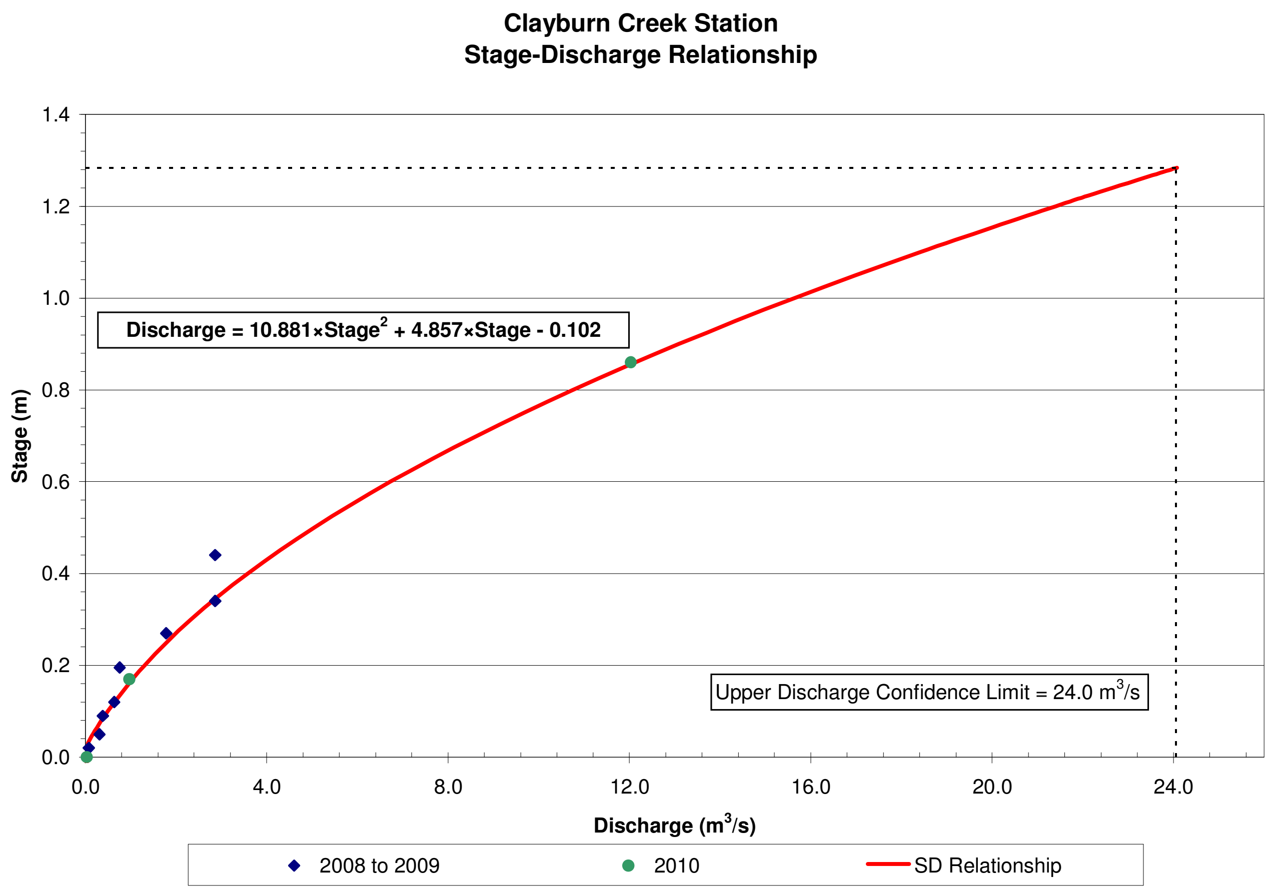


Figure D-2: Clayburn Creek Stage Discharge Relationship

Appendix D – Hydrologic and Hydraulic Modelling

The full 5-minute rainfall record from the Ledgeview rainfall gauge, with data gaps filled with data from the Marshall 2 rainfall gauge was graphed with the Clayburn flow data to determine the periods between storm events during which baseflows can be observed. The summer base flow is 0.029 L/s/ha and the winter base flow is 0.196 L/s/ha. These base flows are high compared to similar watersheds in the lower mainland.

D.3 Clayburn Creek Watershed EIA Estimate

The total impervious area (TIA) for the existing conditions was estimated using assigned percent impervious in the model.

The effective impervious area (EIA) was estimated using the KWL EIA spreadsheet calculator. Hourly rainfall data from the *Abbotsford Municipal Hall* rain gauge was used for this analysis because it was the most complete rainfall record available, both in length and in content. The flow data from the Clayburn Creek gauge at Clayburn Village was used for the flow record. The EIA is estimated to be 16.6% at the Clayburn Creek gauge which is higher than the TIA. This is because some of the pervious areas such as lawns do not adequately replicate forested conditions resulting in higher than forested flows. Table D-2 below shows the TIA and EIA for important locations in the watershed.

Table D-2: TIA and EIA Estimates at Strategic Locations on Clayburn Creek

Location	TIA	EIA[1]
Poignant Creek at Mouth	7.5%	
Diane Creek at Mouth	12.3%	
Stoney Creek at Mouth	21.2%	
Clayburn Mainstem upstream of Poignant	7.1%	
Clayburn Creek at Clayburn Road (Entire Study Area)	11.0%	
Clayburn Creek at Straiton Road (Flow Gauge Location)	7.4%	16.6%

[1] Estimated from recorded flow data.

D.4 XP-SWMM Model Development

The drainage system is shown in Figure 2-3 and includes:

- 60 km of pipes
- 1315 manholes
- Clayburn Creek and its tributaries (Poignant Creek, Diane Creek, and Stoney Creek)

For this study, Clayburn Creek basin is separated into two major sections for assessment, uplands area and lowlands area. The lowlands area is defined as the area with an elevation of 12 m or less, as shown in Figure D-1.

Appendix D – Hydrologic and Hydraulic Modelling

Model Catchments

The Clayburn Creek drainage area was divided into urban and rural areas.

The urban areas were divided into three types of catchments, road catchments which include all areas within road right-of-ways, legal catchments which include all areas that have been developed, and rural catchments which include larger undeveloped areas higher in the Clayburn watershed.

Data for the legal developed catchments was taken from the City's cadastral GIS mapping, using the BC Land Assesment to determine the land use. Data for the rural catchments was taken from the City's GIS mapping, using the Ministry of Environment air photo based land cover mapping GIS layer. Before import into the XP-SWMM model, each parcel was paired with a node representing a manhole, a junction, or an end of a culvert. In cases where more than one parcel connected to the same node, these parcels were grouped together into a single catchment.

Since the City's GIS database did not have right-of-ways defined as small parcel sized catchments, these were split using a Thiessen polygon methodology. This method involves using a GIS algorithm that takes all the manholes used in the model and allocating areas to each one by determining which areas are closer to a particular manhole than any other.

In the rural areas where the drainage network is not as dense, larger catchments were manually defined and assigned to the closest link.

In total, 912 urban catchments, 45 rural catchments, and 900 road catchments were created and imported into the XP-SWMM model. Catchments were assigned the following attributes:

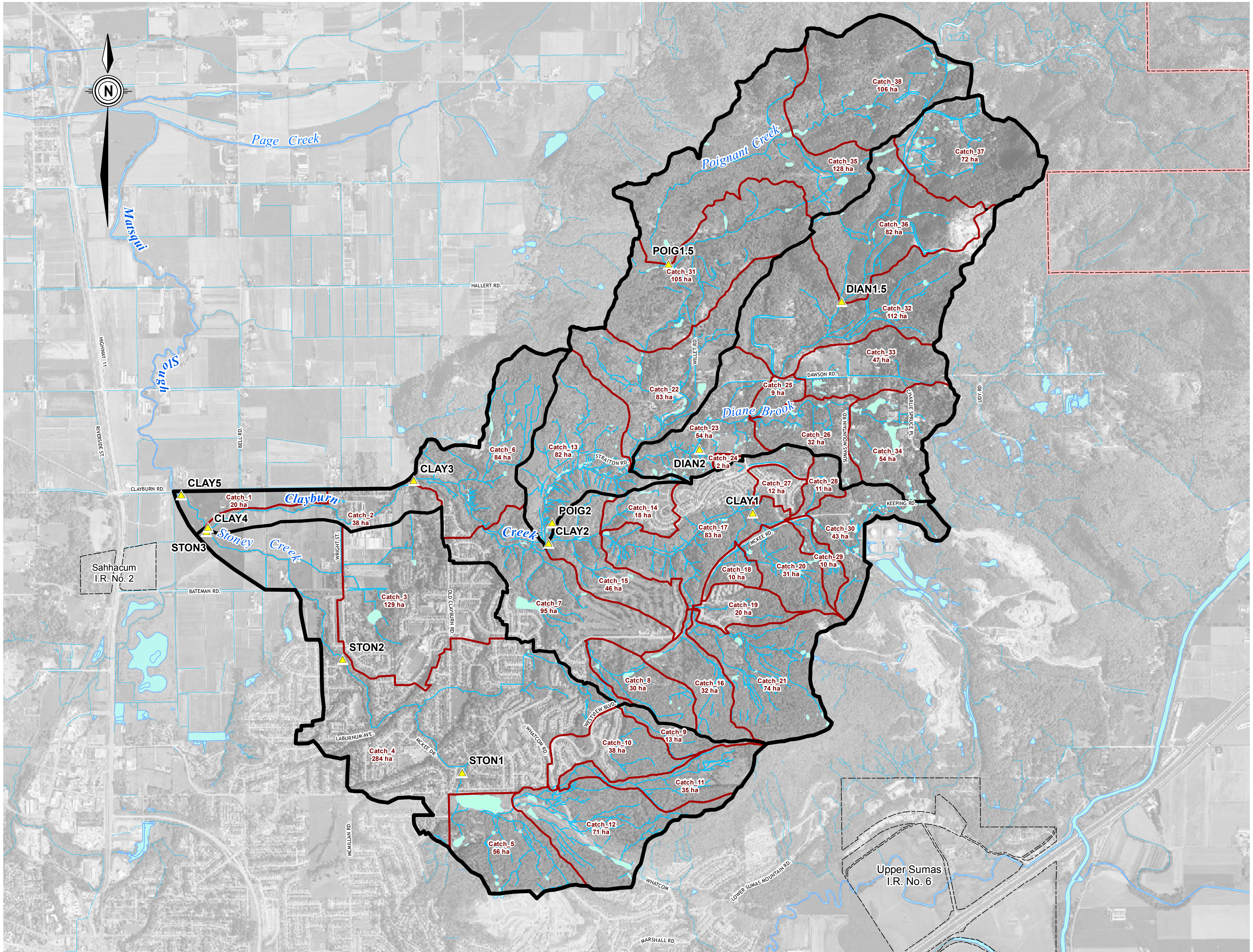
- slopes, using digital elevation mapping (DEM) information
- existing land use impervious area, using the BC Assessment land use GIS information for legal catchments and the MOE land use GIS information for all other catchments
- impervious area for future land use scenarios, using the City's OCP Zoning
- groundwater parameters based on soils mapping

The major modeled catchments are shown in Figure D-3.

Groundwater and Soil Parameters

The groundwater portion of XP-SWMM – RUNOFF was used to better estimate the groundwater and interflow portions of the runoff hydrograph. Infiltration rates, soil depths, and soil hydraulic conductivity were all input based on previously used and typical values.

Figure 2-5 shows the surficial geology (Geological Survey of Canada, 1976) of the Clayburn Creek Basin that was used to determine soil parameters.



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Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- ID Area — Major Model Catchment Boundary
- Creek and Streams
- Open Water and Marshes
- Peak Flow Estimates at Strategic Location

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Model Major Catchments

Figure D-3

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Appendix D – Hydrologic and Hydraulic Modelling

Percentage Impervious

Typical impervious percentages for Metro Vancouver were used as a starting point in the model as shown in below.

Table D-3: Existing and Future Land Use Impervious Percentages

Land Use Type	Total Impervious Percentage	
	Existing	OCP
Agricultural	5	5
Commercial	90	90
Industrial	75	75
Neighbourhood Development	40	
Parks and Open Space	1	1
Mobile Home Park	40	
Multi-Family Residential	80	
Rural Residential	10	10
Resource Conservation		1
Limited Use		10
City Residential		80
Urban Residential		60
Single-Family Residential	50	
Manual (as per air-photo)	Varies	
Institutional	70	90
Road Rights of Way	Varies	

The existing impervious percentage for the legal developed catchments was determined using the BC Land Assessment to determine the land use and then applying the impervious percentages found in Table D-3. The impervious area for the rural catchments was developed using the Ministry of Environment air photo based land cover mapping GIS layer, which gave a total impervious area that was then converted into an impervious percentage.

The future impervious percentage for the legal developed catchments and the rural catchments was developed by applying the impervious percentage values found in Table D-3 to the corresponding land-use from the Abbotsford OCP (2005).

The 2254 ha watershed has an existing total percentage impervious area of 12% and is expected to increase to 27% total impervious area once built-out to the OCP.

Appendix D – Hydrologic and Hydraulic Modelling

Model Network

The model includes most storm sewer pipes, culverts, and watercourses with the Clayburn Creek watershed, as supplied by the City in their GIS databases. Catch basin leads were not modelled. Nodes in the model consist of manholes, catch basins, cleanouts, intakes, outfalls, and junctions. Missing or inaccurate information in the database was corrected with the use of available as-built drawings.

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

Figure 2-3 represents the Clayburn Creek Basin model network.

D.5 Model Calibration

Introduction

The calibration process was completed using two storms that occurred during saturated soil conditions (November 23 to December 3, 2009 and November 11-23, 2008) and one during dry conditions (August 10-13, 2009). The validation process was completed using one storm that occurred during saturated soil conditions (January 11-21, 2010) and one during dry conditions (September 27 to October 5, 2007).

The 5-minute rainfall data from the Ledgeview, Abbotsford City Hall, and Marshall Site 2 stations was used for the calibration and validation. Calibration and validation events were chosen by selecting the largest events with fewest data gaps.

Model calibration involved the adjustment of parameters, within reasonable ranges, until a set of objectives was met. The Clayburn Creek model was calibrated in such a way as to try to:

- maximize the physical basis of XP-SWMM's algorithms
- calibrate to all respects of the runoff hydrograph (peak flow, volumes, the receding portion of the hydrograph from groundwater, and seasonal groundwater baseflow)

The model parameters were adjusted uniformly over the entire watershed during calibration.

Groundwater and Infiltration Parameters

The infiltration and groundwater parameters used in the models were taken from KWL's database of calibrated model parameters for similar soil conditions and adjusted within reasonable ranges during calibration. The available calibration data was insufficient to justify further changes to the parameters.

Impervious Percentages

Impervious percentages were assigned based on land use as presented in Table D-3. No changes were made to these values during calibration.

Appendix D – Hydrologic and Hydraulic Modelling

Dry Calibration Event

The August 10-13, 2009 storm event was used for determining the directly connected or Effective Impervious Area (EIA) of the Clayburn Creek watershed. Antecedent conditions before the storm event were very dry since there was minimal rain in the previous weeks. Total Impervious Area (TIA) was determined using the existing land use mapping and the associated GVRD impervious percentage values listed in Table D-3. This event nearly matched the 2-year return period intensity at the 2-hour duration and was the largest dry initial conditions event recorded during the flow-monitoring period. The dry event calibration is presented in Figure D-4 below.

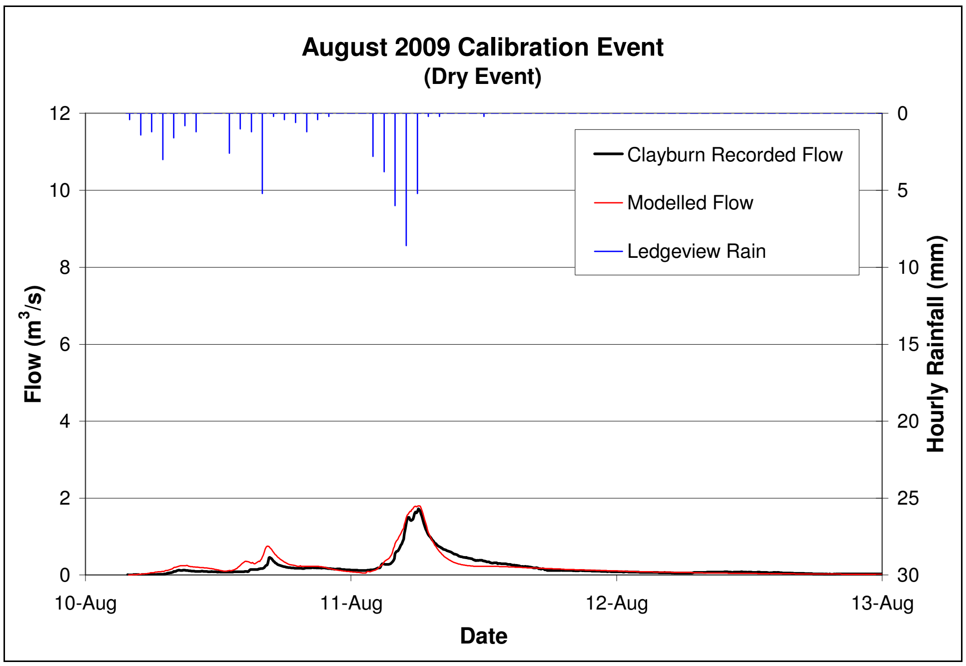

Figure D-4: Dry Event Calibration (August 2009)

The TIA and EIA were found to both be approximately 7% for this event at the Clayburn Creek gauge. Both the modelled and recorded flow volumes are approximately 7% of the rainfall volume.

The modelled peak flow and volume are approximately 4% and 10% higher than the recorded volume for the storm, respectively.

Wet Calibration Events

The November 23 to December 3, 2009 storm was used as the first wet event calibration. This event was just under the 2-year 24-hour rainfall volume and produced the highest non-snowmelt peak flow recorded during the flow monitoring period. It occurred during a warm period where no snow was falling in the upper watershed. The volume of modelled flow was approximately 20% greater than the

Appendix D – Hydrologic and Hydraulic Modelling

recorded volume however it matched the rainfall volume input into the model. The evaporation losses in the model were negligible over the period of this storm. The recorded flow volume may be 20% lower than the rainfall volume because rain from the Marshall Site 2 gauge was used as the Ledgeview gauge record had missing data. The modelled peak flows during this event were approximately 3% higher than the recorded flows. The wet event calibration is presented in Figure D-5 below.

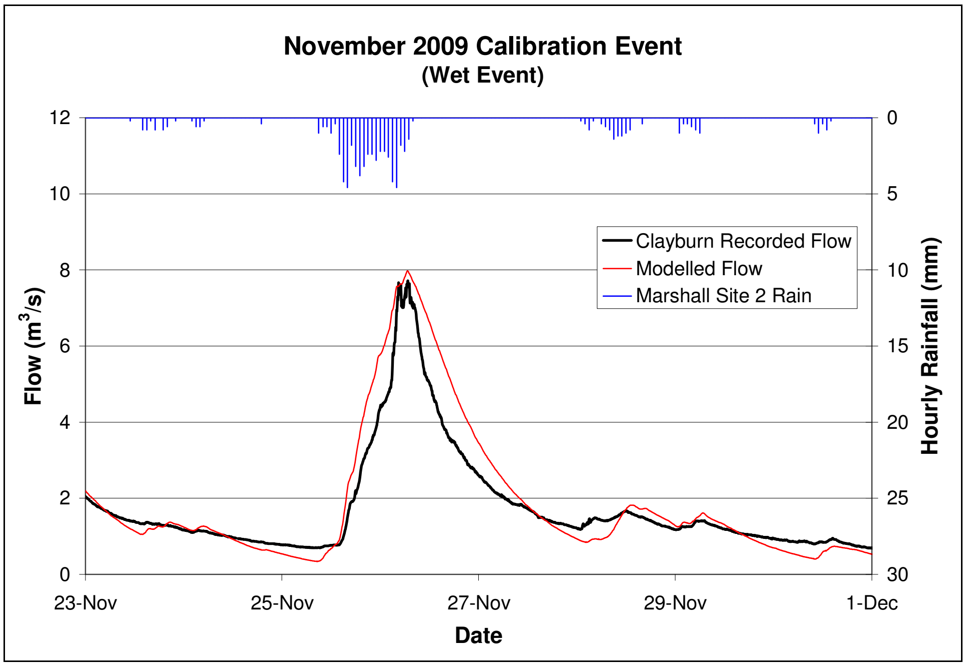

Figure D-5: Wet Event Calibration (November 2009)

The November 11-15, 2008 storm was used as the second wet event calibration. This event, which was smaller than a 2-year storm, was the next largest wet event with available data. The volume of modelled flow was approximately 6% greater than the recorded volume however it matched the rainfall volume input into the model. The evaporation losses in the model were negligible over the period of this storm. The recorded flow volume may not exactly match the rainfall volume because rain from the Abbotsford City Hall gauge was used as the Ledgeview gauge record had missing data. The modelled peak flows during this event were approximately 4% higher than the recorded flows. The second wet event calibration is presented in Figure D-6 below.

Appendix D – Hydrologic and Hydraulic Modelling

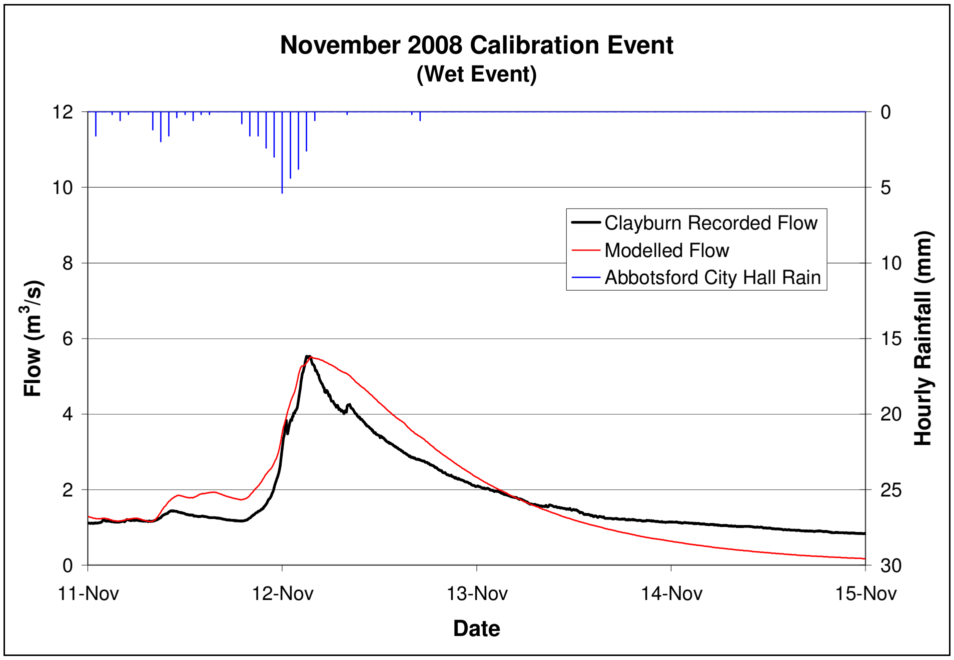

Figure D-6: Wet Event Calibration (November 2008)

D.6 Model Validation

Once calibrated, it is important to validate the hydrologic/hydraulic model against events that were not used in the calibration process. This serves as an independent check on the assumptions made during the calibration. The January 11 – 19, 2010 wet event and September 27 to October 3, 2007 dry event were used for the validation process.

The January 11-19, 2010 wet initial conditions storm was smaller than a 2-year storm. The volume of modelled flow was approximately 7% smaller than the recorded volume however it matched the rainfall volume input into the model. The recorded flow volume may not exactly match the rainfall volume because rain from the Marshall Site 2 gauge was used as the Ledgeview gauge record had missing data in this period. The modelled peak flows during this event were approximately 9% higher than the recorded flows. The second wet event validation is presented in Figure D-7 below.

Appendix D – Hydrologic and Hydraulic Modelling

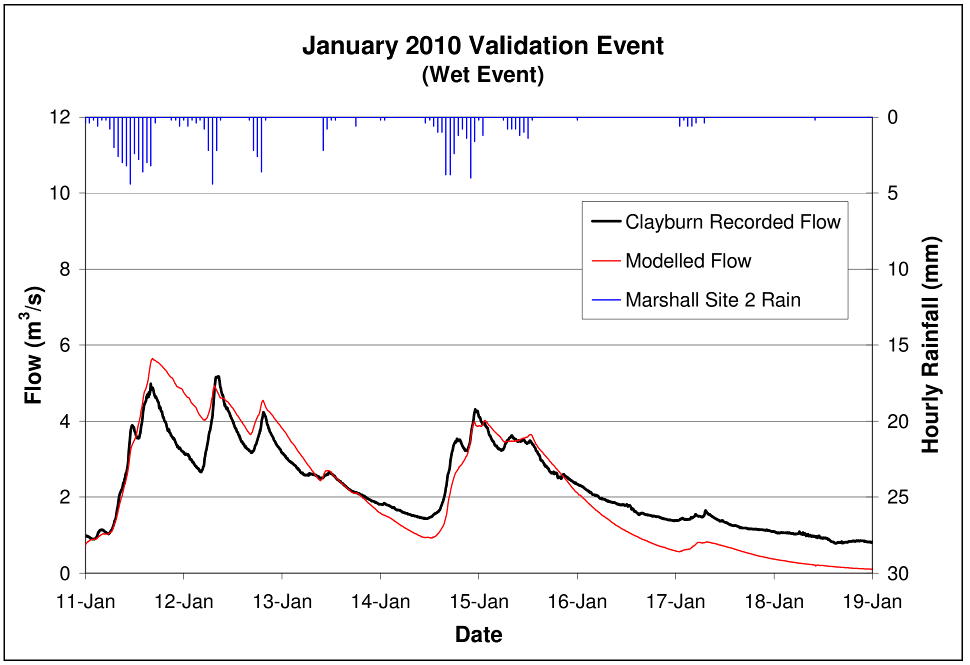

Figure D-7: Wet Event Validation (January 2010)

The September 27 to October 3, 2007 dry initial conditions storm used for validation was also smaller than a 2-year storm. The volume of modelled flow was approximately 20% smaller than the recorded volume. However it appears that there was a small amount of rainfall in the catchment on October 2 that was not captured by the Ledgeview rain gauge. This rainfall could explain the volume difference between the modelled and recorded flows. The modelled peak flows during this event were approximately 25% lower than the recorded flows (see Figure D-8).

Even though the dry event model flows did not match the recorded flows very well, further model adjustments were not pursued. The larger events that were modelled matched fairly well and additional adjustments of the model parameters could not be justified.

Appendix D – Hydrologic and Hydraulic Modelling

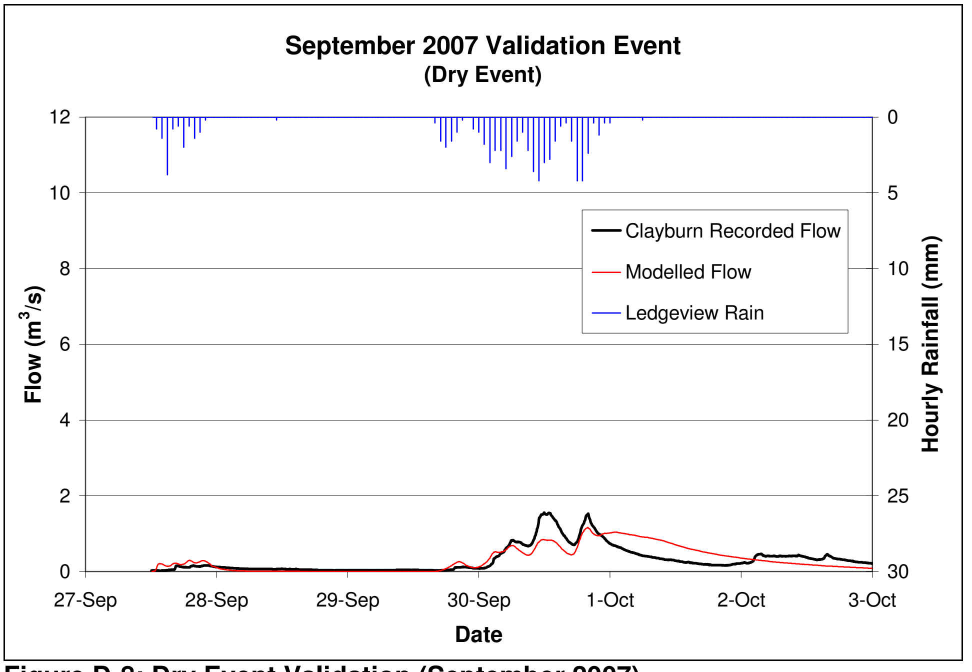

Figure D-8: Dry Event Validation (September 2007)

In summary, the Clayburn model calibration was challenging given the largely undeveloped and steep nature of the catchment upstream of the flow gauge. It appeared as though the catchment response to rainfall varied from one event to another resulting in a lengthy calibration process. Some of the differences in the recorded versus modelled flow can be attributed to processes that are difficult to model, input data imperfections, and the spatial variability of rainfall.

