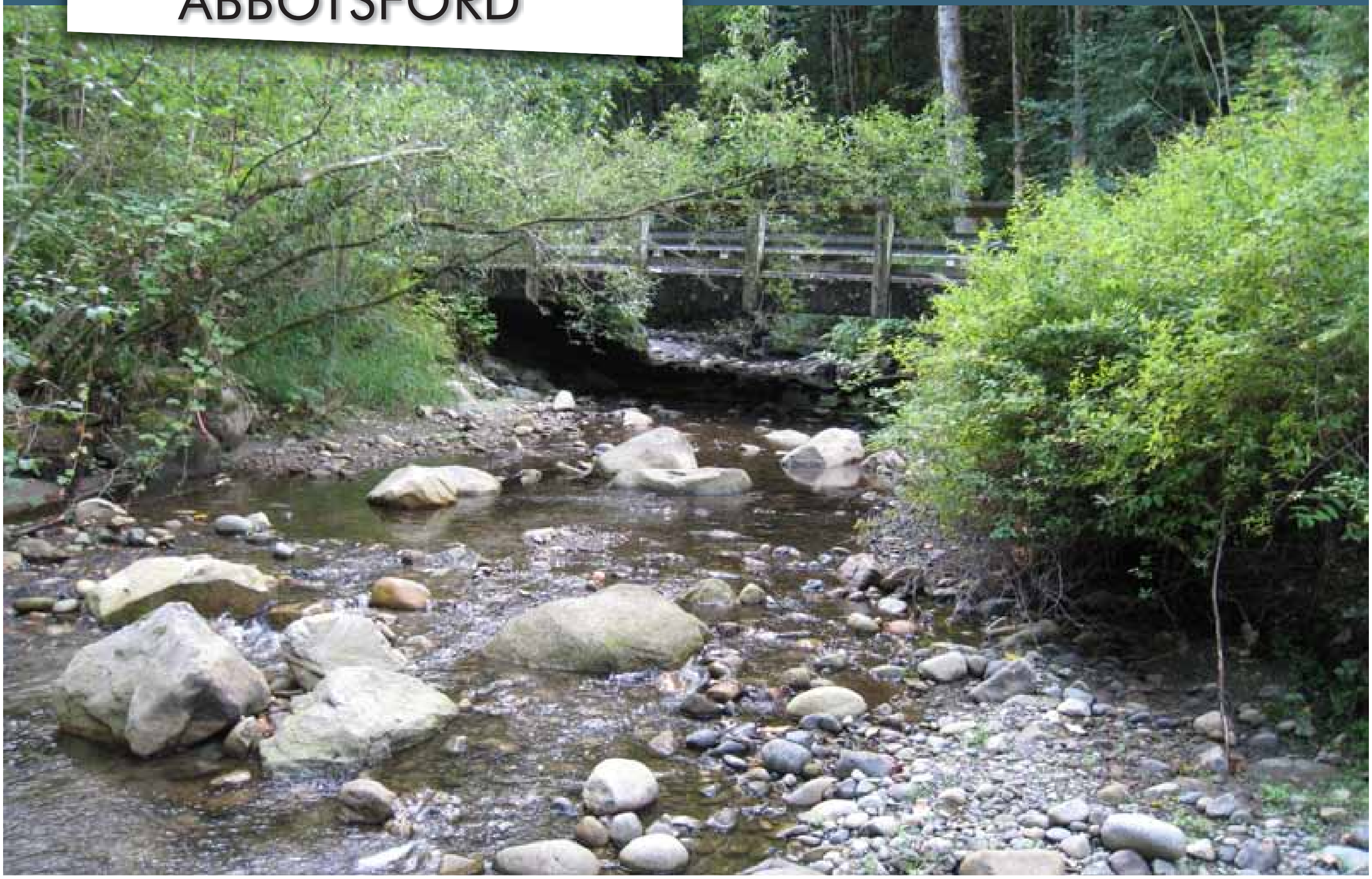
ABBOTSFORD



Final Report

Clayburn Creek Integrated Stormwater Management Plan

May 2012

Submitted by:

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consulting engineers

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May 11, 2012

Ms Kathy Zhang
Drainage Engineer
City of Abbotsford
32315 South Fraser Way
Abbotsford, B.C. V2T 1W7

Dear Ms. Zhang:

RE: **Clayburn Creek Integrated Stormwater Management Plan**
Final Report Submission
Our File 0510.057-300

We are pleased to submit three (3) bound copies, one unbound copy, and a digital copy of our Final Report for the above-captioned project. The comments from the City, agencies, stakeholders and the public have been incorporated into this Final Report. It consists of:

- **Lowland Flood Management Plan** including setback berms, widened channel section, and raising low sections of Clayburn Road,
- **Erosion Management Plan** including 2012 inventory/assessment and bank stabilization for severe sites with high consequences.
- **Sediment Management Plan** including continuing on-going sediment removals and enlarging the existing sediment traps.
- **Future Development Guidelines** including protection of riparian, ravine and wildlife areas, and requirement for volume reduction, detention, and water quality treatment.
- **Environmental Enhancement Projects** including restoration of riparian areas and instream complexing.
- **Monitoring and Adaptation Plan** to ensure the watershed goals will be met and the watershed health protected under the future mitigated development condition.

We have truly enjoyed working on this unique project with the City. Please contact the undersigned should you require any clarifications regarding this submission.

Yours truly,

KERR WOOD LEIDAL ASSOCIATES LTD.

Crystal Campbell, P.Eng.
Stormwater Sector Leader

CC/dz
Encl.

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Executive Summary

Introduction

Clayburn Creek watershed is 2250 ha with multiple tributaries including Stoney Creek, Poignant Creek, and Diane Brook. Clayburn Creek drains through Matsqui Slough into the Fraser River. It is a mountainous watershed with headwater elevations as high as 530 m and lowland area between El. 12m to El. 4m. Some areas are relatively steep exceeding 35% in places. There is existing flooding in the lowland Clayburn Village, Clayburn Road and agricultural areas.

A significant portion of the existing watershed is second growth forest 'greenfield' with some acreage residential and single-family residential and agricultural lowlands. Plans for future development include additional single-family and suburban residential with limited multi-family and commercial/industrial. Total watershed impervious area will increase from 12% to 27%.

Clayburn Creek is a relatively healthy watershed (mean B-IBI score 33) and supports five salmon and trout species: chum, coho, steelhead, cutthroat trout, and possibly pink. There is also much wildlife present and a high number of species at risk and regionally-important species at risk habitat. The riparian corridor is largely intact and there is high watershed forest cover. The water and sediment quality is good with the largest issue being turbidity caused by sedimentation within Clayburn Creek mainstem ravine and possible other localized impacts from development.

Existing Issues

The following major issues are currently found in the watershed.

Active Stream Bank Erosion and Instability of Steep Ravine Slopes

Active stream bank erosion along Poignant, Clayburn and Stoney Creeks was found, together with active natural slope instabilities of the steep ravine slopes along the well incised Poignant and Clayburn Creek ravines. Most of the stream bank erosion sites (80%) were noted on stream gradients greater than 12%, and to a lesser extent (13%) downstream of existing subdivisions. Sediment (sands and gravels) are mobilized in the stream and carried downstream and deposited in the lowland channel reducing its conveyance capacity and causes flooding.

Lowland Flooding

Clayburn Creek has long history of flooding affecting Clayburn Village, Clayburn Road and the lowland agricultural areas. Lowland residents have noted that flooding has exacerbated in recent years. Potential causes of flooding are listed in order of importance:

1. Reduced conveyance capacity through lowland creek channel due to sediment accumulation. DFO stopped permitting large scale channel dredging in 1989. Sediment removed from existing sediment basins is not keeping up with sediment influx. Existing channel capacity is 8 – 10 m^3/s (<2-year flow), 0.5 m excavation of sediment would yield greater than 14 m^3/s (between 10-year and 25-year flow).
2. Increased significant rainfall events in last 10 years. An analysis of the rainfall records over the last 33 years showed that 12 out of 22 significant rainfall events occurred in the last 10 years. Significant events have occurred almost annually (and 4 in 2007) during the 2000's.

3. Decreased channel conveyance capacity because of streambank vegetation growth.
4. Increased frequency of peak flows from upland development.

Alternatives to address the flooding and key issues in the watershed were developed and discussed with City Staff, DFO, stakeholders and the public through an extensive stakeholder consultation process. Components were refined into an ISMP plan.

Objectives

The City of Abbotsford initiated the Clayburn Creek Integrated Stormwater Management Plan primarily to:

- address lowland flooding of Clayburn Village, Clayburn Road and downstream agricultural areas; and
- develop guidance to mitigate the impacts of future upland development to protect the environment and not exacerbate the flooding and erosion.

ISMP Plan

Table i summarizes the recommended ISMP components, costs and priorities. Figure i depicts the lowland flood protection works and Figure ii and Table ii outline requirements for future development.

The recommended plan meets the objectives of this study to minimize lowland flooding, provide guidance to mitigate the impacts of future development and protect the environmental values and ecological health of the watershed. It complements the City's OCP and sustainability goals. We hope that DFO will issue a letter of endorsement for this ISMP and that a Memorandum of Understanding between the City and DFO be drawn up for the Sediment Management Plan.

Capital Projects

The following capital projects and timelines are recommended.

Immediate

- Further Studies – undertake a Functional Feasibility Study for Lower Clayburn Flood Protection Plan, $50,000 estimated cost, start immediately.
- Lowland Flood Management – includes berms/floodwalls, storm sewer for Clayburn Village drainage, and channel widening, $3.7 million estimated cost, construction to start immediately and continue through to 2014.
- 2012 Erosion Inventory & Assessment – reassess erosion and compare to 2006 SHIM mapping to locate areas of increasing erosion, $50,000 estimated cost, to be completed in 2012.
- Sediment Trap Improvements – enlarge and improve efficiency of College, Wright Street, Dutra, and Stoney Confluence sediment traps, $160,000 estimated cost, to be completed during trap cleaning in 2012.
- Bylaws and Standards – Update the City's Development Bylaw (2011) with the following, $30,000 estimated cost, complete in 2012:
    - add capture target (6-month 24-hour event Volume Reduction);

- develop green road standards for stormwater treatment and volume reduction; and
- develop examples and standards for Stormwater Source Controls to aid with implementation.

- Existing Bylaw Revision and Enforcement – includes enhancing the Tree Protection Bylaw to require compensation for <20 cm diameter trees, enforcing the Streamside Protection Bylaw with no-net-loss variances except for creek crossings, and enforcing the Erosion and Sediment Control Bylaw, no cost estimated, to be implemented in 2012.

5-Year Plan

- Clayburn Road Raising – raise low portions of Clayburn Road west of Clayburn Village up to the 100-year flood construction level, $1 million estimated cost, construct within the next 5-years after the 100-year flood level is estimated in the Matsqui Prairie Drainage Study.
- Upland Culvert and Storm Sewer Upgrades – upgrade 14 culverts, 3 bridges and selected storm sewers, $4.9 million estimated cost, complete upgrades over next 5 years.
- Detention Facility Modifications – includes assessing in detail and changing outlet orifice sizes to make better use of available storage volume, $180,000 estimated cost for the first nine high priority facilities, complete upgrades over next 5 years.
- Sediment Management at Wright Street – construct a weir immediately upstream of the bridge to discourage deposition of sediment under the bridge, $20,000 estimated cost, construct at the same time as the fish habitat improvement works (Lowland Flood Management) in 2014.
- Sediment Weirs – construct in-stream rock weirs in upper channels upstream of Clayburn Village to create temporary sediment traps, costs to be determined, construct within 5 years.
- Further Studies – undertake a Terrestrial Habitat Conservation Study, Land Use Planning Process for future Clayburn development areas, and a Lowland Drainage Study for Matsqui Prairie, $350,000 estimate cost, complete studies within 5 years.

Proposed Developer Responsibilities

The following are to be incorporated by developers at the time of development.

- Erosion Control – construct bank stabilization as part of future development in accessible areas to reduce turbidity during high flows.
- Setbacks and Protected Areas – City to require appropriate riparian and geotechnical setbacks. No-net-loss variances on riparian setbacks except for road/utility crossings of creeks, City to strongly encourage use of Species at Risk setbacks, City to establish or enlarge protected areas to provide several large core habitat areas for wildlife and establish designated Wildlife Corridors for connectivity between large core habitat areas.
- Volumetric Source Controls – 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.) sized to capture 72% of the 2-year, 24-hour event (51mm), and construct regional facilities for baseflow augmentation (to sustain baseflows).
- Water Quality Controls – construct Stormwater Source Controls (rain gardens, vegetated swales, vegetated pervious pavers) sized to treat 90% of average annual road and parking lot runoff,

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, and large parking lots, and provide Erosion and Sediment Control measures during construction.

- Peak Flow Control – construct detention/infiltration facilities sized to detain 10-year to 5 l/s/ha, plus 100-year post to pre-development for Clayburn Creek catchment (after Lowland Flood Management Works constructed), and pipe new stormwater outfalls to bottom of ravines to minimize bank erosion/instability.

Environmental Enhancement Projects

The following environmental enhancement projects are proposed at time of development.

- Riparian Areas – reforest impacted riparian areas within designated setbacks, work with agricultural landowners to establish riparian leave strips (tree and shrub cover) to stabilize banks and improve cover for fish, and remove invasive species and reforest with native species, $17 per m^2 estimated cost.
- Instream Complexing – construct in-stream complexing such as wood structures, boulder groups/spurs, stable debris jams & gravel spawning platforms, and off-channel habitats, $5,000 per structure estimated cost.
- Fish Passage – remove old dam on Poignant Creek fish passage barrier, $50,000 estimated cost.

Maintenance Program

The following ongoing maintenance works are proposed.

- Vegetation Management – continue vegetation management in lower Clayburn Creek.
- Sediment Management – continue sediment removals at existing sediment traps and gravel bars, remove sediment from proposed floodplain bench in widened channel, budget $60,000 per year.

Long Term Works

The following long term works are proposed.

- Roof Leader Disconnection – encourage home owners to disconnect roof leaders to maximize infiltration capacity in Stoney Creek existing development well-draining soils areas.
- Detention Facility Modifications – includes assessing in detail and changing outlet orifice sizes to make better use of available storage volume, $260,000 estimated cost for the nine medium and four low priority facilities.

Proposed Monitoring Program

Conduct ongoing watershed performance monitoring and evaluate progress every 5 years. Implement adaptive management to adjust the development requirements to protect the watershed as required. Budget $30,000 per year for monitoring and assessment.

Financial Implications

The capital cost estimates for the lowland flood protection works such setback berms and channel widening is $3.7 million. Due to the nature of flooding every year, these works are considered high priority and should be designed and implemented as soon as possible.

Repair detention facility outlets deficiencies will be funded from developers where possible. Future site-level rainwater source controls, detention facilities, storm sewer system will be the responsibility of the developer. Habitat enhancements may also be undertaken by developers as part of mitigation requirements. Some improvements may also qualify for funding from senior government or environmental grants, such as those provided by the Pacific Salmon Foundation. Environmental groups may also assist with habitat enhancement works and education.

ISMP Performance Monitoring and Accountability of Plan

Monitoring of watershed performance indicators is needed to assess the success of the ISMP implementation and allow for adaptive management in the future. Table iii lists the parameters or “indicators” that should be measured and tracked over time.

The schedule for a full assessment and review for the watershed health indicators should be at least once every five years, to be tracked and utilized in association with the timeline for ISMP implementation. Some indicators should be measured and tracked more frequently to ensure a complete picture and record of the changing indicator values.

Conclusions

The ISMP is the culmination of extensive work by an integrated team including multi-departmental City Staff, multi-disciplinary consulting team, DFO and the project Advisory Committee and the public. The plan strives to protect a 10-year level of service flood protection for the lowlands and to provide the framework for requirements for future development.

The Clayburn Creek watershed will continue to undergo significant changes. The impact of increasing development and impervious area if unmitigated will take a toll on the creek system, and will exacerbate flooding, erosion, further destabilization of the creek ravines, and will degrade aquatic habitat. The Clayburn Creek ISMP lays out a plan to mitigate these impacts, and sets a number of performance metrics to measure the progress of the plan’s implementation.

Table i: Clayburn Creek ISMP Plan & Implementation Strategy

	Proposed ISMP	Priority	Cost Estimate	Responsibility
Flood Management				
1.	**LOWER CLAYBURN FLOOD MANAGEMENT PLAN**			
	• Widen Clayburn Creek channel and create floodplain bench through agricultural lands (downstream of Wright St) to convey 2-year flow. • Construct setback berms to contain 10-year flow along lower Clayburn Creek. • Raise existing Clayburn Road above 100-year flood level. • Continue vegetation management in lower Clayburn Creek.	Immediate Immediate 5-year Plan Ongoing	$332K $3.4M $1M est.[1]	City Engineering & Environmental Services
2.	**UPLAND CULVERT AND STORM SEWER UPGRADES**			
	• Upgrade 14 culverts, 3 bridges and selected storm sewers.	5-year Plan	$4.9M	City Engineering
Erosion Management				
3.	**REHABILITATE EXISTING EROSION SITES & MITIGATE EROSIVE FLOWS**			
	• Undertake 2012 Erosion Inventory & Assessment • Bank stabilization not recommended for all sites as access/environmental impacts are prohibitive. • Construct bank stabilization as part of future development in accessible areas to reduce turbidity. • Disconnect roof leaders and retrofit to maximize infiltration in Stoney Creek well-draining soils.	Immediate At time of development Ongoing	$50K	City Engineering & Environmental Services Developer Homeowner
4.	**EXISTING DETENTION FACILITY MODIFICATIONS FOR EROSION MANAGEMENT**			
	• Modify detention outlets to minimize erosion.	0 – 5 year	$180K[2]	City Engineering
Sediment Management				
5.	**SEDIMENT REMOVALS & NEW WEIRS**			
	• Expand & improve existing College, Wright Street, Dutra, & Stoney Confluence sediment traps. • Remove sediment under Wright Street Bridge (completed 2011) and construct weir to accelerate flows and discourage deposition. • Construct in-stream rock weirs in upper channels for temporary sediment traps. • Continue sediment removals at existing sediment traps and gravel bars. • Remove sediment from proposed floodplain bench in widened channel.	Immediate Immediate 0 – 5 year Ongoing Ongoing	$160K $20K TBD $50K/year $100K/10yrs	City Engineering & Environmental Services
Mitigation of the Impacts of Future Development (Requirements for All Development)				
6.	**PROTECT RIPARIAN, RAVINE, AND WILDLIFE AREAS** to protect stream health, ravine/slope stability & wildlife habitats			
	• Require appropriate riparian and geotechnical setbacks. No variances on riparian setbacks. • Strongly encourage use of Species at Risk setbacks. • Establish or enlarge protected areas to provide several large core habitat areas for wildlife. • Establish designated Wildlife Corridors for connectivity between large core habitat areas.	At time of development		Developer City Environmental & Development Services Approval
7.	**CONSTRUCT HYDROLOGIC VOLUME REDUCTION MEASURES** to maintain baseflows and minimize downstream erosion and habitat degradation			
	• 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.). Size to capture 72% of the 2-year, 24-hour event (51mm). No source controls in geotechnical setbacks. • Regional facilities for baseflow augmentation (sustain baseflows).	At time of development		Developer City Development Services Approval
8.	**CONSTRUCT STORMWATER QUALITY TREATMENT MEASURES** to treat runoff prior to discharge to watercourses			
	• Size to treat 90% of average annual runoff (approx. 72% of the 2-year, 24-hour event (51 mm)). • 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.	At time of development		Developer City Development Services Approval
9.	**CONSTRUCT HYDROLOGIC RATE CONTROL MEASURES** to minimize downstream erosion, habitat degradation and flooding			
	• Size to detain 10-year to 5 l/s/ha, plus 100-year post to pre-development for Clayburn Creek catchment (after Lowland Flood Management Works constructed). • Construct detention/infiltration. • New stormwater outfalls to be piped to bottom of ravines to minimize bank erosion/instability.	At time of development		Developer City Development Services Approval
Environmental Enhancement Projects				
10.	**RESTORE RIPARIAN AREAS**			
	• Reforest impacted riparian areas within designated setbacks. • Work with agricultural landowners to establish riparian leave strips (tree and shrub cover) to stabilize banks and improve cover for fish • Remove invasive species and reforest with native species.	As needed as compensation	$12/m^2 $17/m^2	Developer and/or City
11.	**RESTORE IN-STREAM COMPLEXING**			
	• Construct in-stream complexing such as wood structures, boulder groups/spurs, stable debris jams & gravel spawning platforms, & off-channel habitats.	As needed as compensation	$5K per structure	Developer and/or City
12.	**UPGRADE FISH PASSAGE BARRIERS**			
	• Remove fish passage barrier: old dam on Poignant Creek.	As needed as compensation	$50K per location	Developer and/or City
Municipal Stormwater Management Program				
13.	**BYLAWS AND STANDARDS (APPLY MUNICIPALITY WIDE)**			
	• Update the City's Development Bylaw (2011) with the following: - add capture target (6-month 24-hour event Volume Reduction) - develop examples and standards for Stormwater Source Controls to aid with implementation - develop green road standards for stormwater treatment and volume reduction • Enforce City's *Erosion & Sediment Control and Streamside Protection Bylaws.* No variances. • Enhance and enforce City's *Tree Protection Bylaw* in all areas of the watershed.	Immediate Immediate Immediate	$30K	City Engineering City Development Services
14.	**FURTHER STUDIES IN CLAYBURN CREEK WATERSHED**			
	• Undertake a Functional Feasibility Study for Lower Clayburn Flood Protection Plan. • Undertake a Terrestrial Habitat Conservation Study ($50K), Land Use Planning Process for future Clayburn development areas($100K), and a Lowland Drainage Study ($200 K) for Matsqui Prairie	Immediate 0 – 5 year	$50K $350K	City Engineering & Community Planning
15.	**WATERSHED MONITORING**			
	• Conduct watershed performance monitoring and adaptive management approach.	Every 5-years minimum	$30K/ year	City Engineering & Env. Services
Note: Refer to Figures 8-1 to 8-8 1. Estimate provided by the City. 2. There are nine high priority facility modifications to be completed in the next 5 years. Assume $20k per facility.		City Capital Program City Yearly Maintenance/Monitoring City Studies/Policies	$10.0 Million $90,000 /year $480,000	

Table ii: Recommended Source Controls for Various Land Uses, Slopes, and Soil Types[1]

<table>
<tr><th colspan="2" rowspan="3">Ground Slope & Soil Type</th><th colspan="6">Future Land Use (OCP Zoning)</th></tr>
<tr><th>City Residential</th><th>Commercial, Institutional & Industrial Business</th><th>Urban Residential</th><th>Suburban/Rural Residential</th><th>Park & Agricultural[2]</th><th>Roadways</th></tr>
<tr><th>Imperviousness: 80%</th><th>Imperviousness: 75 to 90%</th><th>Imperviousness: 60%</th><th>Imperviousness: 10%</th><th>Imperviousness: 0 to 5%</th><th>Imperviousness: 50%</th></tr>
<tr><td rowspan="3">Slope < 10%</td><td>Good Infiltration (>50 mm/hr.)</td>
<td>PRESCRIPTION 1A ◙
• 300mm absorbent soil
• Swales or rain gardens for parking areas
• Roof leaders to infiltration facilities
• Pervious surfaces for pedestrian areas</td>
<td>PRESCRIPTION 2A ◙
• 300mm absorbent soil
• Swales or rain gardens for parking areas
• Roof leaders to infiltration facilities
• Pervious surfaces for pedestrian areas</td>
<td rowspan="2">PRESCRIPTION 3A ◙
• 300 mm absorbent soil
• Disconnect roof leaders
• Infiltration trench or rain gardens and rock pits
• Pervious surfaces for pedestrian areas</td>
<td rowspan="3">PRESCRIPTION 4A ◙
• 300 mm absorbent soil
• Disconnect roof leaders</td>
<td rowspan="3">PRESCRIPTION 5A ◙
• 300 mm absorbent soil
• Disconnect roof leaders</td>
<td rowspan="2">PRESCRIPTION 6A ◙
• 300 mm absorbent soil
• Rain gardens
• Swales and ditches in rural areas
• Weirs to limit longitudinal slope to 2%</td></tr>
<tr><td>Moderate Infiltration (10 – 50 mm/hr.)</td>
<td rowspan="2">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</td>
<td rowspan="2">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</td></tr>
<tr><td>Limited Infiltration (0 - 10 mm/hr.)</td>
<td>PRESCRIPTION 3B ◯
• 300 mm absorbent soil
• Disconnect roof leaders
• Regional detention and retention for uplands
• Pervious surfaces for pedestrian areas</td>
<td>PRESCRIPTION 6B ◯WQ
• Curb & gutter, storm sewer in non rural areas
• Swales and ditches in rural areas
• Regional retention/bio-retention</td></tr>
<tr><td rowspan="2">Slopes Between 10% and 35%[3]</td><td>Good and Moderate Infiltration (>10 mm/hr.)</td>
<td>PRESCRIPTION 1C ◯
• Terrace cleared lot area
• 300 mm absorbent soil terraced slopes
• Rain gardens and rock pits for parking areas</td>
<td>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</td>
<td>PRESCRIPTION 3C ◯
• 300 mm absorbent soil on terraced slopes
• Disconnect roof leaders
• Terrace cleared lot area
• Rain gardens and rock pits</td>
<td>PRESCRIPTION 4B ◙
• Terrace cleared lot area
• 300 mm absorbent soil on terraced slopes
• Disconnect roof leaders
• Rain gardens and rock pits</td>
<td rowspan="2">PRESCRIPTION 5B ◙
• Terrace lawn/open landscape areas
• 300 mm absorbent soil on lawn/open landscape areas
• Disconnect roof leaders</td>
<td>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</td></tr>
<tr><td>Limited Infiltration (0 – 10 mm/hr.)</td>
<td>PRESCRIPTION 1D ◯
• Terrace cleared lot area
• 300 mm absorbent soil terraced slopes
• Underground retention
• Regional retention[4] or on-site retention</td>
<td>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</td>
<td>PRESCRIPTION 3D ◯
• 300 mm absorbent soil on terraced slopes
• Disconnect roof leaders
• Terrace cleared lot area
• Regional retention[4] or on-site retention</td>
<td>PRESCRIPTION 4C ◙
• Terrace cleared lot area
• 300 mm absorbent soil on terraced slopes
• Disconnect roof leaders
• Retention or bio-retention</td>
<td>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</td></tr>
</table>

Assumptions: (Refer to Figure ii)

◙ 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.

Table iii: Clayburn Creek Watershed Performance Indicators

Performance Indicator		Method of Analysis	2009	2015
Lowland Flood Protection Plan				
1.	Lowland Flooding	Recorded flooding	Every year	10-year level of service
2.	Lower Clayburn Creek Sediment Aggradation	Creek survey every 2 years	Compare to 2007 / 2009 surveys adjusted for proposed works	Same or Decrease not counting sediment traps
Mitigation of Impacts of Future Development				
3.	No. of Erosion Sites	SHIM mapping	92 severe sites (2006) Reassess in 2012	Same or Decrease
4.	TIA (% of Watershed Area)	GIS Analysis of Aerial Photos and Assessment Data	12%	15% (27% build out)
5.	EIA (% of Watershed Area)	Estimated from Clayburn flow record	16.6% (excluding Stoney Creek)	Same or decrease when source controls implemented
6.	RFI (% of Riparian Area)	GIS Analysis of Aerial Photos every 2 to 5 years	78%	Same or Increase
7.	Watershed Forest Cover (% of Watershed Area)	GIS Analysis of Aerial Photos every 2 to 5 years	70%	Decrease expected due to development
8.	Benthic Invertebrates B-IBI scores	Use methods used in this study	26 to 38 mean = 33	34
9.	Fish Populations	Density, species composition (1) Fish salvage data from gravel removals (2) Annual spawner counts in accessible reference reaches in Clayburn, Stoney, & Poignant Creeks	Limited and out-of-date data	Collect data
10.	Fish Passage Barriers	SHIM Mapping	Manmade Barriers 2 Natural Barriers 3	Progressive Removal of Non-natural Barriers
Flow Regime				
11.	Summer Baseflow (L/s)	From continuous flow measurement at Clayburn Creek Straiton Road station	46 (0.03 L/s/ha)	No decrease
12.	Winter Baseflow (L/s)		310 (0.20 L/s/ha)	Same or increase
13.	2-Year Peak Flow (m^3/s)		9.3 (5.9 L/s/ha)	Same or slight decrease
Water Quality				
14.	Average Summer Water Temperature (°C)	Continuous Monitoring (3 locations) - ongoing	MOE data not yet analyzed	Same or Decrease
15.	Specific Conductivity (μS/cm)			Same or Decrease
16.	Turbidity (NTU)			Decrease
17.	Fecal Coliforms (or E.Coli) (MPN/100mL)	WQ sampling (various locations; geometric mean of 5 samples in 30 days) – every 2 years	High Levels	< 200
18.	Sediment Quality	Total Copper, Manganese, and Zinc, concentrations (mg/kg) (10 locations) – every 2 years	Ranges: Cu: 2.7 – 12.5 Mn: 319 – 921 Zn: 32.0 – 77.1	Same or Decrease

City of Abbotsford
Clayburn Creek
ISMP

Legend

- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Culvert
- Storm Main
- Bridge
- Proposed Floodbox
- Proposed Culvert
- Proposed Berm Centreline Side Slopes; 2H - 1V on Creek Side, 3H - 1V on Land Side
- Proposed Berm Centreline Side Slopes; 2H - 1V on Creek Side, 6H - 1V or Flatter on Land Side
- Proposed Flood Wall
- Proposed Raised Road/Path/Driveway
- Possible Pump Station
- Approximate Spillway Location

Reference: 2010 Orthophoto and existing GIS information from City of Abbotsford.

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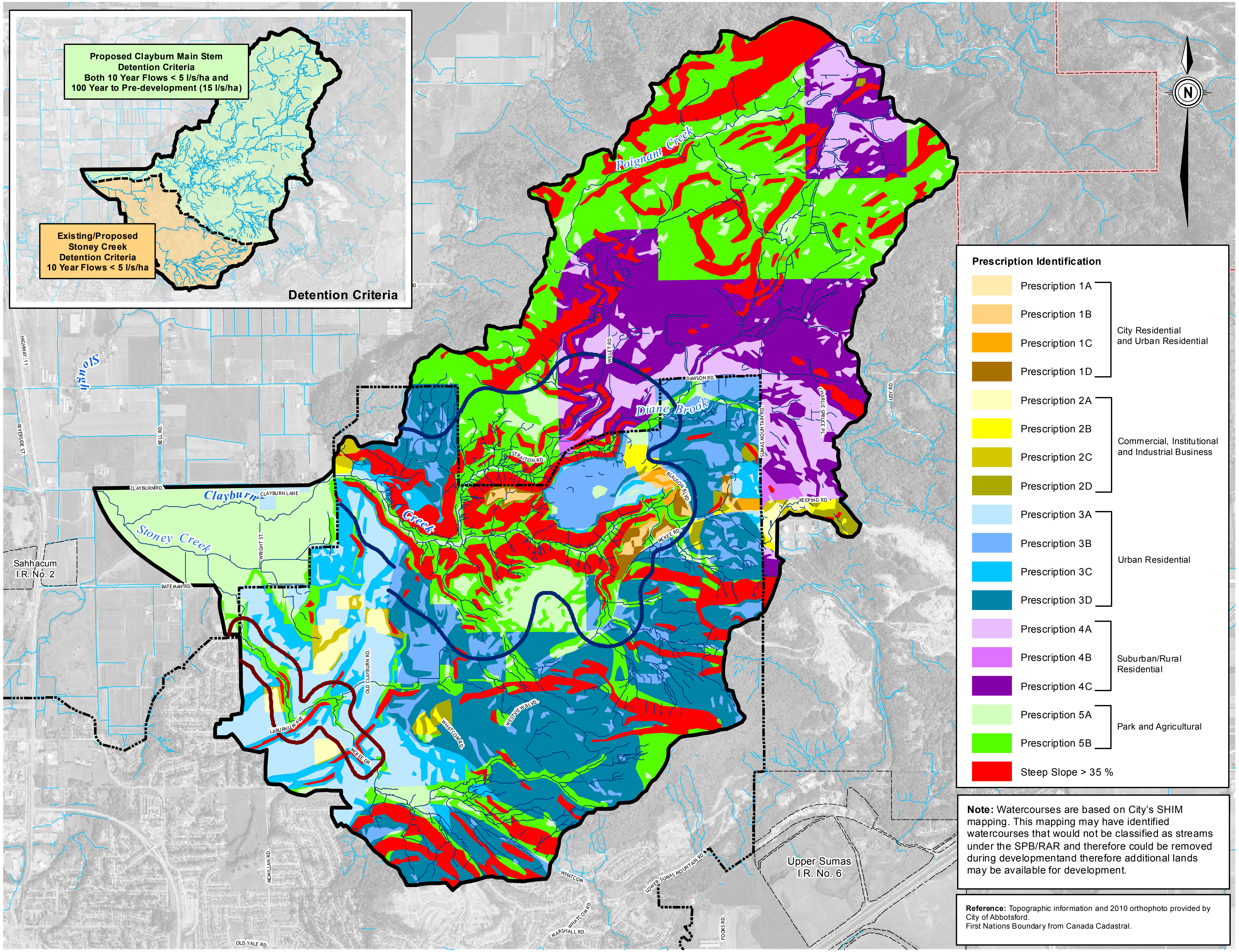
60 0 60 (m)
1:3,000

Project No.	Date
510-057	May 2012

Lower Clayburn Creek Flood Management Plan

Figure i

City of Abbotsford
Clayburn Creek
ISMP



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

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Project No.	Date
510-057	May 2012

Source Control Prescriptions and Detention Requirements

Figure ii

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Section 1

Introduction

1. Introduction

1.1 Background

The City of Abbotsford (City) initiated the Clayburn Creek Integrated Stormwater Management Plan (ISMP) study in 2009. An ISMP is a process of investigating stormwater issues in a holistic approach at the watershed scale. The Clayburn Creek watershed is located in the City of Abbotsford on the west side of Sumas Mountain as shown in Figure 2-1. The study area is located upstream of the Clayburn Road crossing just east of Highway 11, and covers 2253 ha; there are four major tributaries: Clayburn Creek, Stoney Creek, Poignant Creek and Diane Brook. Further downstream and outside of the study area, Clayburn Creek flows north toward and through the Matsqui Slough into the Fraser River. The Fraser River is dyked with a pump station and floodboxes located at the mouth of the Slough to convey water to the Fraser River; this common practice prevents the backflow of water into Clayburn Creek to prevent flooding from the Fraser system.

Photo 1-1: Clayburn Creek Upstream of Straiton Road 2

Photo 1-2: Waterfall at Poignant Creek and Dianne Brook Confluence

1.2 Clayburn Creek ISMP Objectives

The objectives of the study are:

- Safeguard human life and property from flood and erosion damage. Maintain public safety through creek management and address flood overtopping of Clayburn Road and flooding of Clayburn Village;
- Identify slope stability problems, sediment sources and natural hazards;
- Address sediment aggradation in lower channel where the channel slope flattens out and flooding of lowland agricultural areas;
- Preserve watershed ecological health while allowing development to proceed;
- Protect or enhance environmental values (fish, wildlife, vegetation); and
- Develop cost effective solutions (capital, operation, and maintenance) to facilitate orderly land development.

1.3 Clayburn Creek Key Issues and Concerns

There are many key issues and concerns in the Clayburn Creek watershed which can be summarized as follows:

Lowland Flooding

- Clayburn Creek has a long history of flooding affecting Clayburn Village, Clayburn Road and lowland agricultural areas. Lowland residents feel that flooding has been exacerbated in recent years. Flood flows outside the creek channel have occurred annually downstream of Wright Street for several years and now also occur at Wright Street on an annual basis.

Photo 1-3: Clayburn Road and Fields Flooded Dec. 2010

Photo 1-4: Clayburn Village Flooding of 4290 Wright Street Dec. 2010

Photo 1-5: Overtopping and Erosion of Driveway 34416 Clayburn Road Dec. 2010

Photo 1-6: Flooding of Driveway 34481 Clayburn Road Dec. 2010

Photo 1-7: Flooding of West End of Clayburn Village Dec. 2010

Photo 1-8: Clayburn Village Flooding of Wright Street Dec. 2010

Active Stream Bank Erosion and Steep Ravine Instabilities

- There is active stream bank erosion along Poignant, Clayburn and Stoney Creeks and their tributaries and active instability of steep ravines (slope failures) along Poignant and Clayburn Creeks.
- Elevated turbidity and sediment deposition in the upper Clayburn mainstem is the most significant water quality problem noted. Some of this sedimentation is natural, however land use practices can exacerbate the problem and increase erosion rates..

Photo 1-9: Bank erosion 1

Photo 1-10: Bank erosion 2

Sedimentation in Lowland Channels

Sediment aggradation in the lower Clayburn channel is an ongoing natural process and reduces the flow conveyance capacity of the channel. The channel used to be dredged on a regular basis, however environmental agencies have not permitted large-scale sediment excavations since 1989.

Photo 1-11: Sedimentation under Wright Street Bridge

Photo 1-12: Debris on Trash Rack

Mitigate the Impacts of Future Development

- Lowland residents are concerned about the flooding and erosion impacts of existing upland development.
- The City Official Community Plan (OCP) plans for additional future development in the uplands.