The model was able to reproduce the recorded peak flows fairly well and should be adequate for design peak flows estimation. It was not able to replicate sustained groundwater flows and baseflows as well. Therefore low flow results should be used with caution.

D.7 Design Storms

The Calibrated model was used to simulate the 6-month; 2-year, 5-year, 10-year, and 100-year return period 1-hour, 2-hour 6-hour, 12-hour, and 24-hour duration design events. The design rainfall was developed using the Abbotsford A AES station (1100030) and the Mission West Abby AES station (1105192). The intensities for each of the above events were developed by averaging the values from these stations. Table D-4 shows the design storm precipitation totals for all modelled events.

Appendix D – Hydrologic and Hydraulic Modelling

Table D-4: Design Storms for Clayburn Creek

Duration	6-month Total Rainfall (mm)	2-year Total Rainfall (mm)	5-year Total Rainfall (mm)	10-year Total Rainfall (mm)	100-year Total Rainfall (mm)
1-hour	9.72	13.50	17.65	20.50	29.25
2-hour	13.72	19.05	24.55	28.20	39.60
6-hour	25.06	34.80	41.30	45.70	59.25
12-hour	36.79	51.10	61.00	67.55	88.05
24-hour	51.05	70.90	85.70	95.50	126.2

All events were modelled using saturated soil conditions typical of winter conditions.

D.8 Peak Flow Estimates

The peak flow estimates at strategic locations are summarized in the following table for existing and future land use conditions. See Figure D-3 for the locations noted in Table D-5. The future land use, if left unmitigated, would increase the Clayburn Creek 6-month to 100-year peak flows by 0% to 364%, the Poignant Creek 6-month to 100-year peak flows by 0% to 29%, the Dianne Brook 6-month to 100-year peak flows by 0% to 42%, and the Stoney Creek 6-month to 100-year peak flows by 14% to 60%. The 6-month to 100-year peak flows for the total study area catchment would increase by 1% to 44%.

Unit peak flows from the existing model were checked against unit flows estimated for similar creeks in the Lower Mainland. Table D-6 shows the unit peak flow comparison.

Table D-6: Unit Peak Flow Comparison

Location	Peak Flow (L/s/ha)			
	2-year	5-year	10-year	100-year
Largely Undeveloped Catchment				
Clayburn Creek ISMP	5.9	6.1	7.8	15.1
Mackay Creek 363ha 8% TIA (North Vancouver) - recorded	15.4	22.9	28.3	48.3
MacDonald Creek 394ha 9% TIA (West Vancouver) – calibrated model	20	-	44	66
Partington Creek 442ha 3% TIA (Coquitlam) – calibrated model	15	23	24	39
Shaw Creek Undeveloped area 710ha 18% TIA (Delta)	8.4	12.1	14.6	23.6
Morgan Creek 186ha 16% TIA (Surrey) – calibrated model	6	8	-	16
Archibald Creek 220ha 16% TIA (Surrey) – calibrated model	6	12	-	24
Abbotsford Detention Release Rate (City of Abbotsford Development Bylaw No. 1565, 2006 and 2006 Streamside Protection Bylaw)	5	-	-	-

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

Table D-5: Hourly Average Peak Flow Estimates for Existing (2007) & Future (OCP) Land Use Conditions

	Location	Area (ha)	TIA		6-month (m^3/s)		2-year (m^3/s)		5-year (m^3/s)		10-year (m^3/s)		100-year (m^3/s)	
			2007	Future	2007	Future	2007	Future	2007	Future	2007	Future	2007	Future
Clayburn Creek Mainstem	Near McKee Rd. (CLAY1)	98	4%	53%	0.5	1.2	0.7	1.9	0.6	3.0	1.0	3.8	2.0	6.2
	U/S of Poignant Confluence (CLAY2)	392	10%	40%	1.8	3.1	2.4	4.7	2.5	7.4	3.7	9.2	7.7	15.9
	At Clayburn Road Bridge Flow Gauge (CLAY3)	1,580	6%	22%	6.8	6.8	9.3	9.7	9.6	15.3	12.2	18.8	23.2	38.3
	U/S of Stoney Confluence (CLAY4)	1,625	7%	22%	6.7	7.0	9.6	10.0	9.9	14.9	12.4	18.5	23.9	38.5
	U/S of Willband Creek Confluence (study area boundary) (CLAY5)	2,255	12%	27%	10.1	10.2	13.7	14.6	14.7	21.2	18.3	26.4	34.5	49.7
Dianne Brook	Near 5035 Sumas Mountain Road (DIAN1.5)	154	4%	9%	0.7	0.7	0.9	0.9	1.0	0.9	1.3	1.3	2.9	3.2
	Near Mathers Park (DIAN2)	466	5%	8%	2.0	2.0	2.7	2.8	2.9	3.9	3.9	4.9	8.7	12.4
Poignant Creek	Near 5285 Willet Rd. (POIG1.5)	234	6%	7%	1.0	1.0	1.4	1.4	1.4	1.4	2.1	2.0	4.7	4.7
	Near Clayburn Confluence (POIG2)	970	4%	16%	4.1	4.1	5.6	5.7	5.9	5.9	6.9	7.9	12.9	16.6
Stoney Creek	Near McKee Road (STON1)	220	10%	30%	1.2	1.4	1.6	1.9	1.2	2.6	2.2	3.0	4.4	6.4
	Near Stoney Creek Park (STON2)	415	27%	43%	2.7	3.7	3.4	5.0	4.9	7.1	6.0	8.4	10.0	12.1
	At Clayburn Confluence (STON3)	610	28%	41%	3.2	3.7	4.3	5.1	5.7	7.5	7.4	9.3	12.9	15.1

Blue text = upstream of Clayburn Village
TIA - Total Impervious Area, U/S = upstream, D/S = downstream
Refer to Figure D-3 for locations.

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Appendix E

Drainage Assessment

Appendix E – Drainage Assessment

Contents

Figures at end of appendix

Tables

Appendix E – Drainage Assessment

E Drainage Assessment

E.1 Introduction

This section summarizes the hydrotechnical assessments for the:

- storm sewer systems;
- culverts and bridges on the main watercourses; and
- existing detention facilities.

The assessments did not include pipe condition or age and used instantaneous peak flows not adjusted for climate change.

E.2 Urban Storm Sewers

Results from modeling the watershed's pipe network highlighted a number of areas where pipes are undersized and surcharging. The storm sewer assessment does not include culverts or bridges. Culverts and bridges are assessed separately as described in Section E.4.

Minor System

The drainage system was assessed to determine its ability to convey the minor flow, generated by the 10-year return period rainfall event. The following three criteria were used to determine whether each sewer is undersized:

- Modelled instantaneous peak flow is larger than pipe capacity under free-flowing conditions;
- Pipe surcharged for longer than 15 minutes; and
- Water surcharged higher than 0.3 m above the crown of the pipe.

Figures E-1 and E-2 show the results from the 10-year event models for the existing and future land use scenarios respectively.

Existing Conditions Minor System

Figure E-1 schematically shows the pipes that exceeded the three criteria during the existing conditions 10-year event model runs. The models were built to include the benefits of detention being provided by all existing detention facilities according to the information in their respective as-built drawings. Table E-1 lists the pipes that exceeded the minor system criteria, listed above. Pipes are shaded grey in Table E-1 when pipes not only surcharged but also flooding (water reaching the surface). 70 pipes exceeded the criteria of the 2,100 total conduits in the watershed.

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Table E-1: Storm Sewers Undersized for 10-Year Event Existing Land Use Flow

KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow*		Required Diameter (mm)
					Existing (m^3/s)	Future (m^3/s)	
Existing Storm Sewer Undersized by 2 or More Pipe Sizes							
K_400E11	400E11	MCKINLEY DR	250	0.04	0.05	0.06	375
K_420E11	420E11	MCKEE PL	250	0.07	0.31	0.33	525
K_421E11	421E11	MCKEE PL	300	0.18	0.44	0.46	450
K_908E11*	908E11	R/W S OF MCKINLEY DR	300	0.00	0.12	0.12	450
K_1309E11*	1309E11	@3836 OLD CLAYBURN RD	300	0.15	0.37	0.38	450
K_1648E11	1648E11	ANGUS CR	450	0.16	0.30	0.31	600
K_1710E11	1710E11	@3457 WHATCOM RD	450	0.20	0.37	0.40	600
K_1713E11	1713E11	@3457 WHATCOM RD	450	0.20	0.38	0.46	675
K_1262F10	1262F10	@4001 OLD CLAYBURN RD	600	0.88	1.52	1.35	825
K_2349F10	2349F10	@35131 STRAITON RD	200	0.02	0.03	0.19	450
K_2351F10	2351F10	@35131 STRAITON RD	200	0.02	0.03	0.22	525
K_2350F10	2350F10	@35131 STRAITON RD	200	0.02	0.03	0.20	450
K_2342F10	2342F10	@35131 STRAITON RD	200	0.07	0.20	0.21	375
K_1141F11	1141F11	OLD CLAYBURN RD	250	0.00	0.08	0.09	375
K_4F12	4F12	STEPHEN LEACOCK DR	300	0.17	0.27	0.32	450
K_5F12	5F12	STEPHEN LEACOCK DR	300	0.11	0.25	0.31	450
K_6F12	6F12	STEPHEN LEACOCK DR	300	0.07	0.25	0.30	525
K_370F12	370F12	@4401 BLAUSON BLVD	250	0.03	0.29	0.32	600
K_386F12	386F12	@4401 BLAUSON BLVD	250	0.12	0.29	0.32	375
K_388F12	388F12	@4401 BLAUSON BLVD	250	0.14	0.29	0.32	375
K_517E10	517E10	R/W W OF COACHSTONE WAY	525	0.23	0.73	0.72	825
K_481E10	481E10	R/W W OF COACHSTONE WAY	675	0.13	0.74	0.85	825
K_927E10	927E10	TUDOR CT	300	0.07	0.13	0.14	450
K_930E10	930E10	LABURNUM AVE	250	0.04	0.07	0.07	375
K_959E10	959E10	LABURNUM AVE	350	0.10	0.24	0.25	525
K_947E10	947E10	LABURNUM AVE	375	0.13	0.55	0.57	750
K_945E10	945E10	LABURNUM AVE	375	0.14	0.36	0.38	600
K_948E10	948E10	LABURNUM AVE	375	0.13	0.49	0.50	675
K_943E10	943E10	LABURNUM AVE	375	0.11	0.34	0.35	600
K_975E10*	975E10	TERRACE CT	375	0.18	0.26	0.27	525

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KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow*		Required Diameter (mm)
					Existing (m^3/s)	Future (m^3/s)	
K_1095E10	1095E10	HIGH DR	300	0.08	0.16	0.17	450
K_1100E10*	1100E10	HIGH DR	300	0.16	0.36	0.38	450
K_1102E10*	1102E10	HIGH DR	300	0.07	0.12	0.12	450
K_1407E10	1407E10	MONASHEE ST	450	0.17	0.43	0.45	675
K_1408E10	1408E10	MONASHEE ST	450	0.26	0.48	0.50	600
K_1416E10	1416E10	MONASHEE ST	450	0.26	0.43	0.45	600
K_1772E10*	1772E10	HIGH DR	300	0.07	0.17	0.17	450
K_1885E10	1885E10	@35045 EXBURY AVE	525	0.34	0.67	0.73	675
K_1884E10	1884E10	@35045 EXBURY AVE	525	0.30	0.68	0.72	750
K_1938E10	1938E10	@35139 LABURNUM AVE	200	0.04	0.32	0.34	450
K_111E12	111E12	@36260 MCKEE RD	150	0.01	0.35	0.35	600
K_1266F10	1266F10	CLAYBURN RD	250	0.06	0.12	0.12	375
K_1267F10	1267F10	CLAYBURN RD	250	0.05	0.11	0.11	375
K_1269F10	1269F10	CLAYBURN RD	250	0.02	0.09	0.10	375
K_1271F10	1271F10	CLAYBURN RD	250	0.04	0.08	0.08	375
Existing Storm Sewer Undersized by 1 Pipe Size							
K_1272F10	1272F10	CLAYBURN RD	250	0.04	0.06	0.06	300
K_387E11	387E11	PURCELL AVE	375	0.11	0.17	0.18	450
K_745E11	745E11	R/W E OF OLD CLAYBURN RD	375	0.28	0.34	0.34	450
K_453E11	453E11	R/W W OF MCKINLEY DR	150	0.02	0.04	0.04	200
K_454E11	454E11	R/W W OF MCKINLEY DR	200	0.08	0.09	0.09	250
K_199E11*	199E11	R/W N OF TWEEDSMUIR DR	375	0.23	0.29	0.29	450
K_446E11	446E11	MCKINLEY PL	250	0.09	0.10	0.10	300
K_901E11	901E11	R/W N OF MCKEE RD	300	0.07	0.10	0.11	375
K_1246E11*	1246E11	R/W W OF MCKINLEY DR	450	0.02	0.19	0.15	525
K_1312E11*	1312E11	@3836 OLD CLAYBURN RD	450	0.25	0.35	0.37	525
K_1306E11*	1306E11	@3836 OLD CLAYBURN RD	250	0.14	0.14	0.15	300
K_1352E11*	1352E11	NAKISKA CT	300	0.09	0.14	0.16	375
K_1361E11	1361E11	R/W S OF BOXWOOD CT	200	0.13	0.17	1.63	300
K_1010F10	1010F10	BATEMAN RD	300	0.08	0.13	0.13	375
K_2358F10	2358F10	@35131 STRAITON RD	200	0.07	0.18	0.18	300
K_1060F11	1060F11	GOODCHILD ST	450	0.19	0.20	0.22	525
K_1235F11*	1235F11	FIRDALE AVE	600	0.55	0.63	0.66	675

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KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow*		Required Diameter (mm)
					Existing (m^3/s)	Future (m^3/s)	
K_929E10	929E10	SUSSEX ST	350	0.10	0.17	0.18	450
K_940E10	940E10	IMMEL ST	375	0.11	0.18	0.19	450
K_946E10	946E10	IMMEL ST	375	0.15	0.18	0.18	450
K_1068E10	1068E10	R/W W OF MORGAN WAY	375	0.13	0.18	0.17	450
K_1843E10*	1843E10	OLD CLAYBURN RD	750	1.23	1.40	1.43	825
K_109E12*	109E12	@36260 MCKEE RD	525	0.29	0.30	0.28	600
K_1268F10	1268F10	CLAYBURN RD	250	0.08	0.10	0.10	300
K_1270F10	1270F10	CLAYBURN RD	250	0.05	0.09	0.09	300

Note:
Flooding in Existing Conditions – no climate change factors applied
Grey shading represents surcharged and flooding on the surface. Refer to Figure E-1.
*Detention facility upstream. Modification to upstream detention may reduce the required upgrade size.

Future Conditions Minor System

An additional 32 pipes have been flagged as being under capacity in the future land use scenario models. These flagged pipes are adequately sized for the existing conditions but would need to be upgrades to accommodate the future conditions flows. The future conditions models did not account for potential detention that may be implemented as part of ongoing development in the watershed. Fewer pipes would likely need replacing if detention is incorporated into future development plans.

Figure E-2 shows the flagged pipes and Table E-2 lists them. Pipes are shaded grey in Table E-2 when pipes not only surcharged but also flooding (water reaching the surface).

Table E-2: Storm Sewers Undersized for 10-Year Event Future Land Use Flow

KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow (Future) (m^3/s)	Required Diameter (mm)
K_19E11	19E11	R/W S OF MCKEE RD	250	0.03	0.05	300
K_869E11	869E11	R/W W OF WHATCOM RD	375	0.16	0.19	450
K_1353E11	1353E11	R/W S OF BOXWOOD CT	250	0.17	1.61	600
K_1357E11	1357E11	R/W W OF BOXWOOD CT	375	0.37	1.59	750
K_1358E11	1358E11	R/W W OF BOXWOOD CT	300	0.30	1.58	600
K_1359E11	1359E11	R/W W OF BOXWOOD CT	300	0.22	1.56	675
K_1360E11	1360E11	R/W S OF BOXWOOD CT	250	0.28	1.56	525
K_1709E11	1709E11	@3457 WHATCOM RD	450	0.43	0.47	525
K_1711E11	1711E11	@3457 WHATCOM RD	375	0.12	0.13	450
K_1009F10	1009F10	BATEMAN RD	300	0.07	0.09	375

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KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow (Future) (m^3/s)	Required Diameter (mm)
K_2347F10	2347F10	@35131 STRAITON RD	200	0.16	0.18	250
K_7F12	7F12	STEPHEN LEACOCK DR	300	0.12	0.15	375
K_8F12	8F12	STEPHEN LEACOCK DR	300	0.13	0.14	375
K_511E10	511E10	R/W W COACHSTONE WAY	525	0.44	0.86	675
K_518E10	518E10	R/W W COACHSTONE WAY	600	0.43	0.86	825
K_989E10	989E10	R/W N OF WRIGHT ST	150	0.02	0.03	200
K_1340E10	1340E10	MCKEE DR	250	0.05	0.05	300
K_1370E10	1370E10	R/W E OF MONASHEE ST	250	0.06	0.13	375
K_1418E10	1418E10	R/W N OF SKEENA AVE	200	0.06	0.15	300
K_1903E10	1903E10	R/W W OLD CLAYBURN RD	250	0.04	0.06	375
K_1904E10	1904E10	WRIGHT ST	150	0.01	0.03	200
K_1448E10	1448E10	R/W W OLD CLAYBURN RD	300	0.06	0.08	375
K_21E12	21E12	BUCKINGHAM DR	450	0.76	1.03	525
K_27E12	27E12	BUCKINGHAM DR	375	0.51	0.85	525
K_51E12	51E12	WESTMINSTER DR	300	0.33	0.79	450
K_70E12	70E12	WESTMINSTER DR	300	0.17	0.76	600
K_37E12	37E12	WESTMINSTER DR	300	0.33	0.77	450
K_38E12	38E12	WESTMINSTER DR	300	0.33	0.78	450
K_36E12	36E12	WESTMINSTER DR	300	0.31	0.80	450
K_131E12	131E12	BUCKINGHAM DR	600	0.68	1.04	750
K_133E12	133E12	MCKEE RD	600	0.86	1.06	675
K_137E12	137E12	MCKEE RD	600	0.52	0.79	750

Note:
Flooding in Existing Conditions – no climate change factors applied
Grey shading represents surcharged and flooding on the surface. Refer to Figure E-2.

When developing a capital works program for upgrading the storm sewer system, many of the pipes may not need to be upgraded immediately. They can continue to operate surcharged, and as they deteriorate and near the end of their design life, should be replaced with the recommended sizes at the end of their life cycle. Recommendations for upgrades and priorities are included in Section 8.6 of the report.

Appendix E – Drainage Assessment

E.3 Major System

The major system is the conveyance system that carries large storms, greater than the 10-year event and up to the 100-year event. Road surfaces and daylighted sections of creeks make up the majority of the major system in this watershed. Additionally, underground sewers have been designated as part of the major system when they are between daylighted sections of the creeks. This is to ensure that major flows from the daylighted sections have a major flow route and don't cause damage to neighbouring properties.

Some additional checks were carried out on the drainage network and its interaction with the surface grades to confirm the adequacy of the existing major flow system. The first check was to confirm that all pipes crossing private property or located in between residential lots have associated easements. It is standard industry practice to construct an overland swale that parallels the pipe in the easement, usually directly above the pipe. These swales are part of the major system and exist to ensure that large flows would not be directed towards adjacent lots to the easement. The existing of these swales was not verified, but they are assumed to be in place in locations with easements.

The second check was a flow velocity and depth of flow check for overland flow on road. This check was conducted on the largest flow modelled, the 100 year event. For steep roads, the combination of the depth and velocity of large storms can sometimes become dangerous by being able to lift and carry objects downstream and by undermining footing if walking through the flow, especially for children and small pets. The City of Abbotsford does not have a specific criterion for this check; but it is considered standard practice to check the velocity x depth of the maximum overland flow of steep roadway sections.

All road sections above pipes were checked and flagged if V x D was found to be greater than 0.4 m^2/s in the existing conditions 100 year event flow. Those pipes are shown on Figure E-3. For the purposes of this calculation, road slopes were assumed to approximately match the slope of the pipe under the road and roads were assumed to be crowned with 2% cross-fall.

The interactions between contours, the road network and the pipe network were reviewed to flag location that may not have an overland flow path (sag in the road or dead-end/cul-de-sac). No such locations were found.

The following two criteria were used to determine whether each pipe designated as the major system is undersized:

- Modelled 100-year event instantaneous peak flow is larger than pipe capacity under free-flowing conditions; and
- Pipe surcharged for longer than 15 minutes.

Figures E-3 and E-4 show the results from the 100-year event models for the existing and future land use scenarios respectively.

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Existing Conditions Major System

Figure E-3 schematically shows the pipes that exceeded the three criteria during the existing conditions 100-year event model runs. Table E-3 lists the pipes that exceeded the major system criteria, listed above. Pipes are shaded grey in Table E-3 when pipes not only surcharged but also flooding (water reaching the surface). 6 pipes exceeded the criteria of the 2,100 total conduits in the watershed.

Table E-3: Storm Sewers Undersized for 100-Year Event Existing Land Use Flow

KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow		Required Diameter (mm)
					Existing (m^3/s)	Future (m^3/s)	
K_268E11	268E11	BASSANO TERRACE	450	0.74	0.85	0.85	525
K_517E11*	517E11	SANDY HILL RD	600	1.16	1.16	1.21	675
K_525E11*	525E11	MCKINLEY DR	375	0.41	0.64	0.63	525
K_526E11*	526E11	MCKINLEY DR	375	0.54	0.64	0.63	450
K_527E11*	527E11	SANDY HILL RD	675	0.58	1.18	1.23	1050
K_860E11	860E11	R/W N OF BASSANO TERRACE	450	0.16	0.86	0.86	900

Note:
Flooding in Existing Conditions – no climate change factors applied
Grey shading represents surcharged and flooding on the surface. Refer to Figure E-3.
*Detention facility upstream. Modification to upstream detention may reduce the required upgrade size.

Future Conditions Major System

An additional three pipes have been flagged as being under capacity in the future land use scenario models. These flagged pipes are adequately sized for the existing conditions but would need to be upgrades to accommodate the future conditions flows.

Figure E-4 shows the flagged pipes and Table E-4 lists them. Pipes are shaded grey in Table E-4 when pipes not only surcharged but also flooding (water reaching the surface).

Table E-4: Storm Sewers Undersized for 100-Year Event Future Land Use Flow

KWL Conduit ID	City GIS ID	Location	Existing Diameter (mm)	Existing Pipe Capacity (m^3/s)	Inst. Peak Flow		Required Diameter (mm)
					Existing (m^3/s)	Future (m^3/s)	
K_11E11	11E11	R/W S OF LEDGEVIEW DR	375	0.4	0.3	0.8	450
K_13E11	13E11	LEDGEVIEW DR	450	0.7	0.3	0.8	525
K_33E11	33E11	R/W N OF CASTLE PINES CT	525	0.7	0.4	1.0	600

Note:
Flooding in Existing Conditions – no climate change factors applied
Grey shading represents surcharged and flooding on the surface. Refer to Figure E-4.

Appendix E – Drainage Assessment

E.4 Culvert and Bridge Assessment

Using the model results and field inventory, the culverts were assessed on their ability to pass the required peak flow (10-year or 100-year) while limiting surcharging and without flooding the land upstream. The assessment criteria were:

- Upland culverts – conveyance of the 100-year peak flow limiting the upstream surcharge depth to 50% of the culvert height above the culvert obvert.
- Lowland culverts – conveyance of the 10-year peak flow and a maximum head loss of 100 mm over the length of the culvert.

In each case, the proposed upgrades were sized for the greater of the existing or future scenario flow.

E.5 Culvert / Bridge Assessment – Existing Land Use

The results of the existing land use scenario model are presented in the following table and Figure E-5.

Table E-5: Culverts and Bridges Undersized for Existing Land Use

Culvert ID	Criteria Category	Existing Culvert Height (mm)	Inst. Peak Flow		Flooding Upstream (Existing)	Required Diameter or Size (mm)
			Existing (m^3/s)	Future (m^3/s)		
Existing Culvert/Bridge Not Adequate for Existing 100-year Flow						
CV44*	Upland (100-year)	1,500	6.7	11.1	Yes	2,700
CV135		1,000	4.9	5.2	Yes	1,800
CV133		750	1.6	1.8	Yes	1,200
CV221		1,200 & 600	5.6	7.9	Yes	2,200
CV46		600	0.3	0.6		750
CV48		300	0.2	0.2	Yes	500
CV116		350	0.4	0.9	No	900
CV193		1,200	5.7	6.1	Yes	2,000
CV140		900	2.9	5.2	Yes	1,800
CV211		600+250	1.5	1.9	Yes	Upgrade 250 to 600
CV52		550	2.8	4.8	No	1,800
CV76*		2,320	23.8	60.2	Yes	Add (2) 3,600 x 2,400
CV2*		300	7.4	14.0	No	2,700
CV224*		500	1.1	1.9	No	1,200
Existing Culvert/Bridge Not Adequate for Existing 10-year Flow						
CV89*	Lowland (0.1 m Drop)	1,880	7.8	10.4	-	(2) 3,050 x 1,500
CV60*		1,800	7.4	10.8	-	(2) 3,050 x 1,500
CV42*		600	0.4	0.7	-	1,050

Note: Green text = Bridge Refer to Figure E-5.
Flooding in Existing Conditions – no climate change factors applied
Sized for CMP replacement except where box culverts (span x rise) used
*Detention facility upstream. Modification to upstream detention may reduce the required upgrade size.

Appendix E – Drainage Assessment

Of the 45 culverts assessed, 17 were under capacity.

E.6 Culvert / Bridge Assessment – Future Land Use

Under the future land use conditions, 9 additional culvert upgrades and 3 additional bridges would be required as summarized in Table E-6 and Figure E-6.

Table E-6: Culverts and Bridges Undersized for Future Land Use

Culvert ID	Criteria Category	Existing Culvert Height (mm)	Inst. Peak Flow (Future) (m^3/s)	Flooding Upstream	Required Diameter or Size (mm)
CV86*	Lowland (0.1 m Drop)	2,160	27.9	-	(4) 2,400 x 2,100
VL51_BDG.1*		1,720	29.6	-	(5) 3,600 x 1,800
CV83*		2,150	30.6	-	(4) 3,600 x 2,100
CV113	Upland (100-year)	1,600	9.7	Yes	2,400
CV115		1,150	5.5	Yes	1,800
CV117		1,200	7.1	Yes	2,100
CV45*		1,500	8.7	Yes	2,400
CV49*		1,800	9.5	No	2,400
CV84*		1,900	60.8	Yes	(3) 3,400
VL57_BDG*		1,700	60.4	Yes	(2) 3,600 or (3) 3,300
CV50*		500	1.5	No	1,200
CV37*		1,060	10.9	Yes	2,400

Note: Green text = Bridge   Refer to Figure E-5.
Located in Clayburn Mainstem catchment, and will not require upgrade if future detention requirement is 100-year post-development flows to existing conditions.
Flooding in Future Conditions – no climate change factors applied
Sized for CMP replacement except where box culverts used
*Detention facility upstream. Modification to upstream detention may reduce the required upgrade size.

Low impact development and source control measures will not have a substantial impact during large storm events, therefore the recommended pipe sizes are assumed to be independent of these types of measures.

E.7 Proposed Drainage System Upgrades

Priority #1 infrastructure upgrades are recommended because the existing major drainage system does not provide adequate conveyance for the 100-year event and flooding could result. Priority #2 upgrades are for infrastructure that is significantly undersized (2 pipe sizes) for existing flows and Priority #3 represents infrastructure that is slightly undersized (one pipe size) for existing flows. Priority #4 upgrades are for infrastructure that is adequate under existing flows, but would require upgrade with future development. This is prioritization criteria are summarized in the following table.

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Table E-7: Prioritization Criteria for Proposed Storm Sewer, Culvert, Bridge Upgrades

Priority		Criteria		Return Period
1	5-Year Plan	Existing infrastructure inadequate for existing flow	No overland flow route	100-year
2	Long Term Plan		Requires 2 or more pipe dia. upgrade	10-year
3	End of Life		Requires 1 pipe dia. upgrade	10-year
4	DCC	Existing infrastructure adequate for existing flow, but not for future flow	Existing pipe inadequate for future 10-year or 100-year flow	10-year or 100-yr

Some undersized storm sewers are not a priority to upgrade if the area is not experiencing any problematic flooding. Because storm sewers are sized to convey the 10-year event, if they are slightly undersized it would mean that if/when the surcharged water level reached the ground surface it would be safely conveyed along the major overland flow path (road in most cases). Therefore, Priority 2 and 3 upgrades have been included in the upgrade table, but are not necessarily a priority to construct and therefore have been categorized as upgrade over the long term or at the end of the pipe life.

Proposed Storm Sewer, Culvert, Bridge Upgrades Grouped into Projects

Proposed infrastructure upgrades were grouped into projects within the same vicinity. For storm sewers, if the downstream pipes were smaller than the recommended upgrade size, then these downstream pipes were recommended for upgrade to the same pipe size as the upgraded upstream pipe. This will avoid having a smaller pipe diameter downstream of a larger diameter pipe.

Because the grouping resulted in a mix of priorities, the projects were assigned a priority corresponding to the highest priority upgrade contained in each project. Once the Priority 1, 2, and 3 projects were identified, the remaining DCC pipes (Priority 4) were not grouped into projects.

All projects are shown on Figure E-7 and in Table E-8.

Sizing of the conveyance upgrades in the ISMP is conceptual in nature and should be thoroughly assessed during pre-design. The capital cost estimates of the overall proposed infrastructure upgrades are summarized in Tables E-8.

Table E-8: Proposed Storm Sewer,Culvert and Bridge Upgrades & Cost Estimate

Project Number	Pipe / Culvert ID No.	Length (m)	Upgrade Material	Upgrade Size (mm)	Unit Cost ($/m)	Total Cost[1]
PRIORITY 1 - Upgrade to Provide Major Drainage Route						
1	K_CV44*	12	CMP	2,700	$ 37,020	$ 459,564
2	K_CV135	16	CMP	1,800	$ 15,047	$ 511,207
	K_CV133	6	CO	1,200		
	K_CV221	12	CMP	2,200		
3	K_CV46	47	CO	750	$ 6,611	$ 307,692
4	K_CV48	26	CO	500	$ 4,901	$ 127,369
5	K_CV116	34	CO	900	$ 8,540	$ 294,630
6	K_CV193	14	CMP	2,000	$ 18,790	$ 255,847
7	K_CV140	12	CMP	1,800	$ 12,935	$ 427,039
	K_CV211	21	CO	Upgrade ex. 250 to 600		
8	K_CV52	59	CMP	1,800	$ 9,647	$ 564,715
9	K_CV76*	19	CO Box	add 2 x (3,600 x 2,400)	$ 41,330	$ 795,480
10	K_CV2*	14	CMP	2,700	$ 21,465	$ 291,564
11	K_CV224*	25	CP	1,200	$ 9,755	$ 246,674
12	K_268E11	22	CO	525	$ 2,595	$ 108,800
	K_860E11	20	CO	900		
13	K_526E11*	4	CO	450	$ 2,031	$ 384,136
	K_525E11*	38	CO	525		
	K_517E11*	118	CO	675		
	K_527E11*	29	CO	1,050		
					Total Cost of Priority 1 Projects (excl. HST)	**$ 4,775,000**
PRIORITY 2 - Minor Flow Capacity - Multi-Diameter Upgrade						
14	K_CV42*	8	CO	900	$ 15,756	$ 121,703
15	K_CV89*	8	CO Box	2 x (3,050x1,500)	$ 3,130	$ 2,189,418
	K_CV60*	14	CO Box	2 x (3,050x1,500)		
	K_517E10	81	CO	900		
	K_520E10	64	CO	900		
	K_519E10	77	CO	900		
	K_511E10	57	CO	900		
	K_514E10	28	CO	900		
	K_518E10	82	CO	900		
	K_480E10	53	CO	900		
	K_481E10	100	CO	900		
	K_1010F10	135	CO	375		
16	K_111E12	3	CO	600	$ 10,640	$ 31,920
17	K_388F12	71	CO	375	$ 2,099	$ 290,524
	K_386F12	9	CO	375		
	K_370F12	3	CO	600		
	K_371F12	30	CO	600		
	K_374F12	16	CO	600		
	K_684F12	1	CO	600		
	K_72F12	8	CO	600		

Table E-8: Proposed Storm Sewer,Culvert and Bridge Upgrades & Cost Estimate

Project Number	Pipe / Culvert ID No.	Length (m)	Upgrade Material	Upgrade Size (mm)	Unit Cost ($/m)	Total Cost[1]
18	K_930E10	58	CO	375	$ 1,542	$ 1,235,091
	K_940E10	61	CO	450		
	K_946E10	44	CO	450		
	K_927E10	79	CO	450		
	K_929E10	55	CO	450		
	K_959E10	112	CO	525		
	K_943E10	50	CO	600		
	K_945E10	9	CO	600		
	K_948E10	52	CO	675		
	K_947E10	99	CO	750		
	K_967E10	40	CO	750		
	K_975E10*	75	CO	525		
	K_980E10*	64	CO	525		
19	K_420E11	91	CO	525	$ 3,061	$ 279,837
20	K_2351F10	12	CO	525	$ 1,527	$ 226,939
	K_2350F10	40	CO	525		
	K_2349F10	37	CO	525		
	K_2347F10	7	CO	525		
	K_2342F10	27	CO	375		
	K_2358F10	25	CO	375		
21	K_1710E11	29	CO	600	$ 2,293	$ 201,163
	K_1709E11	57	CO	600		
	K_1713E11	2	CO	675		
22	K_1262F10	29	CO	900	$ 3,096	$ 91,284
23	K_6F12	36	CO	525	$ 1,809	$ 145,835
	K_5F12	34	CO	525		
	K_4F12	11	CO	525		
24	K_1407E10	19	CO	675	$ 2,436	$ 173,163
	K_1416E10	26	CO	675		
	K_1408E10	26	CO	675		
25	K_1884E10	30	CO	750	$ 2,298	$ 149,844
	K_1885E10	35	CO	750		
26	K_1938E10	39	CO	450	$ 1,678	$ 94,757
	K_1941E10	17	CO	450		
27	K_400E11	30	CO	375	$ 1,817	$ 54,305
28	K_901E11	69	CO	375	$ 1,582	$ 145,137
	K_907E11	16	CO	375		
	K_908E11*	8	CO	450		
29	K_1309E11*	27	CO	450	$ 1,495	$ 284,825
	K_1307E11*	84	CO	450		
	K_1312E11*	76	CO	525		
	K_1306E11*	5	CO	300		
30	K_1648E11	17	CO	600	$ 3,277	$ 55,159
31	K_1141F11	26	CO	375	$ 1,655	$ 97,628
	K_1140F11	32	CO	375		

Table E-8: Proposed Storm Sewer,Culvert and Bridge Upgrades & Cost Estimate

Project Number	Pipe / Culvert ID No.	Length (m)	Upgrade Material	Upgrade Size (mm)	Unit Cost ($/m)	Total Cost[1]
32	K_1102E10*	18	CO	450	$ 1,333	$ 494,264
	K_1092E10*	37	CO	450		
	K_1772E10*	128	CO	450		
	K_1095E10	116	CO	450		
	K_1100E10*	44	CO	450		
	K_1775E10*	28	CO	450		
33	K_1272F10	69	CO	300	$ 1,389	$ 510,406
	K_1271F10	80	CO	375		
	K_1270F10	41	CO	375		
	K_1269F10	33	CO	375		
	K_1268F10	20	CO	375		
	K_1267F10	43	CO	375		
	K_1266F10	40	CO	375		
	K_1036F10	42	CO	375		
Total Cost of Priority 2 Projects (excl. HST)						**$ 6,873,000**
PRIORITY 3 - Minor Flow Capacity - One Pipe Diameter Upgrade						
34	K_387E11	49	CO	450	$ 1,550	$ 76,687
35	K_745E11	14	CO	450	$ 2,443	$ 211,048
	K_1843E10*	72	CO	900		
36	K_453E11	37	CO	200	$ 1,531	$ 119,084
	K_454E11	41	CO	250		
37	K_199E11*	34	CO	450	$ 1,743	$ 58,530
38	K_446E11	46	CO	300	$ 1,582	$ 72,577
39	K_1246E11*	2	CO	525	$ 13,942	$ 29,279
40	K_1352E11*	5	CO	375	$ 5,174	$ 25,872
41	K_1361E11	15	CO	300	$ 3,182	$ 636,864
	K_1353E11	29	CO	600		
	K_1360E11	12	CO	600		
	K_1359E11	48	CO	675		
	K_1358E11	53	CO	675		
	K_1357E11	31	CO	750		
	K_1362E11	13	CO	750		
42	K_1060F11	79	CO	525	$ 1,484	$ 116,686
43	K_1235F11*	13	CO	675	$ 3,713	$ 49,095
44	K_1068E10	119	CO	450	$ 1,311	$ 156,387
45	K_109E12*	3	CO	600	$ 9,798	$ 32,442
Total Cost of Priority 3 Projects (excl. HST)						**$ 1,585,000**
OVERALL TOTAL						**$ 13,233,000**

[1] Includes: 8% Mobilization / Demobilization and Bonding, 20% Construction Engineering, and 40% Contingency
CO = Concrete Pipe
CMP= Corregated Metal Pipe
Light blue text = Culverts, Dark blue text = Bridges, Black text = Storm Sewers
*Pond upstream. Modification to Upstream Pond(s) may reduce the required upgrade size.
Refer to Figure 6-7 for project numbers and Table I-6 in Appendix I for costing details.

O:\0500-0599\510-057\300-Reports\20120509_FINAL\Tables\[Tables8-6&E-8&I-6_Costs_PipesCulverts.xlsx]Table E-8

Appendix E – Drainage Assessment

E.8 Detention Assessment

A total of 64 existing detention facilities were included in the modelling to determine if these facilities are operating as intended. The following criteria were used:

- In areas tributary to Stoney Creek: 10-year post-development flows detained to 5 L/s/ha[1].
- In areas tributary to Clayburn Mainstem and Clayburn Village: 100-year post-development flows detained to 5 L/s/ha[2].

Table E-9 lists model results of the existing detention facilities located in the Stoney Creek catchment including storage usage and release rate. Table E-10 lists the detention facilities located elsewhere in the Clayburn Watershed. The tables include the tributary catchment area to each facility. In some cases two numbers are shown because the catchment area used in the model as delineated using GIS did not match the tributary area in the design drawings.

Table E-9: Detention Assessment – Stoney Creek (10-Year Detained to 5 L/s/ha Criterion)

KWL Facility ID	Location	Catchment Area (ha) Modelled & [Designed]	Inflow (L/s/ha)	Outflow (L/s/ha)	Available Storage (m^3) & [% Used]	Achieve Release Rate Criteria
Meets 5 l/s/ha Release Criterion						
P27-1 *** P27-2 ***	34700 Hearthstone Ct.	15.4 [7.5]	17.3	4.9	5340 [100%]	YES
P27-3 *** P27-4 ***		4.7	18.4	4.3	2425 [88%]	
Likely Meets Release Criterion for Intended Catchment Area and/or Previous IDF Curves						
P4	35247 Firdale Ave.	3.5 [7.5]	45.2	20.2	3137 [34%]	LIKELY
P15 ***	35410 Sandy Hill Rd.	35.25 [7.5]	13.1	12.0	333 [100%]	
P16 ***	3583 Mckinley Dr.	4.5 [2.5]	16.4	7.3	521 [100%]	
P25	35404 Well Grey Ave.	12.7 [3.8]	19.2	15.1	1141 [100%]	
P28 ***	34800 Hartnell Pl.	14.1	11.8	5.4	6041 [100%]	
P29-1 *** P29-2 ***	3939 Old Clayburn Rd.	0.3 [2.4]	55.6	6.2	4181 [1%]	
P33	35045 Exbury Ave.	6.5 [5.5]	18.8	7.1	1213 [100%]	
P35	3700 Old Clayburn Rd.	1.5 [0.69]	16.2	7.4	261 [100%]	
P48-1	35626 McKee Rd.	21.2 [1.1]	15.7	11.5	137 [100%]	

[1] City of Abbotsford Development Bylaw No. 1565, 2006

[2] City of Abbotsford – enhanced detention criteria to provide added protection to Clayburn Village

Appendix E – Drainage Assessment

KWL Facility ID	Location	Catchment Area (ha) Modelled & [Designed]	Inflow (L/s/ha)	Outflow (L/s/ha)	Available Storage (m³) & [% Used]	Achieve Release Rate Criteria
P48-2					137 [100%]	
P48-3					137 [100%]	
Outflow Exceeds 5 l/s/ha, Orifice Needs to be Smaller						
P10-1 ***	3836 Old Clayburn Rd.	4.3	97.3	65.7	1486 [7%]	NO
P10-2 ***						NO
P11	34315 Mckinley Dr.	4.1 [5.4]	102.9	74.5	792 [16%]	NO
P13 ***	3700 Mckinley Dr.	9.5 [3.0]	55.0	44.6	965 [6%]	NO
P14 ***	35300 Sandy Hill Rd.	6.1	21.0	32.8	116 [50%]	NO
P21	3391 Mckinley Dr.	1.6	75.2	11.5	552 [39%]	NO
P40 ***	35011 Old Clayburn Rd.	3.5	48	N/A	2536 [28%]	NO
P49	35626 McKee Rd.	0.2	14.5	7.4	114 [56%]	NEARLY
P50	35574 McKee Rd.	0.5	15.0	8.6	211 [72%]	NEARLY
P52 ***	34800 Mierau Street	0.2	89.3	71.4	19 [50%]	NO
P53 ***						NO
Outflow Exceeds 5 l/s/ha, Outlet Needs to be Larger to Prevent Overflows						
P20-1	35490 McKee Rd.	5.9 [2.5]	13.1	10.9	405 [92%]	NO
P20-2	35490 McKee Rd.	3.8 [4.3]	15.4	12.5	1274 [76%]	NO
P51 ***	34951 Cassiar Ave.	2.6 [1.7]	35.6	32.9	623 [18%]	NO*
Outflow Exceeds 5 l/s/ha and Facility Has Insufficient Storage Volume						
P6	4001 Old Clayburn Rd.	47.6	27.5	15.8	2730 [100%]	NO
P12	Nakiska Ct.	1.6	17.5	10.0	429 [84%]	NEARLY
P18	3532 Mckinley Dr.	1.88 [2.4]	89.6	82.7	730 [100%]	NO
P19-1	3500 Bassano Terrace	9.4 [7.6]	67.6	64.4	740 [100%]	NO
P19-2			92.2	70.1	746 [100%]	NO
P19-3			92.9	77.4	746 [100%]	NO
P24-1	35479 Tweedsmuir Dr.	5.9 [5.1]	21.5	10.0	721 [74%]	NO
P24-2		5.9 [5.1]	21.9	10.3	119 [99%]	NO
P24-3		5.8 [5.1]	21.2	14.5	346 [100%]	NO
P24-4		5.7 [5.1]	21.3	19.2	415 [100%]	NO
P26-1	3225 Whatcom Rd.	11.6 [8.7]	53.7	52.8	1678 [12%]**	NO
P26-2		11.6 [8.7]	32.8	46.4	1614 [11%]**	NO
P31 ***	35020 Kootenay Dr.	3.9 [5.0]	18.1	12.5	1139 [100%]	NO

Appendix E – Drainage Assessment

KWL Facility ID	Location	Catchment Area (ha) Modelled & [Designed]	Inflow (L/s/ha)	Outflow (L/s/ha)	Available Storage (m^3) & [% Used]	Achieve Release Rate Criteria
P32	3841 Teslin Dr.	8.5 [7.9]	64.1	43.9	2348 [100%]	NO
P36 ***	34900 Exbury Ave.	2.2	49.3	48.3	86 [94%]	NO
P39-1 ***	3292 Vernon Terrace	8.5 [4.1]	63.9	35.3	288 [100%]	NO
P39-2 ***						NO
Facility No Longer in Use or Not a Detention Facility						
P8 ***	3900 Old Clayburn Rd.	27.2	56.9	7.9	762 [18%]	Bypassed
P20-3	35470 McKee Rd.	4.2	76.0	34.3	416 [100%]	Silt Pond
P22	Westview Blvd.	4.8	7.2	2.7	3490 [12%]	Temporary
P23	Boxwood Ct.	27.9	76.2	26.2	819 [89%]	Temporary

Notes:
* Larger pipe out of detention facility required (City GIS ID: 704D10)
** Storage is at an elevation that is too high to be utilized.
*** Built prior to IDF Curve revision in 1995.
Pale blue text = significantly exceeds 5 l/s/ha criterion, >20 l/s/ha
Light blue text = moderately exceeds 5 l/s/ha criterion, 10 – 20 l/s/ha
Dark blue text = slightly exceeds criterion, <10 l/s/ha

Refer to Figure E-8.

The detention facility assessment revealed that out of 51 facilities in the Stoney Creek catchment:

- four met the 10-year flows to 5 L/s/ha criterion.
- 12 likely would meet the 10-year flows to 5 L/s/ha for their intended catchment area and/or for the previous IDF curves if designed/built prior to 1995.
- 11 exceeded the 5 L/s/ha outflow rate because orifice was too large:
  - five significantly exceeded the criterion > 20 L/s/ha
  - one moderately exceeded the criterion 10 - 20 L/s/ha
  - two nearly met the criterion
- three exceeded the 5 L/s/ha outflow rate because the outlet was too small and flows were overtopping:
  - one significantly exceeded the criterion > 20 L/s/ha
  - two moderately exceeded the criterion 10 - 20 L/s/ha
- 17 exceeded 5 L/s/ha outflow rate and appear to have insufficient storage volume:
  - 10 significantly exceeded the criterion > 20 L/s/ha
  - six moderately exceeded the criterion 10 - 20 L/s/ha
  - one nearly met the criterion
- four facilities are either not in use or are not detention facilities.

City Staff indicated that many of the detention facilities within the Stoney Creek catchment were sized and designed using old IDF curves (pre 1995 update) and therefore are rated as inadequate when

Appendix E – Drainage Assessment

assessed with current IDF data. These facilities are identified in Table E-9. Of the 22 facilities designed/built prior to 1995, four meet the criterion even with the updated IDF curves and another five would likely meet the criterion using the old IDF curves.

Table E-10: Detention Assessment – Clayburn Creek (100-Year Detained to 5 L/s/ha Criterion)

KWL Facility ID	Location	Catchment Area (ha) Modelled & [Designed]	Inflow (L/s/ha)	Outflow (L/s/ha)	Available Storage (m^3) & [% Used]	Achieve Release Rate Criteria
Meets 5 l/s/ha Release Criterion						
P43-1 P43-2	35131 Straiton Rd.	5.6 [3.5]	10.4	2.3	[100%]	YES
Likely Meets Release Criterion for Intended Catchment Area						
P5	Armstrong Ave.	0.9 [0.72]	95.5	7.9	[100%]	LIKELY
P7	3800 Golf Course Dr.	4.2 [3.4]	26.6	21.1	[100%]	
P9-1	Angus Cr.	11.1 [6.6]	27.6	20.9	[100%]	
P17	35702 McKee Rd.	20.2 [4.8]	22.1	15.9	[99%]	
P44	36260 McKee Rd.	3.6 [1.0]	32.8	19.9	[100%]	
P45	36260 McKee Rd.	4.8 [2.6]	108	10.7	[100%]	
P46	36217 Buckingham	14.7 [5.2]	60.0	21.5	[100%]	
Outflow Exceeds 5 l/s/ha and Facility Has Insufficient Storage Volume						
P1	Blauson Blvd.	9.9	22.1	7.9	[100%]	NEARLY
P2	4300 Shearwater Dr.	4.9	86.2	82.0	[93%]	NO
P3 ***	35298 S. of Belanger Dr.	6.0	23.2	17.3	[100%]	NO
P47	2nd Auguston Pond	18.4 (3.0)	40.8	16.3	[100%]	NO

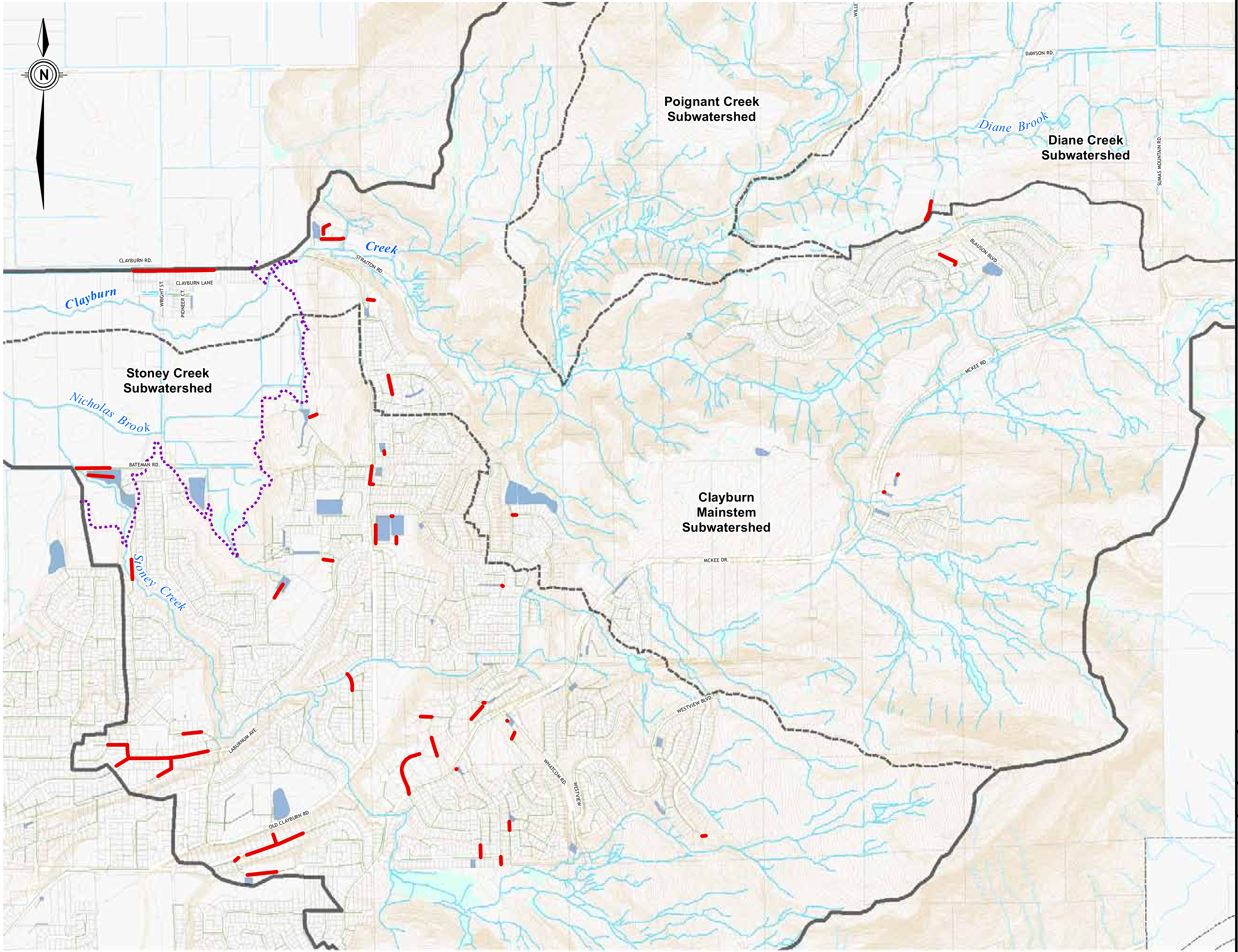
Notes: Refer to Figure E-8.
*** Built prior to IDF Curve revision in 1995.
Pale blue text = significantly exceeds 5 l/s/ha criterion, >20 l/s/ha
Light blue text = moderately exceeds 5 l/s/ha criterion, 10 – 20 l/s/ha
Dark blue text = slightly exceeds criterion, <10 l/s/ha

Out of 13 facilities in the Clayburn Mainstem catchment:

- two met the 100-year flows to 5 L/s/ha criterion.
- seven likely would meet the 100-year flows to 5 L/s/ha for their intended catchment area.
- four exceeded the 5 L/s/ha outflow rate and appear to have insufficient storage volume:
  - one significantly exceeded the criterion > 20 L/s/ha
  - two moderately exceeded the criterion 10 - 20 L/s/ha
  - one nearly met the criterion

The detention facilities were further assessed and prioritized In Section 8.6.

City of Abbotsford
Clayburn Creek
ISMP



Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Minor System Meets Criteria
- Minor System (10-Year) Surcharge 0.3 m over Crown for > 15 min.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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consulting engineers

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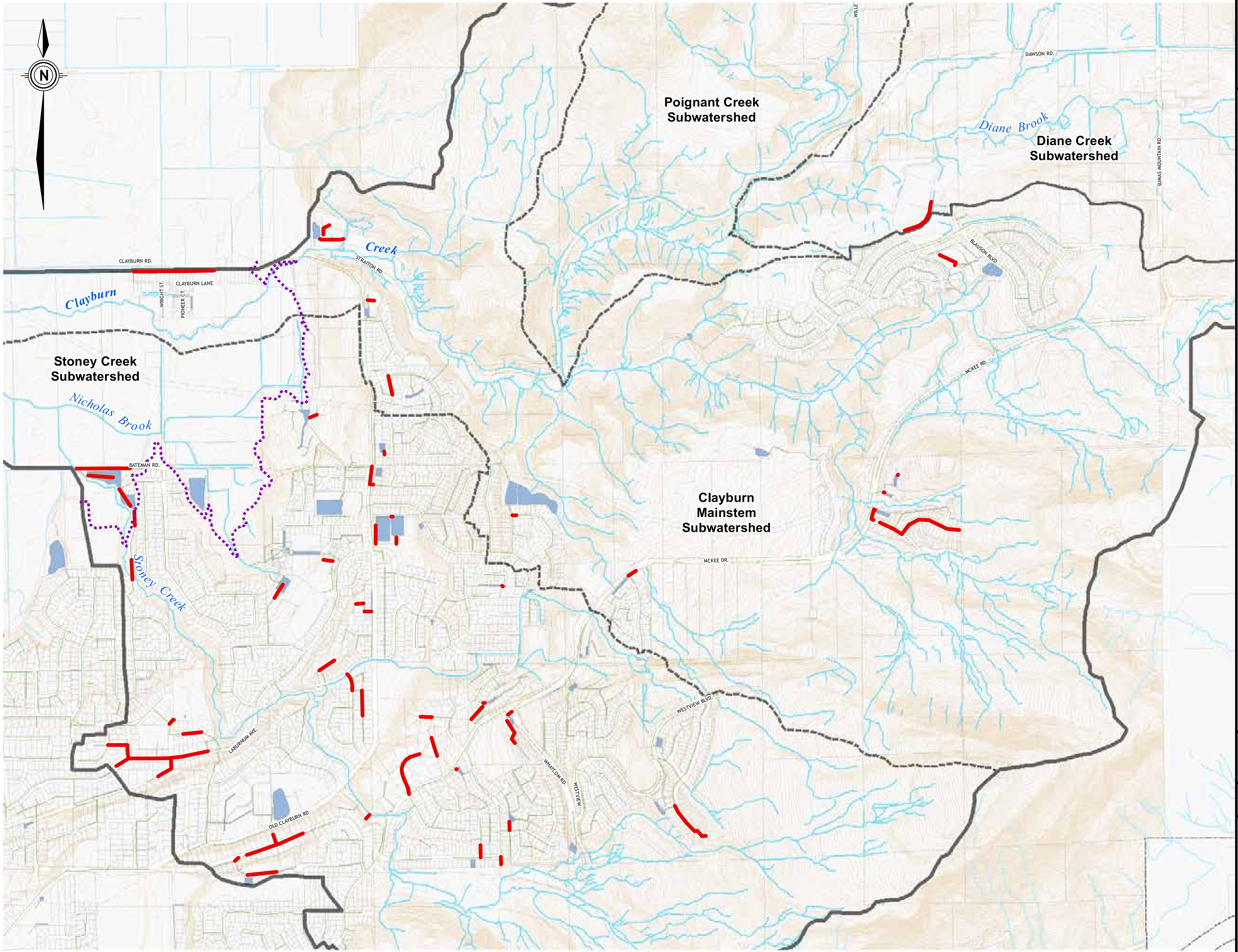
Project No.	Date
510-057	May 2012