Photo 1-13: Auguston Blauson Detention Pond

Photo 1-14: Auguston Instream Detention Facility

Protection of Environmental Values

- One of the primary goals of an ISMP is to preserve watershed health as a whole, while meeting community needs and allowing development to occur.
- Clayburn Creek is a very healthy watershed with diverse and abundant fish and wildlife communities including several species at risk. There is a good watershed and riparian forest cover.
- Water quality concerns include elevated turbidity and suspended sediment in the upper Clayburn Creek mainstem, fecal coliforms in Diane Brook and Stoney Creek, and metals contamination in Stoney Creek and other sites downstream of roads or development.

- The Fisheries and Oceans Canada (DFO) is concerned that instream works and dykes would impact fish and fish habitat and that they would not fully resolve the watershed issues that create the current need for the instream projects.

Photo 1-15: Chum Spawner

Photo 1-16: Pacific Water Shrew

1.4 Scope of Assignment

The study work program is summarized in Table 1-1. A brief summary of impacts of development and understanding stormwater management is included in Appendix A.

Table 1-1: Engineering Work Program

Major Tasks & Meetings		
Phase 1 Data Collection & Assessment	1.	Establish Framework
	2.	Hydrogeology and Geotechnical Inventory & Assessment
	3.	Land Use Assessment
	4.	Environmental Inventory
	5.	Stream Health Assessment
	6.	Drainage Inventory
	• Phase 1 Reporting & Meeting • Habitat Review Panel (HRP) Meeting #1 • Abbotsford Environmental Advisory Committee Meeting • Public Information Meeting #1	

Major Tasks & Meetings		
Phase 2 & 3 Assessment & Alternatives	7.	Hydrotechnical Analysis
	8.	Erosion, Sediment Sources & Natural Hazards
	9.	Ecological Health Analysis
	10.	Assess Mitigative Alternatives
	11.	Management Analysis
	• Phase 3 Reporting • Clayburn ISMP Advisory Group Meeting#1 • HRP Meeting #2 • DFO & HRP Meeting #3 • Public Information Meeting #2	
Phase 4 ISMP	12.	Develop Strategy, Plan and Report
	• Draft Report • Phase 4 Meeting • Clayburn ISMP Advisory Group Meeting #2 • Public Information Meeting #3 • Public Information Meeting #4 • Final Report	

1.5 Stormwater, Drainage and Environmental Protection Criteria

Criteria to manage stormwater and drainage within the City were derived from the following major sources and summarized in Tables 1-2 and 1-3:

1. City of Abbotsford Consolidated Development Bylaw No. 1565-2006 – drainage information is summarized in Appendix A.
2. City of Abbotsford Development Bylaw No. 2070-2011. Adopted at the end of this study.
3. City of Abbotsford Streamside Protection Bylaw, Bylaw No.1465-2005.
4. City of Abbotsford Erosion & Sediment Control Bylaw, 2010.
5. DFO: Urban Stormwater Guidelines And Best Management Practices For Protection Of Fish And Fish Habitat, Draft Discussion Document (http://www.dfo-mpo.gc.ca/Library/277967.pdf).

Table 1-2: Summary of Existing Stormwater Criteria

Application		Criteria/Methodology
Flood and Erosion Protection	Minor Drainage System	10-year return period design event. [1] Detain 10-year (100-year upstream of Clayburn Village) peak flows to 5 L/s/ha. [1]
	Major Drainage System	100-year return period design event. [1]
	Agricultural Lowland Flooding – ARDSA[2]	Limit flooding to 5 days during a 10-year 5-day winter storm. Limit flooding to 2 days during a 10-year 2-day growing season storm. Provide 1.2 m of freeboard during baseflows between storm events.
Environmental Protection	**Volume Reduction** Source Controls	On-site rainfall capture (runoff volume reduction) for 6-month 24-hour storm (72% of the 2-year 24-hour storm). [3]
	Water Quality Treatment	Remove 80% of Total Suspended Solid based on 50 µm particle size from 6-month 24-hour storm (72% of the 2-year 24-hour storm). [3] Limit construction discharge water quality to the lesser of turbidity of 25 NTU or total suspended solids of 25 mg/L at all times expect in the 24 hour period following significant rainfall events (≥25 mm/day) at which time the turbidity can be up to 100 NTU. [4]
	Rate Control Detention / Diversion	Detain 10-year (100-year upstream of Clayburn Village) peak flows to 5 L/s/ha. [1] Control post-development flows in creeks to pre-development levels for 6-month, 2-year and 5-year 24-hour event. [3]
	Riparian	Establish riparian setbacks to comply with City requirements. [1]

1. City of Abbotsford Development Bylaw No. 1565, 2006 and Streamside Protection Bylaw No. 1465-2005.
2. ARDSA = Agriculture and Rural Development Subsidiary Agreement. Not applied during this study.
3. DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat, 2001.
4. City of Abbotsford Erosion & Sediment Control Bylaw, 2010

Table 1-3: Existing Streamside Protection and Enhancement Area Widths

<table>
<tr><th colspan="2" rowspan="3">Existing or Potential
Streamside Vegetation Conditions</th><th colspan="3">Streamside Protection and Enhancement Area Width</th></tr>
<tr><th rowspan="2">Fish bearing</th><th colspan="2">Non-Fish Bearing</th></tr>
<tr><th>Permanent</th><th>Non-Permanent</th></tr>
<tr><td>(a)</td><td>Intact & continuous areas >/= 50 m</td><td colspan="2">30 m</td><td>Min 15 m
Max 30 m</td></tr>
<tr><td>(b)</td><td>Limited & continuous areas = 30 m or discontinuous but occasionally wider areas 30 m to 50 m</td><td colspan="2">30 m</td><td>Min 15 m
Max 30 m</td></tr>
<tr><td>(c)</td><td>Narrow but continuous areas = 15m or discontinuous but occasionally wider areas 15 to 30 m</td><td>Min 15 m
Max 30 m</td><td colspan="2">15 m</td></tr>
<tr><td>(d)</td><td>Very narrow but continuous areas up to 5 m or discontinuous but occasionally wider areas 5 to 15 m</td><td>Min 5 m
Max 15 m</td><td colspan="2">5 m</td></tr>
<tr><td colspan="5">Streamside Protection Bylaw, No. 1465-2005
If a stream is in a ravine that is less than 60 metres wide in total width, not including the stream channel, protection is to be consistent with the above widths, where appropriate, from the top of ravine bank.
If a stream is in a ravine that is more then 60 metres in total width, not including the stream channel, a streamside protection and enhancement area shall be at least ten metres wide measured from the top of ravine bank.</td></tr>
</table>

Watershed specific criteria for environmental protection were assessed and recommended in this study.

1.6 Stakeholder Consultation Program

The stakeholder consultation program included three sets of meetings at key times throughout the study:

- At the beginning – to inform stakeholders of the study and solicit input to ensure that all the key issues are identified, understood and addressed in the study. (April 2010)
- After assessments and alternatives were identified – to present findings and potential solutions, solicit input regarding solution preferences, and identify additional alternatives. We prefer to get feedback prior to developing solution details and costing. Comments and concerns have been documented and addressed to the extent possible given the limitations of the ISMP study process. The preferred solutions are developed further in the ISMP plan. (June 2011)
- After the draft plan – to present the proposed draft plan and solicit any final feedback and hopefully endorsement of the plan. The study team addresses the comments prior to plan and report finalization. (October 2011)

The meetings and dates are listed as follows and further discussed in Appendix H:

- City of Abbotsford Habitat Review Panel Meeting #1: December 10, 2009
- City of Abbotsford Environmental Advisory Committee Meeting: January 28, 2010
- Public Information Meeting #1: April 13, 2010
- Clayburn ISMP Advisory Group Meeting #1: December 14, 2010
- City of Abbotsford Habitat Review Panel Meeting #2: January 13, 2011
- City of Abbotsford Meeting with DFO: April 20, 2011
- Public Information Meeting #2: June 29, 2011

- Clayburn ISMP Advisory Group Meeting #2: October 13, 2011
- Public Information Meeting #3: October 24, 2011
- Public Information Meeting #4: December 13, 2011

Stakeholders included:

- City staff from multiple departments
- DFO
- BC Ministry of Environment (MOE)
- Abbotsford Habitat Review Panel (HRP)
- Abbotsford Agricultural Advisory Committee & Matsqui Prairie Dyking, Drainage & Irrigation Committee
- Area H Transition Advisory Committee
- City Industry Development Advisory Committee
- Abbotsford Environmental Advisory Committee
- Clayburn Village residents
- Streamkeepers and environmental groups

An ISMP Advisory Group was created to include representatives from community stakeholder groups. Two members from each group were included. Input was also solicited through the City website. Four Public Information Meetings were also held. Both written and verbal feedback were received and documented. Stakeholder comments and input has been included and integrated in this study. Refer to Appendix H for more detail.

1.7 Project Team

This project was undertaken by an inter-disciplinary team of professionals. The members and companies involved are outlined as follows:

Table 1-4: Project Team

Firm	Team Members
City of Abbotsford	Kathy Zhang, Project Manager Art Kastelein, Manager, Special Projects
Kerr Wood Leidal Associates	Crystal Campbell, Project Manager David Zabil, Project Engineer Jennifer Young, Modelling Engineer Erica Ellis, Geomorphologist Jack Lau, GIS Specialist
Raincoast Applied Ecology	Nick Page, Senior Biologist Patrick Lilley, Biologist
HB Lanarc Consultants Ltd.	Don Crockett, Land Use Planner
Piteau Associates Ltd.	Kathy Tixier, Senior Hydrogeologist James Hogarth, Senior Geotechnical Engineer

Special Acknowledgements

Special thanks are extended to:

- **City of Abbotsford Staff:**
  - Kathy Zhang, Drainage Engineer
  - Art Kastelein, Manager, Special Projects
  - Jim Gordon, General Manager Engineering & Regional Utilities
  - Frank Pizzuto, City Manager
  - Don Luymes, Director, Strategic and Community Planning (currently with City of Surrey)
  - Rod Shead, Community Sustainability
  - Pauline Favero, Community Sustainability
  - Tanya Bettles, Community Sustainability
  - Frank Wright, Operations and Maintenance (retired)
  - Margaret-Ann Thornton, Director of Planning
  - Carl Johannsen, Director of Community Planning
  - Ron Hintsche, Manager of Development Planning (currently with City of Surrey)
  - Wayne Gordon, Senior Planner
  - Terry Fuhlbohm, Engineering Technologist
  - Mark Rushton, Area H Transition Committee representative
  - Rob Issac, Director of Wastewater, Drainage & Asset Management, Engineering
  - Darren Braun, Senior Planner/ Approval Officer, Acting Director of Community Planning
  - Donald Day, Risk and Insurance Officer
  - Kiejoon Kim, Risk and Insurance Officer (currently with Metro Vancouver)
- **DFO:** Alan Jonsson, Sandra Berg, Craig Sciankowy
- **BC MOE:** Diane Sutherland , Jason McCoy, Sheldon Reddekopp, Scott Barrett
- **BC MAF:** Ted van der Gulik
- **Abbotsford Environmental Advisory Committee** (EAC): Glenn Froese and Stephen Marsh
- **City Industry Development Advisory Committee** (CIDAC): James Kay and Jim Ellis
- Civic Consultants: John Haavisto
- **Matsqui Prairie Drainage and Irrigation Committee** (MPDDI): Frank Keis
- **Clayburn Village Residents:** Dustin Ellis, Neil Carson, Cathy Carder, Ramsey Oren
- **City of Abbotsford Councillors:** Mayor Peary; Councillor Barkman; Councillor Gibson; Councillor Harris; Councillor Loewen; Councillor MacGregor; Councillor Ross, Council Gill, and Council Smith
- **Debbie Cox, Context Research:** Public Meeting Facilitator
- **People** who attended the Public Meetings and provided input.

Their involvement and participation in the study was appreciated.

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Section 2

Watershed Overview

2. Watershed Overview

2.1 Drainage Overview

A number of background reports and GIS layers were available and data was supplemented with field inventory activities; they are listed and described in Appendix A. The following table and Figures 2-1 to 2-7 summarize the key study area characteristics.

Table 2-1: Summary of Watershed Characteristics

Description	Clayburn Creek Watershed
Drainage	• Total watershed area: 2253 ha • Clayburn Mainstem: 657 ha Stoney Creek: 627 ha • Poignant Creek: 504 ha Diane Brook: 465 ha • Clayburn Creek drains via the Matsqui Slough to the Fraser River (Figure 2-1).
Stream Length	• 7.5 km Clayburn Creek - mainly open channel with driveway bridges & culverts. • 6.5 km Stoney Creek - numerous tributaries especially in the McKee Peak area. • 7 km Poignant Creek - numerous tributaries including Diane & Lancaster Brook. • 5 km Diane Brook - numerous tributaries including Carl Creek (Figure 2-2).
Channel Characteristics	• The mountain creek channels are generally well incised. • Mainstem channel slopes range up to 29% in the upland areas, <1% below the gauge (Figure 2-4).
Detention Facilities	• 64 existing detention facilities (Figure 2-3). Stoney subwatershed: 15 ponds, 29 tanks, and 7 trenches. Clayburn subwatershed: 5 ponds, 7 tanks, and 1 trench.
Sediment Basins	• 5 lowland sediment removal basins within the study area boundary and one immediately downstream of the study area (Figure 2-3).
Erosion	• Active stream bank erosion and ravine slope instabilities (Figure 2-3).
Topography	• Elevations range from 530 m at the headwaters to 4 m at the downstream end. • The middle portion of the Clayburn Creek mainstem and the downstream portion of Poignant Creek flow through ravines. • Portions are mountainous with relatively steep slopes exceeding 35% in places. • Stoney and Clayburn Creeks lowland area (below El. 12m) is flat (slope < 1%).
Soils	• Granitic & volcanic rock, till, sandstone, gravel & sand, sand & silt, silt & clay (Figure 2-5).
Land Use	Existing Conditions (from BC Assessment land use in Figure 2-6 and air photo in Figure 2-2): • 42% Vacant, 27% Single-Family Residential, 10% Agricultural, 6% Road ROWs, 6% Crown Land, 3% Parks, 3% Institutional, 2% Industrial, and 1% Commercial Future Conditions (from OCP): • 38% Resource/Conservation, 35% Single-Family Residential, 18% Suburban Residential (acreage), 5% Agricultural, 2% Institutional, 1% Multi-Family Residential, 1% Commercial/Industrial (Figure 2-7).

2.2 Existing and Historical Flooding Problems

Clayburn Creek and Matsqui Slough, have a long history of flooding. Flooding problems occur in Clayburn Village, Clayburn Road and the surrounding lowland agricultural area. Village residents provided the following record of recent flood events in the vicinity of Wright Street:

- November 1935
- October 1990
- November 1997
- January 19, 2005
- January 13, 2006
- November 6, 2006
- January 2, 2007
- March 11, 2007
- March 24, 2007
- January 6, 2009 (rain-on-snow)

Stream flow records for Clayburn Creek are available starting in June 2007. The following is a brief history related to flood protection studies and works:

- 1988 – lower section excavated and cleaned.
- 1991 – Master Drainage Study was completed.
- 1992 – City increased stormwater detention requirements for development.
- 1998 – 2000 Willband detention facility constructed.
- 2003 – lower section studied by D & K, Stoney Creek widened downstream of Bateman Road.
- 2005 – lower section of Clayburn studied by AESL recommendation for berms, set back from creek.
- 2006 – berms not approved, more study required.
- 2007 – emergency works conducted, some deposited material removed.
- 2009 – ISMP initiated, Kerr Wood Leidal Associates Ltd. retained.

2.3 Existing and Future Land Uses

2.3.1 Existing Conditions

The Clayburn Creek watershed contains mainly rural development, undeveloped areas and some urban development. The Stoney Creek watershed is more developed, with single family residential areas in the middle reaches of the watershed (lower portion of the upland area). The lowlands in the study area are largely used by agriculture. The existing land use conditions used in the analysis in this report are shown on the 2008 air photo in Figure 2-2.

2.3.2 Future Development

Future development is designated in the *City of Abbotsford 2005 OCP* and the *Fraser Valley Regional District 2003 OCP* Area H and shown on Figure 2-7. The designated land uses on currently undeveloped lands include:

Within the existing "Urban Development Boundary":

- Agricultural
- Commercial
- Institutional
- Industrial Business
- Resource/Conservation
- City Residential
- Urban Residential
- Suburban Residential

Outside the existing Urban Development Boundary:

- Park
- Forest
- Limited Use
- Rural
- Institutional

Table 2-2 summarizes the existing and unmitigated future total impervious areas. The ISMP will develop a plan outlining recommendations to mitigate the impacts of these impervious area increases.

Table 2-2: Existing and Future Total Impervious Area

Site	Total Impervious Area[1]	
	Existing	Unmitigated Future
Clayburn Mainstem	10%	40%
Diane Brook	4%	9%
Poignant Creek	4%	16%
Stoney Creek	28%	41%
Total	**12%**	**27%**

1. Based on City and Area H OCPs.

A future condition land use was needed to make hydrologic modelling assumptions for an unmitigated future condition. HB Lanarc conducted land use planning assessments as described in Appendix A and reviewed them with City Planning Staff. A detailed land use planning assessment was outside the scope of the study; however the City directed that a potential future land use scenario be developed. The combined City and Area H OCP land use layers were intersected with the following undevelopable areas:

- Extreme slopes – land slopes greater than 35% where development is not feasible
- Riparian areas – streamside development setbacks from creeks in accordance with the City's 2005 Streamside Protection Bylaw. The creek mapping was based on the SHIM information which may have watercourses identified where there are none.

The compilation of these considerations, shown on Figure 2-8, illustrates the future development potential with polygons representing the remaining developable area for each land use type when the excluded areas are removed. This future land use plan is for modelling and conceptual watershed planning uses only.

2.4 Hydrogeology/Geotechnical Inventory & Assessment

Piteau Associates completed a report entitled Hydrogeological and Geotechnical Assessment for Development of ISMP, Clayburn Creek Watershed, Abbotsford, B.C., December 2009. The report is included in Appendix B. A brief summary of the report and its recommendations are below.

2.4.1 Active Stream Bank Erosion and Instability of Steep Ravine Slopes

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 any large scale, deep-seated instability was noted during the field reconnaissance.

2.4.2 Baseflow Estimates

The upper portion of the watershed is underlain primarily by rock, till and glaciomarine sediments. The summer baseflow derived from this area is approximately 2.4 L/s/km^2 (0.024 L/s/ha). The lower portions of the watershed that are underlain by permeable sands and gravels have an estimated baseflow of 5 to 6 L/s/km^2 (0.05 – 0.06 L/s/ha). Unit baseflow rates typically vary between about 1 to 5 L/s/km^2 for creeks in the Lower Mainland. Clayburn baseflows appear to be average for the upper watershed and higher than average for the lower watershed. The winter baseflows based on the continuous flow monitoring on Clayburn Creek is approximately 20 L/s/km^2 (0.2 L/s/ha).

2.4.3 Infiltration Capabilities

Refer to Figure B-6 in Appendix B**:** Infiltration Potential and Setbacks. The soils and sediments underlying a large part of the upland area (Area A) are relatively permeable and offer good potential for infiltration of stormwater. Enhanced infiltration is not recommended where the water table is near the surface (Area B) or where there is already a high density of surface water (Area C). 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 Area D where there are accumulations of relatively well drained soils and should be determined on a site-by-site basis. There is greater potential to infiltrate stormwater in Area E, due to the relatively unsaturated, more permeable sediments and deeper water table.

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 discharging water into a few concentrated areas and into one material type to prevent the potential for water table mounding and the potential for slope instability. Systems that collect and store stormwater runoff for eventual infiltration to groundwater should have adequate storage volume and a clarification system to eliminate sediments and floating detritus that could cause clogging. More detailed hydrogeological assessments should be carried out by a qualified professional in those areas where ground infiltration measures are being considered.

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.

2.4.4 Steep Slope Geotechnical Setbacks

Figure B-6 in Appendix B shows geotechnical areas where detailed geotechnical investigation is required at time of development.

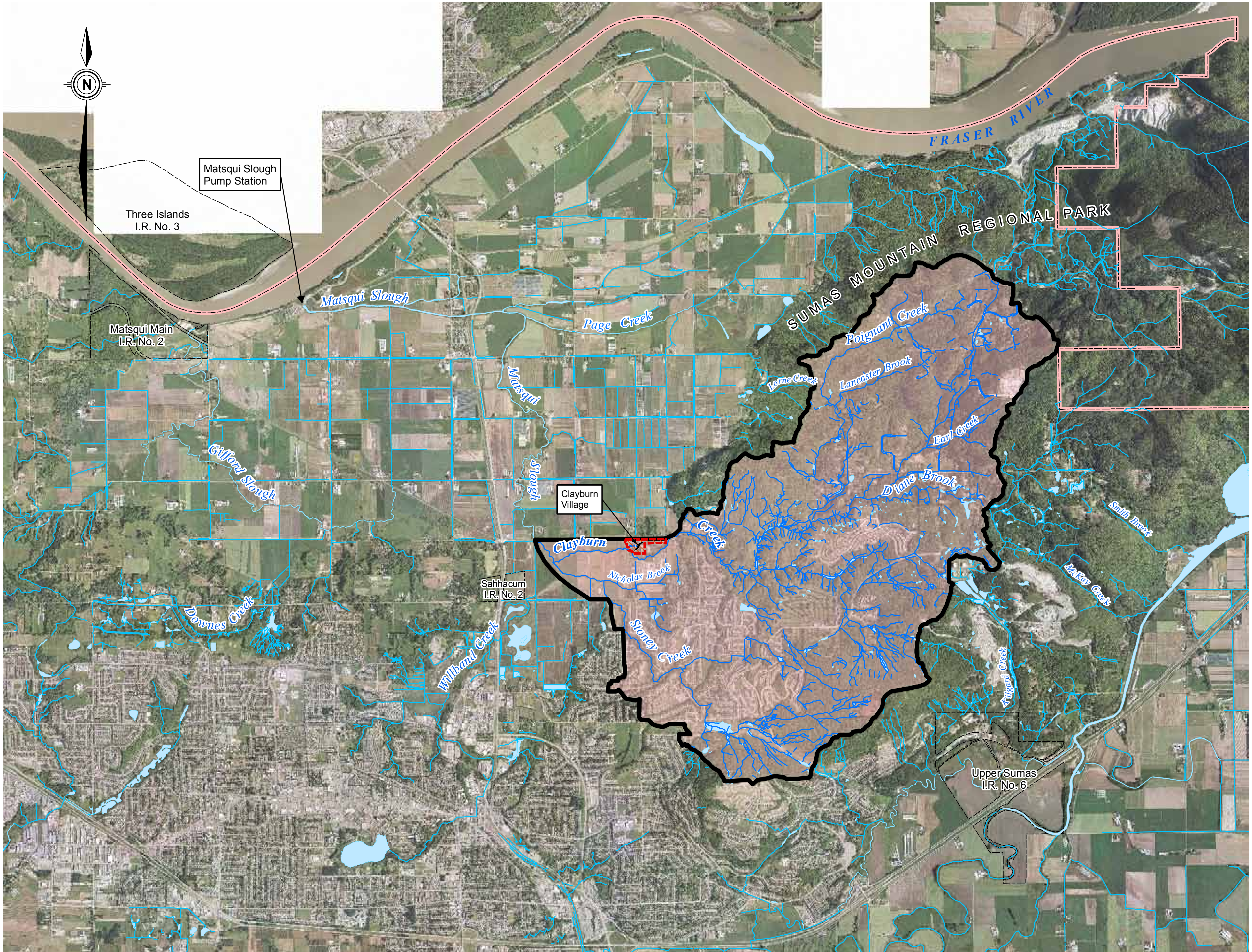
Areas recommended for detailed geotechnical assessments for the implementation of infiltration enhancement works are:

- 4H:1V (25%) from the toe of stream channel or ravine slopes in all areas;
- 200 m to the southwest of the crest of slope above Straiton Road in Area A;
- 100 m from the inner ravine slope of Stoney Creek in Area A; and
- 250 m from the inner ravine slopes of Poignant Creek and Clayburn Creek and their tributaries in Area D.

The geotechnical setbacks will be determined upon detailed assessment by qualified geotechnical professionals during development applications.

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 for planning purposes until detailed geotechnical assessments can be completed. No development or infiltration works should be allowed on inner ravine slopes (sidewall slopes >50%).

City of Abbotsford
Clayburn Creek
ISMP



Legend

- City Boundary
- Study Area
- Sub-Basin Boundary
- Watercourse
- Open Waterand Marshes

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Location Plan within Matsqui Prairie

Figure 2-1

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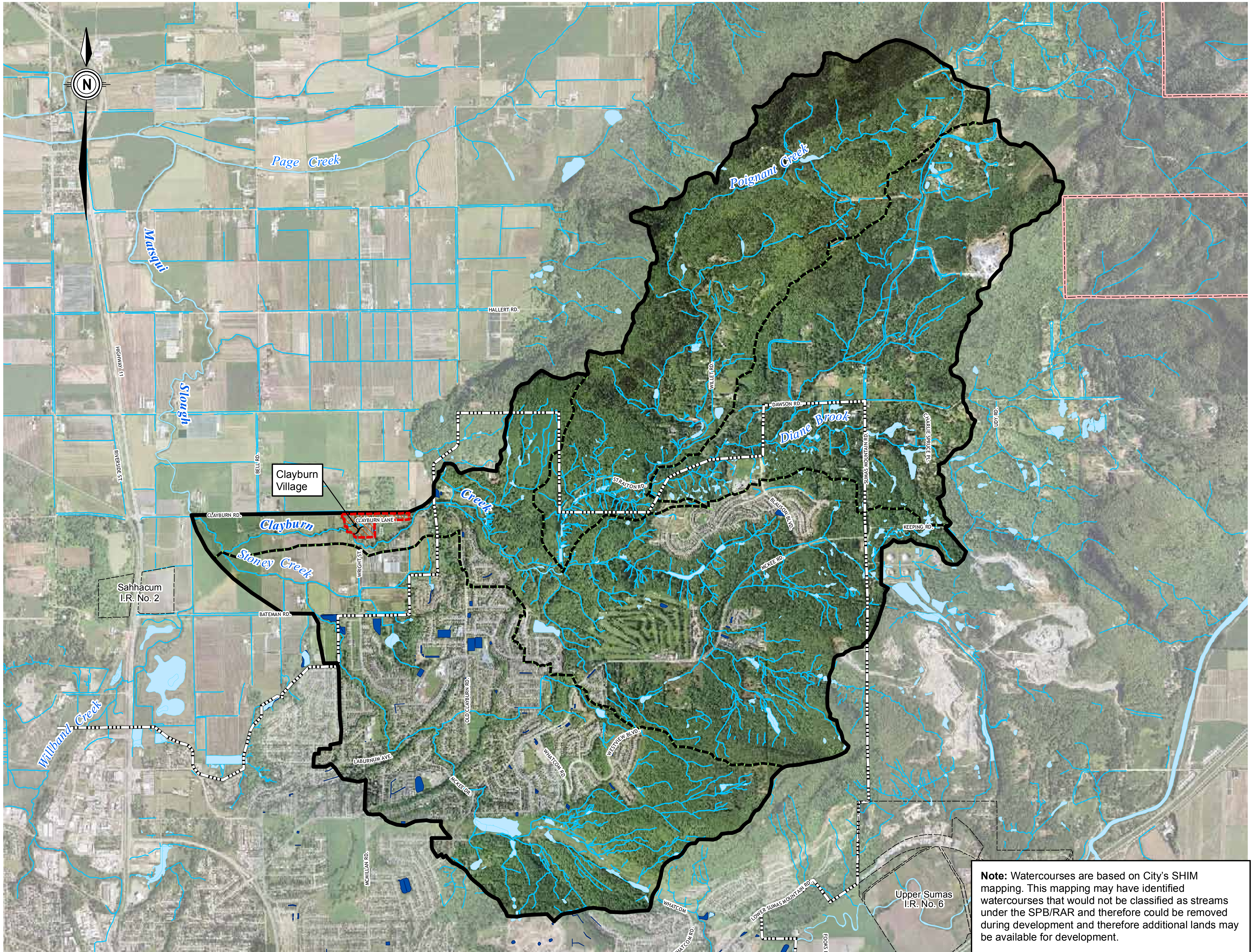

Note: Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Study Area
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Detention Facility
- Open Water and Marshes

Reference: Topographic information and 2008 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Study Area 2008 Air Photo

Figure 2-2

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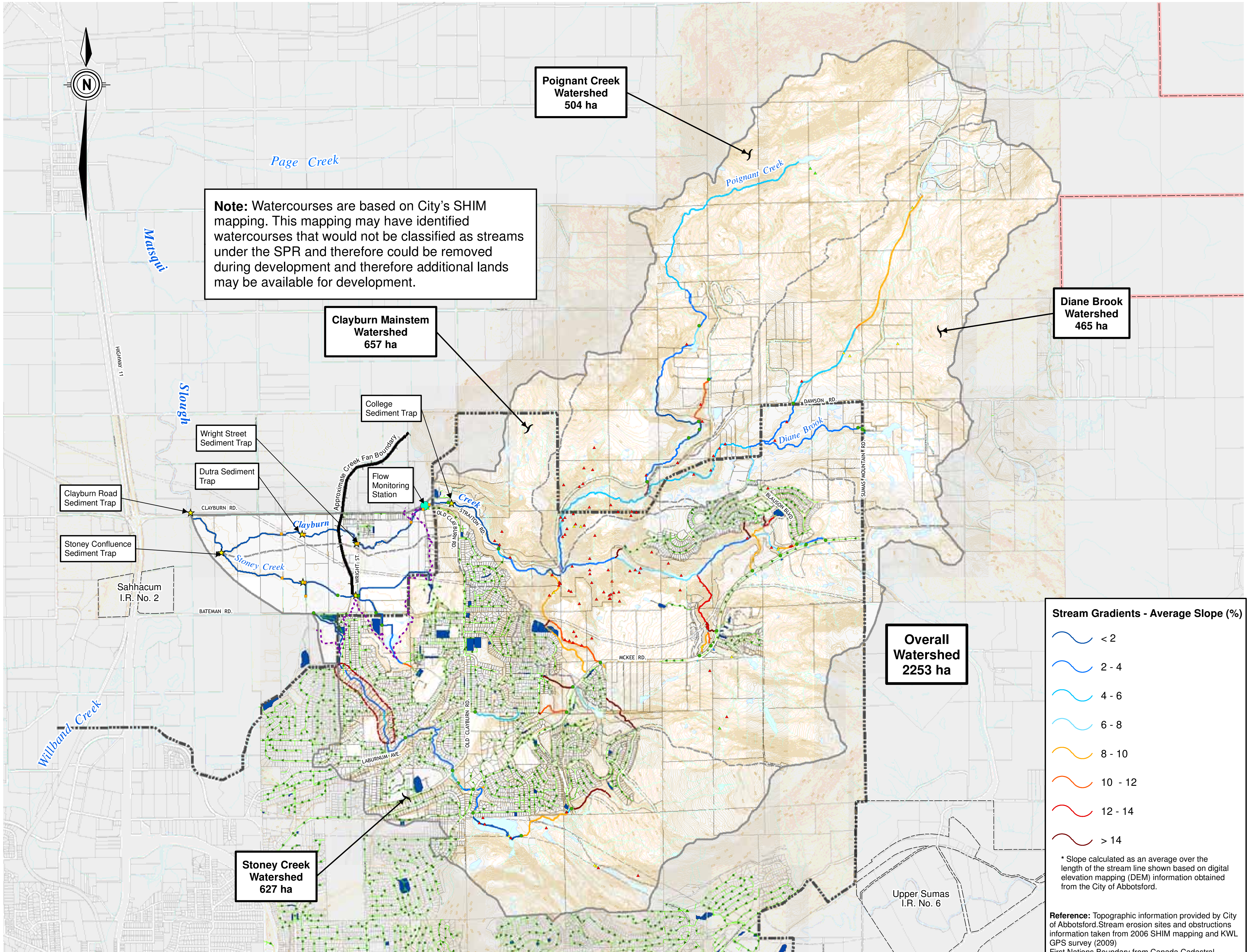

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Study Area
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Contour (2m Interval)
- Lowland Boundary (12 m)
- Approximate Creek Fan Boundary
- Creeks and Streams
- Storm System
- Detention Facility
- Open Water and Marshes
- Bridge
- Culvert
- Approximate Location of Existing Sediment Traps

Erosion (Severity)

- < 5 m^2 / Low
- 5-10 m^2 / Moderate
- > 10 m^2 / High
- Erosion Noted by City

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Drainage Inventory, Erosion and Stream Gradients

Figure 2-3

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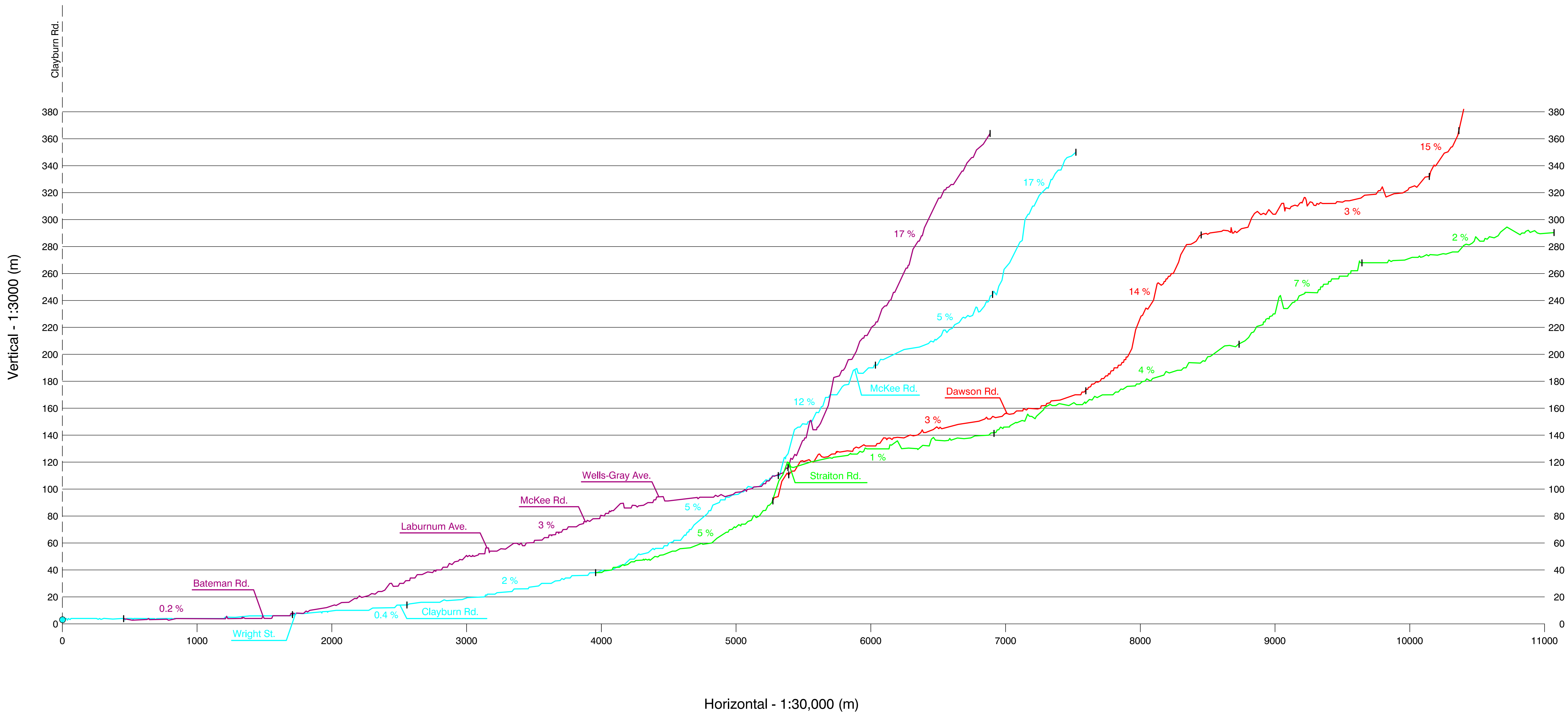


Legend

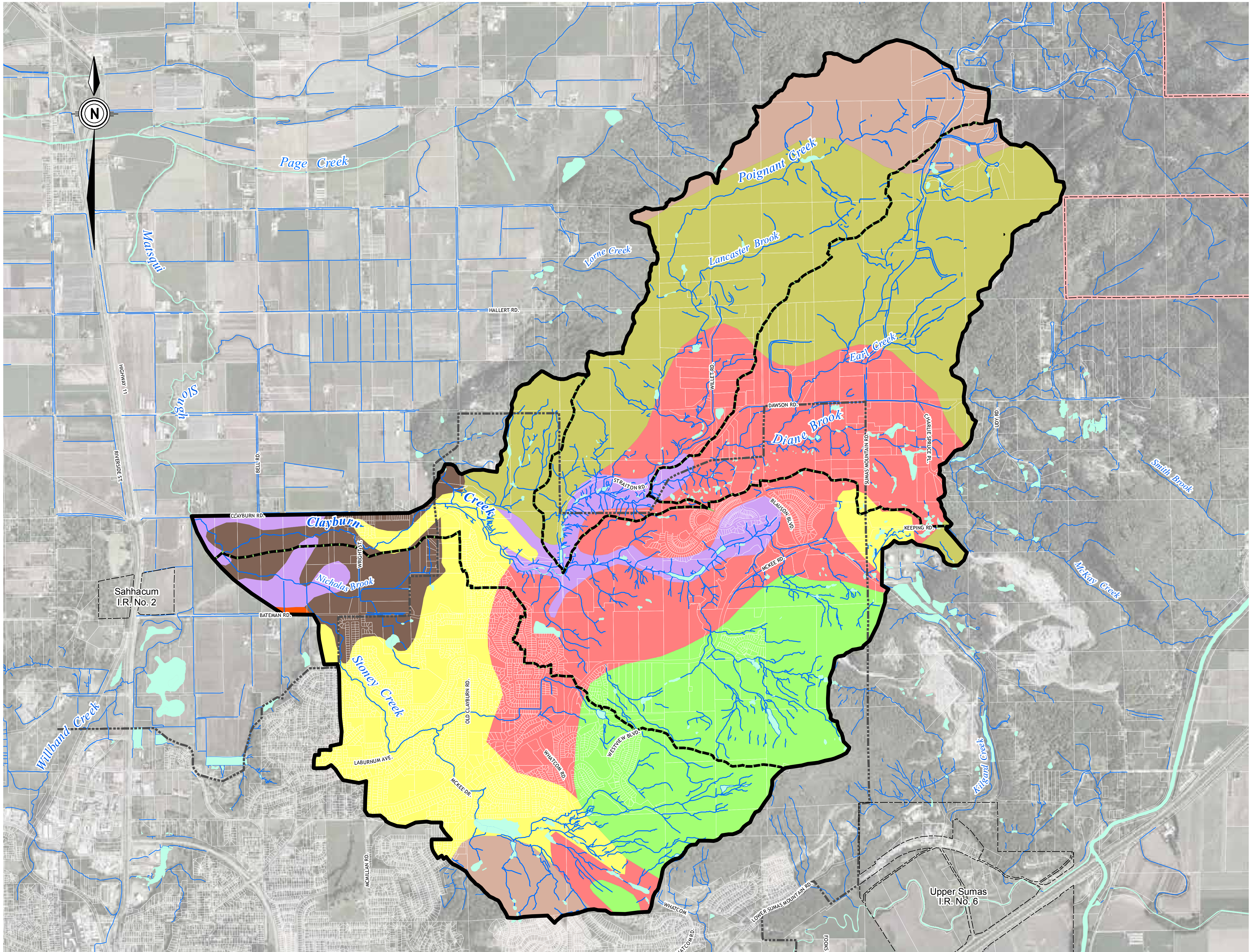
Clayburn Creek	(cyan line)
Diane Brook	(red line)
Stoney Creek	(purple line)
Poignant Creek	(green line)
Grade Break	I

City of Abbotsford
Clayburn Creek
ISMP

Watercourse Profiles

KERR WOOD LEIDAL
consulting engineers

Figure 2-4



City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Open Water and Marshes

Soil Material (Infiltration mm/hr)

- Granitic Rock (n/a)
- Gravel and Sand (100 -250 mm/hr)
- Peat (n/a)
- Sand and Silt (5 - 50 mm/hr)
- Sandstone (n/a)
- Silt and Clay (2 mm/hr)
- Till (2 mm/hr)
- Volcanic Rock (n/a)

Note: More detailed soils map included in Appendix B.