10-Year Event Existing Land Use Storm Sewer Assessment

Figure E-1



City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Minor System Meets Criteria
- Minor System (10-Year) Surcharge 0.3 m over Crown for > 15 min.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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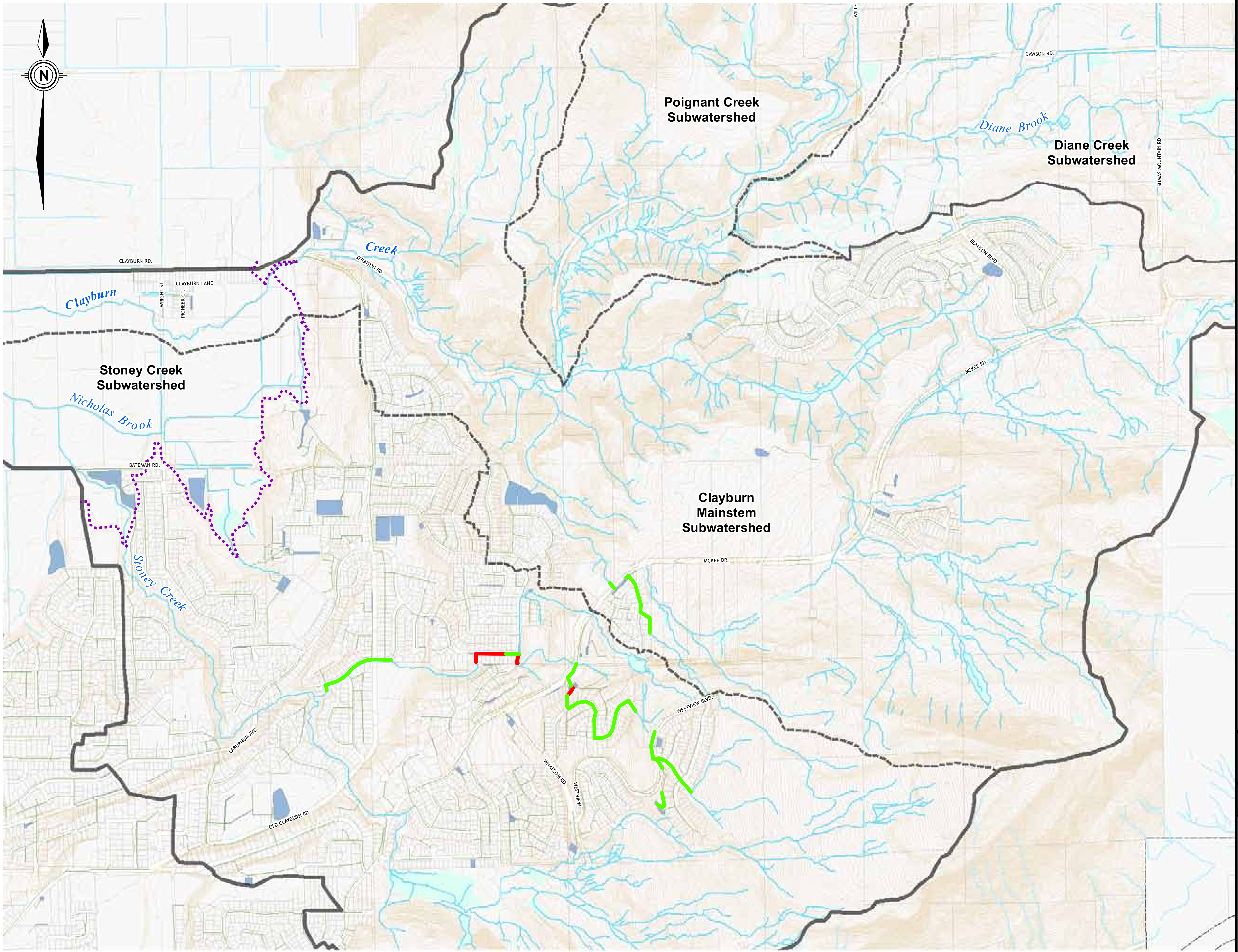
Project No.	Date
510-057	May 2012

10-Year Event Future Land Use Storm Sewer Assessment

Figure E-2

City of Abbotsford
Clayburn Creek
ISMP



Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Minor System
- Major System Meets Criteria
- Major System (100-Year) Surcharge over Crown for > 15 min.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Project No.	Date
510-057	May 2012

100-Year Event Existing Land Use Storm Sewer Assessment

Figure E-3

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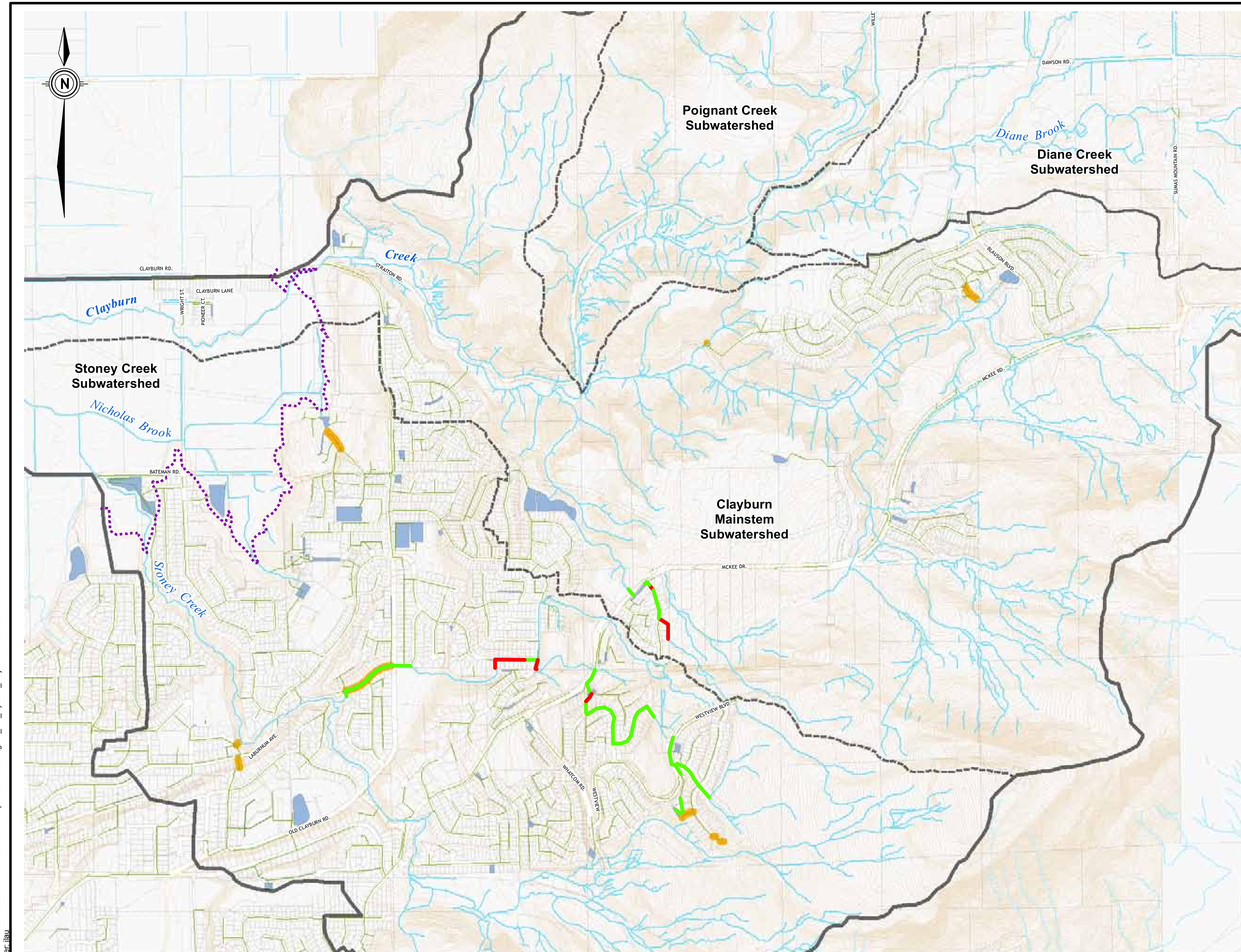

City of Abbotsford
Clayburn Creek
ISMP

Legend

- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Minor System
- Major System Meets Criteria
- Major System (100-Year) Surcharge over Crown for > 15 min.
- Pipe Flagged During Gutter Flow Check (100 Year Velocity x Depth > 0.4 m^2/s)

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Project No.	Date
510-057	May 2012

100-Year Event Future Land Use Storm Sewer Assessment

Figure E-4

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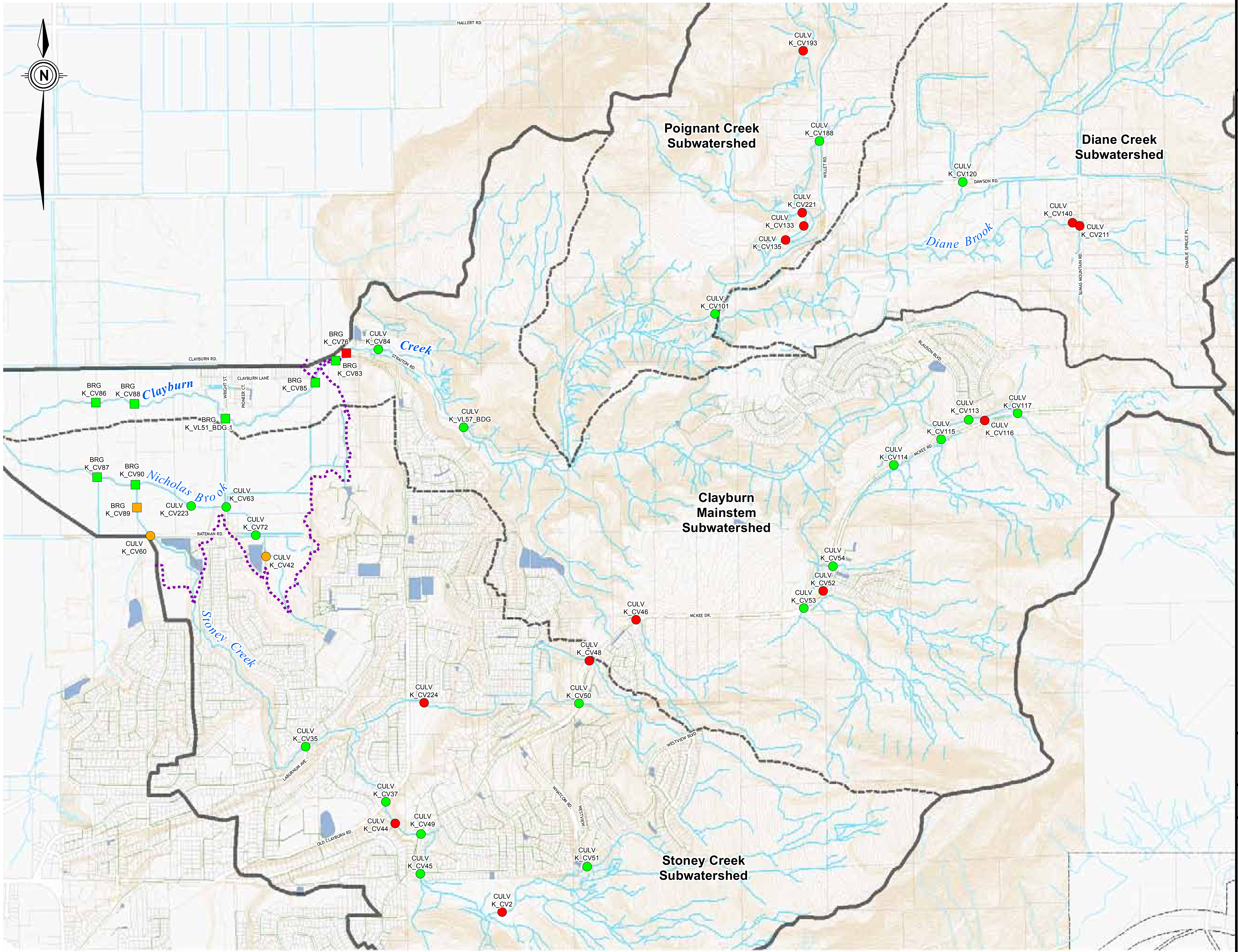

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Storm Main

Existing Culvert and Bridge Upgrades

- Meets Criteria
- Lowland (10-Year) > 10 cm Headloss
- Upland (100-Year) Surcharge > 15 min.
- BRG ID Bridge
- CULV ID Culvert

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Project No.	Date
510-057	May 2012

Culvert/Bridge Capacity Assessment - Existing Land Use

Figure E-5

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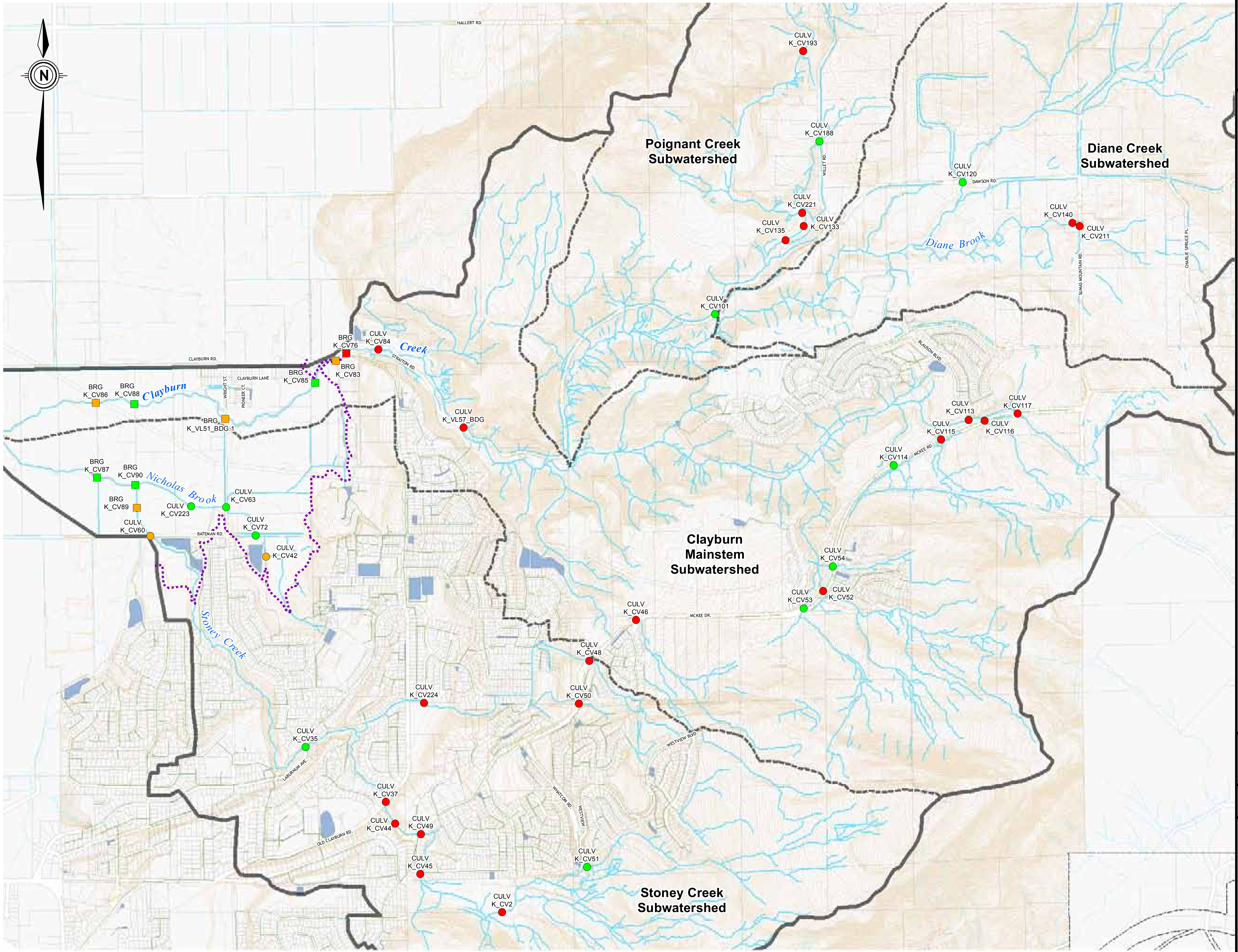

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Storm Main

Future Culvert and Bridge Upgrades

- Meets Criteria
- Lowland (10-Year) > 10 cm Headloss
- Upland (100-Year) Surcharge > 15 min.
- BRG ID Bridge
- CULV ID Culvert

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Project No.	Date
510-057	May 2012

Culvert/Bridge Capacity Assessment - Future Land Use

Figure E-6

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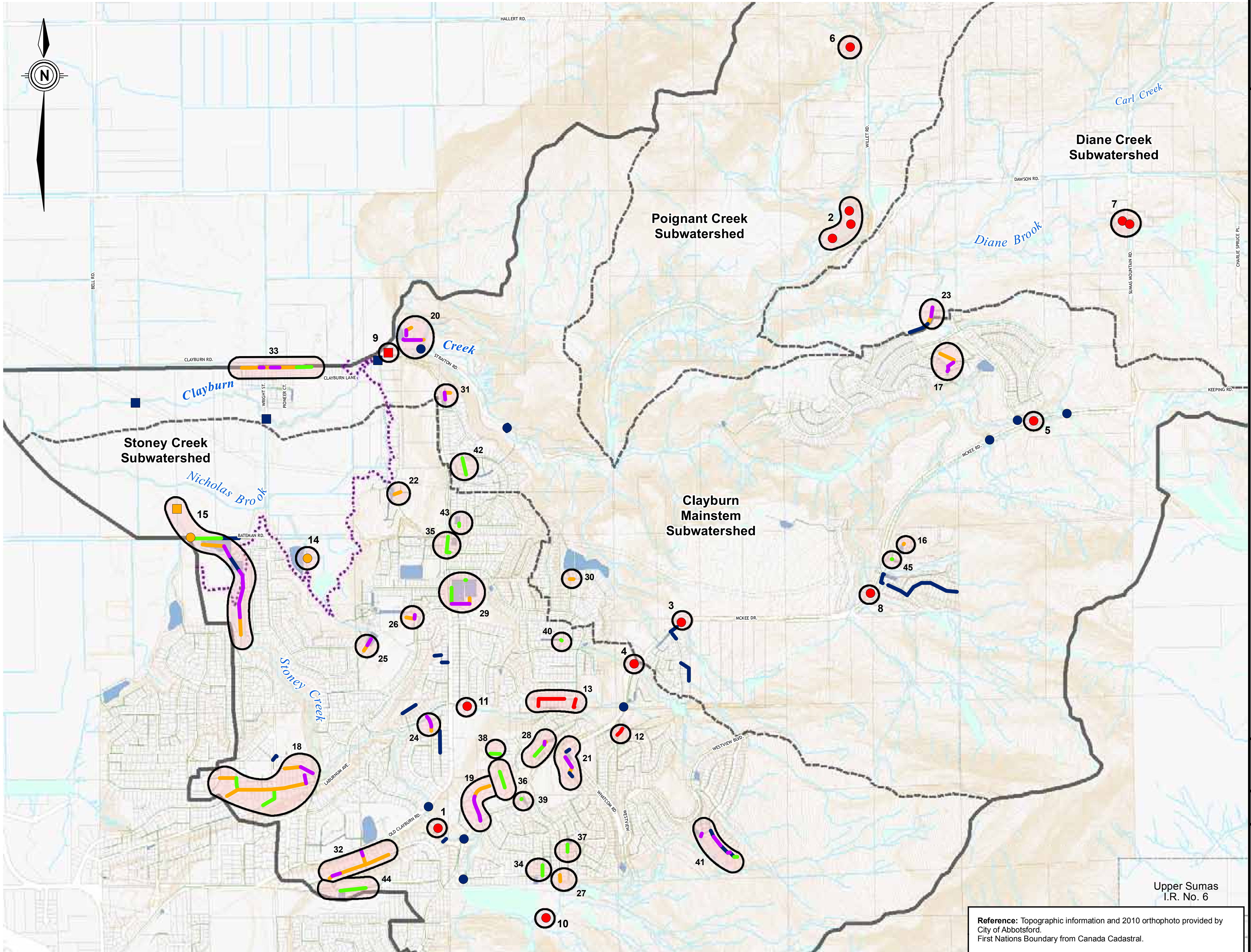

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Detention Facility
- Open Water and Marshes
- Storm Main
- Upgrade Due to Upstream Upgrade

Storm Main Priority Upgrade

- 1
- 2
- 3
- 4

Project ID (Refer to Table E-7)

Bridge/ Culvert Priority Upgrade

- 1
- 2
- 4

Project ID (Refer to Table E-7)

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Project No.	Date
510-057	May 2012

Proposed Storm Sewer and Culvert Upgrades

Figure E-7

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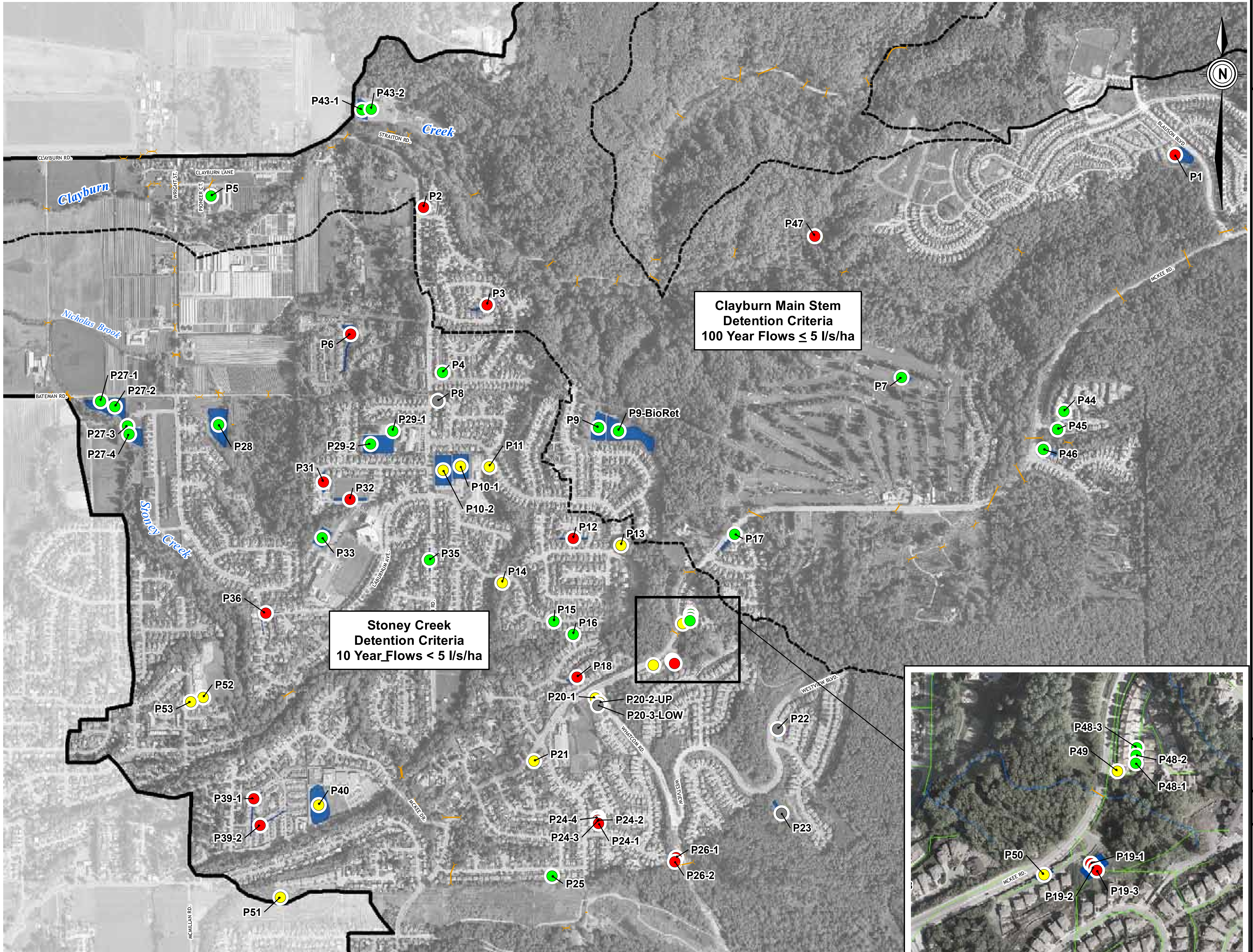
City of Abbotsford
Clayburn Creek
ISMP



Legend

- Watershed Boundary
- Subwatersheds Boundary
- Culvert
- Storm Main
- Creeks and Streams
- Open Water and Marshes
- Detention Facility

Detention Assessment

- 25 - Meets Criteria
- 14 - Outlet Modification Required to Meet Criteria
- 21 - Insufficient Storage Volume to Meet Criteria
- 4 - No Longer in Use or Not a Detention Facility

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Project No.	Date
510-057	May 2012

Detention Assessment Existing Land Use

Figure E-8

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Appendix F

Stream Erosion and Lowland Sediment Management

Appendix F – Erosion and Lowland Sediment Management

Contents

Figures

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Appendix F – Erosion and Lowland Sediment Management

F Erosion and Lowland Sediment Management

F.1 Overview on Sediment Transport Capacity

Creeks are capable of mobilizing and transporting sediment (sand, gravel and even coarser material). The amount of energy available to a given creek to do work is proportional to both:

- discharge (flow); and
- gradient.

Both factors are important and tend to offset each other somewhat, since steep reaches tend to be located in the headwaters of the watershed where discharges are relatively small. Figure 2-3 shows a map of stream gradient for the Clayburn Creek watershed, and profile plots are shown in Figure 2-4. As indicated in these figures, channel gradients tend to be highest in the upper portions of the watershed and decline with distance downstream.

Sediment transport in gravel bed creeks can be correlated with stream power, but it exhibits threshold behaviour in that a certain minimum discharge is required before entrainment occurs. The entrainment threshold is partially a function of the sediment size (i.e., movement of cobbles requires a higher discharge than movement of fine gravel), but is also affected by things like armouring, and other adjustments to the bed surface (imbrication, stone lines, etc.) In general, the threshold for movement of sand is very low: sand can be readily mobilized and transported at quite low flows. In comparison, the threshold for movement of gravel is much more difficult to define, since streambed stability is a function not just of the size of the gravel but also how the individual stones interact.

As the creek's sediment transport capacity declines, material is deposited in the channel. Typically where a creek flows out of a steep upland area and onto a lower-gradient valley floor, it will form a fan from the deposition of material that it has eroded and transported from steeper upstream reaches. Larger material is deposited first, which results in a gradual fining of deposited material with distance downstream. Very fine material such as fine sand and silt can be transported even under extremely low flows and therefore can be transported long distances downstream of where it was mobilized. Figure 2-3 indicates the approximate limits of the Clayburn Creek fan.

F.2 Sediment Sources

Refer to Section 5-5 of report.

F.3 Sediment Management Activities

Sediment management activities on Clayburn Creek include both managed sediment traps and removals from the creek channel at locations other than the sediment traps.

Appendix F – Erosion and Lowland Sediment Management

Sediment Removals from the Channel

Extensive sediment removal from the Clayburn Creek channel occurred 25 to 30 years ago, including unregulated removals by local residents (Golder, 2007[1]). From the early 1990s until very recently, no in-channel removals were conducted. In 2007, a sediment removal was conducted by excavating material from gravel bars in the channel. About 90 m^3 of sediment was removed. On September 18, 2009, a sediment removal was conducted by excavating material from gravel bars in the channel upstream of the Wright Street bridge. Approximately 119 m^3 of sediment was removed.

Sediment Traps

The City maintains a number of sediment traps on Clayburn Creek (Figure F-1). These traps are maintained on an annual or less frequent basis. Removals from the traps have been partially documented.

F.4 Assessment of Sediment Supply

Sediment Budget

In order to effectively manage sediment, the sediment budget for the reach of concern needs to be quantified in order to determine the rate of sediment supply. The simplified sediment budget equation is:

$$I - O = \Delta S$$

where *I* is the volume of sediment coming into the reach, *O* is the volume of sediment leaving the reach and ΔS is the change in sediment stored in the channel. Very little gravel is transported past the Stoney Creek confluence with Clayburn Creek; therefore, for the gravel sediment budget *O* is effectively zero. However, finer sediment is transported downstream.

The fact that most of the coarse sediment is deposited upstream of the Stoney Creek confluence means that the rate of coarse sediment supply (*I*) is effectively equal to the change in storage (ΔS) (i.e. the coarse sediment supplied to the reach is deposited in the channel).

In-Channel Sediment Storage

On Clayburn Creek, the change in sediment storage (ΔS) can be estimated from a comparison of repeat topographic surveys. Topographic survey data for the lower creek channel was collected in 1992, 2006/2007 and 2009 (Figure F-1). The 1992 survey covers the entire reach of interest, from the upper Clayburn Road crossing to the confluence with Stoney Creek. The 2009 survey does not extend downstream of Wright Street so the storage estimate is based on the 2006/7 survey as well.

[1] Golder Associates Ltd., 2007. Geomorphic Review of Proposed Gravel Removal Clayburn Creek, Abbotsford, BC. Report prepared for the City of Abbotsford.

Appendix F – Erosion and Lowland Sediment Management

Cut-fill areas were estimated for repeat cross-sections, and multiplied by a representative channel length to estimate a volume. Volumes are summarized in the following table.

Table F-1: Change in Sediment Storage in Lower Clayburn Creek (1992 to 2006/2007/2009)

Reach	Survey Data	Net Change in Sediment Storage (m^3)
Clayburn Rd Bridge to 180 m U/S of Wright St	1992 and 2009	440
180 m U/S of Wright St to Stoney Creek confluence	1992 and 2006/7	357

Notes: Survey locations shown on Figure F-1.
1. 1992 survey Clayburn Creek Upstream of Clayburn Village down to confluence with Stoney Creek from City Drawing D732.
2. 2006 survey Clayburn Village down to confluence with Stoney Creek from City Drawing D846 (May 2, 2006).
3. 2007 survey through Clayburn Village and Stoney Creek at Bateman Road from City Drawing D887 (Dec. 17, 2007).
4. 2009 survey Clayburn Creek Upstream of Clayburn Village from City Drawing D846E (Sept. 22, 2009).

Sediment Removals

In addition to the measured change in sediment storage based on a comparison of topographic surveys, the sediment budget must also account for any sediment that has been removed from the reach within that same time period (since that sediment would otherwise have remained in the channel and have been accounted for in the topographic survey comparison).

Documentation of sediment removals is somewhat sparse so the removal volumes are uncertain and may be lower-bound (minimum) estimates. The removal volumes are summarized in the following table.

Table F-2: Sediment Removals in Lower Clayburn Creek (1992 to 2009)

Removal Location	Date of Removal	Total Removal Volume
MST1: Clayburn Creek at Straiton Rd / College Sediment Trap	annually	80 m^3/year
MST15: Clayburn Creek at Wright Street	-	unknown
MST12: Clayburn Creek at Dutra Farms	1990 to 2008	576 m^3
MST16: Clayburn Creek at Stoney Creek	-	Unknown
Channel Gravel Bars	2007, 2009	205 m^3

Note:
1. Removal volumes provided by City of Abbotsford staff and are approximate.

Appendix F – Erosion and Lowland Sediment Management

Estimated Sediment Influx

Combining the change in sediment storage with the estimated volume of removals for the same time period yields an estimate of the sediment influx for that same time period. The estimated sediment influx for the 1992 to 2009 period is summarized in the table below.

Table F-3: Estimated Sediment Influx for Lower Clayburn Creek (1992 to 2009)

Time Period	Change in Sediment Storage (m^3)	Sediment Removals (m^3)	Sum (m^3)	Average Annual Rate (m^3/year)
1992 to 2009	797	2,221	3,018	168

Note:
1. Time period 1992 to 2009 is assumed to represent 18 years.

As a secondary check on this value, a typical sediment yield range was estimated using regional data collected in BC (Church et al., 1999[2]). The envelope for sediment yield for a 16 km^2 watershed is approximately 10 to 200 kg/km^2/day. This is equivalent to 27 to 550 m^3 per year. Of note, the regional data are based on measurements of suspended sediment, and typically bedload is a very small fraction of the total sediment yield from a watershed (i.e. the suspended sediment load greatly exceeds the bed material load carried by most creeks and rivers).

Examination of average annual bedload data from Pemberton Creek (near Pemberton) and Lynn Creek (in North Vancouver), and scaling by drainage area gives an estimated bedload of approximately 230 m^3 per year for Clayburn Creek.

The sediment influx estimated using the creek survey falls within the regional sediment yield envelope and is similar to the bedload estimate from other BC watersheds.

Summary

The sediment budget analysis for lower Clayburn Creek yields an estimated average annual sediment influx volume of about 170 m^3/year for the reach between Straiton Road and the Stoney Creek confluence for the past 20 years. This excludes the fine sediment that is transported past this reach and deposited downstream of the Stoney Creek confluence.

In should be noted that the analysis has a degree of uncertainty from the following factors:

- the change in sediment storage for part of the reach was only assessed up to 2006/7; and
- the removal volumes are not well documented and so may be underestimated.

The average rate is provided for illustration only since transport of gravel is an episodic process that is very sensitive to discharge: years that have higher peak flows will result in more gravel transport than years with lower peak flows.

[2] Church et al., 1999. Fluvial clastic sediment yield in Canada: scaled analysis. Canadian Journal of Earth Science, 36: 1267-1280.

Appendix F – Erosion and Lowland Sediment Management

As indicated by the relatively modest change in sediment storage over the reach in the past 20 years or so, the sediment maintenance activities that have been carried out (sediment traps and in-channel removals), have partially kept up with the sediment influx into the reach. If the influx were greatly in excess of the removal rate, we would expect to see much more aggradation over the past two decades.

Exact annual removal volumes are not known, but this analysis suggests that maintenance activities should target an average removal volume of about 170 m^3/year in the reach between the upper Clayburn Road crossing and the Stoney Creek confluence in order to keep up with the estimated sediment influx.

F.5 Watercourse Hazards

Steep mountain creeks may be subject to a spectrum of events, ranging from clear water floods to debris flows. These creek events are typically categorized by sediment concentration, with clear water floods having the lowest concentrations of sediment, debris flows having the highest sediment concentrations, and debris floods having an intermediate sediment concentration between the two.

Debris floods are a very rapid, surging flow of water, heavily charged with debris, in a steep channel (Hungr et al., 2001[3]). The sediment may, furthermore, be transported in the form of massive surges, leaving sheets of poorly sorted debris ranging from sand to cobbles or small boulders. Sediment surges in debris floods are propelled by the tractive forces of water flowing over the debris, and flow velocities are comparable to those of water floods. The peak discharge (flow rate) of debris floods is commonly 2 to 5 times higher than that of 200 year return period water floods (Jakob and Jordan, 2001[4]).

Screening Assessment

A desktop screening assessment was conducted to assess the named tributaries in the upper Clayburn watershed for debris flow or debris flood potential. The results from this screening assessment may be used to assist with future studies that may be conducted to determine whether the tributary watershed is physically capable of debris flow or debris flood generation.

Research has indicated that basic watershed measured attributes are related to the type of hydrogeomorphic hazard that forms (and impacts) the fan at the outlet of the watershed. This is related to the physics of initiation, transport and deposition of these events, which dictate a certain range of slope steepness and channel gradients for each of the different hazards.

It has been shown that a scatter-plot of watershed Melton Ratio vs. watershed length can successfully discriminate between floods, debris floods and debris flow watersheds in BC (Wilford et al., 2004[5]). The Melton Ratio is defined as the ratio of total watershed relief (in km) to the square root of the drainage area (km^2). The watershed length is the planimetric straight line distance from the outlet of the watershed (the fan apex) to the most distant point on the watershed boundary.

---

[3] Hungr, O., Evans, S.G., Bovis, M.J., and Hutchinson, J.N. 2001. A review of the classification of landslides in the flow type. Environmental and Engineering Geoscience VII(3): 221-228.
[4] Jakob, M. and Jordan, P. 2001. Design floods in mountain streams – the need for a geomorphic approach. Canadian Journal of Civil Engineering 28 (3): 425-439.
[5] Wilford, D.J., M.E. Sakals, J.L. Innes, R.C. Sidle and W.A. Bergerud. 2004. Recognition of debris flow, debris flood and flood hazard through watershed morphometrics. *Landslides* **1**:61-66.

Appendix F – Erosion and Lowland Sediment Management

This screening tool was applied to the following tributaries:

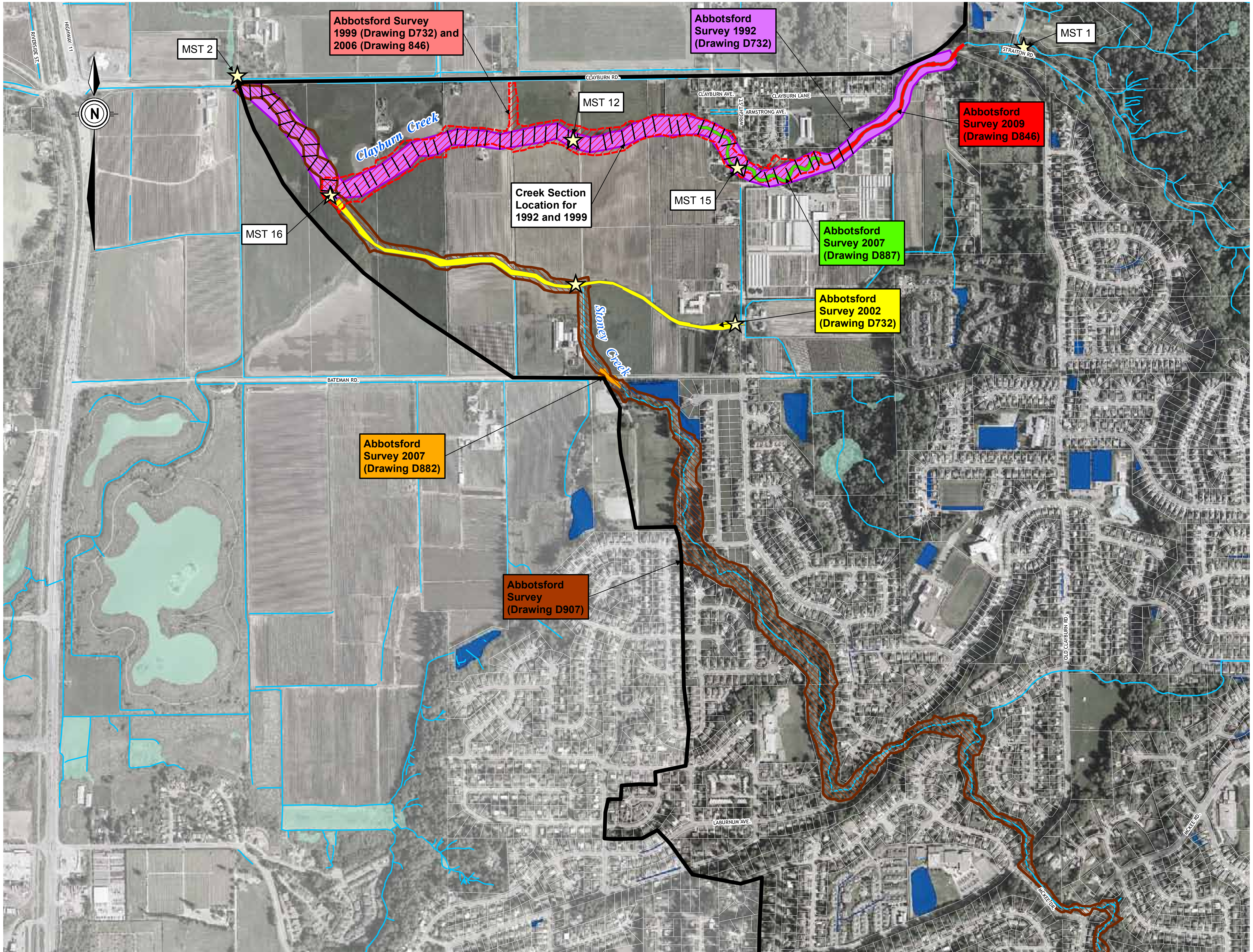
- Poignant Creek
- Diane Creek
- Upper Clayburn Creek
- Upper Stoney Creek

Measurements were based on existing GIS topographic data provided by the City.

Wilford et al. (2004) have defined three zones on the scatter-plot for water floods, debris floods and debris flows. The watersheds were measured and plotted to see where they fall in comparison to the different zones (Figure F-2). All four watersheds plot in the zone of floods.

It should be noted that the morphometric screening alone is insufficient basis to determine the likelihood of a debris flood or debris flow event or the frequency with which they may occur, but may provide a basis for future detailed investigation.

City of Abbotsford
Clayburn Creek
ISMP



Legend

- Watershed Boundary
- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Approximate Location of Sediment Traps

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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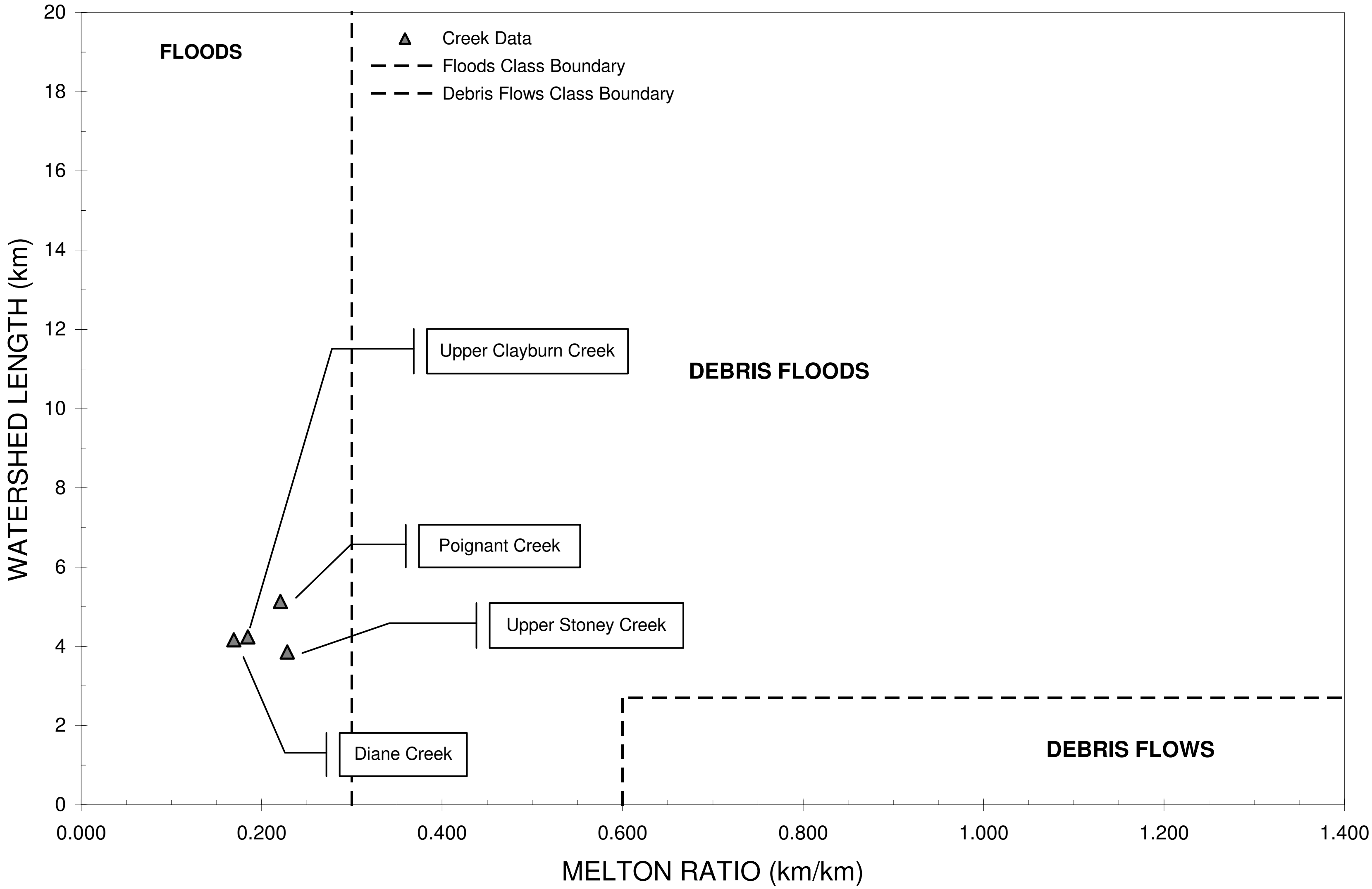
Project No.	Date
510-057	May 2012

Lowland Survey Channel Locations

Figure F-1

Screening for Hydrogeomorphic Processes Based on Melton Ratio and Watershed Length
(after Wilford et al., 2004)



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O:\0500-0599\510-057\400-Work\HazardScreen\DebrisFloodFlow-MorphometricScreen.xls / Screening Figure

Figure F-2

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Appendix G

Hydrologic Mitigation Measures for Environmental Protection

Appendix G – Mitigation Measures

Contents

Appendix G – Mitigation Measures

G Mitigation Measures

G.1 Low Impact Development Practices

Introduction

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

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

Reduced Road Widths

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

Reduced Building Footprints

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

Reduced Parking Standards

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

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

Appendix G – Mitigation Measures

Limiting Surface Parking

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

Pervious Parking Surfaces

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

Reinforced Clean Crushed Gravel

Geogrid

Building Compact Communities

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

Preserving Naturally Significant Features

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

Appendix G – Mitigation Measures

G.2 Stormwater Source Control Technologies

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

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

Absorbent Landscaping

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

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

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

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

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

Appendix G – Mitigation Measures

Absorbent Landscaping

Absorbent Landscaping

Surface Infiltration Facilities

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

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

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

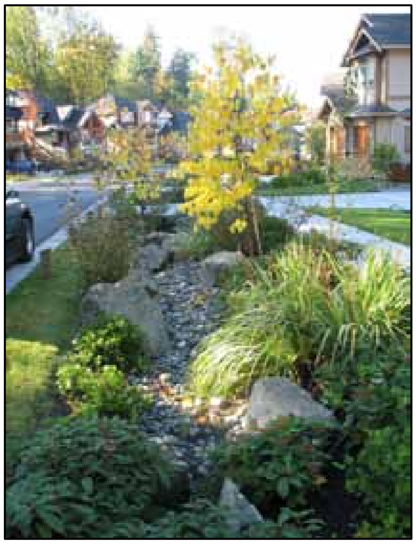
Surface infiltration can also be promoted by the used of permeable pavers or other pervious surfacing materials.

Bio-Retention Facilities

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

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

Appendix G – Mitigation Measures



Bio-Retention Swale

Bio-Retention Swale

Sub-surface Infiltration Facilities

Sub-Surface Infiltration

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

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

Green Roofs

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

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

Appendix G – Mitigation Measures

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

Green Roof

Green Roof

Rainwater Re-use

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

Appendix G – Mitigation Measures

Re-Use Tank

Re-Use Rain Barrel

Water Quality Best Management Practices

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

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

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

Water Quality Best Practical Technologies

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

Appendix G – Mitigation Measures

Biofilters

Biofilters are vegetated filter strips, swales and rain gardens that remove deleterious substances, notably particulate contaminants, though some combination of physical (e.g.: adsorption) and biological (biodegradation) removal mechanisms. Biofilter technology is suitable for sheet flow runoff, typical of large linear impervious developments like roadways and parking lots.

Urban Forests and Leave Strips

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

Infiltration Systems

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

Constructed Wetlands

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

Small Wetland

Wetland

Appendix G – Mitigation Measures

Wet Detention Ponds

Permanent wet ponds remove pollutants and other deleterious substances through physical processes such as sedimentation, filtration, absorption and adsorption and through biological mechanisms such as: uptake and conversion by plants, and microbial degradation. Wet ponds can also detain flows thereby contributing to rate control and volume reduction objectives. General design parameters need to include: vegetation types (floating, emergent and submergent vegetation), water depth and ponding area, and will often require consideration of detailed pond specific operational parameters.

Oil and Grit Separators

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

Oil Grit Separator

Oil Grit Separator

Construction Best Practices

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

Appendix G – Mitigation Measures

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

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

G.3 Stormwater Detention Systems

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

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

G.4 Infiltration Systems

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

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

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

Appendix H

Stakeholder and Public Input

Appendix H – Stakeholder Consultation Program

H.1 Summary of Stakeholder Consultation Process & Feedback

The stakeholder discussions were used to identify all the interdependent aspects and issues to ensure they were covered, offer the opportunity for creative solutions to unfold, and ensure that the final recommendations will have widespread stakeholder support needed for implementation to occur.

Stakeholder meetings are listed with attendees and discussion topics below. These meetings were incorporated throughout the work program to present information and findings and to obtain input along the way. DFO had a particularly important role to ensure the developed solutions were acceptable to them. Additional stakeholder input was collected through the City website and mail-in questionnaires.

Phase 1: Data Collection and Review

- **Habitat Review Panel Meeting on December 10, 2009**

  Attendance included the City of Abbotsford, DFO, BC Ministry of Environment, KWL, and Raincoast Applied Ecology. The ISMP study was introduced and known key issues were presented. Discussion topics included bank erosion and instability, corridors and setbacks, and future development.

- **Letter & Questionnaire Mailout** sent to lowland residents and posted on the City's website to solicit input on key issues in the watershed. January 2010

- **Abbotsford Environmental Advisory Committee Meeting on January 28, 2010**

  KWL presented ISMP information to the Abbotsford Environmental Advisory Committee for input and discussion.

- **Public Information Meeting No. 1 on April 13, 2010**

  Invitations to the first public meeting were sent to residents of Clayburn Village within the study area, City Council and various City Committees. Public invitations were also posted on the City of Abbotsford website and in the Abbotsford News.

  43 people attended the meeting. The City of Abbotsford opened the meeting with a presentation on the background of the project and a summary of flooding issues from 1988 through to present. Information was also presented by KWL, Raincoast Applied Ecology, and residents of Clayburn Village. Presentations were followed by discussion and input from the participants. Written comments were also solicited.

  The main comments and concerns from the meeting and written comments included:

  1. flooding in Clayburn Village and interim measures prior to ISMP finalization
  2. upslope development and impacts to flows downstream
  3. need for low impact development
  4. desire for environmental restoration and enhancement
  5. rare and endangered species, fish populations, invasive species, etc.

Appendix H – Stakeholder Consultation Program

Phase 2: Technical Assessments

- **Clayburn ISMP Advisory Group Meeting on December 14, 2010**

  An ISMP Advisory Group was formed with representatives from: the City Industry Development Advisory Committee (CIDAC); the Environmental Advisory Committee (EAC); the Matsqui Prairie Dyking, Drainage and Irrigation Committee (MPDDI); and Clayburn Village residents. KWL and Raincoast Applied Ecology presented options to the Advisory Group for dealing with key issues in the watershed. City staff also attended.

  Topics examined included the December 12, 2010 flood and prior floods. The mitigation options of a diversion channel and a berm were discussed.

Phase 3: Alternatives

- **Habitat Review Panel Meeting on January 13, 2011**

  Attendance included City of Abbotsford Environmental Staff, DFO, and BC Ministry of Environment. A presentation by KWL and Raincoast Applied Ecology was followed by a discussion of the preferred options for flood protection, rehabilitating existing erosion, removing deposited sediment, protecting fish and wildlife, and improving fish habitat.

- **Ministry of Environment Letter February 17, 2011**

  The Ministry of Environment suggested that when potential future development options are being reviewed, the following areas receive consideration:

  - As an initial step, determine whether proposed land uses are appropriate for the local soil and geological conditions;
  - Enforce the new Erosion and Sediment Control Bylaw;
  - Enforce the City's Streamside Protection Bylaw, by maintaining full intact riparian setbacks;
  - Require source controls and low impact development measures in new developments; and
  - Assess the effectiveness of the ISMP and adapt as appropriate.

- **Habitat Review Panel DFO Meeting on April 20, 2011**

  The City of Abbotsford, KWL and Raincoast Applied Ecology met with DFO to receive feedback on which of the options for addressing flooding along the lower Clayburn Creek channel would be supported by the DFO. Discussion topics included the Wright Street bridge, berms, channel enlargement, a bypass floodway, Clayburn Road flood protection, and sediment removal.

- **Public Information Meeting No. 2 on June 29, 2011**

  The second public meeting was advertised through the City of Abbotsford website and the Abbotsford News. Invitations were hand delivered (during the postal strike) to Clayburn Village residents within the study area, City Council and various City Committees. Presentations from the City of Abbotsford and KWL were followed by a discussion period. Written comments were solicited.

Appendix H – Stakeholder Consultation Program

The key issues brought up during this meeting included:

1. Sediment aggradation in lowland channel and lack of freeboard to drain agricultural lands. Need to get value for tax collected.
2. Sediment aggradation under Wright Street Bridge to be removed in 2011 fisheries window. Possible long term bridge raising.
3. Creek bank erosion adjacent to the school in Clayburn Village.
4. Scouring under Clayburn Creek / Stirling Road Bridge. *This issue was addressed in September 2010 with the installation of a rock weir on the downstream side of the bridge to reduce velocities under the bridge.*
5. Climate change to be considered. Feeling that 10% increase is not enough.
6. Pre-development (forested) should be the baseline, not existing (2008) land use.
7. Check actual function of detention systems, not just modelled theoretical function. Believe that Auguston detention ponds are inadequate.

The key issues brought up in the written comments included:

8. Support for diversion concept, but prefer pipe past Village not open channel.
9. Not supportive of additional channels for fish habitat or additional protected areas or corridors for wildlife.
10. Support for creek dredging and sediment removal.
11. Opposition to all upland development.

In general, the feedback focussed mainly on the Clayburn Village and lowland flooding issues. Key points are summarized below:

- DFO was generally supportive of the lowland flood protection options, preferring the diversion of flows in excess of 2-year and incorporating fish habitat in the bypass floodway. DFO also preferred to maximize the use of existing sediment traps versus in-stream sediment removals. DFO was also supportive of set back berms to preserve the existing riparian vegetation.
- The Clayburn Village residents were not supportive of increasing the conveyance capacity of the lowland creek channel, but preferred emphasis on reducing the upland flows especially from existing development. They were not supportive of berms that would result in loss of private property.
- Some residents within and outside the watershed wanted the natural state of the watershed preserved and to not allow further upland development.
- The lowland agricultural property owners preferred dredging of the Clayburn Creek channel and the Matsqui Prairie channels to improve the poor drainage (DFO does not allow channel dredging). They were not supportive of berms if they impacted the field drainage.
- The City preferred a phased, permanent solution to the flooding issues.

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Phase 4: The ISMP Plan

- **Clayburn ISMP Advisory Group Meeting on October 13, 2011**

  The technical findings of pre-development modelling, causes of lowland flooding, and the draft ISMP Plan were reviewed.

- **Public Information Meeting No. 3 on October 24, 2011**

  Approximately 90 people attended the meeting at the Clayburn Schoolhouse. The technical findings of pre-development modelling, causes of lowland flooding, and the draft ISMP Plan were presented and reviewed.

  The following summarizes the comments received:

1. The owner of 4262 Wright Street wants to be consulted regarding the type and location of berm/wall on his property.
2. The Stirling Property owners noted the erosion under the Stirling Road/Clayburn Creek bridge and expressed their desire to meet on site with KWL.
3. A Clayburn Village resident sent various photos and description of debris carried by the creek, an article regarding ponds becoming popular, a reference to the water balance model, and a summary of mistakes made in the past relating to emergency preparedness and response and the improvements needed to the response process.
4. The owner of 34922 Clayburn Road:
   i. agrees with lowland works
   ii. is more supportive of environmental protection vs development
   iii. is concerned about upland forest clearing
   iv. wants monitoring of effectiveness of facilities into the future
   v. wants regulation of contractors undertaking future development
   vi. wants to know what will happen after the 10 year plan horizon

   In the comment table, strongly agrees with all elements except for oil interceptors with which he agrees
5. The owner of 34980 Clayburn Road agrees with the proposed lowland works and wants the City to be sure developers put in detention ponds that will work. In the comment table, agrees or strongly agrees with all elements.
6. The owner of #15 – 35060 Clayburn Road asked whether any consideration has been given to decreasing the velocity of Clayburn Creek water east of Clayburn Road and noted that bank erosion along the property was not identified in the ISMP.
7. The owner of 34159 Clayburn Road:
   i. currently can only utilize 75% of land due to flooding
   ii. asked how will the farmland be able to drain with the berms in place and if it is to be drained with floodboxes, how to grow year-round crops and not be forced to grow annual crops
   iii. asked how much land does the ISMP require from the property

Appendix H – Stakeholder Consultation Program

iv. asked if the ISMP will guarantee a solution to flooding

In the comment table, disagrees or strongly disagrees with widening creek for conveyance, raising low spots in Clayburn Road, upgrading culverts/bridges/storm sewers, sediment management under Wright Street bridge, and restoring riparian buffers

- **Public Information Meeting No. 4 on December 13, 2011**

  Approximately 20 people attended the meeting at City Hall. The final draft ISMP Plan was presented using poster presentation format.