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

Soils Map

Figure 2-5

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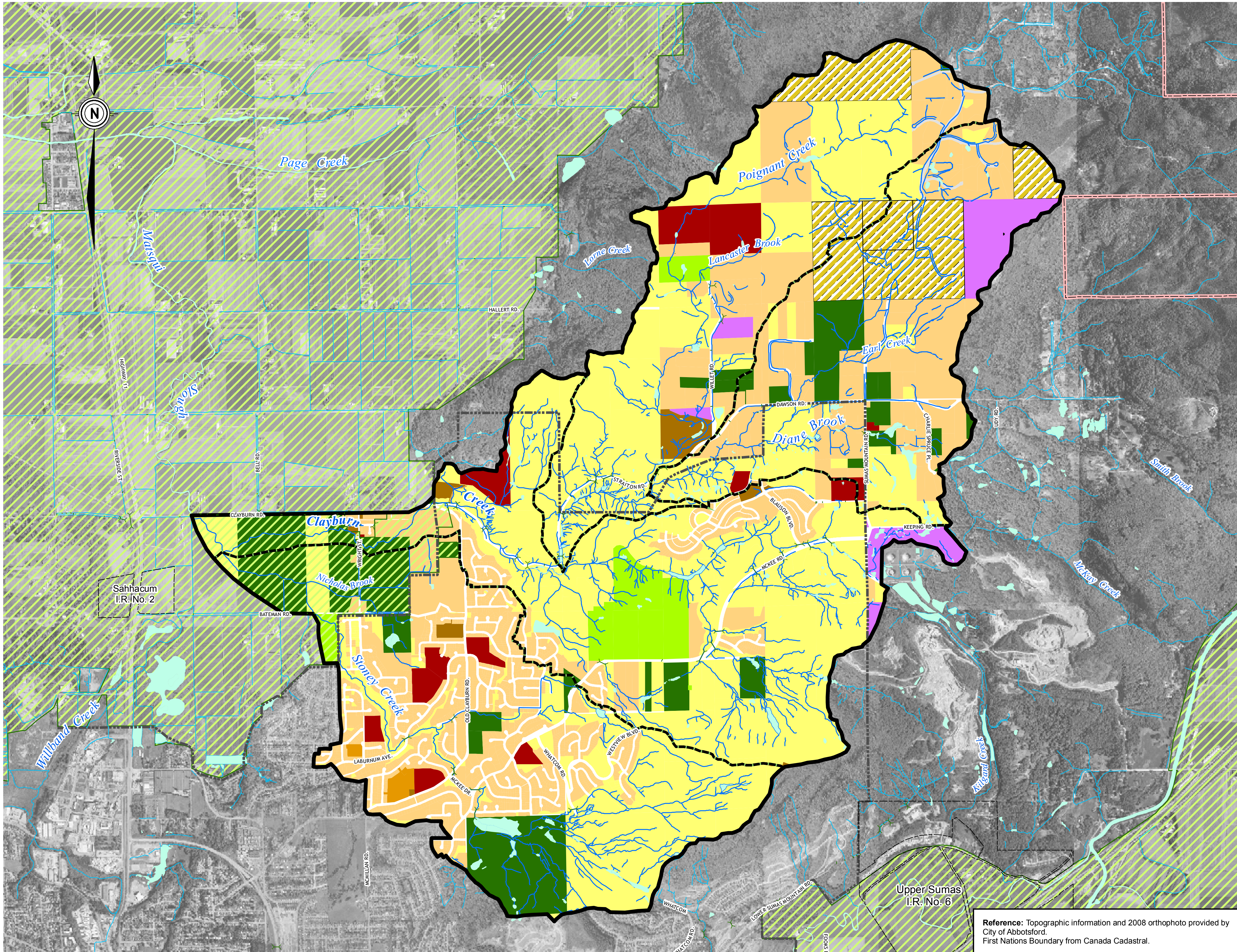

Reference: Topographic information and 2008 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Open Water and Marshes
- Agricultural Land Reserve

Land Use

- Agricultural
- Crown
- Commercial
- Industrial
- Institutional
- Park and Recreational
- Road
- Single-Family Residential
- Multi-Family Residential
- Vacant

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Project No.	Date
510-057	May 2012

Existing Land Use (BC Assessment)

Figure 2-6

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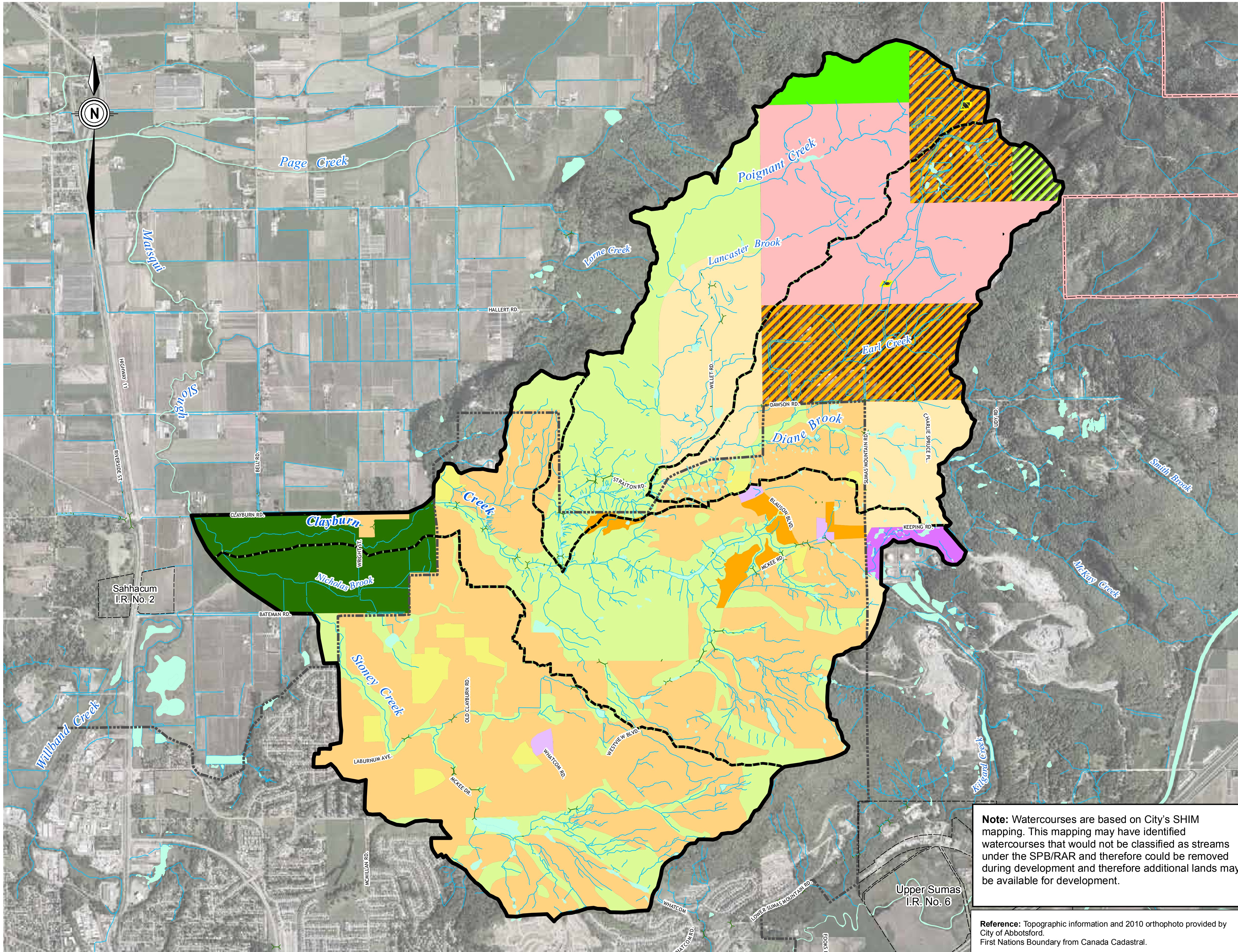
User: jlau

City of Abbotsford
Clayburn Creek
ISMP



Note: Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

Legend

- City Boundary
- Watershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Open Water and Marshes

City of Abbotsford OCP Designation (% Impervious)

- Agricultural (5 %)
- Commercial (90 %)
- Institutional (75 %)
- Industrial Business (90 %)
- Resource/Conservation (1%)
- City Residential (80 %)
- Urban Residential (60 %)
- Suburban Residential (10 %)

Fraser Valley Regional District OCP Designation (% Impervious)

- Forest (1%)
- Institutional (75 %)
- Limited Use (10 %)
- Park (1 %)
- Rural (10 %)

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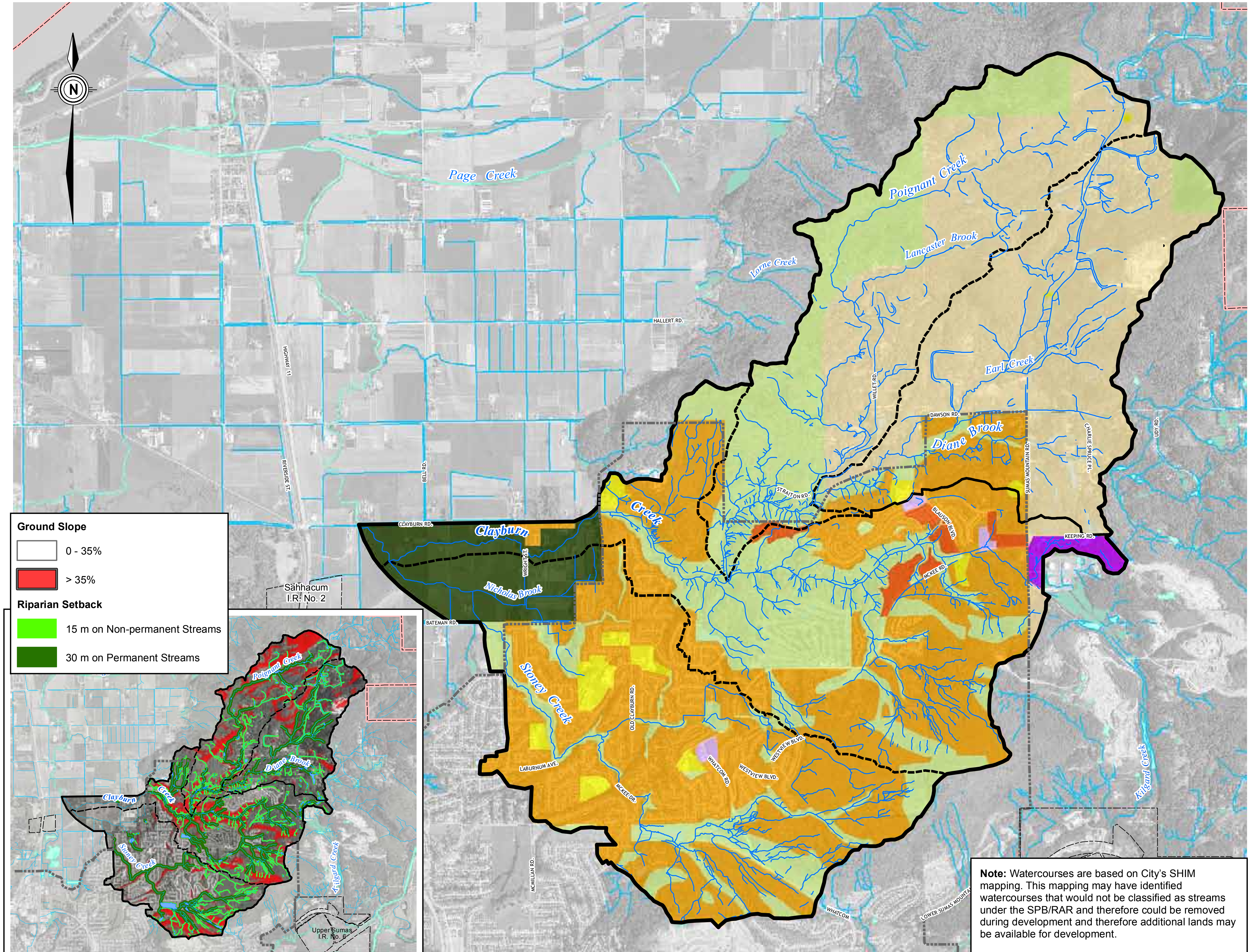
Project No.	Date
510-057	May 2012

OCP Land Use

Figure 2-7



Note: Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Creeks and Streams
- Approximate Urban Development Boundary

FVRD & City of Abbotsford OCP Designation

- Agricultural
- Commercial
- Institutional
- Industrial Business
- Resource/Conservation/Park/Forest
- City Residential
- Urban Residential
- Suburban Residential/Rural/ Limited Use

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

KERR WOOD LEIDAL
consulting engineers

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Project No.	Date
510-057	May 2012

Potential Future Development

Figure 2-8

Section 3

Environmental Values

3. Environmental Values

Raincoast Applied Ecology completed a detailed environmental inventory and assessment which is included in Appendix C. A summary of findings is described here.

3.1 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.

Several priority water quality issues were identified from recent and past sampling by MOE:

- **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 urban 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).
- **Bacteriological contamination in Diane Brook and Stoney Creek**: Sampling from 1997-2001 found elevated levels of fecal coliform in Poignant Creek. The most likely sources 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.
- **Elevated levels of metals, oil, and grease from residential areas in Stoney Creek:** The highest levels of metals contamination were found in Stoney Creek (Quilty 2001). Higher levels of metals are usually associated with urbanizing and urbanized catchments.

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 and type 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).

3.2 Sediment Quality

Stream sediments accumulate metals and other contaminants from a variety of sources in developed watersheds, and analysis of sediments provide a complimentary assessment of environmental chemistry when combined with water quality tests. They are also useful for long-term monitoring of stream conditions because they are much less variable than water quality measurements.

Several priority sediment quality issues were identified from sampling and previous MOE data:

- **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 near the lowland-upland transition were generally lower than upper watershed sites, however, there were some exceptions. Arsenic levels were slightly above the Interim Sediment Quality Guideline (ISQG)[2] 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 lowland site. Elevated arsenic levels are likely natural while the nickel levels, particularly at the lowland site on Clayburn Creek, may represent contamination from human sources.

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.

3.3 Benthic Invertebrates

Benthic invertebrates (streambed insects) are useful indicators of stream condition and can be monitored over time to track changes instream or watershed health. B-IBI (Benthic Index of Biotic Integrity) is a common multi-metric method for summarizing benthic invertebrate data. It has been used extensively to measure the condition of small streams in Metro Vancouver. Figure 3-1 shows the locations of benthic sampling, and the following table summarizes key values. Refer to Table C-1 in Appendix C for a full list of B-IBI values.

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[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.

[2] Interim Sediment Quality Guidelines (ISQGs) are defined by the B.C. Ministry of Environment and provide guidelines for safe levels of substances that will protect aquatic life from adverse effects of a toxic substance”. B.C. guidelines may be specified as two values: one to protect aquatic life from short-term, lethal effects (i.e., the maximum value or the acute criterion) and the other to protect it from long-term, sub-lethal effects (the 30-day average value or the chronic criterion).

Table 3-1: Summary of 2009 B-IBI Scores

Subwatershed	2009 Measured B-IBI (mean of upper & lower sampling sites)	Health Rating
Clayburn Mainstem	**35**	Fair
Diane Brook	**36**	Fair
Poignant Creek	**30**	Fair
Stoney Creek	**30**	Fair
Mean	**33**	**Fair**

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).

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)[3]. 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. The overall mean B-IBI score for the ISMP study area was 32.8 (SD 3.8).

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.

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.

The B-IBI scores based on impervious area and riparian forest integrity were used to predict the watershed health for future development conditions (see Section 7.3.1).

3.4 Watershed and Riparian Forest Cover Assessment

Watershed and riparian forest cover are indicators of stream and watershed health, and measure the effect of changing land use on hydrology, water quality, and other components of stream ecosystems. Riparian forest cover or integrity (RFI), in combination with watershed impervious area and benthic invertebrate sampling, provide data for the Watershed Health Tracking System (WHTS), and will also help to assess the impacts of future land use scenarios. See Figure 3-2 for the watershed and riparian forest cover in the catchments. See Table C-4 in Appendix C for watershed health indicator values.

[3] 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).

Stoney Creek had the lowest watershed forest cover at 42.9%, reflecting the higher levels of urban development within this subwatershed. Poignant Creek had the highest watershed forest cover at 91.6%. This reflects the relatively low levels of development in this subwatershed. Across the entire study area, average watershed forest cover was 69.7%.

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. Riparian forest cover ranged from 55.7% in Stoney Creek to 92.7% in Poignant Creek. The higher RFI values indicate that riparian areas were largely protected during development. Across the entire study area, average riparian forest cover was 78.4%.

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 regulations to protect riparian areas, such as Abbotsford's current Streamside Protection Bylaw,

3.5 Aquatic Species and Habitat Inventory

Fish communities, fish passage barriers and fish habitat characteristics were assessed from existing information as well as during field visits in September 2009, supplemented by additional site visits in January 2011.

Fish Communities

Six (and possibly seven) salmonid species, nine native non-salmonid species, and two introduced fish species are known from the ISMP study area:

- Coho salmon and resident cutthroat trout are the two most abundant salmonid species in the study area. Smaller runs of Chum, Steelhead, searun Cutthroat Trout and possibly Pink salmon (odd years only) are also known from the watershed. Chinook and Sockeye do not reproduce in the study area but may enter as juveniles from the Fraser River.
- Two non-native fish species, Pumpkinseed and Largemouth Bass, are known from the watershed. 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.

Instream Fish Habitat

Fish habitat was assessed across five major areas:

- **Lowland portions of Clayburn Creek and Stoney Creek**: The Clayburn Creek subwatershed is known historically for its high salmon habitat in 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, and reduced 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 have all 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.
- **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 Avenue. Spawning Coho can move up into the Vicarro Ranch area (in the powerline 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 some years between Laburnum Avenue and Old Clayburn Road (see photo).

- **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.

Fish Passage Barriers

Only three manmade structures are known to impede or prevent fish passage within the watershed:

- Matsqui Slough (Gladwin) Pump Station (partial barrier to exchange with Fraser River);
- Small dam on north arm of Poignant Creek (near Camp McLanlin at north end of Willett Road) (full barrier to resident Cutthroat Trout); and
- Impoundment (Cattle Pond) on McKee Creek (Stoney Creek) on Vicarro Ranch property (full barrier to Coho and resident Cutthroat Trout).

They are described in more detail in Appendix C. Some previously existing fish passage barriers have been addressed through recent upgrade projects. Figure 3-4 shows key findings such as extent of fish communities and fish passage barriers.

3.6 Watercourse Classification

Figure 3-3 shows a preliminary watercourse classification map developed based on fish presence and flow regime (permanence) as per Abbotsford’s Streamside Protection Bylaw. The 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.

3.7 Priority Fish and Aquatic Habitat Issues

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. Some erosion is likely natural but may have been exacerbated by past logging activity and changes in flows associated with the upstream changes in 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.

- **Increasing large wood 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.

- **Riparian forest cover in lower watershed:** The riparian assessment indicated relatively high amounts of riparian forest cover in the Clayburn watershed. However, riparian removal in some sections has resulted in bank instability and increased summer water temperatures.

- **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.

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.

3.8 Terrestrial Species and Habitat Assessment

In addition to fish, the Clayburn Creek watershed is a 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 located, is an important large reservoir for biodiversity in the lower Fraser Valley, and is similar in size and significance to Burns Bog.

[4] “Species at risk” is a general term used to describe an extirpated, endangered, threatened species, or a species of special concern.

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 are listed in Table 3-2:

Table 3-2: Confirmed and Potential Species at Risk

Mammals		
Pacific Water Shrew	Townsend's Mole	Snowshoe Hare
Trowbridge's Shrew	Townsend's Big-eared Bat	Mountain Beaver
Birds		
American Bittern	Peregrine Falcon	Barn Owl
Great Blue Heron	Band-tailed Pigeon	Western Screech-Owl
Amphibians and Reptiles		
Red-legged Frog	Western Toad	Rubber Boa
Invertebrates		
Blue Dasher	Oregon Forestsnail	Pacific Sideband
Vascular Plants		
Phantom Orchid	Pacific Waterleaf	
Fish	**Mosses**	
Cutthroat Trout	Silver Hair Moss	

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. 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 and other important ecosystems (OIE).

Pacific Water Shrew Habitat Suitability Modelling

Pacific Water Shrew is listed as Endangered under Canada's Species at Risk Act. Within Canada, it is found only 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*).

Figure 3-5 shows 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 the habitat 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. The habitat area was identified along a high proportion of small tributaries in all of the major subwatersheds, and particularly in the ravine sections of Clayburn and Poignant Creeks as well as the small tributaries of Stoney Creek on the north slope of Eagle Mountain.

Priority Terrestrial Habitat Issues

The following priority issues were identified for terrestrial habitat:

- **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 instream by intercepting and transpiring a large amount of rainfall.
- **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 Himalayan 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.

The presence of rare species and general levels of biodiversity is an indicator of terrestrial ecosystem health. The presence of several Species at Risk and a high proportion of sensitive ecosystems by area indicates that natural habitats (wetlands and riparian areas, large forest patches) function as important habitat reservoirs for biodiversity. Also, with relatively low levels of development, habitat connectivity is also still high within the study area.

3.9 Environmental Restoration and Enhancements

Opportunities for aquatic, riparian, and terrestrial habitat enhancement are confined largely to developed areas of the Clayburn Creek watershed. Most of the potential restoration and enhancement opportunities are found in the agricultural lowlands of Clayburn and Stoney Creeks, residential areas within the Stoney Creek watershed, the rural Straiton community (north of Dawson Road), or recently logged or cleared areas in the headwater reaches of some tributaries. Potential opportunities are summarized in the following sections and shown on Figures 8-4 and 8-5.

a) **Aquatic habitat restoration and enhancement:** The long-term goal of aquatic habitat restoration and enhancement is to increase productive capacity of fish habitat in the watershed by restoring access to historic habitat, improving existing habitat, or developing new habitat.

b) **Riparian habitat restoration and enhancement:** The long-term goal of riparian habitat restoration is to increase native trees and shrubs along Clayburn Creek and its tributaries in order to increase habitat for fish, wildlife, and native plant communities. Because of the relatively undeveloped nature of much of the watershed and protection of riparian areas during recent development within required development setbacks from streams (e.g., in the Stoney Creek watershed), sites for potential riparian restoration are limited to a small number of locations. However, within those locations, substantial restoration may be required.

c) **Terrestrial habitat restoration and enhancement:** As for riparian restoration, the low amount of development limits opportunities for terrestrial habitat restoration. Activities should generally be focused on reducing areas of semi-natural vegetation in the watershed and converting to more natural climax vegetation communities, integrating natural vegetation into developed landscapes, controlling invasive species, and restoring habitat for specific species at risk.

   General opportunities include:

   - **Native tree and shrub planting:** Planting of native conifers within developed areas should be a priority, especially in historically disturbed areas with early seral vegetation or non-native species (e.g., young alder forests, reed canarygrass infested fields). Mature conifers or mixed forests are preferred over young red alder forests in terms of their impact on hydrologic processes, because they intercept rainfall and transpire water year-round. Underplanting of shade-tolerant conifers patch cutting, or more conventional reforestation methods using native conifers are possible habitat restoration options.
   - **Field margins, hedgerows, and landscaping:** Integrating natural vegetation into the agricultural lowlands and residential developments will help to enhance habitat for species that can co-exist with these human land uses. One way to improve habitat values in agricultural areas is through the development of Environmental Farm Plans. Environmental Farm Plans already exist for several farm operations within the ISMP study area.
   - **Control of invasive species:** Especially in developed areas and along the interface between developed and undeveloped areas. Early detection and rapid response measures should be undertaken on a regular basis for species in the watershed such as giant hogweed (*Heracleum mantegazzianum*), and knotweeds (*Fallopia* sp.). Important target species include those that can escape gardens and move into the understory of natural forests, such as yellow lamium (*Lamium galeobdolon*) and periwinkle (*Vinca* sp.), and those that infest specific habitat types, such as Yellow Flag Iris (*Iris pseudacorus*) and Purple Loosestrife (*Lythrum salicaria*) in wetlands. Inventory and mapping of invasive plants in the watershed and development of a management strategy is recommended.

- **Wildlife crossings / corridor restoration:** Major roads can offer significant barriers for movement of wildlife or present problems with roadkill, especially for species such as amphibians and small mammals. The establishment of wildlife crossing zones, possibly with specific features (e.g., dry culverts, modified curbs) should be considered on major roads, such as Straiton Rd and McKee Rd. Signage could also be used to raise public awareness about this issue.
- **Habitat for Species at Risk:** Because of the prevalence of species at risk within the ISMP study area, habitat restoration or enhancement activities focusing on specific species such as Pacific Water Shrew, Pacific Giant Salamander, or Oregon Forestsnail may be appropriate. Activities may focus on providing physical habitat features (e.g., snags, downed logs, or nest sites), creation of specific habitat types (e.g., isolated wetlands for breeding amphibians), or specific plant communities (e.g., bigleaf maple forest with stinging nettle patches for snails). Consult various recovery teams and specialists for individual species as well as the South Coast Conservation Program on how to improve habitat for species known from the watershed.

Terrestrial habitat areas with the greatest potential for restoration and enhancement include Bateman Park, Stoney Creek Park, and school grounds in the watershed, interface zones between natural forest and developed areas, and recently logged areas in the upper reaches of Diane Brook.

3.10 Need for Terrestrial Habitat Management Strategy

An additional consideration for planning and development are the species-at-risk (SAR) implications. Buffer zones ranging from 30 m to 500 m are recommended as Best Management Practices by MOE for protection of the documented listed species and habitat. While these buffer zones do not have direct limitations for development, consideration of SAR should influence planning decisions on the type, location, placement and orientation, and density of development. Based on the known occurrences, the total extent of SAR buffers recommended as Best Management Practices are shown in Figure 7-1.

Additional Riparian Setbacks Beyond the *Streamside Protection Bylaw*

Additional riparian setbacks above and beyond those required by the City's *Streamside Protection Bylaw* would provide better protection of watershed health for Clayburn Creek and its tributaries, in addition to providing better habitat protection for several species at risk. Many of species at risk found in the Clayburn Creek watershed depend on watercourses, waterbodies, and adjacent riparian areas for habitat during some parts of their life cycle. For many riparian-dependent species, stream setbacks required under the City's *Streamside Protection Bylaw* may not meet those suggested by experts as Best Management Practices for protecting habitat for these species (Table 3-3). Therefore, it is recommended that land use planning within the ISMP study area explore tools to gain additional riparian setbacks.

In particular, it is recommended that land use planning tools are used to maximize the protection of identified Critical Habitat areas for Pacific Water Shrew as identified by the recovery team for the species (usually a 100 m setback from known inhabited watercourses). A site specific assessment will need to be conducted to confirm the setback requirements at the time of development. The Pacific Water Shrew Recovery Team should be consulted for further information.

Table 3-3: Suggested BMP Buffers for Eight Species at Risk (or their Habitat)

Common Name	Suggested Best Management Practice Buffer[1]/Proposed Protected Unit	Source
Pacific Water Shrew	Proposed Critical Habitat polygons (identified for known occurrences) and/or 100 m buffer on watercourses rated as High habitat suitability using SHIM data.	Pacific Water Shrew Recovery Team, 2009
Mountain Beaver	50 m around known colonies	B.C. Ministry of Environment, 1999
Red-Legged Frog Pacific Giant Salamander	50 m around watercourses and waterbodies within 150 m of known occurrences	Ovaska et al., 2004
Oregon Forest Snail Pacific Sideband	50 m around known occurrences	Ovaska et al., 2007
Phantom Orchid	500 m around known occurrences	MOE guidance to British Columbia, Timber Sales (BCTS), Forest Practices Board 2006, pg 8
Pacific Waterleaf	30 m around known occurrences	

1. Buffers as recommended by MOE.
Adapted from: Astley, C. 2006. Rare Element Survey and Habitat Ranking – Addendum 1, McKee Peak, Abbotsford, BC. Prepared by Madrone Environmental Consultants for the City of Abbotsford.
Refer to Appendix C, Table C-8.

For non-aquatic or non-riparian species, setbacks are also recommended around known colonies or occurrences (Table 3-3). Protection of terrestrial habitat for species at risk is discussed in the *Terrestrial Habitat Conservation Strategy* section below.

3.10.1 Terrestrial Habitat Conservation Strategy

In order to protect the most important terrestrial habitats in the Clayburn Creek watershed during future development, development of an overall Terrestrial Habitat Conservation Strategy is recommended.

Because of their relevance to stormwater management, the ISMP recommends the following broad goals be included in this Strategy:

- **Wetland protection:** Require all wetlands be protected during any future development for their important hydrologic and water quality functions, and wildlife habitat value. Consultation with DFO has shown their desire to protect remaining wetland areas in the watershed.
- **Forest and tree cover retention:** Because of the important contribution of forest cover to watershed processes, such as the movement and provision of water, sediment, nutrients, organic matter, and wood, incorporate explicit goals for natural forest cover retention (patches) and overall tree retention into development guidelines for key areas of the watershed. At a minimum, a goal of 50% natural habitat protection at the subwatershed scale (not on a lot-by-lot basis) is suggested. Land use planning by the City will be required to identify forested areas to be preserved. Reforestation of an area that is currently not forested would contribute to the overall goal, however, cutting down an existing mature forest and replacing with small trees may not provide full compensation as the tree canopy area/coverage is reduced. Therefore a larger than 1:1 ratio tree

replacement may be required. Density transfers (allowing the same units per acre within a development calculated based on the entire site and allowing that many units outside the riparian area thereby densifying the non-riparian areas), density bonusing, or other mechanisms may be appropriate. Tree cover may also integrate with City goals for carbon storage and sequestration and offsetting emissions.

- **Protection of hydrologically sensitive areas:** Protect areas with important hydrologic functions, including groundwater recharge areas and source areas for headwater streams. Such areas may be defined by topography (e.g., low points), soil or vegetation type (e.g., bogs, wetlands), and may or may not be associated with active stream channels. While some of these areas will be protected through required setbacks from streams and steep slopes, setbacks in headwater streams are typically smaller (minimum of 15 m and a maximum of 30 m for non-fish bearing streams under Abbotsford's *Streamside Protection Bylaw*) can be insufficient to protect the full extent of hydrologically sensitive areas. One potential policy change that would improve protection of these areas is to not allow variances or require the maximum setback under the bylaw (see recommendations in Section 8.4.1). Identification of hydrologically sensitive areas should be made part of the development application process.

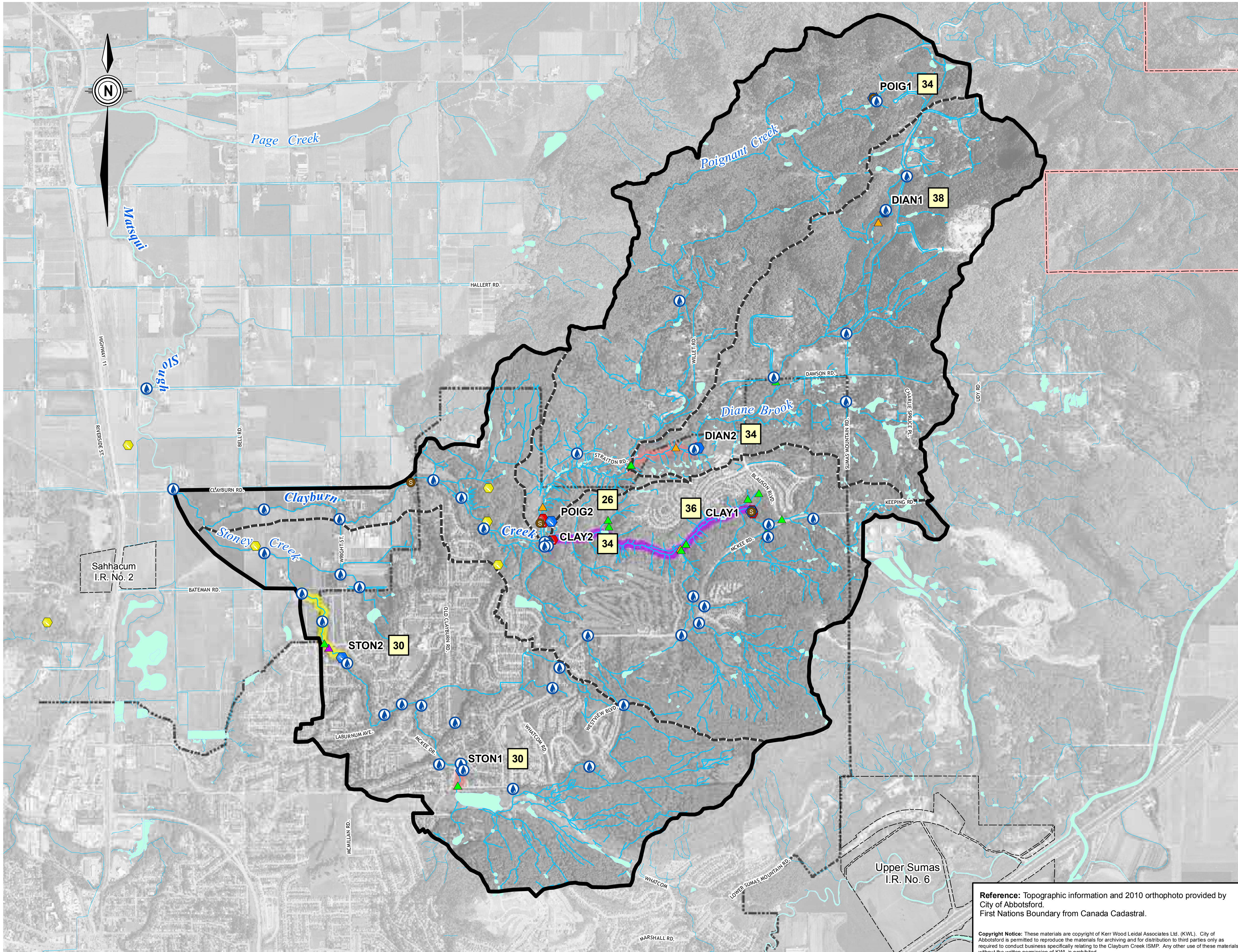
In addition, it is recommended that the Strategy provide comprehensive guidance for how the City will protect sensitive ecosystem types, known and potential habitats for species at risk, core habitat areas, and wildlife corridors during future development.

The following approach is recommended for development of the Strategy:

- **Landscape Analysis and Prioritization:** Using available information on stream setbacks, steep slopes, sensitive ecosystems, species at risk occurrences, recommended species at risk buffers, and other factors, undertake a GIS-based analysis to develop a map which classifies and prioritizes different land areas for protection based on relative ecological importance and/or habitat value.
- **Delineation of Hubs and Corridors:** A green infrastructure (or ecological) network approach to identify hubs, large intact core areas of naturally functioning ecosystems, and corridors, which provide physical or functional linkages between hubs of similar or different ecosystem types. Such an approach is aimed at preserving the most important land areas to ecological function and connectivity within the landscape as well as specific habitat types.
- **Development Guidelines for Specific Habitat Management Areas:** Based on the landscape analysis, develop different habitat management areas with specific objectives for habitat protection and specific development guidelines for achieving those objectives. Examples of development guidelines that could be recommended in the Strategy include requirements or recommendations for allowable development footprint, locating buildings within a site, native tree and vegetation retention, use of native species in landscaping, and appropriate interface planning such as buffers and fencing.

The above suggested approach is beyond the scope of the ISMP. However, the City of Abbotsford has recently undertaken a request for proposals that will hire a consulting team to develop a Sumas Mountain Environmental Management Area Strategy that has the potential to incorporate such an approach. The area proposed for the strategy includes the upland portion of the Clayburn Creek ISMP study area.

City of Abbotsford
Clayburn Creek
ISMP



Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creek
- Open Water and Marshes

Historical Benthic Sites

- MOE Benthic Sites (2001-2006)
- CABIN Benthic Sites (1998-2000)

MOE Monitoring Sites

- Current Grab Sampling Sites (2009)
- MOE Continuous Monitoring Stations (2008)
- MOE FREP Sites (2008-2009)

ISMP Sampling Sites

- In-situ Water Quality Sites (2009)
- Sediment Sites (2009)
- Benthic Sites (2009) 38 2009 B-IBI Score

Water Quality Priority Issues

- Severe Sedimentation
- High Levels of Fecal Coliform
- Elevated Levels of Metals, Oil and Grease

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Project No.	Date
510-057	May 2012

Environmental Sampling Sites

Figure 3-1

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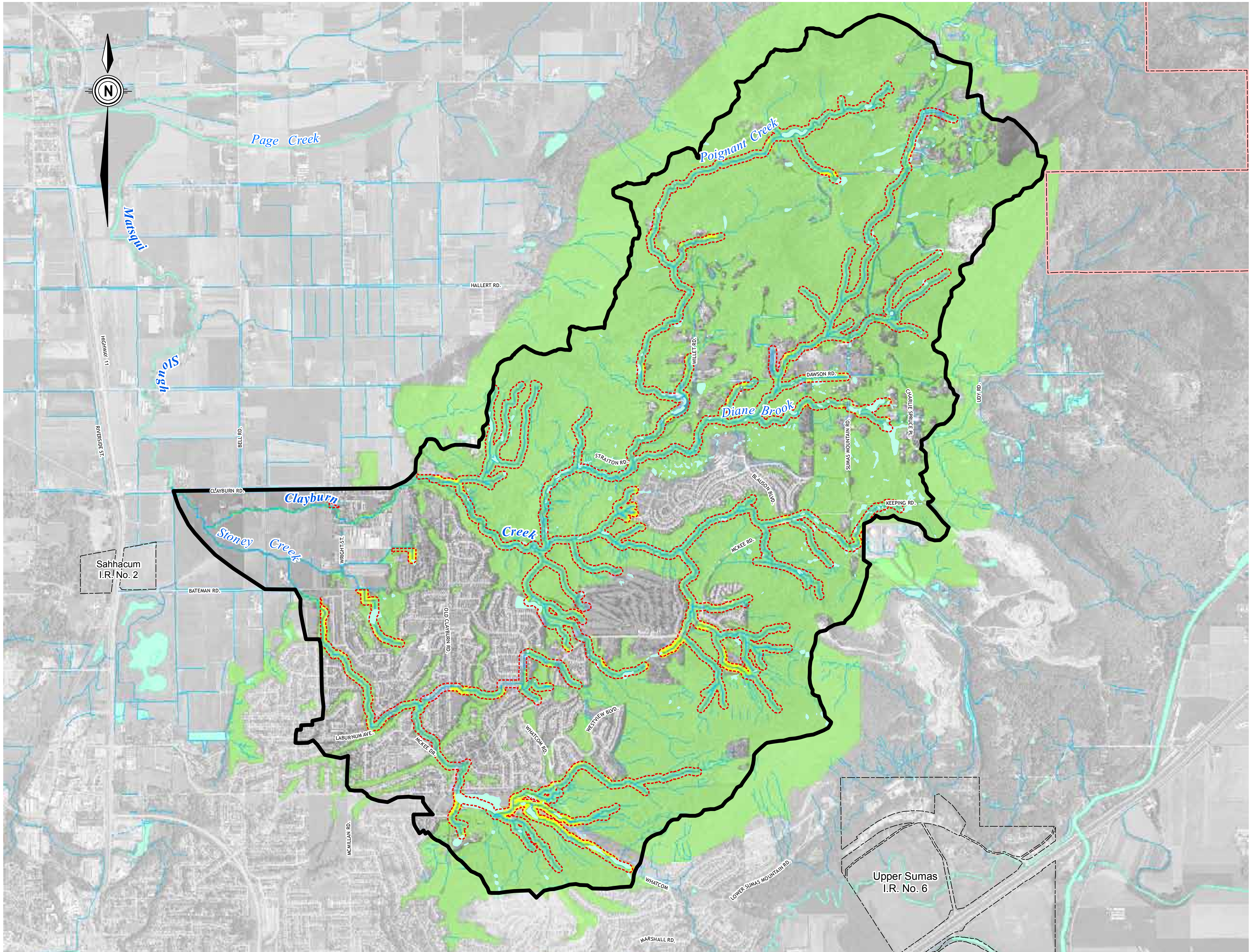

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creek
- Ponds/Wetlands
- 30 m Riparian Buffer on Permanent Streams (Used for RFI Assessmnet)
- Existing Forested Areas
- Potential Riparian/Reforestation Sites within 30 m of Permanent Streams

Note: For planning purposes, setbacks shown from creekline but will be measured from top of banks in field. Subject to detailed on-site assessment.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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Project No.	Date
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Riparian and Watershed Forest Cover

Figure 3-2

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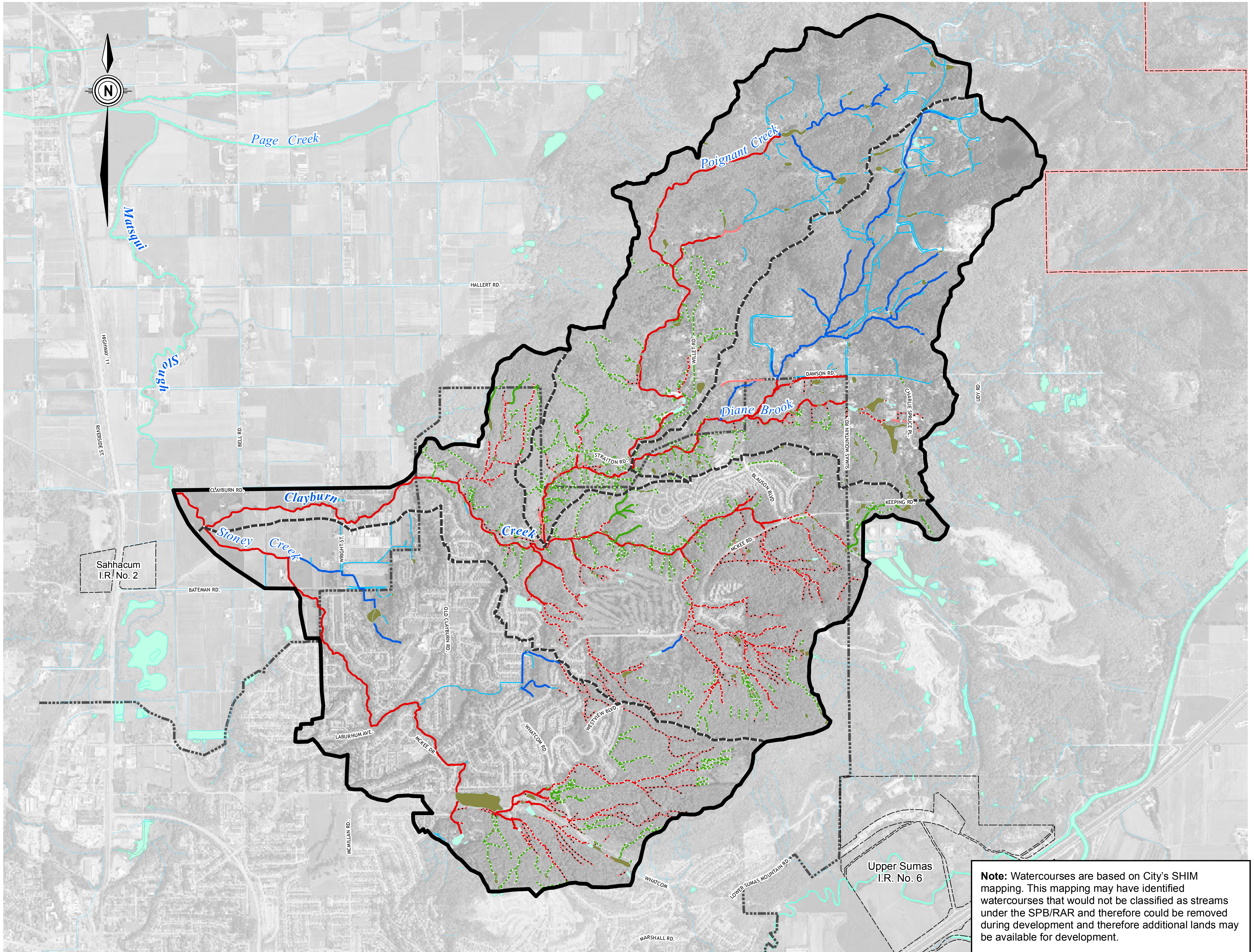

Note: Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creek Outside of Watershed
- Ponds
- Wetlands

Watercourse Classification

- Permanent Fish-Bearing
- Permanent Fish-Bearing (Potential)
- Fish-Bearing (Unknown Flow Regime)
- Fish-Bearing (Potential) (Unknown Flow Regime)
- Permanent Unlikely Fish-Bearing
- Unlikely Fish-Bearing (Unknown Flow Regime)
- Permanent Stream (Unknown Fish Presence)
- Unclassified

Note: Fish classifications based on existing information on fish presence and flow regime.

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

Watercourse Classification

Figure 3-3

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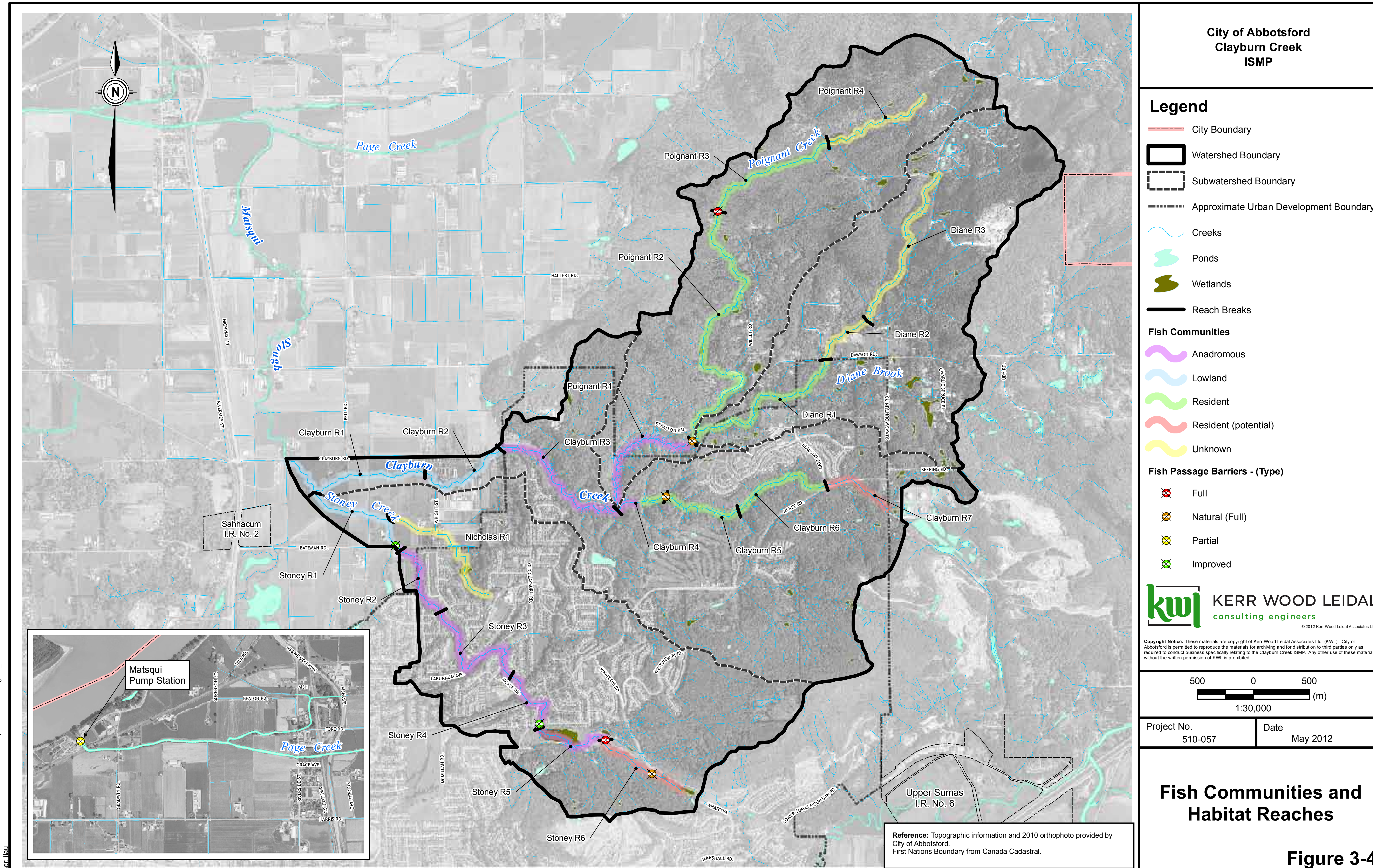

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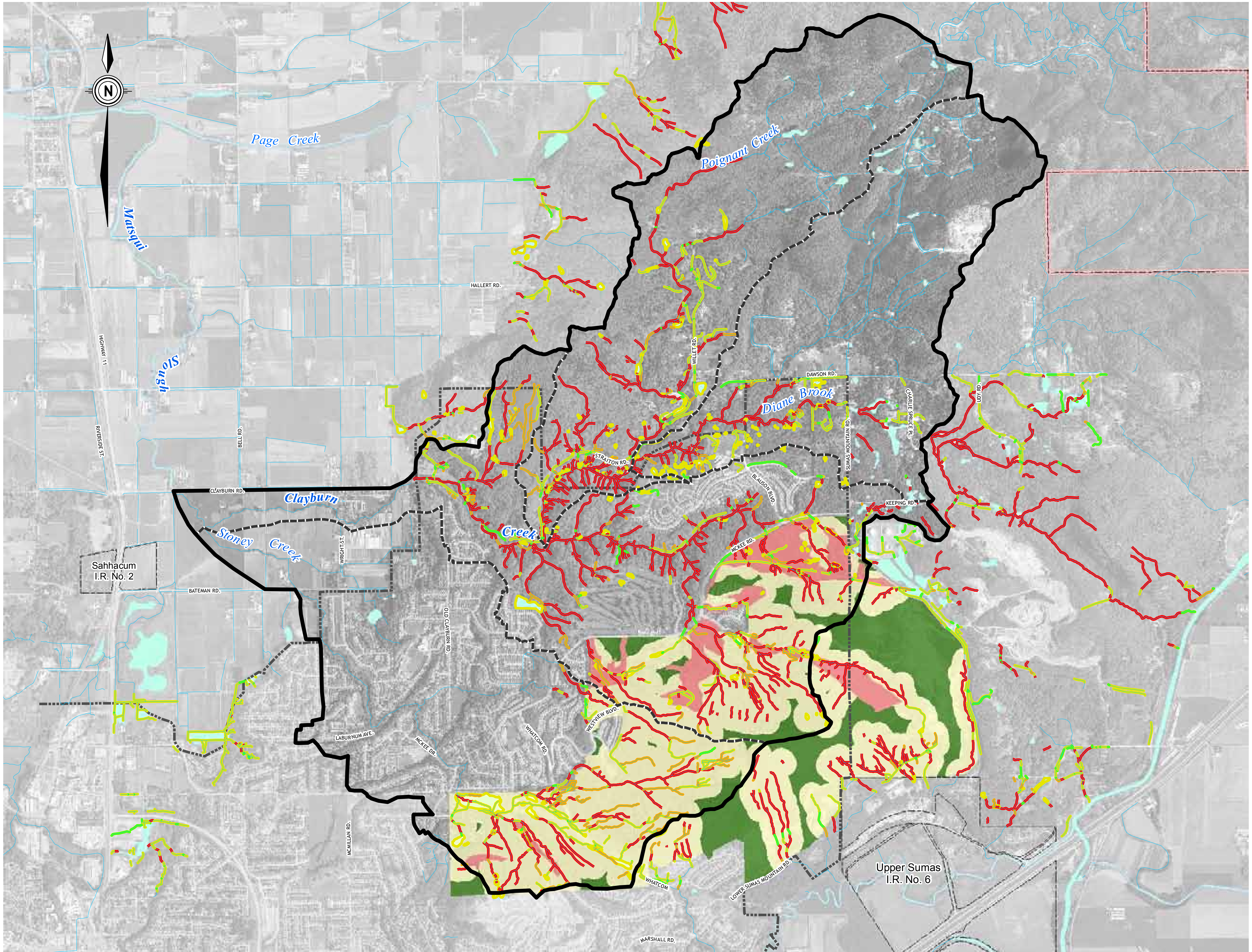

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creek
- Open Water and Marshes

PWS Habitat Suitability (SHIM)

- High
- Moderate
- Low
- Nil

PWS Habitat Suitability (TEM)

- 2 - Moderate
- 3 - Low
- 4 - Nil

Note: Based on SHIM. Subject to detailed on-site investigation,

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

Pacific Water Shrew Habitat Suitability

Figure 3-5

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Section 4

Upland and Lowland Drainage System

4. Upland and Lowland Drainage System

4.1 Minor and Major Drainage System

The minor drainage system is defined as the storm sewer system that can theoretically convey up to the 10-year runoff event. The major drainage system is defined as overland flow paths, culverts, and creek channels that can theoretically convey up to the 100-year runoff event. In urban areas road surfaces and easements with swales or oversized storm sewers make up the majority of the major system.

The minor and major drainage system assessment used peak instantaneous flows and did not take into account future climate change factors.

4.2 Hydrologic and Hydraulic Modelling

XP-SWMM hydrologic and hydraulic modelling was undertaken for the entire Clayburn catchment and drainage system including 912 urban catchments, 45 rural catchments, and 900 road catchments, 60 km of storm sewers, 1315 manholes, 64 detention facilities, and all the creek channels for Clayburn and its tributaries (Poignant, Diane, and Stoney). Models were created for both existing (overall TIA 12%) and future (overall TIA 27%) land use conditions. The model was calibrated and validated using flow monitoring data collected at Clayburn Road Bridge Flow Gauge (2007 – present) using real storm events from 2007 to 2010). AES design storms using rainfall data from Abbotsford and Mission climate stations were used to develop the peak flow estimates summarized in Table D-5 in Appendix D.

4.3 Drainage System Assessment

4.3.1 Storm Sewer Capacity Assessment

Appendix E provides details for the hydrotechnical assessment. Of the 2,100 total conduits in the watershed, the flow in 70 pipes exceeded the design criteria for the 10-year existing land use instantaneous peak flows. An additional 32 pipes do not meet the criteria under 10-year future land use instantaneous peak flows. Of the 57 pipes in the major system, the flow in six pipes exceeded the design criteria for the 100-year existing land use instantaneous peak flows. An additional three pipes do not meet the criteria under 100-year future land use instantaneous peak flows.

4.3.2 Culvert and Bridge Capacity Assessment

The bridges and culverts on the main creeks and tributaries were assessed for conveyance capacity with the following criteria:

- **For lowland areas:** 10-year instantaneous peak flow and a maximum head loss of 100 mm over the length of the culvert/bridge; or
- **For uplands and transitional areas:** 100-year instantaneous peak flow limiting the upstream surcharge depth to 50% of the culvert/bridge height above the crown.

Of the 36 culverts and nine bridges assessed, 15 culverts and two bridges do not meet the criteria for the existing land use scenario and an additional nine culverts and three bridges for the future land use scenario. Refer to Appendix E: Table E-5.

4.3.3 Drainage System Improvement Alternatives

The inadequate drainage infrastructure can be addressed in a number of ways:

a) **Upgrade all undersized structures:** This would bring the structures into compliance with the criteria. This would result in an expensive upgrade program.

b) **Allow more surcharging and overland flows in safe areas:** This would reduce the upgrade program without significantly adversely impacting drainage.

c) **Increase the detention requirements:** Increased detention could bring some of the identified structures into compliance. However, the detention criterion is already quite onerous in the Clayburn Creek watershed. The upper portions of the Stoney Creek watershed that are yet to be developed could possibly benefit from increasing the 5 L/s/ha detention requirement from 10-year to 100-year.

These alternatives were considered and evaluated, together with input from the stakeholders, and preferred improvements were developed further into the ISMP Plan (refer to Table 8-1 and Figure 8-7).

4.4 Existing Detention Facility Assessment

A total of 64 existing detention facilities were included in the modelling to determine if these facilities are operating as intended.

4.4.1 Detention Facilities in Stoney Creek Catchment

The City's current detention standard of detaining the 10-year post-development flows and releasing them at 5 L/s/ha[5], adopted in 1992, was used to evaluate the detention facilities. New rainfall IDF curves were also adopted in 1995, and resulted in a 38% increase in required storage volumes for single family residential subdivisions. It is recognized that many of the detention facilities were designed and constructed to a different standard before the current standard was adopted. Refer to Table E-9 and Figure E-8 for the results of the detention analysis. Out of 51 facilities in the Stoney Creek catchment:

- 16 are expected to meet the 10-year flows to 5 L/s/ha criterion;
- 11 exceeded 5 L/s/ha because orifice was too large;
- 3 exceeded 5 L/s/ha because orifice was too small and flows were overtopping;
- 17 exceeded 5 L/s/ha and appear to have insufficient storage volume; and
- 4 are no longer in use or not detention facilities.

Of the 17 detention facilities in the 4th bullet, two were designed/constructed prior to the IDF Curve update in 1995 and an additional three were constructed before the current 5 l/s/ha criterion was added to the City's requirements in 1992.

[5] City of Abbotsford Development Bylaw No. 1565, 2006

4.4.2 Detention Facilities in Clayburn Creek Catchment U/S of Clayburn Village

The City's current detention criterion was used to evaluate detention facilities in areas tributary to Clayburn Mainstem upstream of Clayburn Village: 100-year post-development flows detained to 5 L/s/ha[6]. Refer to Table E-10 and Figure E-8 for the results of the detention analysis. Out of 13 facilities in the Clayburn Mainstem catchment:

- 9 are expected to meet the 100-year flows to 5 L/s/ha criterion; and
- 4 exceeded 5 L/s/ha and appear to have insufficient storage volume.

Of the 4 facilities in the 2nd bullet, one was designed/constructed prior to the IDF Curve update in 1995.

4.4.3 Existing Detention Facilities Improvement Alternatives

Alternatives for addressing the deficient detention facilities are:

a) **Modify detention criteria:** Perhaps reducing the target storm event return period or allowing a pre-development peak outflow rate (instead of 5 L/s/ha) and modifying the outlet accordingly would be beneficial to downstream erosion issues. Having the detention facility fill and overflow allowing undetained peak flows to be released via the spillway likely has a greater negative impact than allowing a higher release rate through the controlled orifice outlet and preventing overflows. Potential proposed release rates could be the estimated pre-development forested rates. Each facility could be individually optimized to best utilize its volume.

b) **Increase the detention volume:** Along with reconfiguring the outlet, this would allow the current detention criterion to be met, however it is likely difficult to provide the space needed for this additional volume in built-out areas.

c) **Apply stricter criteria elsewhere:** To offset the flow exceeding the 5 L/s/ha from existing facilities, future facilities could overcompensate to release at lower rates. If it is found that this is viable, financial compensation for the future development could be considered.

d) **Reconfigure facilities in series:** Detention in series is not effective because flows that have already been detained flow through the downstream facility, unnecessarily using storage volume. Where possible, separate detained and undetained flows and reconfigure the outlets from the facilities. This would improve the function of stepped detention tanks.

These alternatives were considered and evaluated, together with input from the stakeholders, and preferred improvements were developed further into the ISMP.

[6] City of Abbotsford – enhanced detention criteria to provide added protection to Clayburn Village

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Section 5

Erosion and Sedimentation

5. Erosion and Sedimentation

5.1 Active Stream Bank Erosion and Instability of Steep Ravine Slopes

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 (Figure 2-3). Steep slopes were also noted in the northern and southernmost portions of the watershed, where the 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 5-1 and 5-2).

Photo 5-1: Poignant Creek Eroding Toe of Slope

Photo 5-2: Debris Slide on Lower Ravine Slope

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. Figure 2-3 shows the results of an audit of stream channel erosion provided by 2006 SHIM data. This figure identifies the locations and sizes of sites of active erosion and/or instability along the stream channels.

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.

Photo 5-3: Bank erosion

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 5-3). 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 5-1) and from the trail that follows the north side of Clayburn Creek between Straiton Road and McKee Road. This erosion is a result of the natural meandering of the stream channels. The dense and 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.

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 include:

- 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 or deep-seated instability was noted during the field reconnaissance.

5.2 Erosion on Steeper Stream Gradients

GIS data provided by the City (2006 SHIM mapping) indicated numerous locations of bank erosion (Figure 2-3). Based on this information, 116 documented areas of erosion are located within the Clayburn watershed. Of these, 92 are classified as being greater than 10 m².

Erosion appears to be mainly concentrated within the deeply incised ravines in lower Poignant and Clayburn Creeks. Notes associated with the erosion location markers refer to “slumps”, “slides”, “landslides” and “bank erosion”. Documented eroded material types include clay, till and soil. The grain size distribution is not known for these three material types, but many till deposits and soil deposits are widely-graded, containing a mixture of fine and coarse sediments.

In general, the Clayburn Mainstem, Poignant Creek, and Diane Brook subwatershed were assessed as part of the SHIM mapping, while only the upper areas of Stoney Creek (south of Wells Gray Ave) were assessed. Also, as SHIM mapping is focussed mainly on identification of instream fish habitat conditions and concerns, some areas of erosion may have been missed. Based on the available data, sediment sources are concentrated on the area of the watershed where the tributaries join Clayburn Creek. Some areas of erosion are noted further upstream in the Diane Creek watershed, but in general, observations of erosion are much less common in the upper reaches of the watershed.

Stream Gradients

The steepness of the streambed slopes was reviewed, and 78 erosion sites or 68% of the total erosion sites identified are located on stream reaches with average calculated slopes of greater than 12%. This appears significant, and is an indication that much, though not all, of the ravine erosion may be attributed to the topography and geology of the watershed. Figure 2-3 shows the calculated stream slopes along with the erosion site observations.

5.3 Erosion Sites Downstream of Urban Development

A review of erosion sites, creek sections, subdivision development and detention facility operation is presented in the following table:

Table 5-1: Erosion Sites Downstream of Subdivision Development

Development	As-built Dates	Pond Identification No./Outflow/ Assessment Finding	D/S Creek Slope	# of Erosion Sites[1]
Ledgeview Heights	1998	P17 - 16 l/s/ha Outflow moderately exceeds 5 l/s/ha & facility has insufficient storage volume	13%	4 sites
Auguston	Phases 1 - 5 1999 – 2004 Ph 6 2005	P1 - 8 l/s/ha Outflow moderately exceeds 5 l/s/ha & facility has insufficient storage volume	3% 7%	1 site 1 site
Kensington Park @ Ledgeview	2004	P46 - 22 l/s/ha Outflow significantly exceeds 5 l/s/ha & facility has insufficient storage volume	13%	5 sites
Kingsgate Condo, McKee Road	2004	P44 20 l/s/ha and P45 19 l/s/ha Outflow significantly exceeds 5 l/s/ha, outlet needs to be larger to prevent overflows		
Only subdivisions constructed prior to 2006 were investigated because erosion sites were mapped in March 2006. Creek gradients found on Figure 2-3, detention facility identification numbers and locations found on Figure E-7. 1. Severe (> 10 m^2) erosion sites				

In total, 11 of the severe erosion sites are downstream of these subdivisions and detention facility outfalls, which constitute only 13% of the identified severe erosion sites. This indicates that the subdivision developments and the discharges from their detention facilities are not the primary generating force for erosion in the ravines. There doesn't seem to be a direct correlation to indicate that these upland subdivision developments have exacerbated erosion. Some erosion is below development but the majority appear unrelated to development and rather are related to steep side slopes within the ravines. The watercourses may also still be adjusting to past logging activities in these areas. A more thorough erosion audit should be conducted to monitor erosion and to determine if it is getting worse, staying the same, or stabilizing with vegetation.

Having noted these site-specific findings, it is well documented that removal of forest cover for farming, land development, and other activities increases frequency and magnitude of peak flows, and increases runoff volumes. This increases the velocities / tractive forces / energies within watercourses and exacerbates erosion and bank stability. Every effort must be made to mitigate these impacts to minimize erosion and protect the watercourses. This is especially relevant in this watershed.

5.4 Erosion and Slope Failure Alternatives

Potential solutions include:

1. **Choose strategic outfall locations:** In developed or developing areas, outfalls should be extended down the ravine side slopes to the bottom of the slope where flows are less susceptible to erosion (i.e., where the creek gradient is flatter) and use energy dissipation outfall structures. Intercept overland flows at top of ravine side slopes and pipe them down to the creek.
2. **Stabilize major erosion:** Use hard protection in critical areas and bioengineering in less critical areas. However, access to the steep ravine side slopes is difficult.
3. **Add source controls:** Retrofit existing development with, and incorporate into new development, source controls designed to capture frequently occurring rainfall, thereby reducing the volume, peak and duration of flows. This would reduce the day-to-day erosion.
4. **Detain flows to below erosion threshold:** This would likely mean larger facilities than currently required for the 10-year or 100-year to 5 L/s/ha criteria. Flows from undeveloped forested areas would likely exceed this threshold if not also detained.
5. **Allow natural erosion to continue:** The annual sediment volume transported in Clayburn Creek above the College Sediment Trap (as estimated from the surveys of Clayburn Creek downstream of Straiton Road and the removal volumes from the sediment traps) was checked against other watersheds in BC and was found to be well within the bounds of a watershed of that size. Although MOE notes that turbidity and sediment deposition is notably elevated in the upper watershed, the amount of sediment transported to the lowlands does not appear to be out of the ordinary. Future development however should incorporate source controls to not increase the sediment rate.
6. **Adhere to geotechnical setbacks:** Proposed geotechnical setbacks from the top of ravine and steep slopes must be enforced for development and infiltration facilities.

These alternatives were considered and evaluated, together with input from the stakeholders, and preferred improvements were developed further in later phases of the ISMP.

5.5 Lower Clayburn Channel Sediment Yield

Appendix F provides the details of the sediment assessment. 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.

There are four existing sediment removal basins in lower Clayburn Creek upstream of the Stoney Creek confluence as shown on Figure 2-3. The sediment budget analysis (see Appendix F) showed that the existing sediment traps are able to remove 124 m^3/yr of the 168 m^3/yr of sediment being deposited, resulting in 44 m^3/yr aggrading in the lower Clayburn Creek channel (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. This estimate has a degree of uncertainty because 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. If not addressed, this aggradation will continue to reduce flow conveyance capacity resulting in more frequent overbank flows.

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.

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 Straiton Road crossing and the Stoney Creek confluence in order to keep up with the estimated sediment influx.

5.6 Low Risk of Debris Flows

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[7]). Furthermore, the sediment may be transported in the form of massive surges, depositing sheets of poorly sorted debris ranging from sand to cobbles or small boulders.

A desktop screening assessment was conducted to assess the named tributaries in the upper Clayburn watershed for debris flow or debris flood potential. According to the scatter-plot of watershed Melton Ratio vs. watershed length, the four upper tributaries; Poignant Creek, Diane Creek, Upper Clayburn Creek, and Upper Stoney Creek plotted in the zone of floods only. (Refer to Appendix F.) 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.

5.7 Sediment Aggradation in Lower Clayburn Creek Alternatives

Potential solutions include:

1. **Expand existing sediment traps:** Undertake regular and/or increased monitoring and cleaning.
2. **Construct additional sediment traps:** The channel may benefit from another sediment trap upstream of the Wright Street Bridge where sediment has been depositing.

[7] 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.

3. **Remove sediment from gravel bars:** The existing sediment traps will not be able to capture and contain all sediment. In fact in order to maintain spawning gravels in the lower channel, they should be designed to allow some gravel to continue downstream. However, with periodic sediment removal from gravel bars, the rate of instream aggradation may be reduced, maintaining conveyance capacity.
4. **Dredge the creek channel:** In the past, excavation of the channel bottom was a regular occurrence. This maintained the channel capacity. However, this is no longer an acceptable practice to DFO.
5. **Construct Newbury weir at Wright Street:** There is a large amount of sediment accumulated under the bridge. DFO suggested installation of a Newbury weir to promote scour under the bridge and deposition in the sediment trap downstream. The City noted that they installed a single line of boulders forming a weir across the channel in 2007, however upon further investigation, it is not located at the required location.

These alternatives were considered and evaluated, together with input from the stakeholders, and preferred improvements were developed further in later phases of the ISMP.

KERR WOOD LEIDAL
consulting engineers

Section 6

Lowland Flooding Assessment

6. Lowland Flooding Assessment

6.1 Introduction

Clayburn Creek has a long history of flooding affecting Clayburn Village, Clayburn Road and lowland agricultural areas. Lowland residents feel that flooding has been exacerbated in recent years due to upland urban development with more development planned in the future areas. Flood flows outside the creek channel occur annually downstream of Wright Street and now also occur near Wright Street on an annual basis. Clayburn Village is situated on a gravel fan at the base of the upslope section of the Clayburn Creek watershed (see Figure 2-3).

6.2 Modelling Results

The modelling revealed that the conveyance capacity of the existing Clayburn Creek channel is approximately 10 m^3/s (or approximately a 2-year existing land use flow estimate) upstream of Wright Street. Downstream of Wright Street, the creek channel conveyance capacity was calculated to approximately 6 to 8 m^3/s (less than a 2-year flow). The banks of Clayburn Creek start to overtop and flood the Village near Wright Street during an approximately 2-year flow. The agricultural land, west of Wright Street, begins to flood in less than a 2-year flow, and water flows overland toward Clayburn Road resulting in overtopping of the low spots in the road. This conveyance capacity changes as sediment accumulates in the channel.

The modelling assessment also showed that the Clayburn Creek Straiton Road Bridge (K_CV76) surcharges during the 100-year event resulting in upstream flooding and the Stoney Creek driveway bridge downstream of Bateman Road (K_CV89) is not able to convey the 10-year peak flow with a maximum head loss of 100 mm over the length of the bridge under existing land use flows (see Figure E-5 and Table E-5 in Appendix E).

6.3 Rainfall Return Periods of Historical Flood Records

Table 6-1 summarizes a comprehensive list of historical flood records for Clayburn Village and lowlands provided by the City. Table 6-2 summarizes the associated rainfall return periods for each event where hourly rainfall data was available from the Abbotsford Airport AES Station Climate Station (1977 to 2002.

The results show that Clayburn Village has flooded 11 times in the last 30 years (between 1977 and 2010), and that all the events were:

- a 2-year or larger return period;
- were longer duration events (24-hour); and
- occurred in the rainy winter months.

Clayburn Road and the agricultural lowlands also flooded during these events and also another 9 times, six of which were less than 2-year return period.