  The following summarizes the comments received:

1. There is erosion on the northeast bank of Clayburn Road just past the Clayburn/Straiton Bridge with trees falling into creek.
2. Asked that the proposed floodwall adjacent to the Clayburn Schoolhouse blends in with the historic flavour of the area and positioned farther away from the school to direct the creek back to where it used to be (to the southwest).
3. Prioritize the lowland works to protect the Village first.
4. Confirm that the Wright Street bridge is not a capacity constraint. Concerned about how much Wright Street will be raised to match the berms and the impact on adjacent properties.
5. Is there budget in 2012 for some of the proposed works?
6. How long will the lowland works take?
7. The owners of 4290 Wright Street may not support the berm through their property because:
   i. it will significantly reduce the size of their lot
   ii. they may lose their tree farm status if they can't grow trees on the berm
   iii. it will encourage the City to keep developing the uplands
8. Is sediment management on the proposed flood bench feasible? Does not appear to be enough access points to the bench for trucks.
9. Did MAF provide input and who was consulted? What did they say about the berms?
10. Does DFO still support this lowlands plan? Do we have assurance from them?

Appendix I

Cost Estimates

Appendix I – Cost Estimates

Contents

Tables

Appendix I – Cost Estimates

I.1 Class 'D' Cost Estimates and Assumptions

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

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

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

- Mobilization/Demobilization and Bonding – 8%;
- Construction Engineering – 20%; and
- Contingency – 40%.

HST has not been included in the estimated project costs. The unit prices reflect KWL's recent experience with similar work, and therefore represent the best prediction of actual (2011) costs as of the date prepared. Actual tendered costs would depend on such things as market conditions generally, remoteness factor, the time of year, contractors' work loads, any perceived risk exposure associated with the work, and unknown conditions.

Table I-1: Lowland Flood Protection - Option 2: Channel Enlargement to Contain 100-year Flow

Description	Upgrade Type	Length (m)	New Channel Area (m^2)	Excavation Needed (m^3)	Width (m)	Seeded Area (m^2)	Unit Costs: Equipment	Costs: Equipment	Costs: Seeding 2.2	Costs: Total
Clayburn Creek Bridge Upgrades										
Driveway 35004 Clayburn Road	$1M allowance for bridge replacement									$ 1,000,000
Driveway 34888 Armstrong Ave	$1M allowance for bridge replacement									$ 1,000,000
Wright Street Bridge	$1M allowance for bridge replacement									$ 1,000,000
Driveway 34416 Clayburn Road	$1M allowance for bridge replacement									$ 1,000,000
Driveway 34583 Bateman Road	$1M allowance for bridge replacement									$ 1,000,000
Driveway Lot: 1 Sec: 34 Twn: 16 Plan: 3114	$1M allowance for bridge replacement									$ 1,000,000
Clayburn Creek Channel Enlargement					Bench Width					
Clayburn Channel	Flood Bench	700	10	7,000	10	7,000	$ 33	$ 231,000	$ 15,400	$ 246,400
Clayburn Channel	Flood Bench	1,300	7	9,100	7	9,100	$ 40	$ 364,000	$ 20,020	$ 384,020
SUBTOTAL COSTS										**$ 6,630,000**
Mobilization/Demobilization and Bonding (8%)										$ 530,400
Construction Engineering (20%)										$ 1,326,000
Contingency (40%)										$ 2,652,000
TOTAL COSTS (excl. HST)										**$ 11,138,000**

ROW Land Acquisition Costs

Description	Width of ROW (m)	Area (m^2)	Unit Cost ($\$/m^2$)	Total
Clayburn Channel	10	7,000	$ 19.77	$ 138,390
Clayburn Channel	7	9,100	$ 19.77	$ 179,907
TOTAL COSTS (excl. HST)				**$ 318,000**

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Table I-2: Lowland Flood Protection - Option 3: Berms to Contain 100-year Flow

Description	Upgrade									Unit Costs	Costs					
	Type	Pipe Size or Channel Depth (mm)	Length (m)	Up Invert (m)	Dn Invert (m)	Slope %	Existing Channel Fill (m^3)	Width (m)	Seeded Area (m^2)	Fill Supply	Equipment	Headwalls /Manholes	Access Road 20	Pipe	Seeding 2.2	Total
Clayburn Village Storm Sewer																
100-Year Storm Sewer	Circular	750	1,300	6.00	2.00	0.31						$ 55,900		$ 412,500		$ 468,400
Clayburn Creek Bridge Upgrades																
Driveway 35004 Clayburn Road	$1M allowance for bridge replacement															$ 1,000,000
Driveway 34888 Armstrong Ave	$1M allowance for bridge replacement															$ 1,000,000
Wright Street Bridge	$1M allowance for bridge replacement															$ 1,000,000
Driveway 34416 Clayburn Road	$1M allowance for bridge replacement															$ 1,000,000
Driveway 34583 Bateman Road	$1M allowance for bridge replacement															$ 1,000,000
Driveway Lot: 1 Sec: 34 Twn: 16 Plan: 3114	$1M allowance for bridge replacement															$ 1,000,000
Clayburn Creek Berms								Base Width								
0.5m High Berms	2.5 m2 berm XS area		1,000				2.5	7	7,000	$ 60	$ 150,000		$ 20,000		$ 15,400	$ 185,400
1.0m High Berms	7 m2 berm XS area		1,800				7.0	11	19,800	$ 60	$ 756,000		$ 36,000		$ 43,560	$ 835,560
1.5m High Berms	13.5 m2 berm XS area		1,100				13.5	15	16,500	$ 60	$ 891,000		$ 22,000		$ 36,300	$ 949,300
SUBTOTAL COSTS																**$ 8,439,000**
Mobilization/Demobilization and Bonding (8%)																$ 675,100
Construction Engineering (20%)																$ 1,687,800
Contingency (40%)																$ 3,375,600
TOTAL COSTS (excl. HST)																**$ 14,178,000**

Description	ROW Land Acquisition Costs				
	Width of ROW m	Area m^2	Unit Cost $/$m^2$	Land Sub Total	Total
0.5m High Berms	4	4,000	$ 19.77	$ 79,080	$ 79,080
1.0m High Berms	5	9,000	$ 19.77	$ 177,930	$ 177,930
1.5m High Berms	6	6,600	$ 19.77	$ 130,482	$ 130,482
TOTAL COSTS (excl. HST)					**$ 387,000**

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Table I-3: Lowland Flood Protection - Option 4: 100-Year Diversion Channel

Description	Upgrade															Unit Costs		Costs					
	Type	Pipe Size or Channel Depth (mm)	Bottom Width (mm)	Left Side Slope 1v:x h	Right Side Slope 1v:x h	Length (m)	Up Invert (m)	Dn Invert (m)	Slope %	New Channel Area (m^2)	Existing Channel Fill (m^3)	Excavation Needed (m^3)	Width (m)	Deepening (m)	Seeded Area (m^2)	Equipment	Fill Supply 27	Equipment	Headwalls	Access Road 20	Culvert	Seeding 2.2	Total
Diversion Channel																							
Clayburn Creek to Flow Split													Top Width										
Diversion Channel	Trapezoidal	2,000	9,000	2	2	80	1.70	1.60	0.13	26	0	2,080	17	2	1,360	$ 25	$ 27	$ 52,000		$ -		$ 2,992	$ 54,992
Diversion Culvert	Box	(3) 1,500 x 3,050				50	1.75	1.70	0.10							$ 40	$ 27	$ -	$ 90,000	$ -	$ 890,395	$ -	$ 980,395
Diversion Channel	Trapezoidal	2,000	9,000	2	2	400	2.15	1.75	0.10	26	0	10,400	17	2	6,800	$ 25	$ 27	$ 260,000		$ -		$ 14,960	$ 274,960
Diversion Culvert	Box	(3) 1,500 x 3,050				20	2.20	2.15	0.25							$ 40	$ 27	$ -	$ 90,000	$ -	$ 404,470	$ -	$ 494,470
Diversion Channel	Trapezoidal	2,000	9,000	2	2	140	2.40	2.20	0.14	26	0	3,640	17	2	2,380	$ 25	$ 27	$ 91,000		$ -		$ 5,236	$ 96,236
Diversion Culvert	Box	(3) 1,500 x 3,050				50	2.50	2.40	0.20							$ 40	$ 27	$ -	$ 90,000	$ -	$ 890,395	$ -	$ 980,395
Diversion Channel	Trapezoidal	2,000	6,000	2	2	520	4.40	2.50	0.37	20	0	10,400	14	2	7,280	$ 25	$ 27	$ 260,000		$ -		$ 16,016	$ 276,016
Diversion Culvert	Box	(3) 1,500 x 3,050				10	4.50	4.40	1.00							$ 40	$ 27	$ -	$ 60,000	$ -	$ 154,495	$ -	$ 214,495
Diversion Channel	Trapezoidal	2,000	6,000	2	2	70	5.00	4.50	0.71	20	0	1,400	14	2	980	$ 25	$ 27	$ 35,000		$ -		$ 2,156	$ 37,156
Diversion Culvert	Box	(3) 1,500 x 3,050				100	6.00	5.00	1.00							$ 40	$ 27	$ -	$ 60,000	$ -	$ 1,249,710	$ -	$ 1,309,710
Diversion Channel	Trapezoidal	2,000	5,000	2	2	190	8.00	6.00	1.05	18	0	3,420	13	2	2,470	$ 25	$ 27	$ 85,500		$ -		$ 5,434	$ 90,934
Diversion Culvert	Box	(2) 1,500 x 2,400				60	9.00	8.00	1.67							$ 40	$ 27	$ -	$ 60,000	$ -	$ 519,640	$ -	$ 579,640
Diversion Channel	Trapezoidal	2,000	5,000	2	2	60	9.90	9.00	1.50	18	0	1,080	13	2	780	$ 25	$ 27	$ 27,000		$ -		$ 1,716	$ 28,716
Diversion Culvert	Box	(2) 1,500 x 2,400				60	11.10	9.90	2.00							$ 40	$ 27	$ -	$ 60,000	$ -	$ 519,640	$ -	$ 579,640
Diversion Channel	Trapezoidal	2,000	5,000	2	2	100	12.10	11.10	1.00	18	0	1,800	13	2	1,300	$ 25	$ 27	$ 45,000		$ -		$ 2,860	$ 47,860
Diversion Culvert	Box	(2) 1,500 x 2,400				20	12.50	12.10	2.00							$ 40	$ 27	$ -	$ 60,000	$ -	$ 225,280	$ -	$ 285,280
SUBTOTAL COSTS																							**$ 6,331,000**
Mobilization/Demobilization and Bonding (8%)																							$ 506,500
Construction Engineering (20%)																							$ 1,266,200
Contingency (40%)																							$ 2,532,400
TOTAL COSTS (excl. HST)																							**$ 10,636,000**

ROW Land Acquisition Costs				
Width of ROW m	Area m^2	Unit Cost $\$/m^2$	Land Sub Total	Total
17	1,360	$ 19.77	$ 26,887	$ 26,887
17	850	$ 19.77	$ 16,805	$ 16,805
17	6,800	$ 19.77	$ 134,436	$ 134,436
17	340	$ 19.77	$ 6,722	$ 6,722
17	2,380	$ 19.77	$ 47,053	$ 47,053
17	850	$ 19.77	$ 16,805	$ 16,805
14	7,280	$ 19.77	$ 143,926	$ 143,926
14	140	$ 19.77	$ 2,768	$ 2,768
14	980	$ 19.77	$ 19,375	$ 19,375
	0	$ 19.77	$ -	$ -
	0	$ 19.77	$ -	$ -
13	780	$ 19.77	$ 15,421	$ 15,421
13	780	$ 19.77	$ 15,421	$ 15,421
13	780	$ 19.77	$ 15,421	$ 15,421
13	1,300	$ 19.77	$ 25,701	$ 25,701
13	260	$ 19.77	$ 5,140	$ 5,140
				$ 492,000

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Table I-4: Lowland Flood Protection - Option 5: Channel Enlargement and Berms and Diversion Channel

Description	Upgrade: Type	Pipe Size or Channel Depth (mm)	Bottom Width (mm)	Left Side Slope 1v:x h	Right Side Slope 1v:x h	Length (m)	Up Invert (m)	Dn Invert (m)	Slope %	New Channel Area (m²)	Existing channel Fill (m³)	Excavation Needed (m³)	Top Width (m)	Deepening (m)	Seeded Area (m²)	Unit Costs: Equipment	Unit Costs: Fill Supply	Costs: Equipment	Headwalls /Manholes	Access Road 20	Pipe	Seeding 2.2	Total
Diversion Channel																							
Clayburn Creek to Flow Split																							
Diversion Channel	Trapezoidal	2,000	6,000	2	2	80	1.70	1.60	0.13	20	0	1,600	14	2	1,120	$ 25		$ 40,000		$ -		$ 2,464	$ 42,464
Diversion Culvert	Box	(2) 1,500 x 3,050				50	1.75	1.70	0.10							$ 40		$ -	$ 60,000	$ -	$ 664,650	$ -	$ 724,650
Diversion Channel	Trapezoidal	2,000	6,000	2	2	400	2.15	1.75	0.10	20	0	8,000	14	2	5,600	$ 25		$ 200,000		$ -		$ 12,320	$ 212,320
Diversion Culvert	Box	(2) 1,500 x 3,050				20	2.20	2.15	0.25							$ 40		$ -	$ 60,000	$ -	$ 295,700	$ -	$ 355,700
Diversion Channel	Trapezoidal	2,000	6,000	2	2	140	2.40	2.20	0.14	20	0	2,800	14	2	1,960	$ 25		$ 70,000		$ -		$ 4,312	$ 74,312
Diversion Culvert	Box	(2) 1,500 x 3,050				50	2.50	2.40	0.20							$ 40		$ -	$ 60,000	$ -	$ 664,650	$ -	$ 724,650
Diversion Channel	Trapezoidal	2,000	3,000	2	2	520	4.40	2.50	0.37	14	0	7,280	11	2	5,720	$ 25		$ 182,000		$ -		$ 12,584	$ 194,584
Diversion Culvert	Box	1,200 x 2,400				10	4.50	4.40	1.00							$ 40		$ -	$ 30,000	$ -	$ 83,710	$ -	$ 113,710
Diversion Channel	Trapezoidal	2,000	3,000	2	2	70	5.00	4.50	0.71	14	0	980	11	2	770	$ 25		$ 24,500		$ -		$ 1,694	$ 26,194
Diversion Culvert	Box	1,200 x 2,400				100	6.00	5.00	1.00							$ 40		$ -	$ 30,000	$ -	$ 588,140	$ -	$ 618,140
Diversion Channel	Trapezoidal	2,000	3,000	2	2	190	8.00	6.00	1.05	14	0	2,660	11	2	2,090	$ 25		$ 66,500		$ -		$ 4,598	$ 71,098
Diversion Culvert	Box	1,200 x 2,100				60	9.00	8.00	1.67							$ 40		$ -	$ 20,000	$ -	$ 327,880	$ -	$ 347,880
Diversion Channel	Trapezoidal	2,000	3,000	2	2	60	9.90	9.00	1.50	14	0	840	11	2	660	$ 25		$ 21,000		$ -		$ 1,452	$ 22,452
Diversion Culvert	Box	1,200 x 2,100				60	11.10	9.90	2.00							$ 40		$ -	$ 20,000	$ -	$ 327,880	$ -	$ 347,880
Diversion Channel	Trapezoidal	2,000	3,000	2	2	100	12.10	11.10	1.00	14	0	1,400	11	2	1,100	$ 25		$ 35,000		$ -		$ 2,420	$ 37,420
Diversion Culvert	Box	1,200 x 2,100				20	12.50	12.10	2.00							$ 40		$ -	$ 10,000	$ -	$ 119,400	$ -	$ 129,400
Clayburn Village Storm Sewer																							
100-Year Storm Sewer from Village to Floodway	Circular	750				200	6.00	5.30	0.35										$ 12,900		$ 412,500		$ 425,400
Clayburn Creek Channel Enlargement																							
Clayburn Channel	Flood Bench					200				3.00		600	5		1,000	$ 40		$ 24,000				$ 2,200	$ 26,200
Clayburn Channel	Flood Bench					1,300				2.00		2,600	5		6,500	$ 40		$ 104,000				$ 14,300	$ 118,300
Clayburn Creek Berms																							
0.5m High Berms	2.5 m2 berm XS area					3,820					2.5		7		26,740		$ 60	$ 573,000		$ 76,400		$ 58,828	$ 708,228
SUBTOTAL COSTS																							$5,321,000
Mobilization/Demobilization and Bonding (8%)																							$ 425,700
Construction Engineering (20%)																							$ 1,064,200
Contingency (40%)																							$ 2,128,400
TOTAL COSTS (excl. HST)																							$ 8,939,000

Description	ROW Land Acquisition Costs: Width of ROW m	Area m²	Unit Cost $/m²	Land Sub Total	Total
Diversion Channel	14	1,120	$ 19.77	$ 22,142	$ 22,142
Diversion Culvert	14	700	$ 19.77	$ 13,839	$ 13,839
Diversion Channel	14	5,600	$ 19.77	$ 110,712	$ 110,712
Diversion Culvert	14	280	$ 19.77	$ 5,536	$ 5,536
Diversion Channel	14	1,960	$ 19.77	$ 38,749	$ 38,749
Diversion Culvert	14	700	$ 19.77	$ 13,839	$ 13,839
Diversion Channel	14	7,280	$ 19.77	$ 143,926	$ 143,926
Diversion Culvert	14	140	$ 19.77	$ 2,768	$ 2,768
Diversion Channel	14	980	$ 19.77	$ 19,375	$ 19,375
Diversion Culvert		0	$ 19.77	$ -	$ -
Diversion Channel		0	$ 19.77	$ -	$ -
Diversion Culvert	11	660	$ 19.77	$ 13,048	$ 13,048
Diversion Channel	11	660	$ 19.77	$ 13,048	$ 13,048
Diversion Culvert	11	660	$ 19.77	$ 13,048	$ 13,048
Diversion Channel	11	1,100	$ 19.77	$ 21,747	$ 21,747
Diversion Culvert	11	220	$ 19.77	$ 4,349	$ 4,349
Clayburn Channel	3	600	$ 19.77	$ 11,862	$ 11,862
Clayburn Channel	3	3,900	$ 19.77	$ 77,103	$ 77,103
0.5m High Berms	4	15,280	$ 19.77	$ 302,086	$ 302,086
TOTAL COSTS (excl. HST)					$827,000

O:\0500-0599\510-057\700-CostEstimate\[Costs_LowlandAlternatives-V3.xls]CombinationOption

Table I-5: Lowlands Flood Management Plan: Channel Enlargement and Berms for 10-Year Protection

Description	Upgrade: Type	Pipe Size or Channel Depth (mm)	Length (m)	Up Invert (m)	Dn Invert (m)	Slope %	New Channel Area (m^2)	Berm XS Area (m^2)	Excavation Needed (m^3)	Width (m)	Seeded Area (m^2)
Clayburn Village Drainage											
Floodboxes	Circular	2x 600	20								
Pump Station (if needed)	200 L/s										
Clayburn Creek Channel Enlargement										Bench Width	
Clayburn Channel	Flood Bench		200				3		600	5	1,000
Clayburn Channel	Flood Bench		1300				2		2,600	5	6,500
Clayburn Creek Berms										Base Width	
0.5m High Berms	2.5 m2 berm XS area		2030					2.5		7	14,210
1.0m High Berms	7 m2 berm XS area		1000					7.0		11	11,000
Floodwall			370								
Wright St Raising	100 m3									Top Width	
Gravel Road Raising	assume 0.5m high		420					1.3		2.5	
Floodboxes	Circular	18x 600	20								

Description	Unit Costs: Equipment	Unit Costs: Fill Supply	Costs: Equipment and Fill	Floodwall 300 $/m	Headwalls /Manholes /Flapgates	Access Road 20 $/m	Pipe /Culvert	Seeding 2.2 $/m2	Total
Clayburn Village Drainage									
Floodboxes					$ 4,000		$ 40,000		$ 44,000
Pump Station (if needed)									$ 325,000
Clayburn Creek Channel Enlargement									
Clayburn Channel	$ 40		$ 24,000					$ 2,200	$ 26,200
Clayburn Channel	$ 40		$ 104,000					$ 14,300	$ 118,300
Clayburn Creek Berms									
0.5m High Berms		$ 60	$ 304,500			$ 40,600		$ 31,262	$ 376,362
1.0m High Berms		$ 60	$ 420,000			$ 20,000		$ 24,200	$ 464,200
Floodwall				$ 111,000					$ 111,000
Wright St Raising		$ 240	$ 24,000						$ 24,000
Gravel Road Raising		$ 240	$ 126,000						$ 126,000
Floodboxes					$ 36,000		$ 360,000		$ 396,000
SUBTOTAL COSTS									**$ 2,011,000**
Mobilization/Demobilization and Bonding (8%)									$ 160,900
Construction Engineering (20%)									$ 402,200
Contingency (40%)									$ 804,400
TOTAL COSTS (excl. HST)									**$ 3,379,000**

Description	ROW Land Acquisition Costs: Width of ROW m	Area m2	Unit Cost $/m2	Total
Clayburn Channel	3	600	$ 19.77	$ 11,862
Clayburn Channel	3	3,900	$ 19.77	$ 77,103
0.5m High Berms	4	8,120	$ 19.77	$ 160,532
1.0m High Berms	5	5,000	$ 19.77	$ 98,850
Floodwall	2	740	$ 19.77	$ 14,630
TOTAL COSTS (excl. HST)				**$ 363,000**

O:\0500-0599\510-057\700-CostEstimate\[Costs_LowlandsPlan10YrService-v3.xls]Table I-5

Table I-6: Storm Sewer and Culvert Upgrade Cost Estimate

Project No.	Link Name	Existing Size (mm)	Priority	Length (m)	Upgrade Material	Upgrade Size (mm)	Number of Manhole Upgrades	Number of Days for Culvert Replacement	Storm Pipe Cost	Manhole Cost	Culvert Crew Cost	Culvert Material Cost	Culvert Crane Cost	Culvert Pumping Cost	Total Cost	Total Cost with Mobilization, Construction & Contingency (excl. HST)
1	K_CV44*	1,500	1	12	CMP	2,700		10			$ 86,250	$ 56,300	$ 6,000	$ 125,000	$ 273,550	$ 459,564
2	K_CV135	1,000	1	16	CMP	1,800		20			$ 172,500	$ 40,160	$ 6,000			
	K_CV133	750	1	6	CO	1,200						$ 17,310	$ 6,000			
	K_CV221	1,200	1	12	CMP	2,200						$ 34,320	$ 6,000	$ 22,000	$ 304,290	$ 511,207
3	K_CV46	600	1	47	CO	750		12			$ 103,500	$ 48,650	$ 18,000	$ 13,000	$ 183,150	$ 307,692
4	K_CV48	300	1	26	CO	500		7			$ 60,375	$ 15,440	$ -	$ -	$ 75,815	$ 127,369
5	K_CV116	600	1	34	CO	900		12			$ 103,500	$ 43,875	$ 15,000	$ 13,000	$ 175,375	$ 294,630
6	K_CV193	1,200	1	14	CMP	2,000		10			$ 86,250	$ 38,040	$ 15,000	$ 13,000	$ 152,290	$ 255,847
7	K_CV140	900	1	12	CMP	1,800		21			$ 181,125	$ 33,120	$ 9,000	$ 9,000		
	K_CV211	250	1	21	CO	600						$ 21,945	$ -	$ -	$ 254,190	$ 427,039
8	K_CV52	1,200	1	59	CMP	1,800		20			$ 172,500	$ 115,840	$ 30,000	$ 17,800	$ 336,140	$ 564,715
9	K_CV76*	4250x2300	1	19	CO Box	add 2 x (3,600 x 2,400)		20			$ 172,500	$ 246,000	$ 45,000	$ 10,000	$ 473,500	$ 795,480
10	K_CV2*	300	1	14	CMP	2,700		10			$ 86,250	$ 56,300	$ 6,000	$ 25,000	$ 173,550	$ 291,564
11	K_CV224*	700	1	25	CP	1,200		10			$ 86,250	$ 42,580	$ 9,000	$ 9,000	$ 146,830	$ 246,674
12	K_268E11	450	1	22	CO	525	3		$ 15,076	$ 24,000						
	K_860E11	450	1	20	CO	900			$ 25,685						$ 64,762	$ 108,800
13	K_526E11*	375	1	4	CO	450	0		$ 2,720	$ -						
	K_525E11*	375	1	38	CO	525	5		$ 25,840	$ 40,000						
	K_517E11*	600	1	118	CO	675			$ 118,308							
	K_527E11*	675	1	29	CO	1050			$ 41,785						$ 228,653	$ 384,136
14	K_CV42*	600	2	8	CO	900		5			$ 43,125	$ 15,917	$ 6,000	$ 7,400	$ 72,442	$ 121,703
15	K_CV89*	3,750x2,000	2	8	CO Box	2 x (3,050x1,500)		5			$ 61,000	$ 85,142	$ 15,000	$ 7,400		
	K_CV60*	2,400	2	14	CO Box	2 x (3,050x1,500)		7			$ 85,400	$ 139,060	$ 21,000	$ 9,000		
	K_517E10	525	2	81	CO	900	9		$ 104,918	$ 72,000						
	K_520E10	525	2	64	CO	900			$ 82,901							
	K_519E10	525	2	77	CO	900			$ 100,100							
	K_511E10	525	2	57	CO	900			$ 74,331							
	K_514E10	525	2	28	CO	900			$ 36,387							
	K_518E10	600	2	82	CO	900			$ 105,959							
	K_480E10	600	2	53	CO	900			$ 69,420							
	K_481E10	675	2	100	CO	900			$ 130,646							
	K_1010F10	300	2	135	CO	375	2		$ 91,561	$ 12,000					$ 1,303,225	$ 2,189,418
16	K_111E12	150	2	3	CO	600	2		$ 3,000	$ 16,000					$ 19,000	$ 31,920
17	K_388F12	250	2	71	CO	375	2		$ 48,092	$ 12,000						
	K_386F12	250	2	9	CO	375			$ 6,108							
	K_370F12	250	2	3	CO	600	6		$ 3,000	$ 48,000						
	K_371F12	450	2	30	CO	600			$ 30,250							
	K_374F12	450	2	16	CO	600			$ 16,240							
	K_684F12	450	2	1	CO	600			$ 1,430							
	K_72F12	450	2	8	CO	600			$ 7,810						$ 172,931	$ 290,524
18	K_930E10	250	2	58	CO	375	5		$ 39,364	$ 30,000						
	K_940E10	375	2	61	CO	450			$ 41,736							
	K_946E10	375	2	44	CO	450			$ 29,928							
	K_927E10	300	2	79	CO	450			$ 54,051							
	K_929E10	350	2	55	CO	450			$ 37,335							
	K_959E10	350	2	112	CO	525	10		$ 76,206	$ 80,000						
	K_943E10	375	2	50	CO	600			$ 50,196							
	K_945E10	375	2	9	CO	600			$ 9,451							
	K_948E10	375	2	52	CO	675			$ 52,394							
	K_947E10	375	2	99	CO	750			$ 99,317							
	K_967E10	375	2	40	CO	750			$ 40,380							
	K_975E10*	375	2	75	CO	525			$ 51,091							
	K_980E10*	375	2	64	CO	525			$ 43,724						$ 735,173	$ 1,235,091
19	K_420E11	250	2	91	CO	525	3		$ 62,159	$ 24,000						
	K_421E11	300	2	118	CO	525			$ 80,410						$ 166,569	$ 279,837
20	K_2351F10	200	2	12	CO	525	2		$ 8,125	$ 16,000						
	K_2350F10	200	2	40	CO	525			$ 27,099							
	K_2349F10	200	2	37	CO	525			$ 25,395							
	K_2347F10	200	2	7	CO	525			$ 4,785							
	K_2342F10	200	2	27	CO	375	3		$ 18,678	$ 18,000						
	K_2358F10	200	2	25	CO	375			$ 17,000						$ 135,083	$ 226,939