Eight 2-year or larger return period events occurred between 1977 and 2000 but no flooding was reported. This may be due to one or more of the following reasons:

- the events had dry antecedent conditions and some of the rainfall was held in the trees and soil resulting in less runoff; and

Table 6-1: City Flooding Records for Matsqui Prairie Since 1876

Date	Location	Description	Precipitation (mm) (Abbotsford Airport)	Reference
Jan 5-10, 2009	4290 Wright St. School Building Clayburn Rd.	Flooding on the field of 4290 Wright St. and the school building. Flooding of Clayburn Rd. W. of Wright St.	55.4 – Jan. 7 2009 160 – in 5 days (Jan. 5-10)	Report from residents & Engineering Operation.
Jan 11, 2008	4255 Wright St. Clayburn Rd. 34742 Clayburn Rd.	Bank break on 4255 Wright St. Road flooding between Bell Road & the Village. Field Flooding on agricultural lands west of Wright St.	53.5 – Jan 10th, 2008 18.3 – Jan 11th 2008 It was close 2-yr storm event.	Notifications #10149737 & 10149303
Dec. 5-6, 2007	4255 Wright St. Clayburn Rd	Bank breaching, flooding in the field. Flooding – Clayburn Rd. W. of Wright St.	42 - Dec. 2 2007 42.5 – Dec. 3 2007 33 – Dec. 4 2007 Total 117.5 mm.	Notifications #10147907, 10147902, 10147910 & 10147839
Mar 10-11 & 27, 2007	4290 Wright St. Clayburn Rd.	Flooding in Clayburn Village. Overtopping Clayburn Road between Seldon & Mission Hwy.	18.4 – Mar.10 2007 78.2 – Mar. 11, 2007 23.9 – Mar. 22 2007 31.1 – Mar. 23 2007 53.2 – Mar. 24 2007	Notification #10134659
Jan 2-3, 2007	4255 Wright St. Clayburn Village	4255 Wright St. Field flooding/ Driveway damage. Wright St. flooding.	29.2 – Jan 1 2007 49.4 – Jan 2 2007 14.9 – Jan 3 2007	Notifications #10130148 & 10129997
Nov. 6-7, 2006	Clayburn Village Clayburn Rd.	Flooding on Clayburn Rd. E. of HWY #11.	83.2 – Nov. 6, 2006 151.2 – Nov. 2-6, 2006	Notification #10127173
Jan 13, 2006	4290 Wright St. School Building Clayburn Rd.	Flooding in the field due to bank overflow Flooding - Clayburn Rd. E. of Bell Rd.	51.2 – Jan 13 2006 181.4 – Jan 9-13, 2006	Notification #10111880 Owner of 4290 Wright St. Notification #10111856
Jan 18-21, 2005	4290 Wright St. Clayburn Rd. 34486 Clayburn Rd. 34416 Clayburn Rd.	Frozen ground & 1-week rainfall, flooding in the field and house, creek overflowed. No berm existed along the banks prior to the storm. Fine sand in the riding zone was washed out into the creek. Flooding of Clayburn Rd. E. of HWY #11. D/W breaking away due to flooding. D/W washout.	76.4 – Jan 17 2005 191.8 – Jan 16-20, 2005	Information provided by Dustin Ellis, son of the owner. Notifications #10092281, #10069604, #10092221, #10092492, #10092587 Notification #10092567
Nov. 2-25, 2004	Clayburn Rd. 34416 Clayburn Rd.	Flooding of Clayburn Rd. Creek overflowed and washed out road.	42.6 – Nov 1 2004 77.8 – Nov 24 2004	Notifications #10088039, #10089221
Oct. 17-23, 2003	Agricultural Lands 4250 Wright St. Clayburn Road	Flooding of some agricultural lands, including the field of 4250 Wright St. Overtopping of Clayburn Road east of HWY #11 and a footbridge immediately downstream of Wright St. No flooding on 4290 Wright St.	93.8 – Oct 16 2003 73.6 – Oct 17 2003 50.6 – Oct 20 2003	Notifications #10069369, #10069604 Clayburn Creek Drainage Study (2005) Associated Engineering Ltd. Pg. 2-2.
Apr 16, 2002	Clayburn Rd.	Flooding of Clayburn Rd/ HWY #11.	33.8 – Apr 13 2002 66 – Apr 13-16 2002	Notification #10045309
Feb 22-25, 2002	Clayburn Rd. 34486 Clayburn Rd.	Flooding of Clayburn Rd E. of HWY #11. Driveway washed out again	56.6 – Feb 21 2002 45.8 – Feb 22 2002	Notifications #10043214, #10043276
Dec 2-15, 1999	Clayburn Rd. 34570 Clayburn Rd. Clayburn/ Straiton	Flooding on Clayburn Rd between Wright St. & HWY #11. Creek washout driveway on 14570 Clayburn Rd. Mud slide on east side of Clayburn Village.	31 – Dec 1 1999 22.8 – Dec 2 2009 53.4 – Dec 15 1999	Notifications #10012436, #10013302, #10013294 #10013290
Nov. 11, 1999	Clayburn Rd.	Creek overtopped it bank and flooded Clayburn Rd. east of HWY #11 west of Bell Rd.	27.6 – Nov 15 1999 70 – Nov 11-13 1999	Notification #10011595
1978-1990	4290 Wright St.	The creek overflowed its bank 3 times and flooded the field during heavy rainfalls in the fall and winter. About 1/3 of the land was flooded, and the flooding was limited to the area near the creek. The previous owner (1978-1990) built a berm along the banks of the creek to reduce chances of the creek overflowing, shortly after the road was built (Valley to Straiton). The material used building the berm came from the creek bed, which was washed down from unstabilized banks of the new road and carried into Kelly Creek and filled the stream bed.		Email from previous owner (1978 -1990) dated on May 3, 2007.

Date	Location	Description	Precipitation (mm) (Abbotsford Airport)	Reference
1991	Willband Sump	The three major flooding events occurred in Nov 1989, 1990 and 1991 were used for model calibration of the Matsqui Slough Drainage Study, but there was no detailed description of the flooding.	37.2 – Nov 4, 1991 19.2 – Nov 5 1991 37.2 - Nov 11 1991	Matsqui Slough Drainage Study (UMA, 1993)
1990 Nov. 9-12, 1990	Willband Sump Clayburn Area	Willband sump includes the lowland agricultural area between Clayburn Rd and Bateman Rd west of Wright St., and the existing Willband Creek Detention area. High-intensity, long-duration storm (exceeded 25-yr record at Abbotsford).	21.8 – Nov 7 1990 11.2 – Nov 8 1990 79.6 – Nov 9 1990 61 – Nov 10 1990	Matsqui Slough Drainage Study (UMA, 1993) Archives
1989	Willband Sump		57.6 - Nov 3 1989 39 – Nov 8 1989 70.8 – Nov 9 1989 45.4 – Nov 10 1989 14.4 – Nov 11 1989	Matsqui Slough Drainage Study (UMA, 1993)
Jan. 4-11, 1984	Clayburn Rd	Flooded		Archives
July 1, 1981	Mastqui Prairie	Flooded		Archives
Dec. 3, 1975	Matsqui Prairie	Heavy rain; snowmelt		Archives
June 11-14, 1972	Matsqui Prairie	Above-average snowfalls recorded in Feb. Surveys indicated heavy mountain snowpacks. High temperatures occurred in the Interior - rivers peaked at record levels in the later part of May & first week of June. Substantial snowmelt occurred, followed by heavy rains. Fraser peaked again between June 11 & 14, resulting in floods. Dyking systems prevented large-scale damage.		Archives
Feb. 1951	Clayburn	Flooded by heavy rains, washouts. Clayburn & Bateman Rd inundated & impassable for several days.		Archives
1948		Weather-related flood		Archives
1935		Weather-related floods. Slides and washouts.		Archives
1908		Flooding of low lying areas.		"Comprehensive Review of Fraser River at Hope Flood Hydrology and Flows – Scoping Study" (nhc, 2008).
1896	Matsqui	Water level (WL) within 69 cm of 1894 WL. Large flood, but not as destructive as previous floods. Matsqui dyke failed. Low-lying areas were flooded.		
1894	Matsqui	Largest known flood to date		
1892		Sloughs were overflowing and much of the prairies were submerged		
1890	Matsqui	Flooding		
1882	Matsqui	Freshet flood		
1880		Dyke at Matsqui failed		
1878	Matsqui	Dyke failure at Matsqui (poorly built)		
1877	Matsqui	Dyke failure at Matsqui		
1876	Matsqui Prairie, highlands	Freshet flood – Nearly all of the settler's lands were flooded, except for Sardis. Large areas not considered subject to flooding were inundated.		

O:\0500-0599\510-057\300-Reports\20120509_FINAL\Tables\Table6-1_Flooding Records Since 1948.doc

Table 6-2: Rainfall Return Periods of Historic Flood Events

	Date	Rainfall Return Period	Noted Flooding
DFO No Longer Permits Channel Dredging	Dec 12, 2010	5-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Sep 19, 2010	2-year 2-hour	None reported
	Aug 11, 2009	2-year 6-hour	None reported
	Jan 7, 2009	2-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Aug 9, 2008	2-year 2-hour	None reported
	Jan 11, 2008	Less than 2-year	Clayburn Road, agricultural lowlands
	Dec 4, 2007	2-year 24-hour	4255 Wright St., Clayburn Road, agricultural lowlands
	Mar 11, 2007	2-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Mar 24, 2007	2-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Jan 2-3, 2007	2-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Nov 6-7, 2006	10-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Jan 13, 2006	2-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Sep 28, 2005	2-year 24-hour	None reported
	Jan 19, 2005	5-year 24-hour	Clayburn Village, Clayburn Road, agricultural lowlands
	Nov 24, 2004	5-year 24-hour	Clayburn Road, agricultural lowlands
	Nov 1, 2004	2-year 24-hour	None reported
	Oct 17, 2003	25-year 24-hour	Clayburn Road, agricultural lowlands
	Apr 16, 2002	Less than 2-year	Clayburn Road, agricultural lowlands
	Feb 22, 2002	Less than 2-year	Clayburn Road, agricultural lowlands
	Oct 18, 2000	2-year 2-hour	None reported
	Dec 15, 1999	Less than 2-year	Clayburn Road, agricultural lowlands
	Nov 11, 1999	Less than 2-year	Clayburn Road, agricultural lowlands
	May 29, 1997	2-year 2-hour	None reported
	Nov 7, 1995	5-year 12-hour	None reported
	Nov 9, 1990	2-year 24-hour	None reported
Channel Dredging	Nov 9, 1989	5-year 24-hour	4290 Wright St. Creek overflowed 3 times between 1978 and 1990
	Feb 23, 1986	2-year 24-hour	
	Dec 16, 1979	10-year 24-hour	
	Dec 3, 1987	2-year 2-hour	None reported
	Jan 4, 1984	Less than 2-year	Clayburn Road, agricultural lowlands
	Jul 11, 1983	2-year 24-hour	None reported
	Aug 17, 1978	2-year 6-hour	None reported
	Nov 25, 1977	2-year 12-hour	None reported

Return Period Colour Coding: 10 year or greater 5 year 2-year <2-year
Shading indicates Clayburn Village flooding

- the events were short in duration (lower than the time of concentration) therefore the whole watershed was not contributing surface flow at the same time resulting in lower peak flows and volumes;
- Clayburn Creek channel had more conveyance capacity historically; or
- Flood events were not recorded.

The lowland residents have noted that Clayburn Village started flooding more frequently since 2005. It is supported by the data in Table 6-2, which shows 8 of the 11 Village floods during this period.

6.4 Potential Causes of Lowland Flooding

There are a number of possible causes for this increase in flooding frequency including:

- Increased peak flows from upland development;
- Increased channel roughness due to unrestricted vegetation growth resulting in less conveyance capacity;
- Increased sediment aggradation in the channel resulting in less conveyance capacity; and
- Increased frequency of large rainfall events.

Each of these possible causes is discussed in the subsections below.

6.4.1 Upland Development on Clayburn Creek Peak Flows

The catchment tributaries to Clayburn Creek, upstream of Clayburn Village, are largely forested with some rural development and a few residential subdivision areas including the Auguston development. Refer to Figure 2-2. The area of tributaries to Clayburn Creek at Straiton Road is 1580 ha and has total impervious area of approximately 7%.

Detention: There are 13 existing detention facilities servicing the developed areas as shown on Figure E-8 and the detention facility assessment indicated that four facilities do not meet the current criteria of detaining the 100-year flow to 5 L/s/ha. There are also developments that do not have detention facilities including Phases 1 to 4 of the Auguston development. Upon examination of the recent storm events that caused flooding in Clayburn Village, all were lower than the 10-year return period rainfall during which the detention facilities appeared to nearly detain the flows to forested pre-development conditions, therefore does not have a direct correlation to the recorded flood conditions as a 100-year event has not knowingly occurred in this time period.

Pre-development Conditions: The watershed pre-development conditions were assessed to determine what the impact of peak flow estimates would have been without the residential subdivision developments. Refer to Appendix J: Pre-development Conditions and Modelling Technical Memorandum dated 15 September 2011.

The pre-development flows at Clayburn Village were estimated as approximately equal to the existing land use flows for ≥10-year events, but the estimated pre-development flows for 5-year and lower return period events were higher than the existing land use flows. This is possibly due to the:

- detention facilities for the existing land use conditions detaining flows to lower than forested, pre-development levels for the smaller events; and/or

- timing of the peak flows of forested and developed catchments is different (developed areas peak faster than forested areas) leading to lower overall peak flows in the existing land use.

Flow volumes would be larger and flow durations would be longer for a given peak flow rate under existing land use conditions than under forested conditions. This is because rainfall that would be captured and retained on-site as evaporation and infiltration under the forested condition would become surface runoff from impervious areas under developed conditions. This could exacerbate erosion and sedimentation in Clayburn Creek (see Section 6.4.3 below).

This suggests that the upland subdivision developments have little impact on the peak flows in Clayburn Creek. Even if no development had taken place in the watershed (i.e. pre-development conditions), the recent flooding would have occurred.

6.4.2 Increased Clayburn Creek Channel Roughness

Channel roughness in the lowland creek channel affects conveyance capacity and water levels during rainfall-runoff events. The more resistance to flow posed by overhanging and in-channel vegetation, the higher the water levels for a given flow rate. Vegetation growth can be very significant especially over 10 to 20 years. The likelihood of this being a large contributor to the increased flooding is low as the City has been trimming the vegetation on a yearly basis since 2007.

6.4.3 Increased Clayburn Creek Channel Sediment Deposition

Clayburn Creek has active stream bank erosion and steep ravine slope instabilities. The alluvial fan where the village is located suggests that sedimentation has been depositing in the low gradient channel sections before there was any upland development.

Increased Erosion and Sedimentation Due to Development: The erosion and sedimentation is a natural process that may however have been accelerated in recent years due to upland development. Even with detention facilities in place, development runoff causes detained flows to occur for longer durations than in pre-development forested conditions where trees and soil would have intercepted much of the annual average rainfall. The runoff from development, although detained, may have increased the erosion rates in the creeks resulting in more sediment being carried into the lowland creek reaches and deposited there. This is why current stormwater management philosophy focus on volume reduction measures such as source controls as well as peak flow reduction to strive to replicate the pre-development hydrology.

Channel Dredging of Fish-Bearing Channels is No Longer an Environmentally Acceptable Practice: Historically, sediment deposition was addressed with channel dredging. However, DFO no longer allows large-scale channel dredging on fish-bearing watercourses. In recent years, sediment removal has been limited to cleaning of sediment traps and minor gravel bar scalping. This amount of sediment removal has not kept up with the influx of sediment, resulting in channel aggradation (raising of the creek bed; refer to Appendix F).

Estimated Channel Capacity With and Without Sediment Aggradation: Stakeholders have noted that since the dredging of Clayburn Creek ceased (last dredging operation in 1988), the creek bed has aggraded by several feet in some locations. A comparison of 1992 and 2006 creek surveys shows a maximum aggradation depth of approximately 0.5 m. This value may be larger when comparing the 1988 to 2011 differences by accounting for the four years prior to 1992 and the five years after 2006. The difference in bank full conveyance capacity at the location of maximum deposition is substantial (14 m^3/s in 1992 versus 8 m^3/s in 2006). At a more average deposition location, such as the creek downstream of Wright Street, the 1992 bank full capacity would have been approximately 10 m^3/s and the creek was able to contain a 5-year peak flow. In conclusion, the sediment deposition alone has greatly reduced the conveyance capacity of Clayburn Creek. All the recent flood events since 2005 with the exception of the November 2006 flood, which was a 10-year return period storm, would likely have been contained in the channel if no sediment had been allowed to accumulate since 1992.

6.4.4 Increased Frequency of Large Rainfall Events

Historic flooding records show that between 1978 and 1990, three events caused flooding at Wright Street (at 4290 Wright Street) and that Clayburn Road and the agricultural areas were flooded eight times between 1984 and 2005. The three events causing flooding in the Village were all larger than 5-year events at the Abbotsford Airport climate station and the eight causing flooding of Clayburn Road were all less than 2-year return period.

Between 2005 and 2010, seven events have been observed that have equalled or exceeded a 2-year return period event. On average, three exceedances of the 2-year rainfall would have been expected in this period. This suggests either that in recent years the rainfall has been atypical or that climate change has been resulting in more frequent large rainfall events. This climate change pattern has been analysed and observed in Metro Vancouver and is likely occurring in Abbotsford as well. Therefore one possible cause of the more frequent flooding of Clayburn Road and Clayburn Village is that 2-year and larger rainfall events have been occurring more frequently than they had been in the past. With more rainfall data being constantly collected, an assessment of rainfall changes could be performed, however, because such assessments rely on past data, it will take 10 years (analysis done in 2020) to know how 2010 compared to 1990. The graphic below shows the increasing frequency of large and extreme rainfall events in recent years.

In conclusion, the increased frequency of flooding in Clayburn Village and the lowlands in general has likely been due to a combination of the above factors. It is suspected that the contribution of the various factors from most to least effect is as follows: sedimentation has played the largest role, then climate change, and lastly roughness and development have played a minor role.

6.5 Allowance for Climate Change

Various Green House Gas (GHG) emission scenarios and associated climate change predictions have been made using climate models for the region and globally. The models typically assess how the monthly or seasonal rainfall patterns may change in the future but have difficulty forecasting how the rainfall intensity of 24-hour or shorter durations will be impacted[8]. Relationships developed between monthly rainfall total and maximum short duration (1, 2, 6, 12, 24-hour) rainfall intensity in the same month have been used to predict the effects of climate change on the short duration rainfall intensities in other areas of south-western BC[9,10].

A study to predict the monthly and seasonal rainfall increases due to multiple climate change scenarios and in turn relate that to how IDF curves may change has not been completed for the City of Abbotsford. However, similar studies for Metro Vancouver and Victoria showed that the IDF curves may increase by 1% to 15% by 2050 depending on return period and duration.

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[8] Jakob M and Lambert S (2009) Climate change effects on landslides along the southwest coast of British Columbia. *Geomorphology* 107(3-4): 275-284.

[9] BGC Engineering Ltd. “Victoria Climate Change Adjusted IDF Curves”. Technical Memorandum prepared for KWL dated 4 June 2010.

[10] BGC Engineering Ltd. “Climate Change (2050) Adjusted IDF Curves: Metro Vancouver Climate Stations”. Final Report prepared for Metro Vancouver dated 6 May 2009.

For the purposes of this study, the peak flows used for sizing the lowland flood management works were scaled up by 10% to account for climate change. These flows could be further revised during detailed design if additional climate change studies become available or Abbotsford-specific studies are undertaken by the City.

6.6 Lowland Flooding Alternatives

Solutions to address the existing problems were investigated.

6.6.1 Flooding of Clayburn Village

The City requested that a 100-year level of service be investigated for the Clayburn Village flood protection alternatives. Potential solutions to achieve this included:

a) **Repair existing upland detention shortcomings:** The detention assessment revealed that four of the existing detention facilities upstream of Clayburn Village did not meet the required 100-year event detained to 5 L/s/ha. This solution alone will not eliminate the flooding problem in the Village because the pre-development factored (for climate change) instantaneous peak flow estimates for the 2-year and 5-year return period are 10 m^3/s and 13 m^3/s, respectively, which exceeds the existing channel conveyance capacity.

b) **Divert peak flows around Clayburn Village:** The capacity of Clayburn Creek channel through Clayburn Village is approximately a 2-year peak flow (10 m^3/s). During events larger than this, excess flow could be diverted by pipe or open channel to farther downstream of the Village. Such a diversion would need to convey a factored instantaneous peak flow of approximately 15 m^3/s during a 100-year rainfall event. Depending on what upland detention criterion is used for future development, the diversion would need to carry from approximately 15 m^3/s if the 5 L/s/ha criterion is applied up to 56 m^3/s if no detention is provided.

c) **Deepen and/or enlarge Clayburn Creek channel:** The capacity of the creek channel would need to be increased to 26 m^3/s for the 100-year existing land use factored instantaneous peak flow and up to 66 m^3/s if no upland detention is provided under future land use conditions. Bridges would also need to be enlarged.

d) **Construct berm along right (north) bank:** This would protect the Village and lands north of Clayburn Creek but would result in higher flood levels on the left bank south of Clayburn Creek. Pump(s) may be needed to drain the Village into the bermed creek.

e) **Construct berms along both banks:** This would protect not only the Village but also the lands to the south. However, confining the 100-year flows in the channel would require higher berms. Pump(s) may be needed to drain the Village into the bermed creek.

f) **Construct a ring berm around Clayburn Village:** This alternative would be similar to the right bank berm but would only target protecting residential properties in the Village. Pump(s) may be needed to drain the Village into the creek.

g) **Relocate Clayburn Village to higher ground or raise buildings:** This could be accomplished by raising all low buildings and filling properties to raise them above the flood construction level which would provide the required level of protection and no pumps would be needed for local drainage.

h) **Detain forested area to 5 L/s/ha:** Forested areas currently discharge approximately 15 L/s/ha during a 100-year event, or approximately 20 m^3/s at Straiton Road. If the entire catchment area could be detained to 5 L/s/ha (1,580 ha * 5 l/s/ha = 8 m^3/s), no other works in the lowlands would be required other than ongoing sediment management. The existing Clayburn Creek channel could convey such a flow past the Village. However, this would alter the pre-development flow regime and require very large in-creek detention volumes and land areas, and would have a prohibitive environmental impact. In-creek detention is no longer an environmentally acceptable practice. .

i) **Increase Wright Street Bridge Span:** Stakeholders raised this option, however downstream water levels are not much lower, therefore bridge expansion would not alleviate the flooding.

6.6.2 Flooding of Clayburn Road

Currently the lowest elevations of Clayburn Road overtop in less than 2-year return period events as flows travel from east to west along the road and from south to north across the road. The City requested that alternatives be investigated to protect the road to the 100-year level of service. Potential solutions included:

a) **Raise Clayburn Road:** Raise the low portions of the road to the flood construction level. Preventing flows from crossing the road would likely result in higher flood levels on the south side of the road.

b) **Construct a berm along south side of Clayburn Road:** This would protect the road from Clayburn Creek overbank flows, however it would leave it vulnerable to flooding from backwater conditions in Matsqui Prairie. A berm would also result in higher flood levels on the south side of the berm.

c) **Construct berm along right (north) bank (or along both banks):** Preventing Clayburn Creek from overtopping its banks would protect the road. However, it would remain vulnerable from backwater flooding. Bridge upgrades may also be needed west of Wright Street.

d) **Enlarge Clayburn Creek channel:** This would prevent overbank flows, protecting Clayburn Road. Furthermore if this enlargement was continued downstream to the Fraser River in conjunction with pump station upgrades, Clayburn Road and the lowlands to the north would also be protected from backwater flooding.

6.6.3 Flooding of Clayburn Agricultural Lands

The agricultural areas in the lowlands currently flood in less than a 2-year return period event. Typically, lowland floodplain areas flood once the creek channel capacity is exceeded or if the lowlands are backwatered from downstream conveyance capacity issues. This study only evaluated the former because an overall Matsqui Prairie study is needed to assess the latter. As described in Section 6.4.3, Clayburn Creek did have capacity to contain a 2-year flow in the past when dredging was part of the regular maintenance program. Sedimentation has decreased the capacity to less than a 2-year return period.

For events larger than a 2-year return period, flooding may be acceptable; however, the duration of flooding should be controlled. For example, under the Agri-food Regional Development Subsidiary Agreement (ARDSA), duration of flooding during a 10-year 5-day winter rainfall event is limited to 5 days; while during a 10-year 2-day growing season rainfall event is limited to 2 days. Typically, lowland agricultural areas are not protected to the same level as developed/residential areas. Options for addressing channel capacity flooding include:

a) **Detain upland area peak flows to existing channel capacity:** The upland area currently discharges approximately 6 L/s/ha into the lowlands during a 2-year event. If the entire catchment area could be detained to 3.7 L/s/ha, no other works in the lowlands would be required. However, any future sediment deposition would further reduce the channel capacity and would therefore need to be managed so that removals kept up with influx of sediment. In addition to development areas, forested areas would need to be detained requiring in-creek detention facilities (not an environmentally acceptable practice).

b) **Deepen and/or enlarge Clayburn Creek channel:** The capacity of the creek channel would need to be increased to 10 m^3/s for the 2-year existing land use factored instantaneous peak flow and up to 16 m^3/s if no upland detention is provided under future land use conditions.

c) **Construct berms along both banks:** Confining the 2-year flows in the channel would require low berms in the agricultural areas. Drainage of the fields and ditches would require floodboxes through the berms. The flooding duration criteria would need to be checked to determine if pump stations would be necessary for storm events exceeding the 2-year event which would spill into the fields via spillways at strategic locations.

d) **Fill low spots up to the 2-year water level:** A 2-year water level profile can be produced for the lowland creek channels and the adjacent land filled to this elevation. This alternative would require large amounts of fill material in some locations especially the agricultural areas immediately west of Clayburn Village.

Regarding the berm option, the Ministry of Agriculture provided input on the desirable level of service in the farmlands, noting that pump stations may be preferred by the landowners as they would provide a superior drainage system to that currently in place, and advised that the downstream impacts of berming the floodplain needs to be assessed prior to implementing the lowland works. Pump stations in the farmlands are currently under the jurisdiction of the Matsqui Prairie Dyking, Drainage, and Irrigation (DDI) District. Further investigation by the DDI would be needed to determine the need for pump stations in the lower Clayburn Creek lowlands. A Matsqui Prairie Drainage Study is recommended to evaluate the downstream impacts and to estimate flood elevations in the lowlands.

The berm option together with floodboxes, without local pumping, would limit the flooding of the fields to the rain falling directly onto the fields (i.e. uplands flows would be contained in the bermed creek). Therefore, even without pumping, the berms and floodboxes would provide some benefit over the existing condition.

6.6.4 Lowland Flood Protection Options

The above noted options were explored in more detail at the request of stakeholders. The following options were developed and compared. For all options, sedimentation would still need to be addressed to avoid creek capacity reduction. Furthermore, in addition to the major event detention requirements noted under each option below, the upland mitigation facilities for future development would also need to address erosion.

Option 1 – No Lowlands Works, Detention in Uplands

Continue the 100-year to 5 L/s/ha detention requirement for development in the uplands. This includes addressing any detention facilities that do not meet the criterion and adding detention to undetained development areas.

Under this scenario, flooding of Clayburn Road would continue to be an annual occurrence because the road floods during flows of less than 4 L/s/ha. Flooding of Clayburn Village would continue to be a bi-annual occurrence because the detention in the developing areas would not be able to reduce the flows to less than the channel capacity.

As development proceeds, the detention would slowly reduce the peak flows in Clayburn Creek. Once the watershed is fully built out to the OCP land use (12% of the watershed will be developed to densities greater than Suburban Residential and 88% will remain rural or undeveloped), it is estimated that the factored instantaneous peak flows in Clayburn Creek at Straiton Road would be:

- 2-year: (3.2 L/s/ha x 12% + 5.9 L/s/ha x 88% x 1.1) x 1,580ha = 6.1 L/s/ha x 1,580ha = 9.6 m^3/s
- 5-year: (3.7 L/s/ha x 12% + 6.1 L/s/ha x 88% x 1.1) x 1,580ha = 6.4 L/s/ha x 1,580ha = 10.1 m^3/s
- 10-year: (4 L/s/ha x 12% + 8.0 L/s/ha x 88% x 1.1) x 1,580ha = 8.2 L/s/ha x 1,580ha = 13.0 m^3/s
- 100-year: (5 L/s/ha x 12% + 15.1* L/s/ha x 88% x 1.1) x 1,580ha = 15.2 L/s/ha x 1,580ha = 24 m^3/s (*pre-development flow at gauge, flows are higher farther upstream)

The above peak flows are very similar to the existing land use unfactored instantaneous peak flows for today's conditions and therefore suggest that adding detention to the developing areas may only negate the effects of climate change because the proposed developing area is only 12% of the catchment. The costs associated with adding detention to future development would be paid by the developer and therefore not included here.

Option 2 – 100-year Channel Enlargement

Enlarge the Clayburn Creek channel to convey the existing land use 100-year factored instantaneous peak flow of approximately 26 m^3/s. For future land use, the development would need to limit peak outflows to existing land use values (15 L/s/ha release rate) or less. It is estimated that this would require a doubling of channel cross sectional area through the Village and tripling it through the farmland to the west. There are six bridges that would need to be upgraded to pass the 100-year flow. The cost of the enlargement and bridge upgrades is approximately $11.5 million (see Appendix I for detailed cost estimates).

Natural lowland creek channels at equilibrium typically have a 2-year flow capacity in the channel with excess flows spilling into the overbank floodplain areas. Enlarging the channel to a 100-year capacity would encourage rapid deposition of sediment as the creek tried to adjust back into equilibrium. This option is not recommended and furthermore, would not be supported by DFO.

Option 3 – 100-Year Berms

Construct berms to contain the 100-year existing land use factored instantaneous peak flow of approximately 26 m^3/s. Again, future development would need to limit post-development peak flows to existing land use values or less. Berms to contain the 100-year flow would need to extend from Straiton Road to a downstream tie-in point. This downstream point is assumed to be Clayburn Road for the north bank berm and the Stoney Creek berm for the south bank berm. Both of these (Clayburn Road and Stoney Creek berms) may need to be higher than they are currently to effectively contain the 100-year peak water levels.

This option would require approximately 1,100 m of 1.5 m high berm, 1,800 m of 1.0 m high berm, and 1,000 m of 0.5 m high berm, totalling 25,000 m^3 of material. There are six bridges that would need to be upgraded to pass the 100-year flow within the study area. Because the water levels in Clayburn Creek adjacent to the Village may be too high to drain the Village by gravity during peak flows, this option would also likely require that the drainage from Clayburn Village be piped westward to a location where the creek levels are lower (included in cost estimate) or be pumped into the bermed creek channel (pumps not included in cost estimate).

Floodboxes may be adequate to drain the agricultural lands protected by the berms. Flooding of these fields would be limited to the rain falling directly onto the fields (i.e. uplands flows would be contained in the bermed creek); however, the drainage of the fields may be delayed until the creek water levels drop allowing the floodboxes to open. Therefore, while the flooding depths would be much shallower, the duration of flooding may be longer. Small pump stations (not included in the cost estimate) would alleviate this issue. A lowlands drainage study is needed to determine the level of service criteria and floodbox/pumping requirements.

This option would cost $14.6 million (see Appendix I).

Option 4 – 100-Year Bypass

Divert flows in excess of the existing channel capacity west of Clayburn Village (6 to 8 m^3/s) away from Clayburn Creek into a bypass floodway channel along the north side of Clayburn Road. In order to protect the lowlands up to the 100-year factored instantaneous peak flow, approximately 20 m^3/s of the existing land use peak flow would need to be diverted. Again, future development would need to limit peak flow to existing land use values or less.

This option would require restricting the Straiton Road Bridge opening to encourage more flow toward the bypass. This would mean that the bridge would not need to be upgraded. The bypass would require large box culverts (double 1.5 m x 2.4 m at upstream end to triple 1.5 m x 3.0 m at downstream end) and a 5 to 9 m wide open channel. This option would cost approximately $11.1 million (see Appendix I).

Creation of a high flow bypass around Clayburn Village provides an opportunity to create additional new fish habitat. Addition of a small year-round wetted channel within the bottom of the larger bypass channel along the north side of Clayburn Road would provide an additional coldwater refuge for rearing juvenile salmonids in the watershed. Such a channel would be fed during low flow conditions by either a groundwater well or groundwater interception channel at the upstream end of the bypass. The channel would provide an additional 1,800 m of rearing habitat in the lower watershed. A formal agreement between DFO and the City of Abbotsford would need to be pursued that allows for regular maintenance of the bypass for flood control purposes.

Option 5 – 100-Year Combination Bypass/Channel Enlargement/Berms

Given the feasibility issues, costs and preferences from stakeholders for Options 2, 3, and 4, a combination option including channel enlargement, berms, and bypass floodway was developed. The channel would be enlarged to carry the 2-year existing land use factored instantaneous peak flow only (10 m^3/s at Straiton Road) in the sections where the capacity is less than this (i.e. west of the Village). The bypass floodway would be used to convey excess flows during 2-year and larger events. During the 100-year event, Clayburn Creek would carry approximately 15 m^3/s and the bypass floodway would carry 11 m^3/s (factored instantaneous flows). To contain the 15 m^3/s flow in the creek, setback berms would be constructed along both sides of the creek. Again the future land use peak flows would need to be limited to existing land use values or lower.

Similar to Option 3 above, the Clayburn Village drainage would need to be addressed by piping some of the flows farther downstream where creek water levels are lower or pumping through the berms. Drainage of the agricultural lands would need to be addressed with floodboxes and possibly pump stations. A lowland flooding assessment for the entire Matsqui Prairie is required to determine flooding durations and peak flood levels and the need for pump stations.

This option is estimated to cost $9.8 million (see Appendix I).

10-Year Level of Service

Any of the above Options 2 to 5 could be revised to provide protection up to the 10-year event instead of the 100-year event. This would reduce the amount of channel enlargement, berm heights, or bypass floodway size and therefore costs. Providing protection for events up to the 10-year event would mean that during larger than 10-year events, flooding would occur. The berms would overtop at designated spillway locations, or the enlarged channel would flow full and spill into adjacent lands,

Phased Implementation

Any of the above options could be built in phases with the most critical portions built first.

The channel enlargement option could be built so that the most constricted sections downstream of Clayburn Village were enlarged first thereby reducing the peak water levels around Wright Street where the flows leave the channel first. The remainder of the channel around the more densely-populated Village area could be enlarged next and the agricultural portion enlarged last.

Ideally, it would be best to build the berms along the whole section as one project to prevent flow from being forced into those properties without berm protection if built in phases.

The bypass floodway option does not readily lend itself to a phase approach. The entire length of the floodway would need to be constructed before water is diverted into it. It could be built smaller initially and then expanded/widened at a later stage. Similarly, only a single box culvert could be installed at each driveway/road crossing and then twinned (or tripled) at a later date. This would be inefficient but is a possibility.

The combination option also lends itself to a phased approach following a similar pattern. The berm through Clayburn Village could be built first providing immediate benefit to the Village for lower return period flows. The channel excavation could be done next followed by building the bypass floodway. The north berm west of the Village and the south side berm could be constructed last.

These alternatives were considered and evaluated, together with input from the stakeholders, and preferred improvements were developed further in later phases of the ISMP. Refer to Appendix H for a detailed list of meetings and summary of stakeholder input.

Section 7

Mitigation of Impacts of Future Land Development

7. Mitigation of Impacts of Future Land Development

7.1 Land Development Restrictions and Special Requirements

Any development site will be restricted by several aspects including zoning, slopes, geohazards, riparian setbacks, and soil types. Initial review of the development site should consider all of these issues, and plan the development accordingly. This may include, but not be limited to:

a) **Protect ravine/steep slope geotechnical setbacks**

b) **Protect riparian setbacks:** Following the City's *Streamside Protection Bylaw* would result in protection of ecological health. However, variances are currently allowed which may result in some impact to ecological health. Ecological health is best protected with 30m setbacks on all permanent streams.

c) **Retain forested areas:** The OCP land use for the watershed identifies Resource, Conservation, Park, Forest areas that will remain forested. Rural, Limited Use, Suburban Residential areas will also likely retain some forest cover. At a minimum, a goal of 50% natural habitat protection at the subwatershed scale is suggested. Land use planning tools such as density transfers, density bonusing, or other mechanisms may be used.

d) **Preserve wildlife habitat and movement corridors:** Identify SAR buffers and propose careful development within these zones. Protect wetlands. Preserve contiguous forested corridors between forest and riparian areas.

Development Restricted and Special Requirement Areas	TO PROTECT HUMAN/PROPERTY SAFETY AND THE ENVIRONMENT **No development except road and utility crossings within:** • Extreme slope areas (above 35%) • Geotechnical setbacks from steep/ravine slopes (2H:1V (50%) from toe of stream channel or ravine slope) • Streamside Protection areas (15 – 30 m from top of bank or 10 m from top of ravine 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)
Site specific analysis required during the development application process to determine adequate setbacks.	

Based on detailed geotechnical and environmental studies, City staff propose to divide development into the following four development categories including an overlay category reflecting buffers relating to rare species:

1. No-Development Areas
2. Special Development Areas
3. Standard Development Areas
4. Special Management Overlay

No-development Areas are those areas that have extreme slopes (above 35%) or are within the required streamside setbacks. These areas will not be approved for development, except in special circumstances where access roads or similar works are unavoidable. In these cases, mitigation and habitat compensation for any disturbance will be sought.

Special Development Areas are those areas that lie within High or Moderate Habitat Sensitivity rankings, or are areas with steep slopes (10% to 35%). Development proposed for these areas must be approved by the City's Habitat Review Panel (HRP) with respect to wildlife and fisheries habitat management, in addition to the requirements set out in the City's Environmental Development Permit process.

Standard Development Areas are those areas not covered by any of the items identified above. Development in these areas will be subject to the City's Streamside Protection Bylaw and the standard Environmental Development Permit process, including geotechnical, tree, wildlife and fisheries assessments, appropriate stormwater management, tree preservation, erosion and sediment controls.

Special Management Overlay are cases where Special or Standard Development Areas fall within established BMP buffer areas around identified rare elements (plants or wildlife). The special management and/or mitigation measures may be required by the HRP or by senior levels of government.

This proposed approach does not preclude development in Clayburn Creek, but rather ensures that development is held to a high environmental standard, and that the ecological values of the area are protected. This approach also allows senior government regulatory agencies to place individual applications in a larger context, and clarifies and streamlines the approvals process.

Figure 7-1 shows riparian setbacks and detailed geotechnical investigation areas, and MOE's species-at-risk (SAR) best management practice buffer areas as applied to the Clayburn Watershed. Note: the riparian setbacks are drawn from the centerline of the stream channel; however, in application, the setback is actually measured from the top of bank, which can result in a larger setback than depicted in this figure.

7.2 Impacts of Development

Section A.1 in Appendix A describes typical impacts of land development on watercourses including:

- Increased volumes and faster responding runoff peak flow rates can cause flooding and erosion.
- Increased frequency in peak flows and increased volumes can trigger watercourse instability and deteriorate aquatic habitat.
- Decreased infiltration reduces base flows during dry weather periods, which reduces the fish supporting capacity of a watercourse.
- Decreased stream water quality.

One of the primary objectives of this ISMP is to develop a plan to mitigate the impacts of future development.

7.3 Environmental Hydrologic Impacts Associated with Development

7.3.1 Watershed Health Tracking System

The watershed health tracking system uses two watershed health indicators: (1) riparian forest; and (2) watershed imperviousness. Maintaining riparian forest and minimizing imperviousness are the two most effective methods of preserving watershed health.

Importance of Imperviousness (Indicator #1)

Research shows a strong relationship between the impervious area in the watershed and a stream's health (based on its fish and benthic insect community) as outlined in the following table:

Table 7-1: Stream Health Relative to Impervious Area

Health	Total Impervious Area (%TIA)
Stressed (minor changes to watershed health)	1 - 10 %
Impacted (moderate changes to watershed health)	11 - 25 %
Degraded (severe changes to watershed health)	26 - 100%
The Importance of Imperviousness, 1994, by T.R. Schueler.	

Importance of Riparian Forest Integrity (Indicator #2)

Riparian areas are those adjacent to watercourses that may be subject to temporary, frequent, or seasonal inundation, and which support plant life typical of the wetter soil conditions. These riparian areas provide natural features, functions and conditions that support a productive fish community, such as:

- multi-canopied forest and ground cover that:
  - moderates water temperature,
  - provides a source of food, nutrients, and organic matter,
  - stabilizes the soil with root systems, thereby minimizing erosion,
  - filters sedimentation and pollution;
- sources of large woody debris;
- active floodplain areas;
- side channels, intermittent streams; and
- infiltration that can aid in sustaining baseflows.[11]

Figure 3-2 shows the Riparian Forest Integrity (RFI) assessment areas on the permanent watercourses.

Clayburn Creek Existing and Future Watershed Health Indicators

Watershed health indicators were used to quantify predicted changes between existing and future conditions and to define targets to be achieved. They are:

- B-IBI (benthic index of biological integrity);

[11] Jan 2001, Streamside Protection Regulation

- TIA and EIA (Total and Effective Impervious Area) – meet the DFO Stormwater Guidelines to mitigate the hydrologic impacts of development; and
- RFI (Riparian Forest Integrity).

The existing and post-development values associated with the indicators are summarized in Table 7-2 and are shown on Figures 7-2 and 7-3 for multiple locations throughout the watershed. This does not account for any riparian/watercourse losses with the assumption that the City's Streamside Protection Bylaw will be enforced.

The goal of the ISMP is to achieve a no-net-loss of ecological health for the watershed as a whole and strive to maintain the indicators at 2009 levels. One way to define no-net-loss of ecological health is within the context of the Watershed Health Tracking System (WHTS) – mitigating the hydrologic impacts of impervious area using source controls and detention, and protecting riparian areas.

Both existing and unmitigated future land use scores are predicted based on the relationship between TIA, RFI, and B-IBI. These predicted scores are compared to the actual measures B-IBI values obtained from creek samples in 2009. The future predicted B-IBI score changes assume the impacts of the proposed development:

- without mitigation measures to reduce EIA; and
- With protection of RFI based on the City's Streamside Protection Bylaw setbacks (30 m setbacks on permanent watercourses on which the WHTS system is based).

As shown, the largest watershed health degradation, if not mitigated, would be expected in upper Clayburn Creek (locations C1 and C2) where much of the densification is proposed in the OCP. Upper Stoney Creek (location S1) and lower Poignant Creek (location P2) also show some potential health degradation. The goal of the ISMP is to propose works that will prevent the unmitigated future B-IBI degradation, and therefore the mitigated B-IBI values should match the existing B-IBI values. The following sections describe the proposed plan to achieve a no-net-loss of watershed health.

Table 7-2: Measured and Predicted Watershed Health Indicators (TIA, RFI, B-IBI Scores)

Site	2009 Measured B-IBI	Existing			Unmitigated Future		
		Imp. Area	Riparian Integrity	Predicted B-IBI	Imp. Area	Riparian Integrity	Predicted B-IBI Change
C1 - Clayburn Cr @ McKee Rd	**36**	4%	92%	37	53%	92%	-22
C2 - Clayburn Cr @ Poignant Cr	**34**	10%	89%	33	40%	89%	-16
D1 - Diane Br @ Highland Quarry	**38**	5%	80%	33	8%	80%	-2
D2 - Diane Br @ Mathers Park	**34**	5%	88%	36	8%	88%	-3
P1 - Poignant Cr @ Russel Rd	**34**	10%	95%	36	8%	95%	-2
P2 - Poignant Cr @ Clayburn Cr	**26**	4%	90%	36	16%	90%	-9
S1 - Stoney Cr @ McKee Rd	**30**	10%	64%	24	30%	64%	-7
S2 - Stoney Cr @ Stoney Cr Park	**30**	27%	64%	18	43%	64%	-3

Refer to Figures 7-2 and 7-3.

Stormwater Mitigation for the Protection of Watershed Health

Because of the significance of the erosion and instability issues within the Clayburn watershed, it is recommended that all development be implemented with Low Impact Development (LID) approaches and source controls to mitigate the impacts of development on the health of the watershed. It is important to investigate measures to provide:

- **Water Quality Treatment** to treat stormwater prior to discharge to watercourses;
- **Reduce Runoff Volumes** to preserve baseflows & minimize downstream erosion and habitat degradation; and
- **Reduce Post-development Peak Flow** to minimize downstream erosion and flooding.

LID planning should be included at the initial stages, as the most important aspect of LID is to retain existing natural hydrologic elements as much as possible.

The plan of the development must allow sufficient space, either open space, green space or underground space, for the implementation of mitigation source controls. This should be acknowledged and planned as the site is laid out, so that the mitigation is not just an afterthought for which there is no space allowed. Planning space for mitigation in the initial phases will keep design costs lower than re-designing a site at a later stage to introduce the space for mitigation.

7.3.2 Need for Low Impact Development Design

Due to the sensitivity of the ravines and streams within the Clayburn watershed, all new development within the watershed should be approached with LID in mind. The goal is to minimize the impacts of development and retain as much of the natural hydrological function of the land as possible. Methods that should be used in the Clayburn watershed include:

- Forest cover should be protected and maintained as much as possible in conjunction with development. Construction should be staged and managed to retain existing trees, singly and in groups, wherever possible as large and mature trees provide significant interception and detention for rainfall whereas new landscape trees and shrubs provide very little until they mature.
- Riparian areas should be rigorously protected, and riparian setbacks increased where possible to protect the ravines and species at risk, as well as to provide wildlife corridors.
- Impervious surfaces should be reduced where possible, such as road widths, surface parking requirements, and building sprawl.

Other potentially useful LID approaches are discussed in Appendix G.

7.3.3 Source Controls on Steep Slopes and Poorly Draining Soils

In assessing the application of source controls within Clayburn watershed, a number of factors were considered such as land use, geotechnical setbacks, topographic slopes and soils. Figures 7-4 and 7-5 show the future development overlaid with slopes and soils respectively.

- Infiltration Areas – Based on soil types and ravine slopes, geotechnical setbacks of 100 – 250 m are recommended (Piteau, 2010) unless site specific geotechnical study is done to reduce these setbacks.

- Steep Slopes – Sites with slopes between 10- and 35-percent merit careful consideration in the planning of development and stormwater management.
- Soils – Soils are divided into three categories of soil type based on geotechnical information as "Good Infiltration Capacity > 50 mm/hr", "Moderate Infiltration Capacity 10 - 50 mm/hr" and "Limited Infiltration Capacity 0 - 10 mm/hr" (Piteau, 2010).

Source Controls on Slopes

There will necessarily be some limitations on the application of source controls. Steep areas of 5% to 10% slope and greater than 10% slope, require special design and considerations. Surface installations may require terracing on slopes of 5% to 10% in order to prevent erosion due to high flow velocities. On slopes of 10% to 35%, terracing may be used to flatten portions of the site to improve infiltration at the surface. Sites with slopes between 10% to 35% should also be viewed as less desirable for full build-out, so minimizing impervious lot area should be part of the approach for sloped sites. It is recommended to use piping and underground infiltration or retention facilities to prevent surface erosion.

No infiltration or retention source controls should be constructed within the geotechnical setbacks in order to reduce the risk of destabilizing steep slopes and stream banks.

Source Controls for Different Soil Types

A significant portion of the upland area within the watershed is underlain by glacially deposited till soils and rock. Concern regarding the use of various types of source controls in areas underlain by till and rock is common, but evidence has shown that properly designed facilities work well even in these conditions. Till soils and rock have a low hydraulic conductivity relative to sandier soils, on the order of 1 mm/hr, vs. 25 mm/hr or higher for sandy types of soils. The low conductivity means that water can infiltrate and travel in the soil layer very slowly, which places limitations on the use of infiltration source controls, but not on retention source controls, for volume reduction and water quality treatment.

When infiltration is limited as it is in till soils, source controls can rely on retention of runoff to achieve the volume reduction targets and achieve water quality treatment. Retention simply allows storage of the target volume of runoff that can then be infiltrated very slowly into till soils.

Source Controls Above and Below Ground

The types of source controls recommended for the Clayburn watershed include on-site source control facilities to mitigate the runoff from a single site or lot, and regional source controls to mitigate a group of lots or sites together. In-ground source controls such as infiltration or retention rain gardens, trenches and galleries, swales and bio-retention are generally the default for a site, but they require space for in-ground installation. It may not be possible to mitigate a high-density development on-site given space, soils, slope and other limitations. For these cases, regional facilities on separate dedicated land may be the solution or alternatives to in-ground source controls may be necessary.

Typical above-ground source controls include storage and re-use tanks located either on the ground or on the roof. Stormwater harvesting and re-use can be allocated to irrigation, but a more efficient non-potable usage would be a "purple pipe" or grey water system for residential, institutional, or industrial uses. This type of system is covered by the British Columbia Building Code, Section 7, and can be permitted and approved by municipalities similar to any other building system.

Another above-ground approach is a green roof to mitigate the impervious building footprint. A green roof is most cost-effective on mid- to high-rise structures in an urban setting, but could be applied in any commercial, industrial, or institutional context[12].

Source Control Prescriptions Based on Land Use

The application of source controls to the various land use, slope and soil combinations was developed into "Prescriptions" described in Section 8.4.3. Source controls should be sized and designed to capture and hold 51 mm of rainfall from the subject site in order to have stormwater benefits. This is equivalent to the 72% of the 2-year, 24 hour design rainfall event.

Source Control Stormwater Target for Clayburn Creek Watershed: 51 mm

Supplement with Baseflow Augmentation Facilities

If the full 51 mm of rain source control volume reduction cannot be met, alternatively baseflow augmentation type facilities can be considered such that water is released to the storm conveyance system to the creek at a very low rate. The rate of discharge should be equivalent to a baseflow contribution rate per hectare of contributing watershed area. This baseflow discharge rate is approximately 0.025 L/s/ha for the upper Clayburn watershed, and 0.05 L/s/ha in the lower watershed. Such a slow discharge rate can lead to long storage times within these facilities and therefore they should be located underground to keep the water temperature cool and minimize mosquito problems.

7.4 Detention Criteria for Clayburn Watershed

The detention criteria applied in the Clayburn Creek watershed needs to address multiple issues: flood protection, erosion, and aquatic habitat. Possible criteria include:

a) **Flood Protection Criteria for Clayburn Creek upstream of Clayburn Village:**
   1. Existing City Standard for Clayburn: 100-year to 5 L/s/ha.
   2. 100-year post-development flow to existing levels (after Lowland Flood Protection Plan constructed).

b) **Flood Protection Criteria for Stoney Creek:** Typical City Standard - 10-year to 5 L/s/ha. The City estimates that this is equivalent to about 760 m^3/ha of impervious area

c) **Aquatic Habitat Protection Criteria:** DFO: 6-month Volume Reduction and WQ treatment and flow control 6-month, 2-year, 5-year post-development flows to pre-development levels.

d) **Minimize Erosion Criteria:**
   1. Existing City Standard: 10-year to 5 l/s/ha.
   2. **Western Washington Stormwater Management Manual (2005):** states *"Stormwater discharges shall match developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. The pre-developed condition to be matched shall be a forested land cover unless:*
      1) reasonable, historic information is provided that indicates the site was prairie prior to settlement (modeled as "pasture" in the Western Washington Hydrology Model); or

[12] Metro Vancouver "Design Considerations for the Implementation of Green Roofs", 2009.

2) *the drainage area of the immediate stream and all subsequent downstream basins have had at least 40% total impervious area since 1985. In this case, the pre-developed condition to be matched shall be the existing land cover condition. Where basin-specific studies determine a stream channel to be unstable, even though the above criterion is met, the pre-developed condition assumption shall be the "historic" land cover condition, or a land cover condition commensurate with achieving a target flow regime identified by an approved basin study.*

This standard requirement is waived for sites that will reliably infiltrate all the runoff from impervious surfaces and converted pervious surfaces."

This WWSWMM requirement minimizes the instream erosion caused by development by limiting flow energy to pre-development levels. To assess such a criterion, a long record of flows must be simulated for the forested pre-development case and for the development with stormwater controls case and a flow exceedance duration graph created.

Such a simulation was performed for a single hectare of impervious area to determine the required stormwater controls. Using runoff from a 1 ha 100% impervious catchment, the following was required:

- a source control sized to meet the 6-month volume reduction target resulted in land area requirement of 11% (0.11ha) of the contributing impervious area,
- an 800 m^3 detention facility sized to match the flow durations over a 35-year precipitation record (1964 to 1998). (800 m^3/ha unit detention size).

This volume does not include the additional volume that would be required to control the 10-year or 100-year peak flows to the City's standard 5 L/s/ha outflow rate.

Table 7-3 shows the detention volumes that various criteria would dedicate using a similar analysis.

Table 7-3: Detention Requirements for Various Hydrologic Criteria

Criteria	Required Unit Detention Volume w/o FOS (m^3/ imp ha)[1]
Flood Protection Criteria	
100-Year (all durations) Events to 5 L/s/ha [current Clayburn Creek standard]	680[2]
100-Year (all durations) Events Post to Pre-development levels (15 L/s/ha) [maintaining 100-year flows only at pre-development rate	300
10-Year (all durations) Events to 5 L/s/ha [current Stoney Creek standard]	440[3]
10-Year (all durations) Events to 5 L/s/ha plus 100-Year (all durations) Events to 15 L/s/ha [proposed criteria for Clayburn Creek once lowland works completed]	600
DFO Aquatic Habitat Protection Guideline	
6-month, 2-year, 5-year 24-hour events Post to pre-development levels	320

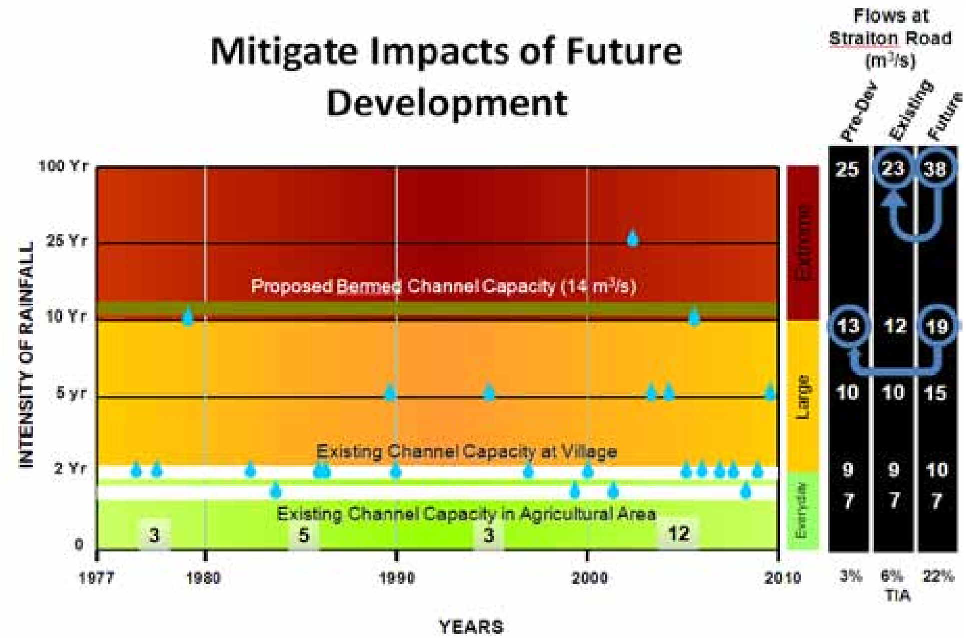
Criteria	Required Unit Detention Volume w/o FOS (m^3/ imp ha)[1]
Match Full Spectrum of Natural Flows - Minimize Erosion Criteria	
Exceedance – duration with 35 years rainfall record 50% 2-year to 50-year post- to pre-development levels	800

[1] FOS = Factor of Safety, m^3/ imp ha = m^3 per impervious ha
[2] The City's analysis method results in approximately 860 m^3 per impervious ha (or 1290 m^3 per impervious ha including 1.5 factor of safety) detention volume for 100 year to 5 L/s/ha peak flow attenuation.
[3] The City's analysis method results in approximately 506 m^3 per impervious ha (or 760 m^3 per impervious ha including 1.5 factor of safety) detention volume for 10 year to 5 L/s/ha peak flow attenuation.

The Western Washington detention criterion is stringent and requires a large detention volume. Given that the 6-month pre-development peak flow (Appendix J) is approximately 5 l/s/ha, it would appear that the City's standard detention criterion to detain the 10-year to 5 l/s/ha would provide better erosion protection (reduced flows and velocities) than DFO's habitat protection criteria. Based on this and results in Table 7-3, it is recommended that the City's current detention criteria in the Clayburn watershed be adjusted as follows:

- **Habitat/Erosion/Flood Protection:** Detain 10 Year (all durations) post-development peak flows to 5 L/s/ha. Once developed to the OCP, the 10-year peak flow at Straiton Road would be 13 m^3/s.
- **For Clayburn Mainstem Catchment only:** Detain 100-Year (all durations) post-development peak flows to 15 L/s/ha to maintain flows through Clayburn Village at existing rates. Once developed to the OCP, the 100-year peak flow at Straiton Road would be 23 m^3/s.

The graphic below shows the existing capacity of Clayburn Creek through the Village and downstream in the agricultural area as 2-year or lower peak flow. Berming the creek would increase the capacity to 14 m^3/s, and the proposed detention would lower the future 10-year peak flow to 13 m^3/s. The proposed detention would also reduce the future 100-year peak flow to match the existing 100-year peak flow of 23 m^3/s.



The above proposed criteria change should come into effect after the proposed lowland works (berms) are constructed. Relaxing the 100-year detention criterion by increasing the allowable release rate from 5 L/s/ha to 15 L/s/ha will reduce the required Unit Detention Volume from approximately 680 m^3/ha to 600 m^3/ha.

7.5 Mitigating the Impacts of Future Development Alternatives

Potential solutions included:

a) **Identification of Land Development Restrictions and Special Requirements:** Protect ravine/steep slope geotechnical setbacks, riparian setbacks, forest retention areas, wildlife habitat and corridors. Additional studies such as a Terrestrial Habitat Conservation Strategy would be useful.

b) **Land Use Neighbourhood Planning Studies:** would be useful to provide guidance to such large scale development and to identify impervious area and forest retention targets.

The ecological health of a watershed is affected by numerous factors: water quality, baseflows, peak flows and their durations, riparian forest integrity, watershed forest cover, wildlife habitat and corridors, fish habitat, etc. The watershed ecological health can be maintained or improved with the following:

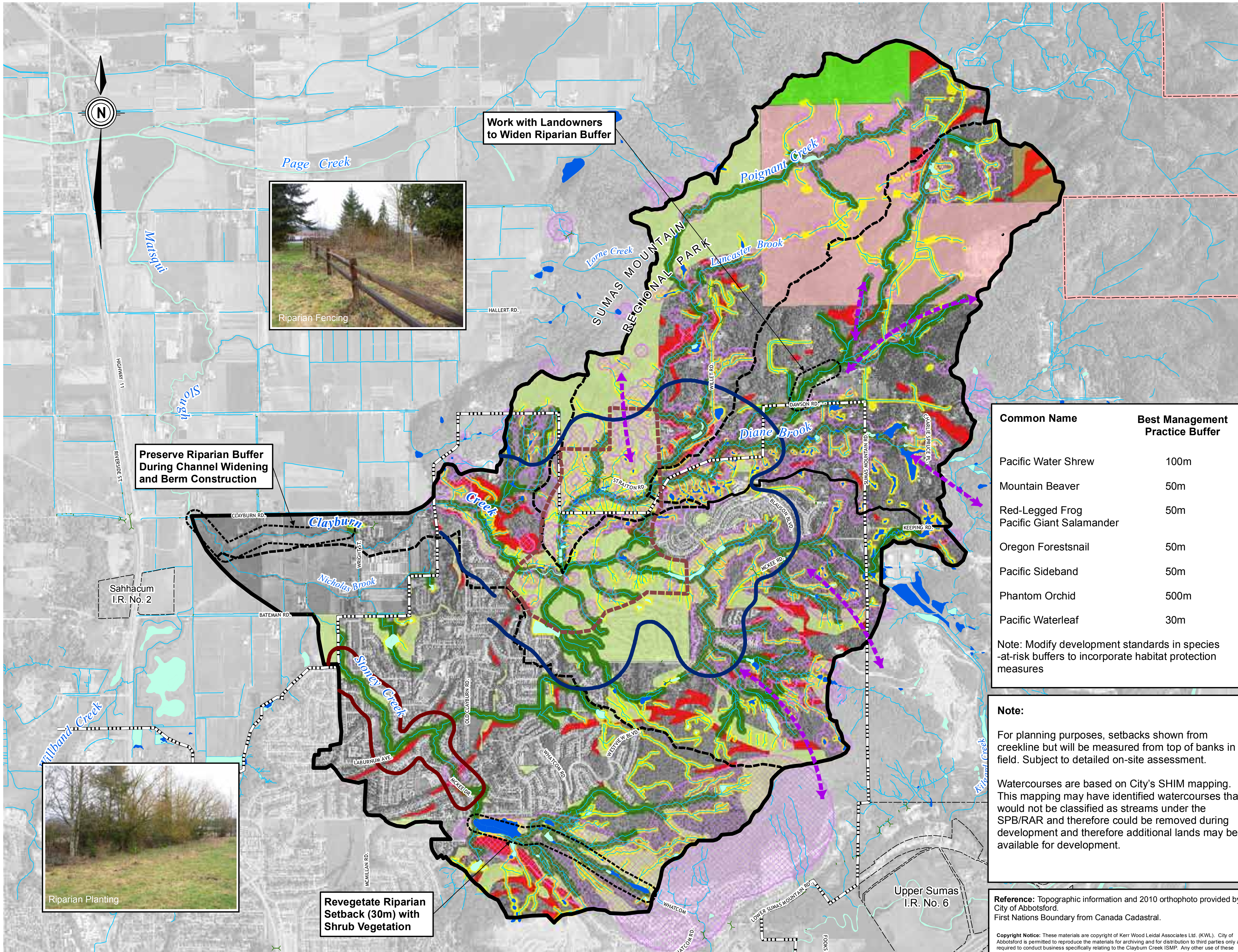
c) **Construct water quality treatment facilities:** To treat the runoff from paved or pollutant-generating surfaces, facilities such as vegetated swales, rain gardens, wetlands, or manufactured treatment systems could be used. Fencing of creeks to exclude livestock, sediment and erosion control during construction, and spill emergency response plans help to protect water quality.

d) **Construct baseflow protection facilities:** To maintain the natural baseflows in creeks, infiltration trenches, rain gardens, baseflow release facilities, or well-based augmentation could be used.

e) **Construct peak flow and duration reduction facilities:** To limit the flows the streams experience to pre-development conditions, use stormwater capture facilities in conjunction with peak flow reduction facilities targeting all storms up to the 2-year or 5-year event. Rain gardens, infiltration trenches, stormwater harvesting and reuse, green roofs could be used in conjunction with detention tanks and ponds to maintain pre-development stream flows.

These alternatives were considered and evaluated, together with input from the stakeholders, and preferred improvements were developed further into the ISMP.

City of Abbotsford
Clayburn Creek
ISMP



Common Name	Best Management Practice Buffer
Pacific Water Shrew	100m
Mountain Beaver	50m
Red-Legged Frog Pacific Giant Salamander	50m
Oregon Forestsnail	50m
Pacific Sideband	50m
Phantom Orchid	500m
Pacific Waterleaf	30m

Note: Modify development standards in species-at-risk buffers to incorporate habitat protection measures

Note:

For planning purposes, setbacks shown from creekline but will be measured from top of banks in field. Subject to detailed on-site assessment.

Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Ponds
- Wetlands
- Combined Best Management Practice Buffers for 8 Species at Risk
- Proposed Habitat and Steep Slope Protection Area
- Wildlife Corridor Study Area/Opportunity
- Ground Slope (> 35 %)

Riparian Setback (See Note)

- 15 m on Non-permanent Streams
- 30 m on Permanent Streams

OCP Designation

- Limited Use
- Park
- Resource/Conservation
- Forest

Detailed Geotechnical Investigation Required

- 100 m from Inner Ravine Slope in Stoney Creek
- 250 m from Inner Ravine Slope in Poignant and Clayburn Creeks

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consulting engineers

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Project No.	Date
510-057	May 2012

Special Requirement Development Areas

Figure 7-1

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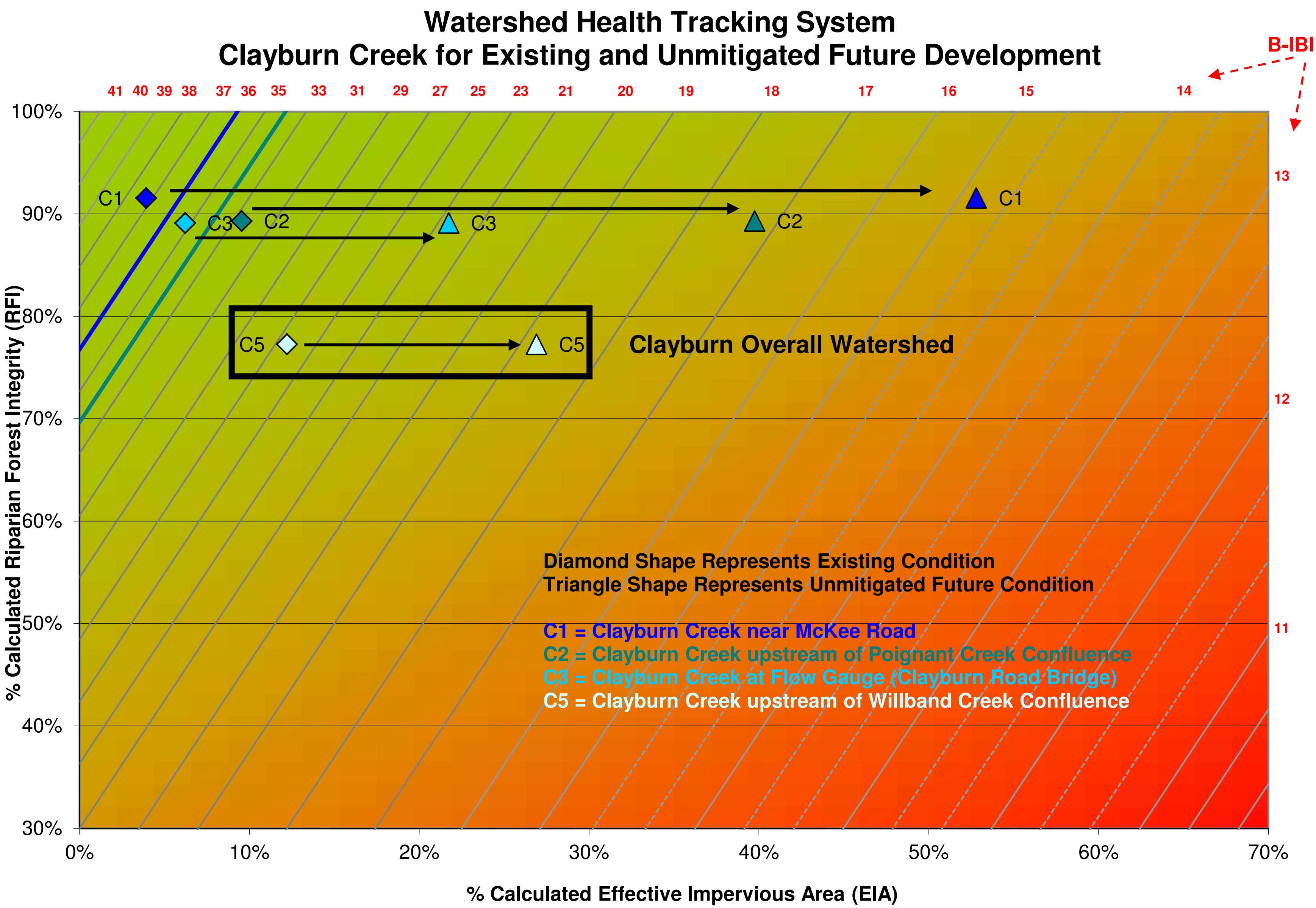

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Figure 7-2

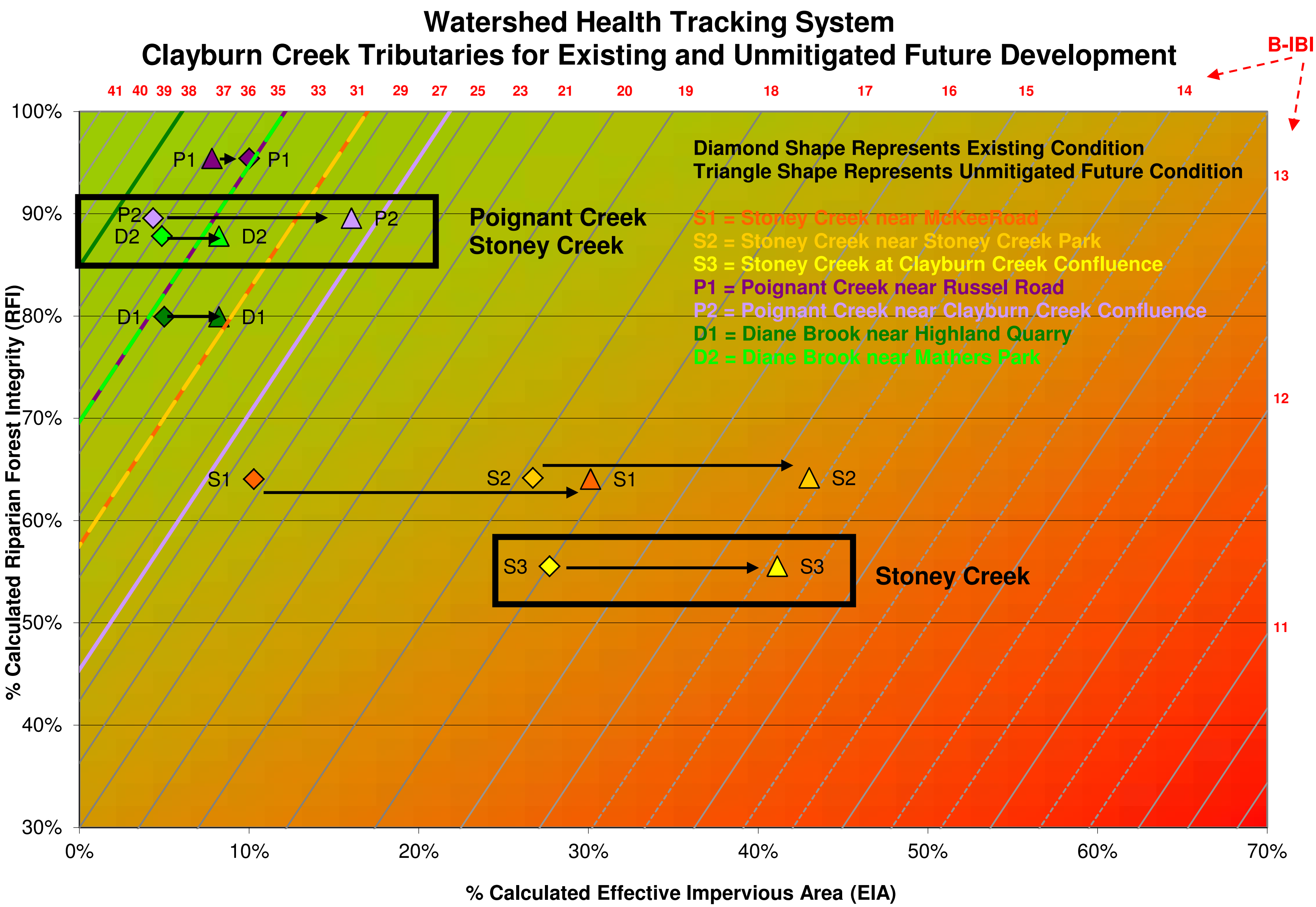

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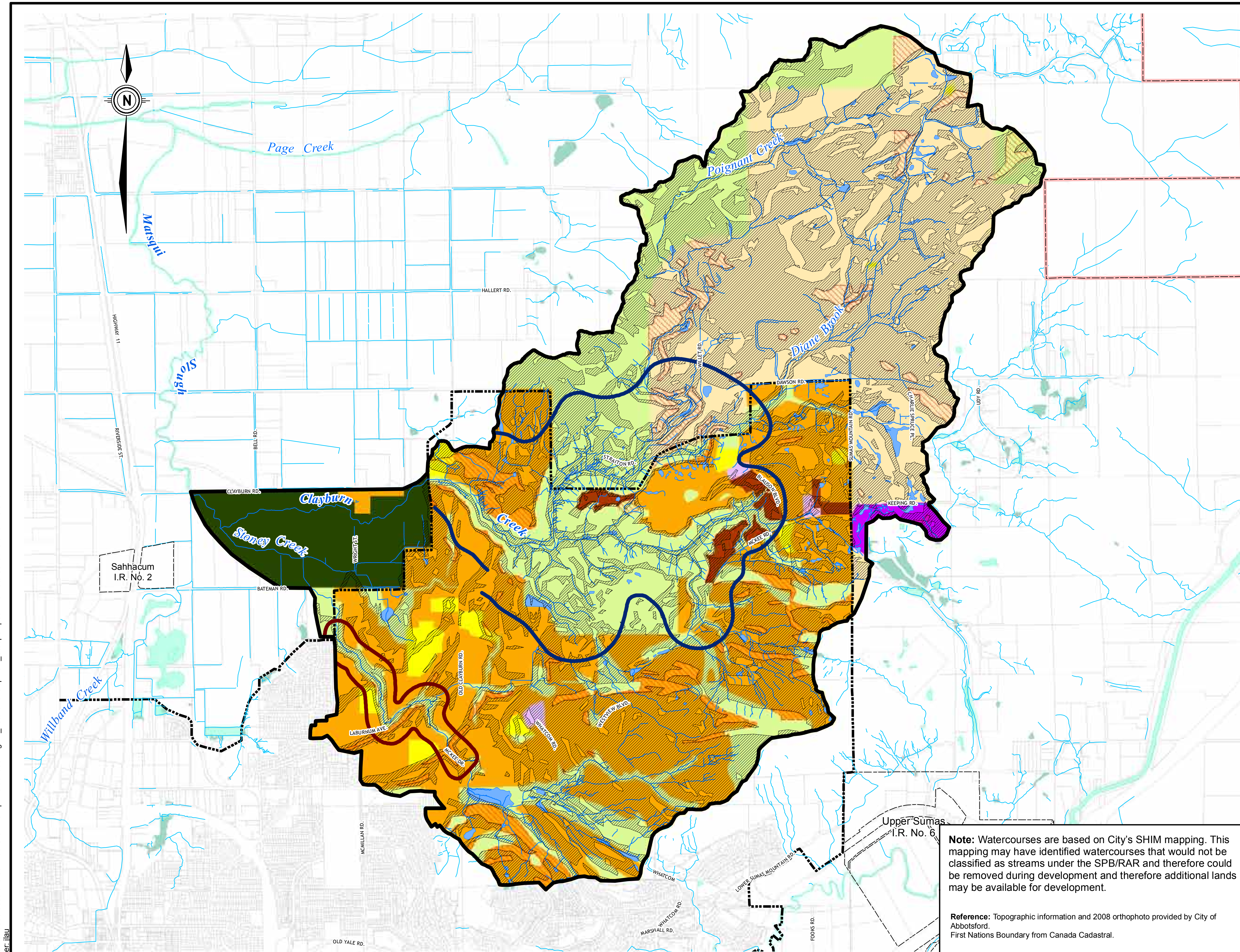
Figure 7-3



Note: Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

Reference: Topographic information and 2008 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Open Water and Marshes
- Slope 10 - 35 %
- Slope > 35 %

Detailed Geotechnical Investigation Required

- 100 m from Inner Ravine Slope in Stoney Creek
- 250 m from Inner Ravine Slope in Poignant and Clayburn Creeks

FVRD & City of Abbotsford OCP Designation

- Agricultural
- Commercial
- Institutional
- Industrial Business
- Resource/Conservation/Park/Forest
- City Residential
- Urban Residential
- Suburban Residential/Rural/Limited Use

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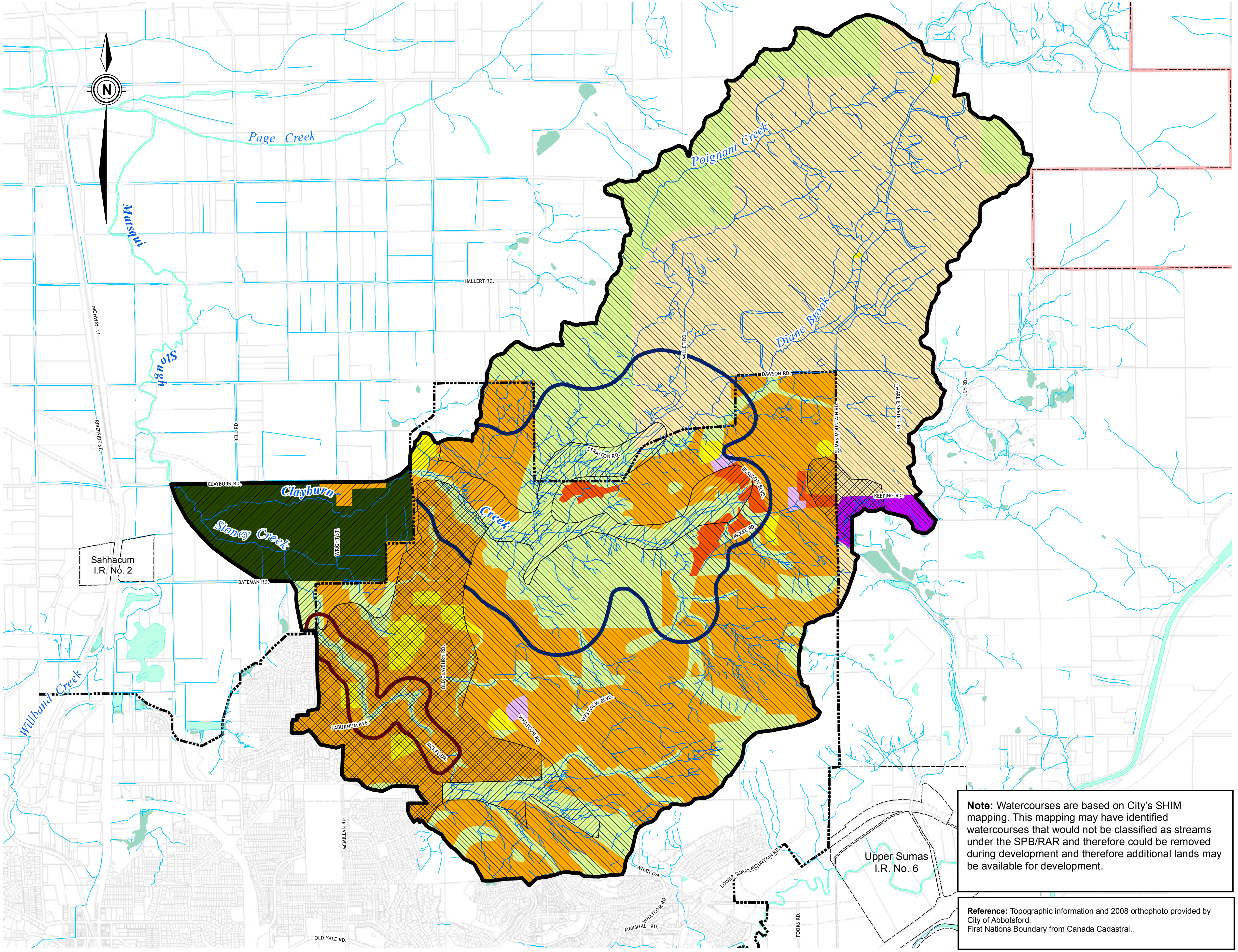
Project No.	Date
510-057	May 2012

Future Development Potential with Steep Slopes

Figure 7-4

City of Abbotsford
Clayburn Creek
ISMP



Note: Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

Reference: Topographic information and 2008 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

Legend

- City Boundary
- Watershed Boundary
- Creeks and Streams
- Approximate Urban Containment Boundary

Geotechnical Investigation Required

- 100 m from Inner Ravine Slope in Stoney Creek
- 250 m from Inner Ravine Slope in Poignant and Clayburn Creeks

Soil Infiltration Type

- Good Infiltration (> 50 mm/hr)
- Moderate Infiltration (10 - 50 mm/hr)
- Limited Infiltration (0 - 10 mm/hr)

FVRD & City of Abbotsford OCP Designation

- Agricultural
- Commercial
- Institutional
- Industrial Business
- Resource/Conservation/Park/Forest
- City Residential
- Urban Residential
- Suburban Residential/Rural/Limited Use

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consulting engineers

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Project No.	Date
510-057	May 2012

Future Development Potential with Soil Infiltration Type

Figure 7-5

Section 8

The Plan

8. The Plan

8.1 Introduction

The overall ISMP for the Clayburn Creek watershed, developed together with the City and stakeholders, consists of many components for:

- Lowland flood protection;
- Erosion and sedimentation management;
- Requirements to mitigate the impacts of future development;
- Environmental restoration and enhancement projects; and
- Municipal stormwater management program (bylaws, standards, monitoring, etc.).