Table I-6: Storm Sewer and Culvert Upgrade Cost Estimate

Project No.	Link Name	Existing Size (mm)	Priority	Length (m)	Upgrade Material	Upgrade Size (mm)	Number of Manhole Upgrades	Number of Days for Culvert Replacement	Storm Pipe Cost	Manhole Cost	Culvert Crew Cost	Culvert Material Cost	Culvert Crane Cost	Culvert Pumping Cost	Total Cost	Total Cost with Mobilization, Construction & Contingency (excl. HST)
21	K_1710E11	450	2	29	CO	600	4		$ 28,934	$ 32,000						
	K_1709E11	450	2	57	CO	600			$ 56,706							
	K_1713E11	450	2	2	CO	675			$ 2,100						$ 119,740	$ 201,163
22	K_1262F10	600	2	29	CO	900	2		$ 38,336	$ 16,000					$ 54,336	$ 91,284
23	K_6F12	300	2	36	CO	525	4		$ 24,751	$ 32,000						
	K_5F12	300	2	34	CO	525			$ 22,847							
	K_4F12	300	2	11	CO	525			$ 7,208						$ 86,807	$ 145,835
24	K_1407E10	450	2	19	CO	675	4		$ 18,667	$ 32,000						
	K_1416E10	450	2	26	CO	675			$ 26,173							
	K_1408E10	450	2	26	CO	675			$ 26,233						$ 103,073	$ 173,163
25	K_1884E10	525	2	30	CO	750	3		$ 29,989	$ 24,000						
	K_1885E10	525	2	35	CO	750			$ 35,204						$ 89,193	$ 149,844
26	K_1938E10	200	2	39	CO	450	3		$ 26,510	$ 18,000						
	K_1941E10	375	2	17	CO	450			$ 11,893						$ 56,403	$ 94,757
27	K_400E11	250	2	30	CO	375	2		$ 20,325	$ 12,000					$ 32,325	$ 54,305
28	K_901E11	300	2	69	CO	375	4		$ 46,663	$ 24,000						
	K_907E11	300	2	16	CO	375			$ 10,628							
	K_908E11*	300	2	8	CO	450			$ 5,100						$ 86,391	$ 145,137
29	K_1309E11*	300	2	27	CO	450	2		$ 18,020	$ 12,000						
	K_1307E11*	375	2	84	CO	450			$ 56,780							
	K_1312E11*	450	2	76	CO	525	2		$ 51,340	$ 16,000						
	K_1306E11*	250	2	5	CO	300	2		$ 3,399	$ 12,000					$ 169,539	$ 284,825
30	K_1648E11	450	2	17	CO	600	2		$ 16,833	$ 16,000					$ 32,833	$ 55,159
31	K_1141F11	250	2	26	CO	375	3		$ 18,019	$ 18,000						
	K_1140F11	300	2	32	CO	375			$ 22,093						$ 58,112	$ 97,628
32	K_1102E10*	300	2	18	CO	450	7		$ 12,575	$ 42,000						
	K_1092E10*	300	2	37	CO	450			$ 24,983							
	K_1772E10*	300	2	128	CO	450			$ 86,820							
	K_1095E10	300	2	116	CO	450			$ 78,938							
	K_1100E10*	300	2	44	CO	450			$ 29,834							
	K_1775E10*	300	2	28	CO	450			$ 19,054						$ 294,205	$ 494,264
33	K_1272F10	250	2	69	CO	300	9		$ 46,631	$ 54,000						
	K_1271F10	250	2	80	CO	375			$ 54,729							
	K_1270F10	250	2	41	CO	375			$ 27,867							
	K_1269F10	250	2	33	CO	375			$ 22,533							
	K_1268F10	250	2	20	CO	375			$ 13,375							
	K_1267F10	250	2	43	CO	375			$ 28,956							
	K_1266F10	250	2	40	CO	375			$ 27,386							
	K_1036F10	250	2	42	CO	375			$ 28,336						$ 303,813	$ 510,406
34	K_387E11	375	3	49	CO	450	2		$ 33,647	$ 12,000					$ 45,647	$ 76,687
35	K_745E11	375	3	14	CO	450	1		$ 9,517	$ 6,000						
	K_1843E10*	750	3	72	CO	900	2		$ 94,107	$ 16,000					$ 125,624	$ 211,048
36	K_453E11	150	3	37	CO	200	3		$ 24,878	$ 18,000						
	K_454E11	200	3	41	CO	250			$ 28,005						$ 70,884	$ 119,084
37	K_199E11*	375	3	34	CO	450	2		$ 22,839	$ 12,000					$ 34,839	$ 58,530
38	K_446E11	250	3	46	CO	300	2		$ 31,200	$ 12,000					$ 43,200	$ 72,577
39	K_1246E11*	450	3	2	CO	525	2		$ 1,428	$ 16,000					$ 17,428	$ 29,279
40	K_1352E11*	300	3	5	CO	375	2		$ 3,400	$ 12,000					$ 15,400	$ 25,872
41	K_1361E11	200	3	15	CO	300	1		$ 10,200	$ 6,000						
	K_1353E11	250	3	29	CO	600	8		$ 28,500	$ 64,000						
	K_1360E11	250	3	12	CO	600			$ 11,638							
	K_1359E11	300	3	48	CO	675			$ 47,839							
	K_1358E11	300	3	53	CO	675			$ 53,169							
	K_1357E11	375	3	31	CO	750			$ 30,824							
	K_1362E11	500	3	13	CO	750			$ 13,190						$ 265,360	$ 636,864
42	K_1060F11	450	3	79	CO	525	2		$ 53,456	$ 16,000					$ 69,456	$ 116,686
43	K_1235F11*	600	3	13	CO	675	2		$ 13,223	$ 16,000					$ 29,223	$ 49,095
44	K_1068E10	375	3	119	CO	450	2		$ 81,087	$ 12,000					$ 93,087	$ 156,387
45	K_109E12*	525	3	3	CO	600	2		$ 3,311	$ 16,000					$ 19,311	$ 32,442
														Total Costs for Storm Sewer and Culvert Upgrades	$ 7,763,000	$ 13,232,000

*Pond upstream. Modification to Upstream Pond(s) may reduce the required upgrade size.

O:\0500-0599\510-057\300-Reports\20120509_FINAL\Tables\[Tables8-6&E-8&I-6_Costs_PipesCulverts.xlsx]Table I-6

KERR WOOD LEIDAL
consulting engineers

Appendix J

Pre-development Conditions and Modelling

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T 604 294 2088
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Technical Memorandum

DATE: October 21, 2011

TO: Kathy Zhang, City of Abbotsford

FROM: Jennifer Young, P.Eng,
David Zabil, P.Eng

RE: **Clayburn Creek ISMP**
Pre-Development Modelling
Our File 0510-057

Introduction

This memorandum summarizes the results of the hydrologic modelling for the pre-development conditions for Clayburn Creek. The Clayburn Creek Integrated Stormwater Management Plan (ISMP) includes hydrologic and hydraulic modelling for the existing (2007) and future (OCP) land use conditions. The City requested that additional pre-development modelling be done to determine the peak flow estimates for the catchment tributary to Clayburn Village to determine the impact of existing development on the lowland flows and flooding.

The 2,253 ha Clayburn Creek watershed is located on the west side of Sumas Mountain along Straiton and McKee Roads. The watershed includes Clayburn Creek, Stoney Creek, Poignant Creek and Diane Brook. The Clayburn Creek 1580 ha catchment, upstream of Clayburn Village (Village), under existing land use conditions contains mainly rural development, undeveloped areas and 145 ha urban subdivision development. For the pre-development conditions, the urban areas were assumed to be forested, but the rural areas were left the same as existing conditions. The areas modified for the predevelopment conditions are depicted on Figure 1.

XP-SWMM Model

A description of the Clayburn Creek model is summarized in Appendix D of the Clayburn Creek ISMP Report.

Catchment Parameter Modification

The model was modified to pre-development conditions by removing all subdivision urban development upstream of the Village. To achieve this, the following changes were made to the calibrated / validated existing land use model:

- Impervious percentage for all developed catchments upstream of the Village was changed to 1%. This reflects undeveloped forested conditions. Larger headwater catchments with rural residential land use remained at the existing impervious percentage (1% to 5% impervious). A total of 145 ha of developed area upstream of the Village with an average impervious percentage of 61% were changed to 1% impervious. This area includes Auguston, Kensington Park at Ledgeview, the Kings Gate Condos, Golf Course Drive, Ledgeview Estates, and the portion of the Neighbourhood east of Old Clayburn Road that drains to Clayburn

Creek. The total impervious percentage at the flow monitoring gauge was changed from 6% in the existing model to 3% in the pre-development model;

- Infiltration parameter was changed from 1.5 mm/hr to 2.5 mm/hr to match that used for undeveloped catchments;
- Runoff lengths for overland flow were changed from a typical urban value of 30 m to an undeveloped value of 100 m; and
- The existing detention pond storage volumes and flow control orifices were removed from the model.

The groundwater parameters were not modified, as they are based on the surficial geology (Geological Survey of Canada, 1976) of the Clayburn Creek Basin.

Modelled Rainfall Events

The pre-development model was run using real rainfall events used in the model calibration and using the 2-year, 5- year, 10-year, and 100-year design storms (described in Section D.7), as follows:

The **November 23 to December 3, 2009** event was 2.1 mm/hr, just under the 2-year 24-hour rainfall intensity of 2.8 mm/hr, and produced the highest non-snowmelt peak flow recorded during the flow monitoring period. It occurred during a warm period when no snow was falling in the watershed.

The **November 11-15, 2008** event was the next largest event that occurred with saturated ground conditions from the available data and was smaller than a 2-year storm return period.

The **December 11-12, 2010** event was going to be used, however, upon examination of the rainfall recorded at the Ledgeview climate station it appeared that the rain gauge had malfunctioned. The nearby Marshall Creek 'Marshall 2' rain gauge appeared to have recorded a much larger rainfall depth (81 mm) than the volume of flow recorded at the Clayburn Creek flow gauge (50 mm rain equivalent) and therefore could not be used to accurately simulate the event.

XP-SWMM Model Results

The peak flow estimates at strategic locations are summarized in Table 1 for pre-development, existing and future land use conditions. Figure D-3, in Appendix D, shows the strategic locations.

The hydrographs for the each of the real and design storms were compared to the existing conditions model hydrographs as shown in Figures 2-9. The hydrographs were compared at the Clayburn Creek flow monitoring gauge at Straiton Road and directly downstream of the Blauson Pond located in the Auguston development. The findings are summarized in Table 2.

Initiatively it was expected that pre-development, forest condition flows would be less than post-development, urban condition flows, however in many of the events the pre-development flow was estimated higher than the existing condition flows, particularly immediately downstream of the Blauson Pond. This indicates that the existing developed conditions with the Blauson Pond is detaining the existing flows to less than pre-development in all of the design storms that were modelled. The Blauson Pond assessment in Appendix E showed that the pond did not meet the City criterion of detaining the 100-year flow to 5 L/s/ha; it is noted that 5 L/s/ha flow rate is lower than the pre-development 100-year rate of approximately 15 L/s/ha.

The results are less pronounced at the gauge compared with downstream of the pond because of varying time of peaks coming from various catchment sizes, slopes and land use and flows are also attenuated as they are conveyed through the rough channels.

Table 2: Summary of Hydrograph Results (Peak Instantaneous Flows)

Event	D/S of Blauson Pond	@ Flow Gauge
	Pre-dev is % higher or lower than Existing Conditions	
November 23 to December 3, 2009 event (Figures 2A and 2B)	28% **higher**	2% **lower**
November 11-15, 2008 event (Figures 3A and 3B).	20% **higher**	3% **lower**
6-month 24-hour design storm event (Figures 4A and 4B).	22% **higher**	1% **higher**
2-year 24-hour design storm event (Figures 5A and 5B).	29% **higher**	1% **higher**
5-year 24-hour design storm event (Figures 6A and 6B)	20% **higher**	3% **higher**
10-year 12-hour design storm event (Figure 7A)	44% **higher**	5% **higher**
10-year 24-hour design storm event (Figures 7B and 7C)	21% **higher**	
100-year 2-hour design storm event (Figure 8A)		32% **higher**
100-year 6-hour design storm event (Figures 8B and 9A)	73% **higher**	12% **higher**
100-year 24-hour design storm event (Figure 9B)	48% **higher**	

Impact on Existing Development on Clayburn Village Flooding

The modelling results indicate that the existing development above the Village does not significantly increase the flows at the Clayburn hydrometric gauge for 2-year and 5-year events. Although the peak 10-year and 100-year flow occurs at a different storm duration between the existing and pre-development scenarios, the magnitude of the peak flows are very similar (10-year: 12.7 m^3/s existing (12 hour) vs. 13.4 m^3/s pre-development (12 hour) and peak 100-year: 23.8 m^3/s existing (6 hour) vs. 33.4 m^3/s pre-development (2 hour)).

The results also indicate that the Blauson Pond is detaining the existing flows to less than pre-development in all of the storms that were modelled.

KERR WOOD LEIDAL ASSOCIATES LTD.

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David Zabil, P.Eng
Title

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Encl.

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Revision History

Revision #	Date	Status	Revision	Author

Table 1: Hourly Average Peak Flow Estimates for Pre-development, Existing (2007), and Future Land Uses

			TIA					6-month					2-year					5-year					10-year					100-year				
						% Difference		Hourly Average Flows (m^3/s)			% Difference		Hourly Average Flows (m^3/s)			% Difference		Hourly Average Flows (m^3/s)			% Difference		Hourly Average Flows (m^3/s)			% Difference		Hourly Average Flows (m^3/s)			% Difference	
	Location	Area (ha)	Pre-Dev	2007	Future	Pre/ 2007	2007/ Future	Pre-Dev	2007	Future	Pre/ 2007	2007/ Future	Pre-Dev	2007	Future	Pre/ 2007	2007/ Future	Pre-Dev	2007	Future	Pre/ 2007	2007/ Future	Pre-Dev	2007	Future	Pre/ 2007	2007/ Future	Pre-Dev	2007	Future	Pre/ 2007	2007/ Future
Clayburn Creek Mainstem	Near McKee Rd. (CLAY1)	98	2%[1]	4%	53%	2%	49%	0.5	0.5	1.2	-2%	167%	0.6	0.6	1.9	0%	189%	0.7	0.6	3.0	-9%	364%	1.0	1.0	3.8	-4%	292%	2.0	2.0	6.2	0%	211%
	U/S of Poignant Confluence (CLAY2)	392	2%[1]	10%	40%	8%	30%	1.8	1.8	3.1	1%	77%	2.4	2.4	4.7	0%	95%	2.5	2.5	7.4	0%	194%	3.6	3.7	9.2	2%	149%	7.8	7.7	15.9	-2%	108%
	At Clayburn Road Bridge Flow Gauge (CLAY3)	1,580	3%[1]	6%	22%	3%	16%	6.8	6.8	6.8	-1%	0%	9.4	9.3	9.7	-1%	5%	9.9	9.6	15.3	-3%	59%	13.0	12.2	18.8	-6%	53%	25.4	23.2	38.3	-9%	65%
	U/S of Stoney Confluence (CLAY4)	1,625	4%[1]	7%	22%	3%	15%	7.0	7.0	7.0	-1%	0%	9.7	9.6	10.0	-1%	5%	10.2	9.9	14.9	-3%	51%	13.0	12.4	18.5	-5%	50%	26.2	23.9	38.5	-9%	61%
Diane Brook	Near 5035 Sumas Mountain Road (DIAN1.5)	154	4%	4%	9%	0%	5%	0.7	0.7	0.7	0%	0%	0.9	0.9	0.9	-1%	1%	1.0	1.0	0.9	-4%	-3%	1.3	1.3	1.3	-2%	3%	2.9	2.9	3.2	-1%	10%
	Near Mathers Park (DIAN2)	466	4%[1]	5%	8%	1%	3%	2.0	2.0	2.0	-1%	1%	2.7	2.7	2.8	1%	2%	2.9	2.9	3.9	-1%	37%	4.0	3.9	4.9	-2%	24%	9.0	8.7	12.4	-3%	42%
Poignant Creek	Near 5285 Willet Rd. (POIG1.5)	234	6%	6%	7%	0%	1%	1.0	1.0	1.0	0%	-2%	1.4	1.4	1.4	-2%	-2%	1.4	1.4	1.4	2%	-1%	2.1	2.1	2.0	-1%	-5%	4.7	4.7	4.7	0%	0%
	Near Clayburn Confluence (POIG2)	970	4.1%[1]	4.3%	16%	0%	12%	4.1	4.1	4.1	-1%	0%	5.7	5.6	5.7	-2%	1%	6.0	5.9	5.9	-2%	0%	7.5	6.9	7.9	-8%	14%	13.8	12.9	16.6	-7%	29%

Red text = flows upstream of Clayburn Village

Existing (2007) Land Use, Future (OCP) Development, TIA - Total Impervious Area, U/S = upstream, D/S = downstream

[1] TIA was not the only parameter changed between the pre-development and existing models. Some pre-development areas have higher infiltration and depression storage to better represent undeveloped conditions.

Refer to Figure 2-12

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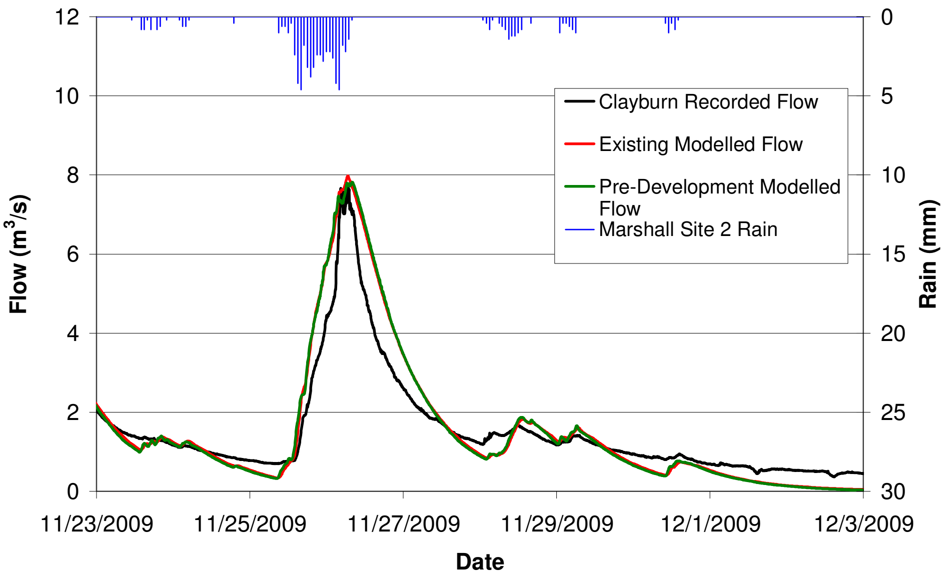
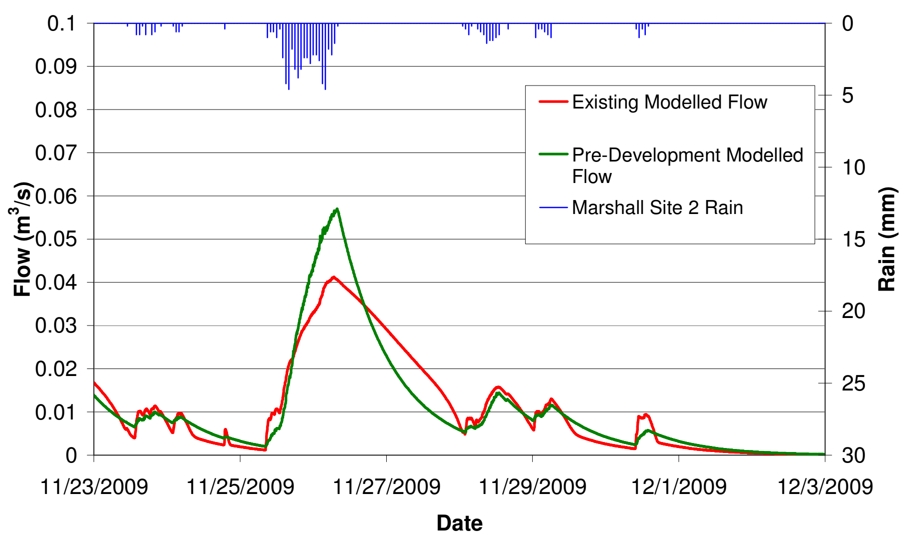
Figure 2: November 2009 Event

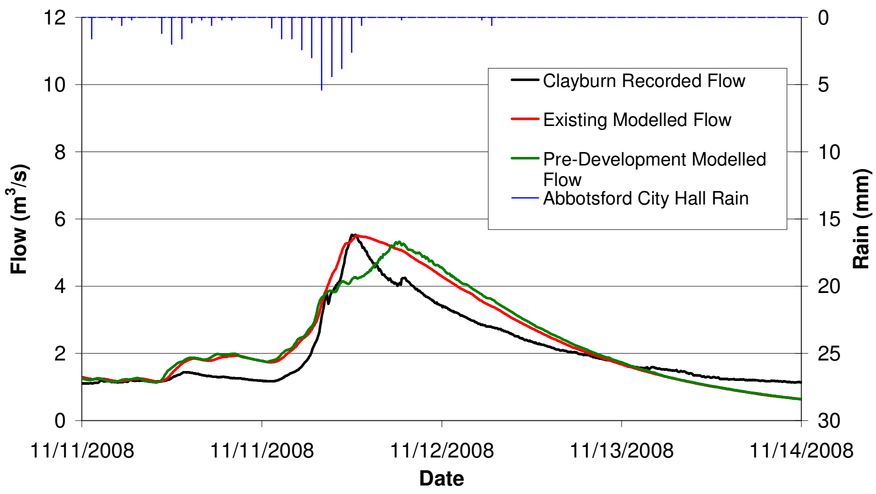


A: Hydrographs at Clayburn Gauge

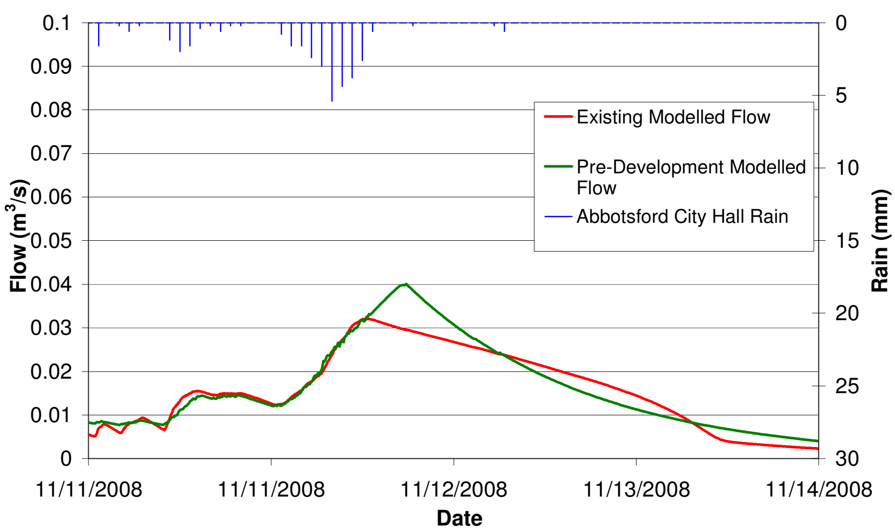


B: Hydrographs at Clayburn Downstream of Blauson Pond

Figure 3: November 2008 Event

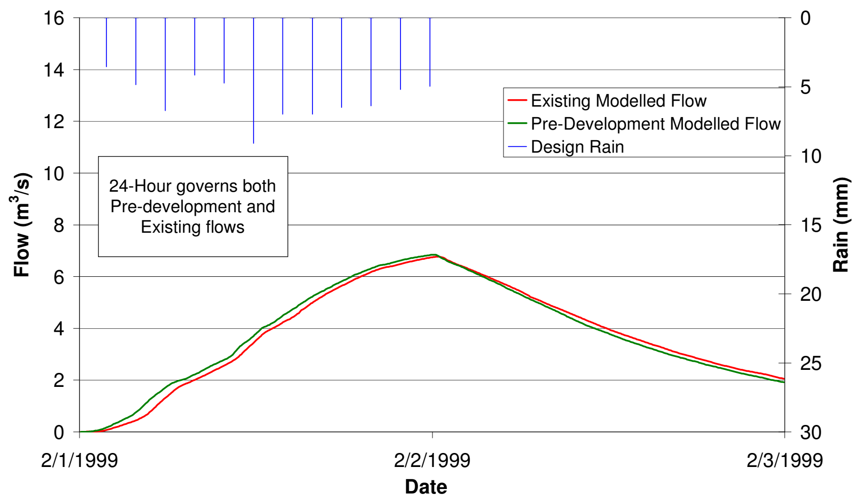


A: Hydrographs at Clayburn Gauge

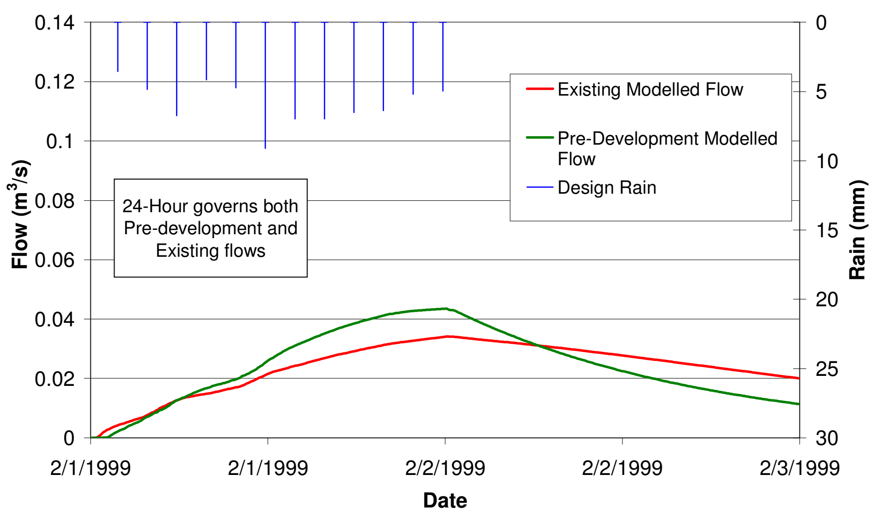


B: Hydrographs at Clayburn Downstream of Blauson Pond

Figure 4: 6-Month 24-Hour Event

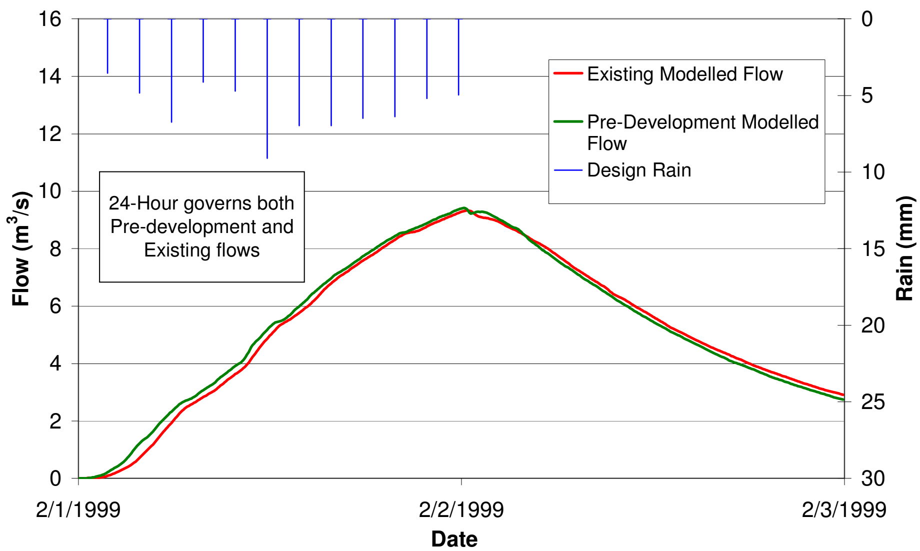


A: Hydrographs at Clayburn Gauge

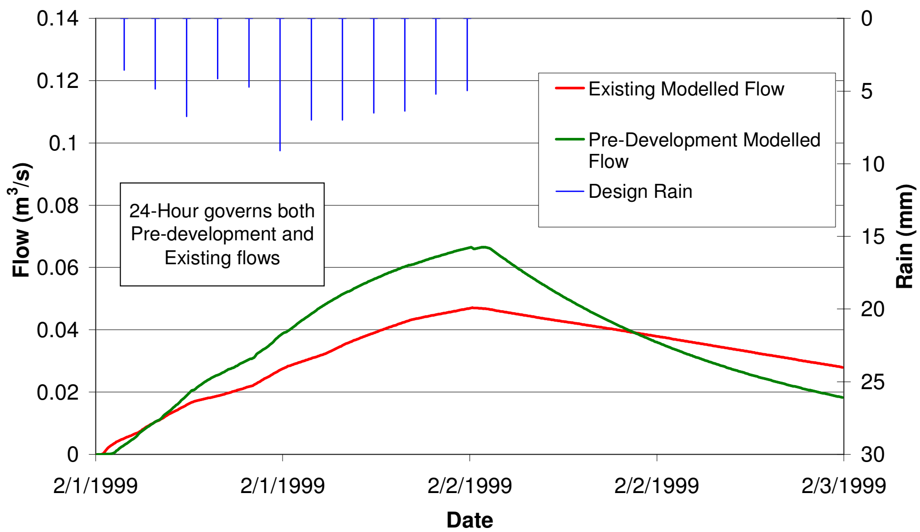


B: Hydrographs at Clayburn Downstream of Blauson Pond

Figure 5: 2-Year 24-Hour Event

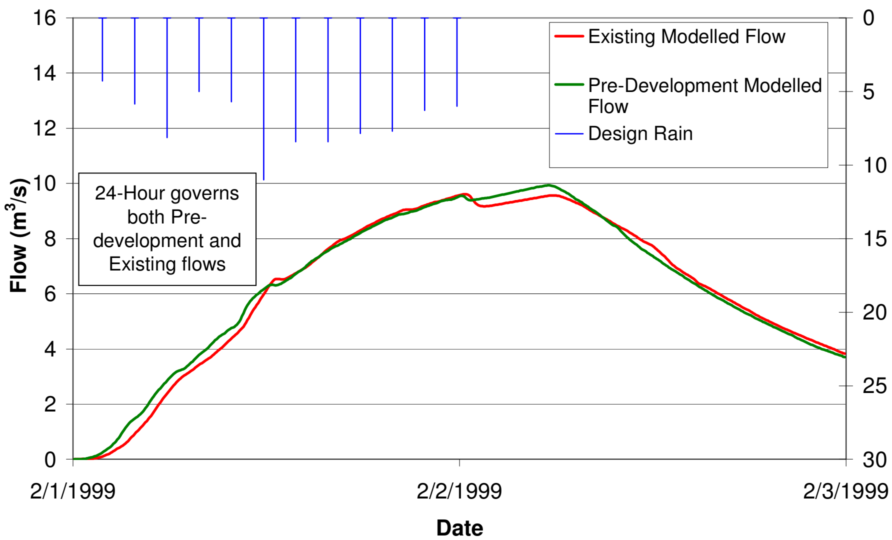


A: Hydrographs at Clayburn Gauge

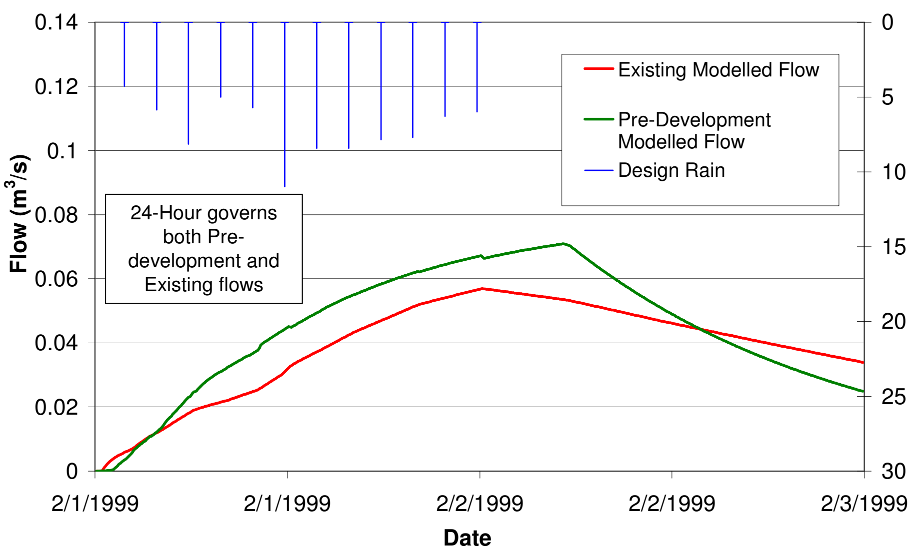


B: Hydrographs at Clayburn Downstream of Blauson Pond

Figure 6: 5-Year 24-Hour Event

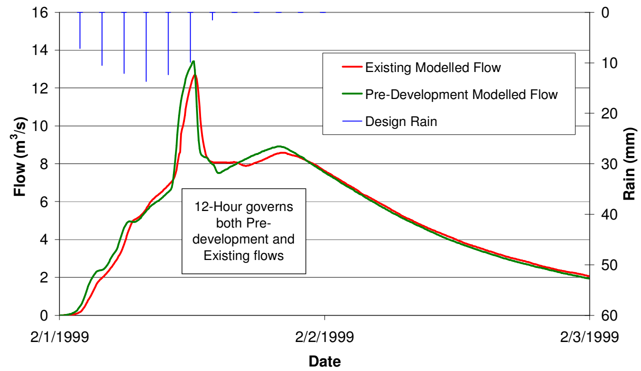


A: Hydrographs at Clayburn Gauge

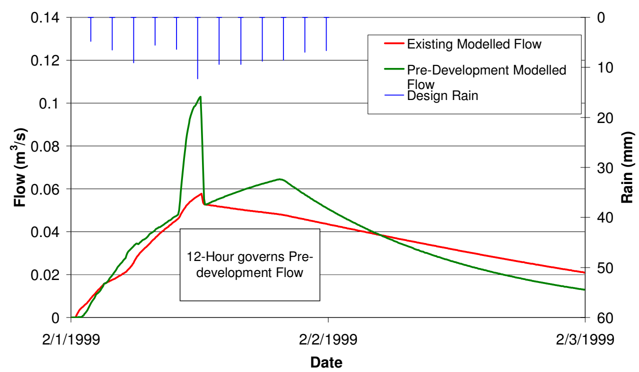


B: Hydrographs at Clayburn Downstream of Blauson Pond

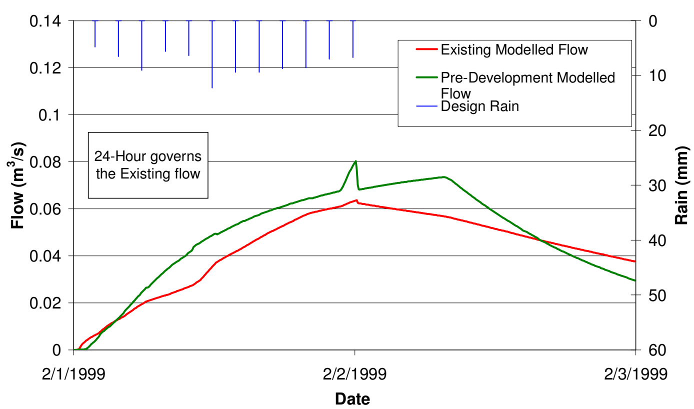
Figure 7: 10-Year Event



A: 12-Hour Event at Clayburn Gauge

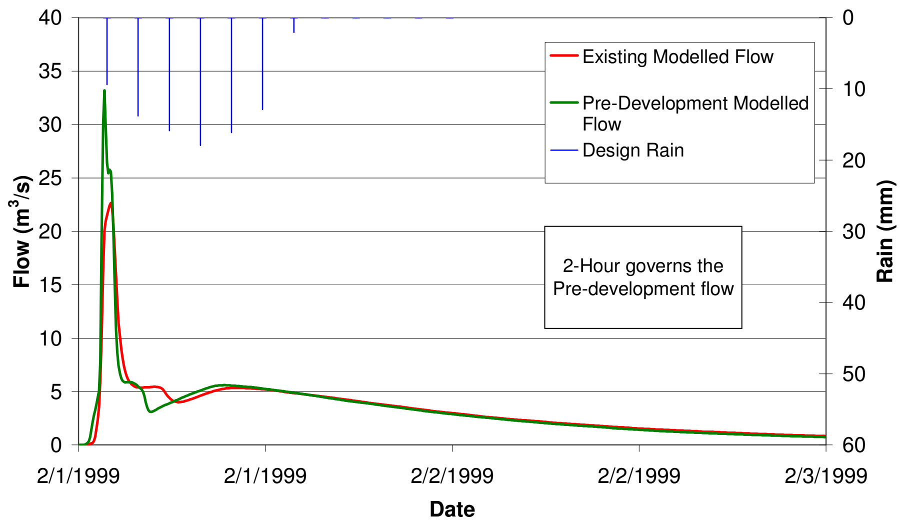


B: 12-Hour Event at Clayburn Downstream of Blauson Pond

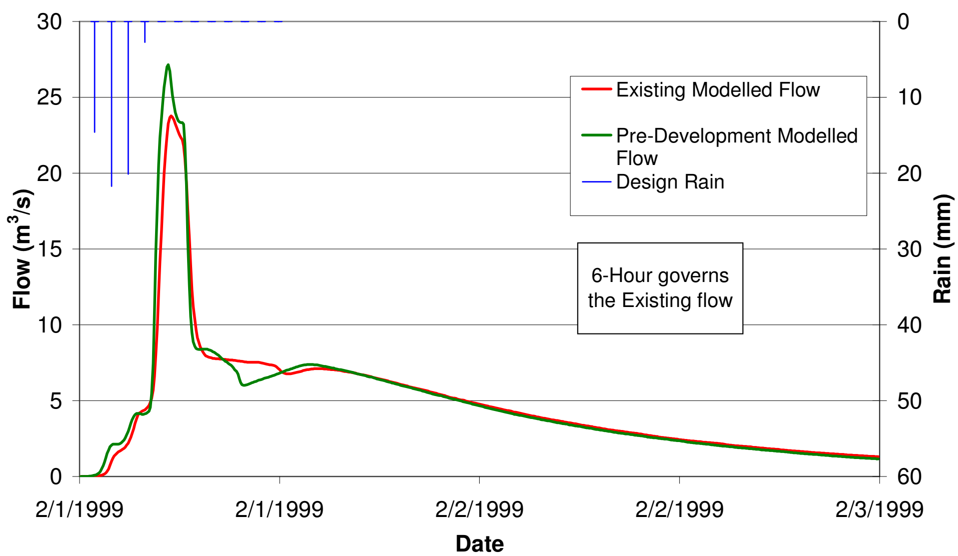


C: 24-Hour Event at Clayburn Downstream of Blauson Pond

Figure 8: 100-Year Event at Clayburn Gauge

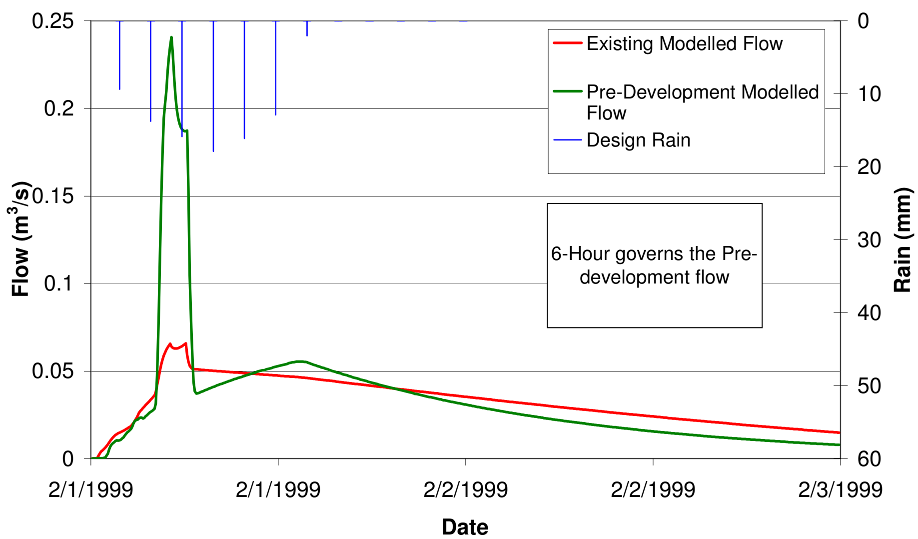


A: 2-Hour Event

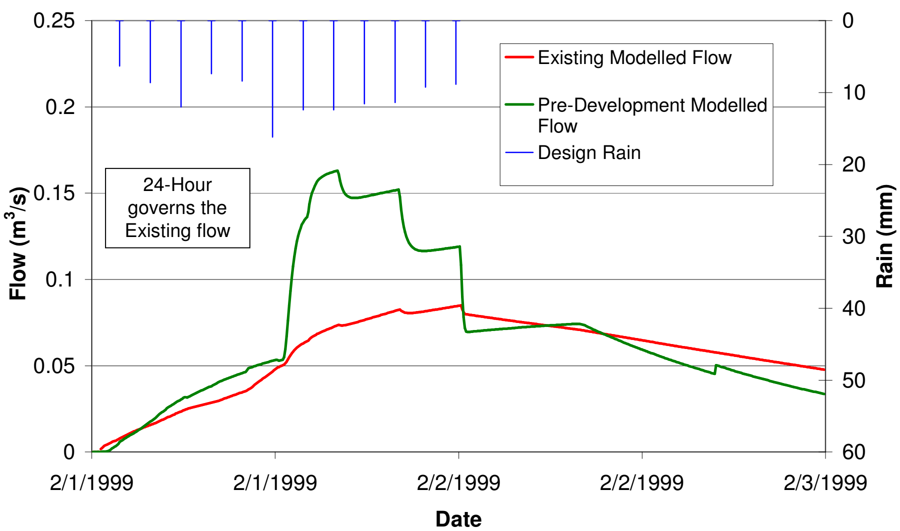


B: 6-Hour Event

Figure 9: 100-Year 100-Year Event Downstream of Blauson Pond



A: 6-Hour Event



B: 24-Hour Event

Appendix K

Development Guidelines

Guidelines for Future Development in Clayburn Creek Watershed

Clayburn Creek Integrated Stormwater Management Plan: The City of Abbotsford (City) recently completed the Clayburn Creek Integrated Stormwater Management Plan (ISMP) Study in May 2012. In addition, to the City's *Development Bylaw No. 1565, 2010*, the ISMP recommends overall watershed criteria to mitigate the impacts of future development summarized in Table 1.

Low Impact Development Techniques and Source Controls: Because of the significant erosion and ravine slope instability issues within the Clayburn watershed, all future development is recommended to implement Low Impact Development (LID) approaches and source controls to reduce runoff volume and protect the health of the watershed. Source controls are not recommended in geotechnical setbacks from steep slopes and ravines because the added saturation can further destabilize slopes. The application of source controls to the various proposed land uses, slopes and soil combinations has been divided up as separate "Prescriptions" for each application. The prescriptions are shown in Table 2 and spatially on Figure 1. This table can be used to determine what type of source controls would be appropriate for each prescription.

Source controls should be sized to meet the stormwater volumetric target as follows:

- Water Balance Model to capture 90% of the annual average rainfall (allowing only 10% direct runoff); or
- The water balance equation to achieve the **Clayburn Creek Stormwater Target of 51 mm** as follows:

$$\frac{Ac \times R}{1000} = (0.20 \times As \times Ds) + (At \times Dt \times P) + \frac{24 \times At \times f}{1000}$$

Where:

Ac = catchment area draining to source control (m^2)

R = 51 mm (72% of 2-year 24-hour rainfall) (mm)

As = source control surface footprint area, if applicable (m^2)

Ds = source control topsoil depth (m)

At = bottom area of retention trench, if applicable (m^2)

Dt = retention trench depth (m)

P = retention trench porosity fraction (unitless)

f = native soil infiltration rate, if applicable (mm/hr)

The retention trench shall be capable of draining from full to empty within 4 days after the end of a storm. To ensure this, the maximum depth of the rock trench shall be the smaller of:

a) 2 m; or
b) infiltration rate (mm/hr) x 24 hr/day x 4 days / (1,000 mm/m x porosity).

Detention Requirements: Detention criteria requirements are also summarized on Figure 1. After the construction of the Lower Clayburn Flood Protection Works, the City's current detention criteria for areas tributary to Clayburn Village can be modified to

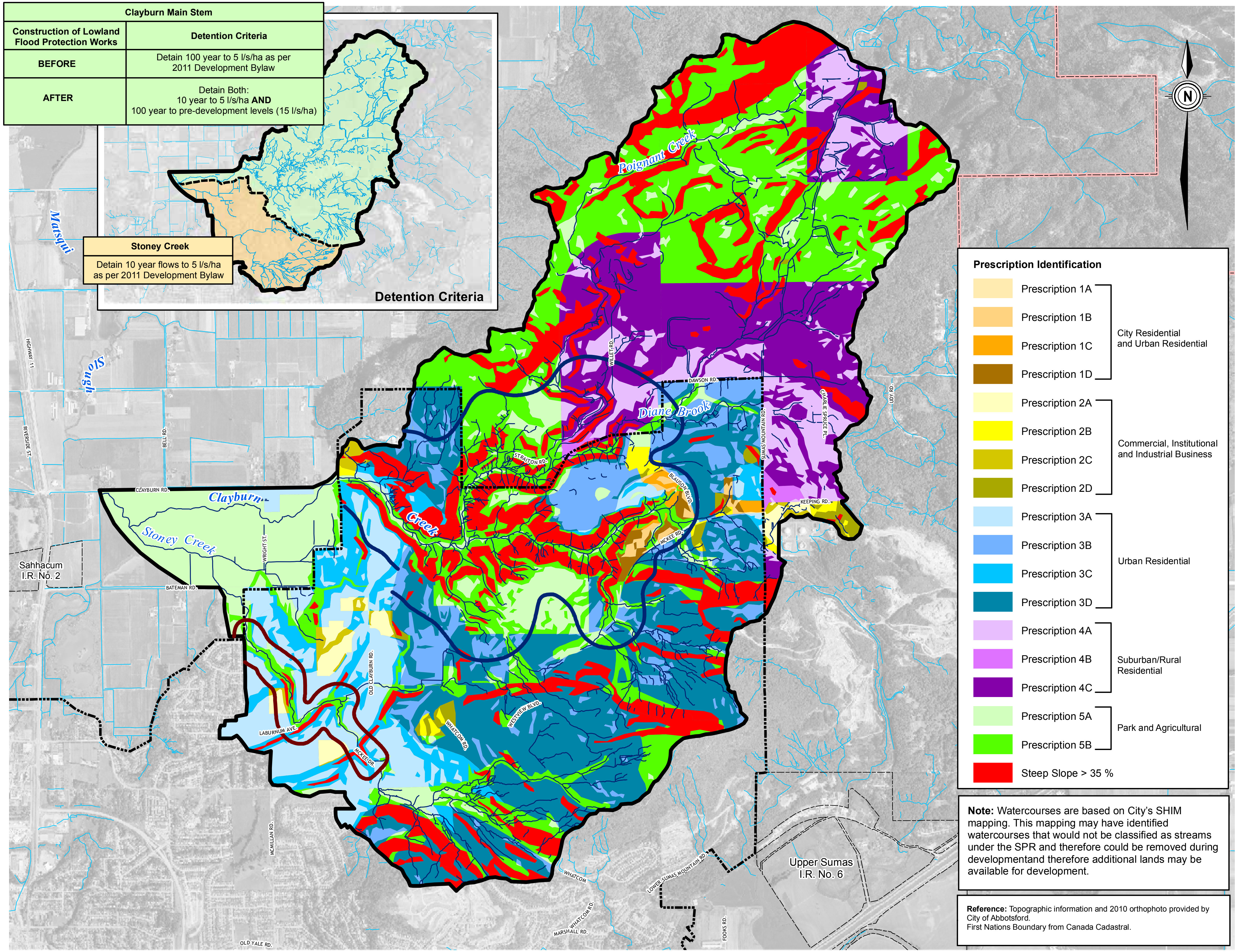
1. Detain the 100-Year (all durations) post-development peak flows to 15 L/s/ha (to maintain existing flows through Clayburn Village); AND
2. Detain the 10-Year (all durations) post-development peak flows to 5 L/s/ha.

Riparian and Instream Compensation Works: Section 8-5 of the Clayburn ISMP report lists environmental restoration and enhancement opportunities within the watershed should developers need compensation works.

Table 1: Recommended Clayburn Creek Watershed Criteria

CATEGORY	Purpose / Criteria / Solutions
Development Restricted and Special Requirement Areas	**TO PROTECT HUMAN/PROPERTY SAFETY AND THE ENVIRONMENT** **No development (excluding road and utility crossings) within[1]:** • Extreme slope areas (above 35%) • Detailed geotechnical assessments required in areas of steep/ravine slopes (2H:1V (50%) from toe of stream channel or ravine slope), no development within geotechnical setbacks • Streamside Protection areas[2], with **no variance and maximum protection policy[1]** specific to Clayburn Creek watershed to provide increase riparian protection (5, 15, or 30 m from top of bank) **Development Permitted with Special Requirements:** • Steep slope areas (10% to 35%) • High or moderate habitat sensitivity ranking areas • Within Wildlife Corridor and Species at Risk BMP buffers (to be determined)
Stormwater – Water Quality Treatment	**TO TREAT STORMWATER PRIOR TO DISCHARGE TO WATERCOURSES** Size to treat 90% of average annual runoff (equivalent to 72% of the 2-year, 24-hour event (51mm)) to remove 80% of Total Suspended Solids. • Construct Stormwater Source Controls (rain gardens, vegetated swales, vegetated pervious pavers) to filter contaminants from roads and parking lots. • Alternatively consider regional water quality facilities such as wetlands and wet ponds. • Construct oil/grit separators as spill control devices for gas stations, high risk spill industry, large parking lots. • Provide Erosion and Sediment Control measures during construction[3].
Stormwater – Reduce Runoff Volume	**TO PRESERVE BASEFLOWS & MINIMIZE DOWNSTREAM EROSION AND HABITAT DEGRADATION** Size to capture 72% of the 2-year, 24-hour event (51mm) or to limit direct runoff to 10% on an annual basis (Water Balance Model). No infiltration/retention facilities within geotechnical setbacks, site specific geotechnical studies are required. • Maximize low impact development techniques • Construct Stormwater Source Controls (bio-retention rain gardens or swales, pervious pavers, absorbent soil layers, green roofs, rainwater harvesting & reuse, etc.) • Regional facilities for baseflow augmentation (sustain baseflows)
Stormwater – Reduce Runoff Peaks	**TO MINIMIZE DOWNSTREAM EROSION, HABITAT DEGRADATION AND FLOODING** Size to detain the 10-year (for Stoney Creek) and 100-year (for Clayburn Village) post-development flows to 5 l/s/ha[4]. • Construct detention/infiltration • New stormwater outfalls should be piped to bottom of ravine side slopes to minimize erosion and bank instability **AFTER THE CONSTRUCTION OF LOWER CLAYBURN FLOOD PROTECTION WORKS, DETENTION CRITERIA WILL BE CHANGED TO MAINTAIN EXISTING FLOWS THROUGH CLAYBURN VILLAGE** 100-year post-development flows 15 L/s/ha plus 10-year post-development flows to 5 l/s/ha.

1. Site specific analysis required during development application process to determine adequate setbacks.
2. City of Abbotsford *Streamside Protection Bylaw No. 1465-2005.* No variances except for utility/transportation corridors.
3. City of Abbotsford *Erosion & Sediment Control Bylaw, 2010.*
4. City of Abbotsford *Development Bylaw No. 1565, 2010.*



City of Abbotsford
Clayburn Creek
Developer Guildelines

Legend

- City Boundary
- Watershed Boundary
- Approximate Urban Development Boundary
- Creek

Detailed Geotechnical Investigation Required

- 100 m from Inner Ravine Slope in Stoney Creek
- 250 m from Inner Ravine Slope in Poignant and Clayburn Creeks

KERR WOOD LEIDAL
consulting engineers

300 0 300 (m)
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Project No.	Date
510-057	February 2012

Source Control Prescriptions and Detention Requirements

Figure 1

Path: O:\0500-0599\510-057\430-GIS\Mxd-Rp\DeveloperGuidelines\510057Fig1_DeveloperGuidelineSourceControls.mxd Date Saved: 2/8/2012 11:25:24 AM
User: llau

Table 2: Recommended Source Controls for Various Land Uses, Slopes, and Soil Types[1]

Ground Slope & Soil Type		Future Land Use (OCP Zoning)					
		City Residential	**Commercial, Institutional & Industrial Business**	**Urban Residential**	**Suburban/Rural Residential**	**Park & Agricultural**[2]	**Roadways**
		Imperviousness: 80%	**Imperviousness: 75 to 90%**	**Imperviousness: 60%**	**Imperviousness: 10%**	**Imperviousness: 0 to 5%**	**Imperviousness: 50%**
Slope < 10%	Good Infiltration (>50 mm/hr.)	**PRESCRIPTION 1A** ◙ • 300mm absorbent soil • Swales or rain gardens for parking areas • Roof leaders to infiltration facilities • Pervious surfaces for pedestrian areas	**PRESCRIPTION 2A** ◙ • 300mm absorbent soil • Swales or rain gardens for parking areas • Roof leaders to infiltration facilities • Pervious surfaces for pedestrian areas	**PRESCRIPTION 3A** ◙ • 300 mm absorbent soil • Disconnect roof leaders • Infiltration trench or rain gardens and rock pits • Pervious surfaces for pedestrian areas	**PRESCRIPTION 4A** ◙ • 300 mm absorbent soil • Disconnect roof leaders	**PRESCRIPTION 5A** ◙ • 300 mm absorbent soil • Disconnect roof leaders	**PRESCRIPTION 6A** ◙ • 300 mm absorbent soil • Rain gardens • Swales and ditches in rural areas • Weirs to limit longitudinal slope to 2%
Slope < 10%	Moderate Infiltration (10 – 50 mm/hr.) / Limited Infiltration (0 - 10 mm/hr.)	**PRESCRIPTION 1B** ○ • 300 mm absorbent soil • Swales or rain gardens for parking areas • Roof leaders to infiltration/retention or re-use facilities • Regional detention for uplands • Pervious surfaces for pedestrian areas	**PRESCRIPTION 2B** ○ • 300 mm absorbent soil • Swales or rain gardens for parking areas • Roof leaders to infiltration/retention or re-use facilities • Regional detention for uplands • Pervious surfaces for pedestrian areas • Green roof	**PRESCRIPTION 3B** ○ • 300 mm absorbent soil • Disconnect roof leaders • Regional detention and retention for uplands • Pervious surfaces for pedestrian areas			**PRESCRIPTION 6B** ○WQ • Curb & gutter, storm sewer in non rural areas • Swales and ditches in rural areas • Regional retention/bio-retention
Slopes Between 10% and 35%[3]	Good and Moderate Infiltration (>10 mm/hr.)	**PRESCRIPTION 1C** ○ • Terrace cleared lot area • 300 mm absorbent soil terraced slopes • Rain gardens and rock pits for parking areas	**PRESCRIPTION 2C** ○ • Terrace cleared lot area • 300 mm absorbent soil terraced slopes • Stormwater re-use for roof water • Rain gardens and rock pits for parking areas • Green roof	**PRESCRIPTION 3C** ○ • 300 mm absorbent soil on terraced slopes • Disconnect roof leaders • Terrace cleared lot area • Rain gardens and rock pits	**PRESCRIPTION 4B** ◙ • Terrace cleared lot area • 300 mm absorbent soil on terraced slopes • Disconnect roof leaders • Rain gardens and rock pits	**PRESCRIPTION 5B** ◙ • Terrace lawn/open landscape areas • 300 mm absorbent soil on lawn/open landscape areas • Disconnect roof leaders	**PRESCRIPTION 6C** ○WQ • Curb & gutter, storm sewer in non rural areas • Perforated storm sewers in infiltration trench • Armoured ditches in rural areas • Underground infiltration/retention
Slopes Between 10% and 35%[3]	Limited Infiltration (0 – 10 mm/hr.)	**PRESCRIPTION 1D** ○ • Terrace cleared lot area • 300 mm absorbent soil terraced slopes • Underground retention • Regional retention[4] or on-site retention	**PRESCRIPTION 2D** ○ • Terrace cleared lot area • 300 mm absorbent soil terraced slopes • Stormwater re-use for roof water • Green roof • Underground retention • Regional retention[4] or on-site retention	**PRESCRIPTION 3D** ○ • 300 mm absorbent soil on terraced slopes • Disconnect roof leaders • Terrace cleared lot area • Regional retention[4] or on-site retention	**PRESCRIPTION 4C** ◙ • Terrace cleared lot area • 300 mm absorbent soil on terraced slopes • Disconnect roof leaders • Retention or bio-retention		**PRESCRIPTION 6D** ○WQ • Curb & gutter, storm sewer in non rural areas • Armoured ditches in rural areas • Bio-retention/regional retention[4] or on-site retention • Underground retention

Assumptions: (Refer to Figure 1)

◙ indicates that on-site Source Controls may be designed to achieve both Volume Reduction **(51mm of rain capture target)** and Detention criteria.

○ indicates that regional Volume Reduction and Detention measures may be required in addition to on-site Source Control.

WQ indicates that separate water quality treatment is required.

[1] Application of Source Controls is not recommended within the infiltration setback from the ravine unless approved for the site by a geotechnical engineer

[2] Includes: Resource/Conservation, Forest and Limited Use designations; these designations are expected to experience minimal development unless re-zoned for development as part of a Community Plan

[3] Development not possible on slopes steeper than approximately 35%.

[4] Regional retention refers to a community retention facility that serves multiple properties or developments and is paid-for by the contributing owners/developers when an on-lot retention facility is not able to fully meet the capture criterion. It is an end-of pipe facility to hold, reuse, and/or infiltrate impervious runoff (i.e. community infiltration trench, or non-portable collection and reuse).

Swales refer to vegetated swales. 300 mm Absorbent Soil for pervious areas. Connect Roof Leaders = Connect to storm sewer system, Disconnect Roof Leaders = Drain to pervious areas or facility for capture.