Table 8-1 summarizes and prioritizes all the ISMP components, including cost estimates, implementation priority, and responsibility for implementation. Although much of the implementation work will be done by the City, the various municipal divisions and personnel will have different roles to play, and the interactions between the City, government agencies, and the other stakeholders in the community will be a large part of making the ISMP work. The implementation includes immediate, short-term (5 Year Plan) and long-term initiatives. Stakeholder input is summarized in Appendix H.

8.2 Lower Clayburn Flood Management Plan

In order to reduce the lowland flooding along Clayburn Creek, the following works are proposed:

1. Construct a flood bench within the creek channel along the north side of Clayburn Creek downstream of Wright Street to increase conveyance capacity to the 2-year return period flow.
2. Construct setback berms along both sides of Clayburn Creek to contain the flow up to the 10-year return period. Add spillways at strategic locations to allow safe overtopping of berms during greater than 10-year return period events.
3. Raise low portions of Clayburn Road to Flood Construction Level.
4. Continue sediment removals (instream and at sediment traps).

Figure 8-1 shows the proposed Lower Clayburn Flood Management Plan. The first three items above are described in the subsections below and the fourth in Section 8.3.2.

At the request of the lowland residents, a 10% climate change factor was applied to the design flows when sizing the conveyance works. Scaling up the design flows will make the works more robust in handling flows well into the future. The factored existing land use instantaneous peak flows were used to size the lowland conveyance works, with the understanding that future development will be required to detain 10 year post-development flows to 5 L/s/ha thereby not increasing flow peak above existing values.

8.2.1 Proposed Flood Bench within Clayburn Creek D/S of Wright Street

Because the bankfull capacity of Clayburn Creek downstream of Wright Street is less than a 2-year peak flow, it is proposed to widen the creek cross section by adding a flood bench. This flood bench would be constructed on the north bank so as to not disturb the vegetation on the south side that provides shade to the watercourse most of the year. Construction would also make all attempts at preserving larger, significant trees on the north side.

The proposed flood bench is sized so that the channel capacity is increased to the 2-year instantaneous peak flow of 10 m^3/s resulting in an approximately 3 m wide bench constructed approximately 0.5 m above the channel invert in order to maintain a low flow channel for fish movement and prevent shallow flows over a wide area during low flows and baseflows.

The bench widening was assumed to end immediately upstream and downstream of each of the private bridges in this section of Clayburn Creek and therefore the estimated costs do not include upgrading the bridges to span the flood bench. Two of the three lowland bridges in this section were modelled. No information was available for the driveway bridge near the downstream end of the study area and therefore it was not included in the model. The assessment showed that neither of the two modelled bridges would overtop during the 10-year flow, however, a portion of the flow would leave the channel and travel through the adjacent fields around the bridge as the land is lower than the bridge decks. Once the berms (discussed in the next section) are built, the approaches to the bridges would be raised and the entire 10-year flow conveyed through the bridges. This scenario was tested and model results show that these two bridges would not overtop. The capacity of all bridges in Clayburn Creek downstream of Straiton Road, including those not modelled in this study, should be assessed in detail during the design phase to determine if replacement is required.

The flood bench would need to be maintained to prevent uncontrolled vegetation growth reducing its conveyance capacity. Some vegetation growth is expected and the capacity analysis has assumed a roughness Manning's n of 0.045. The vegetation would be cut down during every maintenance cycle (estimated to occur every 5 to 15 years) and would regrow. Plant selection will be critical to ensure the bench does not become completely overgrown, and to allow for regrowth after a maintenance cycle.

8.2.2 Proposed Setback Berms along Clayburn Creek

The bankfull capacity of the lowland channel is approximately a 2-year flow upstream of Wright Street, and with the proposed flood bench will be increased to a 2-year flow downstream of Wright Street. However, during larger events, the flows will exceed the channel capacity. To prevent these larger events from flooding Clayburn Village and the farmlands, setback berms, approximately 0.5 m to 1.5 m high, are proposed along both sides of the Creek. The approximate alignment shown on Figure 8-1 was developed to minimize disturbance to the existing vegetation along the creek. The berm crest profiles should be designed to contain the factored 10-year instantaneous peak flow (14 m^3/s). Spillways to protect the berms should be incorporated in areas that have historically flooded during 10-year and larger events (into the farmlands, into the properties at the upstream end of the berms, and into the properties on the east side of Wright Street). The spillway crest elevations would be set at the 10-year peak creek water level (without freeboard) and the berm crest would be the 10-year peak water levels with freeboard.

Portions of the proposed berm are along existing paths, roads, and driveways. In these cases, the paths/roads/driveways could be raised to form the flood protection berm. Similarly, there are locations where structures are close to the creek and a berm may not fit. In these cases, a flood wall would be more appropriate as shown with the yellow symbol on Figure 8-1. One such area in particular is the bend in Clayburn Creek next to the school in Clayburn Village. A flood wall would also help stabilize this bend to prevent further creek erosion and movement toward the building.

At the request of the landowner and the City, property 4262 Wright Street was looked at in more detail to determine the alignment and type of embankment. The owner has noted that most of the length along the creek is already raised with berms, retaining walls, and fill placement. Reportedly, these locations have not overtopped since at least 1985. After a detailed survey is performed, the design needs to be discussed with the owner as he may opt to accept the current level of service in some locations. There are two locations (shown with the floodwall symbol on Figure 8-1) along this property where the owner would like to raise the bank using an Allen Block wall (d/s location) and Lock-Blocks (u/s location).

Table 8-1: Clayburn Creek ISMP Plan & Implementation Strategy

	Proposed ISMP	Priority	Cost Estimate	Responsibility
Flood Management				
1.	**LOWER CLAYBURN FLOOD MANAGEMENT PLAN**			
	• Widen Clayburn Creek channel and create floodplain bench through agricultural lands (downstream of Wright St) to convey 2-year flow. • Construct setback berms to contain 10-year flow along lower Clayburn Creek. • Raise existing Clayburn Road above 100-year flood level. • Continue vegetation management in lower Clayburn Creek.	Immediate Immediate 5-year Plan Ongoing	\$332K \$3.4M \$1M est.[1]	City Engineering & Environmental Services
2.	**UPLAND CULVERT AND STORM SEWER UPGRADES**			
	• Upgrade 14 culverts, 3 bridges and selected storm sewers.	5-year Plan	\$4.9M	City Engineering
Erosion Management				
3.	**REHABILITATE EXISTING EROSION SITES & MITIGATE EROSIVE FLOWS**			
	• Undertake 2012 Erosion Inventory & Assessment • Bank stabilization not recommended for all sites as access/environmental impacts are prohibitive. • Construct bank stabilization as part of future development in accessible areas to reduce turbidity. • Disconnect roof leaders and retrofit to maximize infiltration in Stoney Creek well-draining soils.	Immediate At time of development Ongoing	\$50K	City Engineering & Environmental Services Developer Homeowner
4.	**EXISTING DETENTION FACILITY MODIFICATIONS FOR EROSION MANAGEMENT**			
	• Modify detention outlets to minimize erosion.	0 – 5 year	\$180K[2]	City Engineering
Sediment Management				
5.	**SEDIMENT REMOVALS & NEW WEIRS**			
	• Expand & improve existing College, Wright Street, Dutra, & Stoney Confluence sediment traps. • Remove sediment under Wright Street Bridge (completed 2011) and construct weir to accelerate flows and discourage deposition. • Construct in-stream rock weirs in upper channels for temporary sediment traps. • Continue sediment removals at existing sediment traps and gravel bars. • Remove sediment from proposed floodplain bench in widened channel.	Immediate Immediate 0 – 5 year Ongoing Ongoing	\$160K \$20K TBD \$50K/year \$100K/10yrs	City Engineering & Environmental Services
Mitigation of the Impacts of Future Development (Requirements for All Development)				
6.	**PROTECT RIPARIAN, RAVINE, AND WILDLIFE AREAS** to protect stream health, ravine/slope stability & wildlife habitats			
	• Require appropriate riparian and geotechnical setbacks. No variances on riparian setbacks. • Strongly encourage use of Species at Risk setbacks. • Establish or enlarge protected areas to provide several large core habitat areas for wildlife. • Establish designated Wildlife Corridors for connectivity between large core habitat areas.	At time of development		Developer City Environmental & Development Services Approval
7.	**CONSTRUCT HYDROLOGIC VOLUME REDUCTION MEASURES** to maintain baseflows and minimize downstream erosion and habitat degradation			
	• 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.). Size to capture 72% of the 2-year, 24-hour event (51mm). No source controls in geotechnical setbacks. • Regional facilities for baseflow augmentation (sustain baseflows).	At time of development		Developer City Development Services Approval
8.	**CONSTRUCT STORMWATER QUALITY TREATMENT MEASURES** to treat runoff prior to discharge to watercourses			
	• Size to treat 90% of average annual runoff (approx. 72% of the 2-year, 24-hour event (51 mm)). • 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.	At time of development		Developer City Development Services Approval
9.	**CONSTRUCT HYDROLOGIC RATE CONTROL MEASURES** to minimize downstream erosion, habitat degradation and flooding			
	• Size to detain 10-year to 5 l/s/ha, plus 100-year post to pre-development for Clayburn Creek catchment (after Lowland Flood Management Works constructed). • Construct detention/infiltration. • New stormwater outfalls to be piped to bottom of ravines to minimize bank erosion/instability.	At time of development		Developer City Development Services Approval
Environmental Enhancement Projects				
10.	**RESTORE RIPARIAN AREAS**			
	• Reforest impacted riparian areas within designated setbacks. • Work with agricultural landowners to establish riparian leave strips (tree and shrub cover) to stabilize banks and improve cover for fish • Remove invasive species and reforest with native species.	As needed as compensation	\$12/m² \$17/m²	Developer and/or City
11.	**RESTORE IN-STREAM COMPLEXING**			
	• Construct in-stream complexing such as wood structures, boulder groups/spurs, stable debris jams & gravel spawning platforms, & off-channel habitats.	As needed as compensation	\$5K per structure	Developer and/or City
12.	**UPGRADE FISH PASSAGE BARRIERS**			
	• Remove fish passage barrier: old dam on Poignant Creek.	As needed as compensation	\$50K per location	Developer and/or City
Municipal Stormwater Management Program				
13.	**BYLAWS AND STANDARDS (APPLY MUNICIPALITY WIDE)**			
	• Update the City's Development Bylaw (2011) with the following: - add capture target (6-month 24-hour event Volume Reduction) - develop examples and standards for Stormwater Source Controls to aid with implementation - develop green road standards for stormwater treatment and volume reduction • Enforce City's *Erosion & Sediment Control and Streamside Protection Bylaws.* No variances. • Enhance and enforce City's *Tree Protection Bylaw* in all areas of the watershed.	Immediate Immediate Immediate	\$30K	City Engineering City Development Services
14.	**FURTHER STUDIES IN CLAYBURN CREEK WATERSHED**			
	• Undertake a Functional Feasibility Study for Lower Clayburn Flood Protection Plan. • Undertake a Terrestrial Habitat Conservation Study (\$50K), Land Use Planning Process for future Clayburn development areas(\$100K), and a Lowland Drainage Study (\$200 K) for Matsqui Prairie	Immediate 0 – 5 year	\$50K \$350K	City Engineering & Community Planning
15.	**WATERSHED MONITORING**			
	• Conduct watershed performance monitoring and adaptive management approach.	Every 5-years minimum	\$30K/ year	City Engineering & Env. Services
Note: Refer to Figures 8-1 to 8-8 1. Estimate provided by the City. 2. There are nine high priority facility modifications to be completed in the next 5 years. Assume \$20k per facility.	City Capital Program City Yearly Maintenance/Monitoring City Studies/Policies		\$10.0 Million \$90,000 /year \$480,000	

The proposed berm cross section is shown and described on Figure 8-1 and consists of 2H:1V side slopes on the creek side and 6H:1V or flatter side slopes on the land side. The flatter side slopes are proposed to make the side of the berm useable for farming or as part of residential yards and would not be included in ROW acquisition. The berm top width is assumed to be approximately 3m for the purposes of this ISMP.

Because the water levels in the bermed Clayburn Creek adjacent to the Village may be too high to drain the Village by gravity during peak flows, drainage from Clayburn Village will likely require a storm sewer to pipe the local drainage westward to a location where the creek levels are lower.

Floodboxes may be adequate to drain the agricultural lands protected by the berms. Flooding of these fields would be limited to the rain falling directly onto the fields (i.e. uplands flows would not spill into the fields and would be contained in the bermed creek up to the 10-year event) however, the drainage of the fields may be delayed until the creek water levels drop allowing the floodboxes to open. Therefore, while the flooding depths would be much shallower, the duration of flooding may be longer. The need for small pump stations should be assessed during a drainage study of the overall Matsqui Prairie lowlands as proposed in the recommendations of this report.

During the preliminary design, all bridges, including all private crossings, on Clayburn Creek through the lowlands should be assessed. The capacity assessment in this study showed that the lowland bridges are adequate for the 10-year peak flow, however not all the private bridges were included in the analysis. Both capacity and condition should be evaluated to determine if any bridges need to be replaced during the construction of the lowland works.

8.2.3 Proposed Clayburn Road Raising

Currently Clayburn Road west of Clayburn Village is frequently overtopped by events smaller than a 2-year return period. In order to provide a secondary floodproofed access road to Clayburn Village and the residents along Clayburn Road, it is proposed to raise the low portions of the road up to the flood construction level (FCL). The City indicated that the FCL could be based on the Matsqui Slough Drainage Study (UMA, 1993) 100-year water level of El. 4.2m and refined during the proposed overall Matsqui Prairie drainage study.

8.2.4 Cost Estimates

The Lower Clayburn Flood Management Plan is estimated to cost $3.7 million excluding the Clayburn Road raising. The road raising costs will be estimated in detail once the FCL is determined during the overall Matsqui Prairie drainage study. The detailed costs estimate is included in Appendix I.

8.2.5 Implementation of Lowland Works

The lowland works could be built in phases with the most critical portions built first. After securing ROWs ($363,000 or the Clayburn Village portion at first), the Village could be protected up to a 5-year return period event first with a berm along only the north side of the creek from just upstream of Wright Street to the west end of the Village ($422,000). The downstream end of the berm could be temporarily tied in to Armstrong Avenue with a north-south running berm. The channel excavation could be done next in the fisheries window ($244,000). During subsequent phases, the north side berm could be extended upstream and downstream to ultimately provide 10-year protection for the Village and the entire south side berm built ($2.7M). The in-stream fish enhancements could follow in the fisheries window ($5,000 per structure). Further investigation into the impacts of phasing protection work will be required to minimize making conditions worse for those without protection in the earlier phases.

A preliminary timeline for the lowland works could be as follows.

1) Preliminary Design ($50,000) – early 2012
2) Negotiations for ROWs ($363,000) – early 2012
3) Interim works near Clayburn Village ($150,000) – Summer 2012
4) Detailed Design of Ultimate Works and Phasing ($352,000) – Fall 2012
5) Clayburn Village berm/floodwall section ($222,000) – Spring/Summer 2013
6) Channel widening west of Wright Street ($215,000) – Fisheries Window 2013
7) In-stream fish enhancements west of Wright St ($5,000 per structure) – Fisheries Windows 2013
8) Remainder of berms/floodwalls and pump station ($2.4M) – Spring/Summer 2014
9) In-stream fish enhancements east of Wright St ($5,000 per structure) – Fisheries Window2014

8.3 Erosion and Sedimentation Management Plans

8.3.1 Erosion Management

General Strategies to Minimize Erosion

Strategies to address existing erosion and minimize future erosion include:

- intercept overland flows at the top of ravine and pipe flows down to the toe of ravine slope;
- pipe stormwater outfalls to the toe of ravine slope for future storm systems;
- avoid infiltration and land clearing near the top of ravine slopes and observe recommended streamside protection and geotechnical setbacks;
- retain and enhance vegetation on creek banks;
- construct instream bank stabilization works in high consequence areas where erosion may threaten roads or development (e.g. along Stoney Creek from Laburnum Avenue to the lowlands) within 5-years; and
- construct instream bank stabilization work at existing erosion locations adjacent to proposed development in non-ravine areas at time of future development.

Enforce Geotechnical Setbacks to Minimize Erosion and Slope Instabilities

No infiltration structures should be constructed within steep slope areas without detailed investigations and design by a qualified geotechnical engineer. Additional detailed geotechnical investigations are required in the following areas (see Figure 6 in Appendix B):

- A 200 m to the southwest of the crest of slope above Clayburn Creek;
- A 100 m from the inner ravine slope of Stoney Creek; and
- A 250 m from the inner ravine slopes of Poignant and Clayburn Creeks and their tributaries.

More detailed geotechnical assessments should be carried out by a qualified professional within the above defined setback areas.

No development or infiltration works should be allowed on inner ravine slopes (ravines defined as having side slopes of >50%).

Monitor Watershed Erosion

The SHIM mapping completed in 2006 identified many erosion locations throughout the watershed. It is recommended that additional erosion monitoring be implemented in two phases as described below.

- **High Priority Area Monitoring Program:** The SHIM mapping and information from the City showed that a number of severe erosion spots are located adjacent to roadways and development such as Straiton Road adjacent to Poignant Creek and Clayburn Creek, McKee Road adjacent to Clayburn Creek, and the development along Stoney Creek downstream of Laburnum Avenue. These areas should be revisited in 2012 to assess whether the erosion has increased or stabilized. Where erosion is threatening infrastructure, the area should be immediately stabilized. The remaining areas should be monitored on an ongoing basis to anticipate future threats.
- **SHIM Mapping Review Monitoring Program:** The remaining areas where SHIM mapping noted erosion away from roads and development should be visited within the next two years to confirm the status of the erosion. As development continues and incorporates erosion mitigation measures, ongoing erosion monitoring will allow an evaluation of the benefits.

Minor Erosion on 35060 Clayburn Road

At the Public Meetings, the owner of 35060 Clayburn Road pointed out erosion along the south bank of Clayburn Creek immediately downstream of the Clayburn/Straiton Road Bridge. A site visit confirmed the erosion which currently is minor and would be relatively easy to address if done before more of the bank is eroded. Rock placement at the toe of the slope and bioengineering protection above the rock would minimize further creek movement. This is a low priority project relative to the other more severe erosion sites in the watershed.

8.3.2 Sediment Management Plan

Background

A preliminary sediment budget conducted for this study (Appendix F) has identified that, on average, approximately 168 m^3 per year of sediment has been accumulating in the lower reaches of Clayburn Creek since 1990. Approximately 69% of that sediment has been removed in existing sediment traps, while approximately 5% has been removed from the creek bed at other locations.

Sediment management in the lowland portion of Clayburn Creek and downstream of Clayburn Village will continue to be required, regardless of upstream source controls or detention facilities, due to on-going, natural erosion occurring in the Clayburn ravines. However, based on the preliminary sediment budget, it appears that the bulk of the sediment management may be achieved through operation of the existing sediment traps.

DFO supports minimization of all instream maintenance work, including sediment removals. Therefore, it is recommended that instream work be limited to the following:

- flood protection measures;
- critical stream restoration areas, such as critical erosion rehabilitation sites; and
- sediment removal at designated sediment traps and other removal areas.

In recognition of the important fish habitat value of the Clayburn Creek gravel reach, sediment removal activities should attempt to maintain the necessary flood conveyance capacity of the stream system while minimizing disturbance to the reach. Any necessary instream work should be timed and staged to minimize the impacts to fish habitat (e.g., occur in the instream works window from August 1 to September 15).

The City should work towards an ongoing agreement with DFO regarding sediment management activities, as other measures required by the ISMP are implemented. Consultations with DFO yielded the following suggestions:

- Look at improving the capacity and efficiency of existing sediment traps before proposing instream removals. This would include changes to the configuration of the traps to intercept a larger percentage of the sediment being carried by Clayburn Creek.
- Install permanent flow bypass pipes in sediment traps for dewatering and remove sediment without bypass pumping of the creek or using inflatable dams.
- Consider new sediment trap areas on the inside of bends in the creek. Sediment could be removed from the deposition area at any time of low flows even outside of the fisheries window.
- Improve gravel retention in the upper watershed by creating check dams in the upper creek channels where sediment is being generated and transported. These would be one time installations that would not be cleaned out and would reduce the sediment load downstream until they were filled up.
- Ensure that excavating the sand from the channel invert downstream of the Dutra Sediment Trap is done in a way that will preserve water velocities and not result in stagnant water with lower dissolved oxygen. This reach has rearing habitat value.

These ideas may be revisited in the future, as part of on-going creek management.

Objectives

A sediment management plan has been developed to address the need to maintain flood conveyance capacity in the lower Clayburn Creek channel. The goal of the sediment management plan is to address increases in the flood profile that arise due to transport and deposition of coarse sediment (sand, gravel and cobble) in lower Clayburn Creek.

Typically, sediment management in BC rivers is targeted to the need to maintain freeboard on existing dykes, which are designed to contain the 200-year return period flood. In the case of Clayburn Creek, the proposed berms and widened channel cross-section will be designed to contain the 10-year return period flood. During flows in excess of the 10-year return period flood, spillways incorporated into the berms will allow water to leave the bermed channel and enter the Clayburn Village and agricultural floodplain. Incorporating spillways will prevent overtopping of the remainder of the berm.

On-going Sediment Management Activities

The comparison of cross-sections in lower Clayburn Creek indicates that existing sediment management activities, mostly in the form of removals from the sediment traps, have attempted to keep up with aggradation over time in the lower channel (see Table F-3). Therefore, it is suggested that these activities be continued and that repeat channel survey be used to identify any areas that may require additional removals.

Specific actions that comprise the proposed Sediment Management Plan are summarized in Figure 8-2, and include:

- Constructing rock weirs in the headwaters upstream of Clayburn Village to improve sediment retention in the upper reaches and reduce the influx into the lower Clayburn channel in the short term. The sediment deposited behind these weirs would not be removed.
- Enlarge the existing sediment traps (College, Wright Street, Dutra, and Clayburn/Stoney confluence) by widening the traps at these locations and installing bypass pipes for dewatering.
- Remove sediment from the traps annually, and document removal volumes.
- Review the effectiveness of the weir constructed by the City in 2007 at the upstream end of the Wright Street Bridge, to minimize deposition of sediment under the bridge. Reconstruct if needed.
- Remove sediment from select gravel bars on an as-needed basis to maintain flood conveyance; likely every 10 to 15 years.
- At the time of flood bench construction, remove sand/silt from Clayburn Creek channel downstream of the Dutra Sediment Trap lowering the invert by 0.5 m to allow the farmlands to drain into the creek.
- Remove sand/silt deposited on the proposed Clayburn Creek bench as required to maintain overall flood conveyance capacity in the cross-section; possibly every 5 to 15 years.

It should also be noted that sediment was removed from under the Wright Street Bridge in 2011, to address aggradation at this location. The proposed weir reconstruction, if needed, will minimize the deposition under the bridge allowing the sediment to be removed at the trap downstream of the bridge.

As indicated above, it is assumed based on the preliminary sediment budget that annual operation and maintenance of the expanded sediment traps will address most of the average annual aggradation in the lower creek. However, the sediment traps may not be able to completely maintain the channel bed profile with greater sediment movement in larger storms. Historically, additional small removals have been carried out at select areas of the creek to maintain flood conveyance. In order to identify areas of the creek that may require additional maintenance, it is recommended that the City conduct a creek survey every 2 years to start and then adjust the interval as needed depending on the rate of accumulation. The surveys can be compared over time to identify reaches that appear to be aggrading, which will allow for additional sediment removals to be planned and executed.

Magnitude and Timing of Instream Sediment Removals

The frequency of instream removals has been estimated based on the existing comparative survey data. However, the proposed repeat surveys should be used to validate these estimates.

Sediment removals outside of the existing sediment traps should be designed to address deficiencies in flood conveyance that have arisen as a result of on-going aggradation. It is suggested that the City consider updating and running the hydraulic model of the lower creek every 10 years or so, to accurately identify whether and how any changes to the creek channel bed elevations have affected the flow conveyance. The hydraulic model can also be used to establish the location and magnitude of instream removals that would address any identified freeboard deficiencies. The affected landowners should be consulted regarding these capacity or freeboard deficiencies and the options for addressing them.

8.4 Mitigation of the Impacts of Future Development

8.4.1 Need for Additional Conservation and Land Use Planning Studies

Land use and environmental planning is a vital part of ISMP planning. Due to the large scale development proposed within the Clayburn watershed, additional comprehensive studies should be developed to guide development appropriately for this sensitive area. The City will further discuss and study these recommendations prior to implementation.

Need for Terrestrial Habitat Conservation Strategy

In order to protect the most important terrestrial habitats in the Clayburn Creek watershed during future development, development of an overall Terrestrial Habitat Conservation Strategy is recommended.

Because of their relevance to stormwater management, the ISMP recommends the following broad goals be included in this Strategy:

- **Wetland protection:** Require all wetlands (even those not connected by surface flow to watercourses) be protected during any future development for their important hydrologic and water quality functions, and wildlife habitat value. Consultation with DFO has shown their desire to protect remaining wetland areas in the watershed.
- **Forest and tree cover retention:** Because of the important contribution of forest cover to watershed processes, such as the movement and provision of water, sediment, nutrients, organic matter, and wood, incorporate explicit goals for natural forest cover retention (patches) and overall tree retention into development guidelines for key areas of the watershed. At a minimum, a goal of 50% natural habitat protection at the subwatershed scale (not on a lot-by-lot basis) is suggested. Land use planning by the City will be required to identify forested areas to be preserved. Reforestation of an area that is currently not forested would contribute to the overall goal, however, cutting down an existing mature forest and replacing with small trees may not provide full compensation is the tree canopy area/coverage is reduced. Therefore a larger than 1:1 ratio tree replacement may be required. Density transfers, density bonusing, or other mechanisms may be appropriate. Tree cover may also integrate with City goals for carbon storage and sequestration and offsetting emissions.
- **Protection of hydrologically sensitive headwater streams:** Protect areas of dense headwater streams or groundwater source areas during development. These areas often have *de facto* protection because of required stream setbacks but setbacks are typically small and can be insufficient to protect hydrologic functions.

In addition, it is recommended that the Strategy provide comprehensive guidance for how the City will protect sensitive ecosystem types, known and potential habitats for species at risk, core habitat areas, and wildlife corridors during future development.

The following approach is recommended for development of the Strategy:

- **Landscape Analysis and Prioritization:** Using available information on stream setbacks, steep slopes, sensitive ecosystems, species at risk occurrences, recommended species at risk buffers, and other factors, undertake a GIS-based analysis to develop a map which classifies and prioritizes different land areas for protection based on relative ecological importance and/or habitat value.

- **Delineation of Hubs and Corridors:** A green infrastructure (or ecological) network approach should be used which identifies hubs, large intact core areas of naturally-functioning ecosystems, and corridors, which provide physical or functional linkages between hubs of similar or different ecosystem types. Such an approach is aimed at preserving ecological function and connectivity within the landscape as well as specific habitat areas.
- **Development Guidelines for Specific Habitat Management Areas:** Based on the landscape analysis, develop different habitat management areas with specific objectives for habitat protection and specific development guidelines for achieving those objectives. Examples of development guidelines that could be recommended in the Strategy include requirements or recommendations for allowable development footprint, locating buildings within a site, native tree and vegetation retention, use of native species in landscaping, and appropriate interface planning such as buffers and fencing.

The City of Abbotsford has recently undertaken a request for proposals that will hire a consulting team to develop a *Sumas Mountain Environmental Management Area Strategy* that has the potential to incorporate such an approach. The area proposed for the strategy includes the upland portion of the Clayburn Creek ISMP study area.

Land Use Plan

It is recommended that future land planning efforts within the Clayburn watershed use a comprehensive constraints-based approach to identifying candidate development sites in order to protect key environmental features and consider the following:

1. Consider and integrate existing and future alternative transportation modes and corridors.
2. Future development sites must make allowance for and incorporate adequate on-site, local or regional source controls to meet the proposed stormwater criteria. Include a review of stormwater harvesting and reuse options to reduce potable water demand.
3. Investigate the potential of adjusting the Urban Development Boundary (UDB) and Area H to capture some of the more desirable development sites while protecting key environmental features not suitable for development within the UDB. For example, the portion of Area H on the north side of Dawson Road features gentle slopes and a sparse stream network and may be more suitable for higher density land uses than the steeper McKee Peak area that also has a dense stream network. There are also large areas of land north of Straiton Road east of Pacific Summit College that are currently zoned resource/conservation that are less than 35% slope with few streams. Trading with ‘harder to develop’ areas within the UDB could be considered. The adjustment could be net zero change 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 require 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. Also establish a maximum limit on elevation for development parcels. For example, no development permitted above El. 300 m.
6. Set Impervious Area and Forest Protection Targets within developing areas.
7. Gain additional riparian setbacks for critical habitat areas and wildlife corridors.
8. Consult with the landowners and the public.

It would also be useful to amend the Zoning Bylaw to prohibit land clearing in RR2 zoned areas for agricultural purposes (livestock grazing). Should an owner wish to pursue agricultural land uses in these areas, the land should be rezoned as agricultural and perhaps placed in the ALR. This will prevent vast land clearing for speculative development under the guise of pursuing agriculture.

8.4.2 Watercourse Preservation

Both fish-bearing and non-fish bearing streams are important to the sustainability of fish populations within watersheds and contribute to overall watershed health. Small headwater streams provide important baseflows and nutrients which support fish populations in downstream areas. Stream setbacks provide protection for both the stream channel and the adjacent riparian area which also provides important functions through provision of cover, organic matter, and wood debris.

Stream setbacks for new development will generally follow the City of Abbotsford's *Streamside Protection Bylaw* (No. 1465-2005). However, because of the particular environmental sensitivities in the study area, adoption of a **no-net-loss variance protection policy on stream setbacks** is recommended for watercourses within the ISMP study area. Setback variances, on a case-by-case basis, are currently possible through discussion and approval of the City's Habitat Review Panel (HRP). Adoption of such a policy would mean that variances would not be considered by the HRP. This policy would apply to development parcels and would allow road and utility crossings of streams, and other site specific conditions where necessary. However, constructing roads or utilities parallel to a stream within the riparian setback should be avoided.

Furthermore, for streams under the Bylaw where the required buffer width is provided as a range (e.g., minimum 15 m, maximum 30 m), it is recommended that the maximum setback be required. For example, for a non-permanent non-fish bearing stream with a setback requirement of between 15 and 30 m under the Bylaw, a 30 m setback would be required. Such measures will provide better protection of riparian functions and habitat for species at risk, while providing certainty and fairness for developers. A site specific assessment should be conducted to confirm the setback requirements for species at risk at the time of development.[13]

Although initial setbacks have been determined using existing data in this report (see Figure 8-5 shown from creek centrelines and not top of bank for conceptual ISMP planning purposes), prior to any land use changes, detailed assessments must be undertaken to confirm the appropriate setback required. Information about the responsibilities involved in developing near streams and ravines is available in the City's *Information Package for Developing Near Streams and Ravines in Accordance with the Streamside Protection Bylaw*. The ISMP does not account for any potential loss of watercourses or riparian areas associated with new development in the watershed.

8.4.3 Requirement for Stormwater Source Controls

Because of the significance of the erosion and instability issues within the Clayburn watershed, all future development is recommended to be implemented with Low Impact Development (LID) approaches and source controls to mitigate the impacts of development on the health of the watershed. The proposed criterion for source controls is summarized in Section 8.4.4. Source controls are not recommended in

[13] Should a variance be approved by the HRP the City should require proponents to mitigate the impacts of the riparian encroachment through riparian restoration or enhancement on a nearby stream on a 2-for-1 basis. All mitigation works should be undertaken within 30 m of permanent streams (preferred) or within 15 m of a non-permanent streams. Enlarging riparian setbacks to greater than 30 m on permanent streams or 15 m on non-permanent streams should not be considered as compensation for watershed health tracking purposes.

geotechnical infiltration setbacks from steep slopes and ravines because the added saturation can further destabilize slopes.

The application of source controls to the various land use, slope and soil combinations has been divided up as separate “Prescriptions” for each application. The prescriptions are shown in Table 8-2 and spatially on Figure 8-3.

Source Controls on Higher Density Land Uses

Higher density land uses, including City Residential, Commercial, Institutional, and Industrial business have high expected TIA values of 75 to 90% impervious coverage. Source controls for these situations must be fit onto smaller portions of the site and may include combinations of:

- absorbent landscape areas with min. 300 mm deep soils, including over underground parking garages (required in the Revised 2011 City Development Bylaw);
- treatment infiltration/retention swales or rain gardens associated with surface roadways or parking;
- in-pipe or in-manhole water quality measures at source;
- pervious paving for pedestrian areas;
- street tree rainwater capture systems to accept paving runoff;
- detention/retention tanks or vaults These may be sized to allow slow decanting to infiltration trenches with overflow to storm drains, or may be part of a water re-use scheme for outdoor watering, toilets and laundry (see Figure 8-3); and
- green roof.

Water quality treatment must be a prime consideration for industrial land uses and all paved surfaces exposed to vehicle traffic.

Source Controls on Lower Density Land Uses

Implementing source controls to mitigate TIA and the impacts of development on lower density land uses, such as suburban, rural, and agricultural and park lands, can be achieved by directing impervious surface runoff to the pervious areas.

Source Controls on Roads and Lanes

It is assumed that roughly 50% of the road right-of-way is paved, leaving 50% of the area for mitigation. As recommended for LID, any methods of narrowing and reducing road or pavement widths reduces the volume of mitigation required to provide water quality treatment, volume reduction and detention/ retention of roadway runoff.

In general, the road areas should be mitigated with on-site facilities located in the rights-of-way wherever possible. Terracing of surface facilities may be required on streets between 5 and 10% slope to improve infiltration of runoff. On streets with greater than 10% slope, mitigation facilities may need to be underground infiltration or retention facilities such as street tree rainwater capture facilities and have separate water quality treatment. Or road mitigation may take the form of regional facilities, located in flatter portions of the area.

In areas of geotechnical risk, street tree rainwater capture wells could be closed systems – surrounded by impermeable membrane rather than filter cloth – performing as retention and overflow systems. When under overhead power lines, the trees would be lower growing varieties (e.g. flowering cherries).

Tree Retention

While not strictly a source control, ordinary planted street trees can be a useful tool in a re-developing watershed. Trees provide interception of rainfall before it reaches the ground to become runoff, promoting evapotranspiration of rainfall and reducing the sharp runoff peaks seen in urban areas by slowing the intensity of the rainfall that lands on pavement below the trees. While trees do not replace source controls as they cannot provide water quality treatment for runoff, they provide assistance to source controls in mitigating the hydrologic impacts of impervious area. This is primarily an advantage for street trees and other trees that intercept rainfall before it reaches the impervious area on the ground. Trees over pervious soils also help to promote evapotranspiration of rainfall, but do not provide as much improvement in mitigating hydrologic impacts of development. Street trees are a useful tool for a municipality to employ in either a developed or a developing watershed for rainfall interception. A key consideration is that large and mature trees provide these significant benefits; planting smaller or decorative varieties of trees will not provide the same level of benefits and larger variety trees must be allowed to grow to maturity and high enough to be effective in this role. Similarly, preservation of existing healthy and mature street trees should be a priority for municipalities for their stormwater benefits in addition to other recognized benefits of mature trees.

Wide Distribution of Infiltration / Retention Systems

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. 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

Cost and Maintenance of Stormwater Source Controls

In the proposed approach, the costs and maintenance of most stormwater source controls are associated with private land. This is consistent with the philosophy of ‘polluter pays’, where in this case the ‘pollution’ is impervious developed area. For any case where stormwater source controls are not provided on private land, a mechanism should be developed to provide funds for downstream mitigation by the City.

The exception to this is the installations on City roads and lanes. Construction of roads and lanes would be funded by the City, or in partnership through local improvement projects, by development cost charges, or by frontage improvement at time of redevelopment.

Maintenance of roads and lanes is to be done by the City, however maintenance of boulevard vegetation is the responsibility of the property owner as per the City’s *Consolidated Good Neighbour Bylaw, 2003 Bylaw No. 1256–2003* which typically includes a requirement for boulevard maintenance. Maintenance for on-lot source controls is to be done by the property owner.

8.4.4 Hydrologic Criteria for Clayburn Creek

It is recommended that the City’s current detention criteria in the Clayburn watershed be adjusted as follows:

- **Habitat/Erosion/Flood Protection:** Detain 10 Year (all durations) post-development peak flows to 5 L/s/ha.

- **For Clayburn Mainstem Catchment only:** Detain 100-Year (all durations) post-development peak flows to 15 L/s/ha to maintain flows through Clayburn Village at existing rates.

The above proposed criteria change should come into effect after the proposed lowland works (berms) are constructed.

The recommended overall watershed criteria are summarized in Table 8-3.

Source controls are sized using volumetric analysis. Continuous simulation using the Water Balance Model, SWMM or spreadsheets may be used.

8.4.5 Importance of Erosion and Sediment Control During Construction

Land clearing and construction activities have large impacts on sediment transport in streams by increasing turbidity and sediment concentrations as well as the deposition of fine sediments in streambeds (http://ks.water.usgs.gov/studies/millcreek/). These are all factors which have been found to impair the integrity of aquatic ecosystems, with some of the impacts persisting over the long term.

Enforcement of the City's Erosion and Sediment Control Bylaw is imperative.

Table 8-2: 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%
	Moderate Infiltration (10 – 50 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				
	Limited Infiltration (0 - 10 mm/hr.)			**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
	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 8-3)

◙ 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.

Table 8-3: 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 except road and utility crossings within:** • 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, with **no-net-loss variance protection policy** 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)). • 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.[14]
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) 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 AND HABITAT DEGRADATION Size to detain the 10-year post-development flows to 5 l/s/ha. • Construct detention/infiltration • New stormwater outfalls should be piped to bottom of ravines to minimize erosion and bank instability TO MAINTAIN EXISTING FLOWS THROUGH CLAYBURN VILLAGE 100-year post-development flows 15 L/s/ha for Clayburn Creek catchment.
Site specific analysis required during development application process to determine adequate setbacks.		

[14] As required under the City of Abbotsford *Erosion & Sediment Control Bylaw, 2010*

8.5 Environmental Habitat Restoration and Enhancement Projects

Environmental habitat restoration and enhancement projects are summarized here and shown in Figures 8-4 and 8-5. Five types of instream or floodplain activities were identified and are summarized in Table 8-4 and Figure 8-4. Projects have been prioritized as high, medium, or low depending on a range of factors. These include: contribution to fish habitat productivity, contribution to overall watershed health, integration with proposed flood protection and drainage upgrades, whether the project is located on public or private land, and general ease of implementation. Sites for potential riparian restoration are summarized and prioritized in Table 8-5 and shown in Figure 8-5.

8.5.1 Fish Habitat Restoration and Enhancement Strategies

Six major strategies are proposed to restore and enhance fish habitat in Clayburn Creek and its tributaries. The focus is on improving instream and riparian habitat for fish populations. Together with riparian setbacks, stormwater source controls, and habitat protection, they will contribute to the mitigation of the impacts of development in the watershed and could provide a net improvement in watershed health.

1. Restore Instream Complexity, Floodplain Wetlands, and Riparian Forest in Lowlands

Historical land clearing, dredging, and channelization of the lowland section of Clayburn Village downstream to Clayburn Road has resulted in a less complex stream channel with lack of seasonal floodplain habitats and a limited riparian forest buffer. Creation of a narrow floodplain bench and berms to increase channel capacity through this area presents an opportunity to incorporate additional enhancements for fish habitat, including adding instream habitat complexity, creation of seasonally accessible floodplain wetlands, and restoration of a wider riparian buffer. Sediment traps will continue to be used to minimize the need for instream maintenance.

The proposed works will benefit all the aquatic species that use the lowland portion of the creek, but will provide increased rearing capacity for juvenile coho and cutthroat trout, in particular.

3. Floodgate/Pump Operation for Fish Passage

Although the Matsqui Slough (Gladwin) Pump Station has been previously deemed to be fish passable, recent tests of fish passage were inconclusive and further evaluation was recommended (A. Thomson, pers. comm. in LGL Limited et al., 2009). It is also not known how often the flapgate on the floodbox remains open during the fall spawner migration period and what the mortality rates of outgoing coho smolts passing through the pump station are. Some spawners were observed in 2011. Further evaluation should be undertaken and improvements made (if any needed) to maximize fish passage through the pump station.

Subsection 20(1) of the Fisheries Act requires that the City provide for the free passage of fish through the dyke and section 30 requires that all water intakes, irrigation ditches, and pumps are screened to prevent the entry of fish into these facilities where they could be injured or killed.

4. Remove Barriers or Improve Fish Passage

The priority fish passage barrier for removal or retrofitting to allow fish passage is the large impoundment on the Dive Pond on Stoney Creek within the powerline right-of-way portion of Vicarro Ranch. Because of the value of deep pool habitat for rearing juvenile salmon, it would be preferable to modify the impoundment to allow fish passage but retain pool habitat, rather than removing the barrier and pond completely. Removal of the barrier will allow fish access to approximately 400 m of additional spawning and rearing habitat.

Table 8-4: Aquatic Habitat Restoration and Enhancement Opportunities

Site		Description	Priority
Removal of Fish Passage Barriers			
1.	**Matsqui** (Gladwin) Pump Station	Assessment and improvement (if necessary) of floodgate and pump operation for fish passage through Fraser River dyke.	High
2.	**Poignant Creek**, at north end of Willet Rd in McLanlin (Girl Guide) Camp	Replacement or retrofitting of old wooden dam to allow resident fish movement.	Low
3.	**Stoney Creek**, in powerline ROW portion of Vicarro Ranch property	Replacement or retrofitting of impoundment on Cattle Pond to allow upstream fish passage.	Medium
Off-channel Habitat Creation			
4.	**Clayburn Creek**, u/s of upper Clayburn Rd bridge to confluence with Poignant Creek	Addition of off-channel rearing pools and/or spawning channels in wider portions of lower ravine in and around Straiton Road to create additional rearing and spawning habitat capacity.	Medium
5.	**Stoney Creek**, in powerline ROW portion of Vicarro Ranch property	Existing pond enlargement (e.g., "Dive Pond"), channel construction, and instream complexing.	High
Restoration of Floodplains with Complexing			
6.	**Clayburn Creek**, d/s of upper Clayburn Rd bridge to Wright St	Narrow floodplain bench creation within residential area using berms and channel enlargement; increased channel capacity would allow some complexity to be restored (e.g. instream cover, vegetation, etc.). Enhanced sediment traps to be used to minimize need for instream maintenance.	High
7.	**Clayburn Creek**, d/s of Wright St	Partial floodplain restoration or bench creation within agricultural area using berms and sediment traps; increased flood capacity would allow some complexity and channel roughness to be restored (e.g. instream cover, vegetation, etc.). Sediment traps to be used to minimize need for instream maintenance.	High
In-stream Habitat Complexing			
8.	**Clayburn Creek**, u/s of upper Clayburn Rd bridge to confluence with Poignant Creek	Addition of structural complexity (large wood and/or boulder placement). Priority sites u/s of college sediment trap.	High
9.	**Clayburn Creek**, u/s of confluence with Poignant Creek (adjacent to Auguston development)	Addition of rock weirs within ravine sections to retain sediment and create pools for additional rearing habitat.	High
10.	**Stoney Creek**, u/s of Bateman Road	Addition of structural complexity (large wood and/or boulder placement).	Low
Refer to Figure 8-4			

Table 8-5: Riparian Habitat Restoration and Enhancement Opportunities

		Site	Description	Priority
Clayburn Creek	1.	**Clayburn Creek**, Wright St to lower Clayburn Rd bridge	Work with agricultural landowners to widen tree and shrub buffer adjacent to creek through ALR lands.	Medium
	2.	**Clayburn Creek**, d/s & u/s of Pacific Summit College access road	Work with landowners to re-establish wider riparian buffer by planting native trees and shrubs.	Completed in 2011
	3.	**Clayburn Creek tributary**, south of McKee Rd	Reforest riparian corridor along headwater tributary on south side of McKee Rd, across from Ledgeview Golf Course.	Medium
	4.	**Clayburn Creek tributary**, u/s of McKee Rd	Reforest riparian corridor along headwater tributary 400 m upstream McKee Rd.	Medium
Stoney Creek	5.	**Stoney Creek**, Bateman Rd to lower Clayburn Rd bridge	Work with agricultural landowners to widen tree and shrub buffer adjacent to creek through ALR lands.	Medium
	6.	**Nicholas Brook**, u/s of Wright St	Work with agricultural landowners to widen tree and shrub buffer adjacent to creek through ALR lands.	Medium
	7.	**Stoney Creek**, within Bateman Park	Reforest grass areas within riparian buffer with native trees and shrubs. Plant understory shrubs in areas with streamside trees but lack of understory vegetation. Relocate trail away from stream (preferred) or re-build trail to prevent bank erosion	High
	8.	**Stoney Creek**, within powerline ROW portion of Vicarro Ranch property	Revegetate with native shrubs and trees (where possible) around existing ponds, channels, and tributaries within area under and adjacent to powerlines.	High
	9.	**Stoney Creek tributary** (Trib. A in Enkon 2009 report), within powerline ROW portion of Vicarro Ranch property	Plant degraded riparian area (due to cattle grazing) with native shrubs.	High
	10.	**Poignant Creek** u/s of Straiton Rd	Sections of stream and ponds with extensive landscaping; work with landowners to naturalize vegetation.	Medium
	11.	**Diane Brook** u/s of Dawson Rd	Work with rural landowners to widen riparian vegetation buffer in areas with less than 30 m buffer currently.	Low
Refer to Figure 8-5				

A lower priority fish barrier for removal or retrofitting is the small wooden dam on Poignant Creek at the north end of Willet Rd near Camp McLanlin (Girl Guide Camp).

5. Habitat Improvements in Upper Stoney Creek

A comprehensive restoration program should be undertaken to improve fish habitat within the upper reaches of Stoney Creek under the powerlines in Vicarro Ranch. This would include removing one major fish passage barrier (see section above), removing overburden to restore an existing channel, potential additional off-channel habitat creation, as well as instream complexing and extensive riparian planting. The City recently completed some riparian planting in this area as part of compensation works for the Whatcom Road connector.

6. Replant Riparian Forest

Residential and agricultural development has resulted in the loss of some riparian forest. Underplanting of shade-tolerant conifers to restore mixed and coniferous forests is the preferred approach for riparian restoration. In the portion of the Vicarro Ranch area under the powerlines, planting may be restricted to shrubs and low-growing trees (BC Hydro should be consulted about appropriate species for this site.) Priority sites for riparian reforestation have been identified in the Riparian Restoration and Enhancement section. High priority sites include, Stoney Creek under the powerlines within the Vicarro Ranch property (private land), and Bateman Park (public land). Riparian reforestation efforts may be coordinated and facilitated by the City of Abbotsford, if part of a City-led infrastructure project or project on public lands, or by private landowners, if part of development compensation works. When degraded riparian sites are subject of a development proposal, riparian reforestation should be made part of the requirement for development approval.

8.5.2 Wildlife Corridors

In a relatively intact natural watershed like Clayburn Creek, wildlife connectivity is relatively high. However, as development proceeds, connectivity will be reduced without the identification and protection of key linkages between larger habitat areas, such as riparian corridors, ravines, parks, and other undeveloped habitat areas. Riparian corridors and steep slopes can provide some connectivity, but additional upland corridors are needed in some areas to provide connections where streams do not exist. Figure 8-6 shows an initial network of potential wildlife corridors to be incorporated into future development. These corridors should be further refined as part of the proposed Terrestrial Habitat Conservation Strategy.

8.6 Upland Drainage Management

8.6.1 Proposed Drainage System Upgrades

Priority 1 proposed infrastructure upgrade projects are shown on Figure 8-7 and in Table 8-6. Priority 2, 3, and 4 projects are included in Appendix E.

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 proposed infrastructure upgrades are summarized in Tables 8-6.

Table 8-6: Proposed Priority One 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**

[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 8-7 for project numbers and Table I-6 in Appendix I for costing details.

O:\0500-0599\510-057\300-Reports\20120528_FINAL\Tables\[Tables8-6&E-8&I-6_Costs_PipesCulverts.xlsx]Table 8-6

Stakeholders reported that the storm sewer manhole lids were blown off or removed downstream of Tom Thomson Court at the west end of the Auguston development. Even though the hydraulic assessment did not show any undersized pipes in this area, it is proposed that the manhole lids be bolted down in this area to prevent their movement (likely by air pressure buildup in the storm sewer).

8.6.2 Proposed Modifications to Detention Facilities to Minimize Erosion

For existing detention facilities that failed to meet the existing release rate criteria and were located upstream of steep creek sections with known erosion problems, modifications are proposed to reduce flows in order to minimize erosion. There are four facilities upstream of Clayburn Village that have been identified. All four appear to have insufficient storage volume to meet the 100-year to 5 L/s/ha detention criteria and therefore, modification is proposed to maximize the use of the available storage to reduce erosion. Such modifications are expected to have little effect on the 100-year peak flows near Clayburn Village. The proposed modifications are described and prioritized as follows:

- **High Priority:** facilities that appear to have sufficient storage volume and only require an outlet modification to meet the City's criteria. There are no high priority modifications in the Clayburn watershed and 9 in the Stoney Creek watershed.
- **Medium Priority:** facilities that appear to have insufficient storage volume and require a larger outlet and a change to the criteria to reduce the frequency of overflows. The possible criteria changes could include reducing the return period of the storm to be detained to 5 L/s/ha (for example targeting the 2-year or 5-year storm instead of the 10-year or 100-year) or detaining post development flows to forested pre-development values instead of to 5 L/s/ha. There are 2 medium priority modifications proposed in the Clayburn watershed and 7 in the Stoney Creek watershed.
- **Low Priority:** facilities that drain to steep creeks without known erosion problems and they appear to have insufficient storage volume and require a larger outlet and a change to the criteria to reduce the frequency of overflows. There are 2 low priority modification projects in the Clayburn watershed and 2 in the Stoney Creek watershed.
- **Lowest Priority:** facilities that drain to lowland creeks and therefore have minimal risk of erosion. No modification projects are proposed in this category.

Table 8-7 list the detention projects in the Clayburn and Stoney watersheds, respectively. These projects are shown on Figure 8-8.

Table 8-7: Proposed Detention Facility Modification Projects

Project No.	KWL Facility ID	Location	Proposed Works
Within Stoney Creek Catchment			
High Priority – Drains to Steep Creek with Known Erosion and Can Meet 10-Year to 5 L/s/ha			
Det1	P13	3700 Mckinley Dr.	Reduce Orifice to Meet 5 L/s/ha
Det2	P14	35300 Sandy Hill Rd.	
Det3	P21	3391 Mckinley Dr.	
Det4	P40	35011 Old Clayburn Rd.	
Det5	P49	35626 McKee Rd.	
Det6	P50	35574 McKee Rd.	

Project No.	KWL Facility ID	Location	Proposed Works
Det7	P52, P53	34800 Mierau Street	
Det8	P20-1, P20-2	35490 McKee Rd.	Enlarge Outlet to Prevent Overflows to Meet 5 L/s/ha
Det9	P51*	34951 Cassiar Ave.	
Medium Priority – Drains to Steep Creek with Known Erosion but Requires Criteria Change			
Det12	P12	Nakiska Ct.	Enlarge Outlet to Meet Different Criteria and Prevent Frequent Overflows
Det13	P18	3532 Mckinley Dr.	
Det14	P19-1, P19-2, P19-3	3500 Bassano Terrace	
Det15	P24-1, P24-2, P24-3, P24-4	35479 Tweedsmuir Dr.	
Det16	P26-1** P26-2**	3225 Whatcom Rd.	
Det17	P36	34900 Exbury Ave.	
Det18	P39-1, P39-2	3292 Vernon Terrace	
Low Priority – Drains to Steep Creek without Known Erosion and Requires Criteria Change			
Det21	P31	35020 Kootenay Dr.	Enlarge Outlet to Meet Different Criteria and Prevent Frequent Overflows
Det22	P32	3841 Teslin Dr.	
Lowest Priority – Drains to Lowlands – No Change Recommended			
n/a	P8	3900 Old Clayburn Rd.	Reduce Orifice to Meet 5 L/s/ha
n/a	P10-1, P10-2	3836 Old Clayburn Rd.	
n/a	P11	34315 Mckinley Dr.	
n/a	P6	4001 Old Clayburn Rd.	Enlarge Outlet to Meet Different Criteria and Prevent Frequent Overflows
Within Clayburn Creek Mainstem Catchment			
Medium Priority – Drains to Steep Creek with Known Erosion but Requires Criteria Change			
Det10	P1	Blauson Blvd.	Enlarge Outlet to Meet Different Criteria and Prevent Frequent Overflows
Det11	P47	2nd Auguston Pond	
Low Priority – Drains to Steep Creek without Known Erosion and Requires Criteria Change			
Det19	P2	4300 Shearwater Dr.	Enlarge Outlet to Meet Different Criteria and Prevent Frequent Overflows
Det20	P3	35298 S. of Belanger Dr.	

Notes: Refer to Figure E-9.
* Larger pipe out of detention facility required (City GIS ID: 704D10)
** Storage is at an elevation that is too high to be utilized.

Identification of the changes required to the detention facilities is conceptual in nature and should be thoroughly assessed during pre-design. A $20,000 allowance should be made to assess each project to determine the required outlet size and to physically change the orifice size in the field. The nine High Priority projects are included in the 5-Year Plan. The nine Medium Priority and four Low Priority projects are included in the Long Term Plan.

8.7 Implementation Plan

The proposed works, studies and regulations described in the preceding sections are categorized below as Immediate, 5-Year Plan, At Time of Development, or Ongoing.

8.7.1 Immediate Works

The Immediate category works should be initiated as soon as possible in order to address pressing issues and to allow future works to proceed in a timely manner.

1. Undertake a Functional Feasibility Study for Lower Clayburn Flood Protection Plan, $50,000 estimated cost, start immediately.
2. Construct Lower Clayburn Flood Protection Works including berms/floodwalls, channel widening, and pump station for Clayburn Village drainage, $3.7 million estimated cost, construction to start immediately and continue through to 2014
   a. Preliminary Design ($50,000) – early 2012
   b. Negotiations for ROWs ($363,000) – early 2012
   c. Interim works near Clayburn Village ($150,000) – Summer 2012
   d. Detailed Design of Ultimate Works and Phasing ($352,000) – Fall 2012
   e. Clayburn Village berm/floodwall section ($222,000) – Spring/Summer 2013
   f. Channel widening west of Wright Street ($215,000) – Fisheries Window 2013
   g. In-stream fish enhancements west of Wright Street ($5,000 per structure) – Fisheries Window 2013
   h. Construct remainder of berms/floodwalls and PS ($2.4M) – Spring/Summer 2014
   i. In-stream fish enhancements east of Wright Street ($5,000 per structure) – Fisheries Window 2014
3. 2012 Erosion Inventory & Assessment – reassess erosion and compare to 2006 SHIM mapping to locate areas of increasing erosion, $50,000 estimated cost, to be completed in 2012.
4. Sediment Trap Improvements – enlarge and improve efficiency of College, Wright Street, Dutra, and Stoney Confluence sediment traps, $160,000 estimated cost, to be completed during trap cleaning in 2012.
5. Bylaws and Standards – Update the City's Development Bylaw (2011) with the following, $30,000 estimated cost, complete in 2012:
   a. add capture target (6-month 24-hour event Volume Reduction);
   b. develop green road standards for stormwater treatment and volume reduction; and
   c. develop examples and standards for Stormwater Source Controls to aid with implementation.

6. Existing Bylaw Revision and Enforcement – includes enhancing the Tree Protection Bylaw to require compensation for <20 cm diameter trees, enforcing the Streamside Protection Bylaw with no-net-loss variances except for creek crossings, and enforcing the Erosion and Sediment Control Bylaw, no cost estimated, to be implemented in 2012.

8.7.2 5-Year Plan

The 5-Year Plan works include recommended studies and capacity upgrades.

1. Clayburn Road Raising – raise low portions of Clayburn Road west of Clayburn Village up to the 100-year flood construction level, $1 million estimated cost, construct within the next 5-years after the 100-year flood level is estimated in the Matsqui Prairie Drainage Study.
2. Upland Culvert and Storm Sewer Upgrades – upgrade 14 culverts, 3 bridges and selected storm sewers, $4.9 million estimated cost, complete upgrades over next 5 years.
3. Detention Facility Modifications – includes assessing in detail and changing outlet orifice sizes to make better use of available storage volume, $180,000 estimated cost for the first nine high priority facilities, complete upgrades over next 5 years.
4. Sediment Management at Wright Street – construct a weir immediately upstream of the bridge to discourage deposition of sediment under the bridge, $20,000 estimated cost, construct at the same time as the fish habitat improvement works (Lowland Flood Management) in 2014.
5. Sediment Weirs – construct in-stream rock weirs in upper channels upstream of Clayburn Village to create temporary sediment traps, costs to be determined, construct within 5 years.
6. Further Studies – undertake a Terrestrial Habitat Conservation Study, Land Use Planning Process for future Clayburn development areas, and a Lowland Drainage Study for Matsqui Prairie, $350,000 estimate cost, complete studies within 5 years.

8.7.3 At Time of Development

There are a number of proposed works to be completed by the City during future development stages (funded by DCCs) or required of developers at the time development. These are included in this category.

1. Erosion Control – construct bank stabilization as part of future development in accessible areas to reduce turbidity during high flows.
2. Setbacks and Protected Areas – City to require appropriate riparian and geotechnical setbacks. No-net-loss variances on riparian setbacks except for road/utility crossings of creeks, City to strongly encourage use of Species at Risk setbacks, City to establish or enlarge protected areas to provide several large core habitat areas for wildlife and establish designated Wildlife Corridors for connectivity between large core habitat areas.
3. Volumetric Source Controls – 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.) sized to capture 72% of the 2-year, 24-hour event (51mm), and construct regional facilities for baseflow augmentation (to sustain baseflows).
4. Water Quality Controls – construct Stormwater Source Controls (rain gardens, vegetated swales, vegetated pervious pavers) sized to treat 90% of average annual road and parking lot runoff, 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, and large parking lots, and provide Erosion and Sediment Control measures during construction.

5. Peak Flow Control – construct detention/infiltration facilities sized to detain 10-year to 5 l/s/ha, plus 100-year post to pre-development for Clayburn Creek catchment (after Lowland Flood Management Works constructed), and pipe new stormwater outfalls to bottom of ravines to minimize bank erosion/instability.
6. Riparian Areas – reforest impacted riparian areas within designated setbacks, work with agricultural landowners to establish riparian leave strips (tree and shrub cover) to stabilize banks and improve cover for fish, and remove invasive species and reforest with native species, $17 per m2 estimated cost.
7. Instream Complexing – construct in-stream complexing such as wood structures, boulder groups/spurs, stable debris jams & gravel spawning platforms, and off-channel habitats, $5,000 per structure estimated cost.
8. Fish Passage – remove old dam on Poignant Creek fish passage barrier, $50,000 estimated cost.

8.7.4 Ongoing Works

Ongoing works include periodic maintenance, monitoring, and long term projects.

1. Vegetation Management – continue vegetation management in lower Clayburn Creek.
2. Sediment Management – continue sediment removals at existing sediment traps and gravel bars, remove sediment from proposed floodplain bench in widened channel, budget $60,000 per year.
3. Roof Leader Disconnection – encourage home owners to disconnect roof leaders to maximize infiltration capacity in Stoney Creek existing development well-draining soils areas.
4. Detention Facility Modifications – includes assessing in detail and changing outlet orifice sizes to make better use of available storage volume, $260,000 estimated cost for the nine medium and four low priority facilities.
5. Conduct ongoing watershed performance monitoring and evaluate progress every 5 years. Implement adaptive management to adjust the development requirements to protect the watershed as required. Budget $30,000 per year for monitoring and assessment.

8.8 Performance Monitoring and Adaptive Management

In order to measure and track the levels and changes in the watershed, a suite of performance indicator parameters should be considered. Table 8-8 lists a variety of parameters or “indicators” that may be measured and tracked over time. Measurement of each indicator is performed separately; many indicators require specific tests or specific analyses of data and/or modelling results. The general measurement approach, as well as the 2009 baseline values, and expected changes for each watershed performance indicator are summarized.

Each indicator must be tracked over the long term in order to be useful in evaluating changes in the watershed. The indicators do not have to all move in a particular direction, up or down, in order to show improvement or degradation in overall watershed health. Rather the tracked suite of indicators should be reviewed every few years to:

- Note movement in particular indicators,

- Evaluate possible causes of the movement,
- Determine if the movement of the indicators represents an impact or improvement,
- Evaluate if the indicator movement is expected or unforeseen, and
- Review the goals, elements, and implementation plan of the ISMP to assess if changes should be made to the plan in order to remain on track and achieve the overall watershed goals over the implementation timeline for the ISMP.

The schedule for a full assessment and review for the watershed health indicators should be at least once every five years, to be tracked and utilized in association with the timeline for ISMP implementation. Therefore, four full reviews of the indicators should occur during a 20-year expected timeline for implementation, and tracking to assess the impacts of full implementation should be continued, at least once every five years, beyond that horizon.

Performance monitoring is the repeated collection of measurements to measure changes or trends in environmental condition. For the Clayburn Creek ISMP, the monitoring program should focus on one essential question: are stormwater management activities improving (or at least maintaining) the overall condition (health) of the creeks? Specific questions and detailed methods for answering them should be developed before any monitoring is undertaken.

To monitor the success of the ISMP in mitigating the impacts of future development, several forms of ongoing monitoring are recommended. These include:

1. flow monitoring;
2. benthic invertebrate monitoring;
3. continuous water quality monitoring;
4. ongoing sediment quality monitoring;
5. watershed and riparian forest cover monitoring; and
6. fish population monitoring.

Water quality performance indicators should be compared to absolute numbers such as the BC Water Quality Guidelines (water column and sediments) and site-specific water quality objectives (once these have been developed by the Ministry of Environment) in order to determine the status of the watershed in terms of aquatic health at any single point in time.

Table 8-8: Clayburn Creek Watershed Performance Indicators

	Performance Indicator	Method of Analysis	2009	2015
Lowland Flood Protection Plan				
1.	Lowland Flooding	Recorded flooding	Every year	To 10-year level of service
2.	Lower Clayburn Creek Sediment Aggradation	Creek survey every 2 years	Compare to 2007 / 2009 surveys adjusted for proposed works	Same or Decrease not counting sediment traps
Mitigation of Impacts of Future Development				
3.	No. of Erosion Sites	SHIM mapping	92 severe sites (2006) Reassess in 2012	Same or Decrease
4.	TIA (% of Watershed Area)	GIS Analysis of Aerial Photos and Assessment Data	12%	15% (27% build out)
5.	EIA (% of Watershed Area)	Estimated from Clayburn flow record	16.6% (excluding Stoney Creek)	Same or decrease when source controls implemented
6.	RFI (% of Riparian Area)	GIS Analysis of Aerial Photos every 2 to 5 years	78%	Same or Increase
7.	Watershed Forest Cover (% of Watershed Area)	GIS Analysis of Aerial Photos every 2 to 5 years	70%	Decrease expected due to development
8.	Benthic Invertebrates B-IBI scores	Use methods used in this study	26 to 38 mean = 33	34
9.	Fish Populations	Density, species composition (1) Fish salvage data from gravel removals (2) Annual spawner counts in accessible reference reaches in Clayburn, Stoney, and Poignant Creeks	Limited and out-of-date data	Collect data
10.	Fish Passage Barriers	SHIM Mapping	Manmade Barriers 2 Natural Barriers 3	Progressive Removal of Non-natural Barriers
Flow Regime				
11.	Summer Baseflow (L/s)	From continuous flow measurement at Clayburn Creek Straiton Road station	46 (0.03 L/s/ha)	No decrease
12.	Winter Baseflow (L/s)		310 (0.20 L/s/ha)	Same or increase
13.	2-Year Peak Flow (m^3/s)		9.3 (5.9 L/s/ha)	Same or slight decrease
Water Quality				
14.	Average Summer Water Temperature (°C)	Continuous Monitoring (3 locations) - ongoing	MOE data not yet analyzed	Same or Decrease
15.	Specific Conductivity (µS/cm)			Same or Decrease
16.	Turbidity (NTU)			Decrease
17.	Fecal Coliforms (or E. Coli) (MPN/100mL)	WQ sampling (various locations; geometric mean of 5 samples in 30 days) – every 2 years	High Levels	< 200
18.	Sediment Quality	Total Copper, Manganese, and Zinc, concentrations (mg/kg) (10 locations) – every 2 years	Ranges: Cu: 2.7 – 12.5 Mn: 319 – 921 Zn: 32.0 – 77.1	Same or Decrease

- **Flow monitoring:** Flow monitoring should continue at the Clayburn Creek Straiton Road station. The rating curve may need to be revised after the sediment management plan is implemented especially the proposed sediment trap immediately downstream. Additional flow monitoring immediately downstream of several future subdivisions is also recommended. The results of the flow monitoring can be used to estimate the effectiveness of the source controls and detention facilities that are proposed for the upland development.
- **Benthic invertebrate monitoring:** Benthic invertebrate communities are a useful indicator of trends or stability in watershed health and tie in directly to the ISMP Watershed Health Tracking System. Annual sampling using consistent field, lab and analysis methods is recommended at eight sites as were sampled in 2009. This includes one upstream and one downstream site in each of the major subwatersheds (8 sites in total). Standardization of existing 2001-2006 data would also allow for additional baseline information to be obtained. The estimated annual cost is $1,000 per site (sampling, taxonomy, data analysis, brief report).
- **Fecal coliform monitoring:** Bacteriological contamination is an ongoing concern because of previously detected high levels at several locations in the watershed and because of ongoing sensitive water uses in the Clayburn Creek watershed. Because of the existence of baseline data collected by MOE for several sites, ongoing monitoring work should use the sites and methods used previously. Sampling should consist of five samples in 30 days and should occur every two years at three sites in Clayburn Creek, two sites in Stoney Creek, one site in Poignant Creek, and one site in Diane Brook (seven sites in total). Because of MOE's experience and interest in monitoring in this watershed, sampling should continue to be undertaken as a partnership between the City of Abbotsford and MOE.
- **Continuous water quality monitoring:** Because the largest portions of new development are likely to occur in the upper reaches of Clayburn Creek and Stoney Creek, and in the Diane Brook subwatershed, a minimum of three continuous water quality stations should continue to be maintained and/or upgraded within the Clayburn Creek watershed with a focus on monitoring water temperatures, specific conductivity, and turbidity. Recommended sites are: (1) Clayburn Creek, upstream of confluence with Poignant Creek; (2) Poignant Creek, upstream of confluence with Clayburn Creek; and (3) Stoney Creek in Bateman Park. Data analysis costs are $1,500–$7,500 per year depending level of detail and data quality.
- **Sediment quality monitoring:** As an additional monitoring tool, sediment sampling should be conducted every two years at each benthic sampling site plus two additional lowland sites, one on Clayburn Creek and one on Stoney Creek (10 sites in total). The estimated annual cost for ten sites is $1,800 for total metals ($700 for field sampling, $500 for lab analysis, and $600 for letter report). Sampling for PAHs or other contaminants will increase costs substantially.
- **Total watershed and riparian forest cover monitoring:** Total watershed forest cover and riparian forest cover (within 30 m of permanently flowing streams) should be measured every 2–5 years (dependent on availability of orthophoto) as a broad indicator of hydrologic function and riparian-stream channel interactions. Forest is all woody vegetation greater than 5 m in height and a closed canopy. Forest cover should be measured by an experienced GIS technician in Arcview using recent orthophotos, with assistance from a biologist or forest ecologist. It should be expressed as a percentage and total amount of forest for the overall watershed and by catchment.
- **Fish population monitoring:** Fish salvages associated with annual gravel removals from sediment traps is an opportunity to monitor fish populations. Continuing the current practice of annual enumeration of fish trapped and removed during these activities is recommended. Additionally, annual spawner counts should be conducted in accessible reference reaches (e.g., 500 m reach) on

Clayburn, Stoney, and Poignant Creeks to monitor fish populations over time. Counts could be carried out by a school or local Streamkeeper group.

Water quality (grab sample) monitoring for metals is not recommended for performance monitoring because lab analyses are expensive, results are generally highly variable, and it is difficult to collect meaningful data with only a small number of samples.

8.9 Operation and Maintenance

Regular drainage system and stormwater facility maintenance is required to effectively convey design flows, minimize flooding and erosion, and mitigate the impacts of development. The following general inspection and maintenance procedures are recommended.

Inspection: The drainage systems should be inspected annually during low flow conditions, ideally in the spring so that identified problems can be undertaken during the dry summer months. The primary purpose of the inspection is to assess the condition of the conveyance facilities including creek channels for erosion locations and hydraulic structures, and identify the need for maintenance. The annual inspection should include all open channels, culverts, detention facilities, diversions, flow splitters, and floodboxes. An overall drainage system inspection should also be completed after major storm events.

Vegetation Maintenance: Conveyance ditches should be maintained to prevent the growth of weeds, small trees and bushes; this needs to be balanced with fish habitat requirements. The hydraulic conveyance capacities of the ditches must be maintained. Ditch maintenance should occur annually.

Sediment Removal: Because of the ongoing natural erosion occurring in the Clayburn ravine, sediment removal in the lowland portion of Clayburn Creek through and downstream of Clayburn Village will continue to be required, regardless of upstream source controls, diversions, and sediment removal facilities. The proposed sediment management plan is summarized in Section 8.3.2 and on Figure 8-2.

Debris Control: Debris blockages at hydraulic structures can cause flooding problems. Regular debris removal (at least annually) from the ditches, culverts and floodboxes is necessary.

Wet Pond: Inspect periodically during wet weather to observe function, clean sediment forebay every 5 to 7 years or when 50% capacity has been lost, remove accumulated sediment form pond bottom when 10 to 15% of pool volume is lost, inspect hydraulic and structural facilities annually and mow side-slopes, embankments and spillways as required to prevent over growth.

Detention Tanks: Inspect annually and remove floating debris and oil.

Wetlands: Inspect annually and after each major storm event. At beginning of wet season remove trash and floatables and unclog outlet structures.

Grassed Swales: Inspect routinely especially after large storm events. Correct erosion problems as necessary, mow to keep grass in the active growth phase, remove clippings to prevent clogging of outlets, and remove trash and debris.

Bioretention with Underdrain: Remove leaves each autumn, inspect overflow, hydraulic and structural facilities annually.

City of Abbotsford
Clayburn Creek
ISMP

Legend

- Creeks and Streams
- Open Water and Marshes
- Detention Facility
- Culvert
- Storm Main
- Bridge
- Proposed Floodbox
- Proposed Culvert
- Proposed Berm Centreline Side Slopes; 2H - 1V on Creek Side, 3H - 1V on Land Side
- Proposed Berm Centreline Side Slopes; 2H - 1V on Creek Side, 6H - 1V or Flatter on Land Side
- Proposed Flood Wall
- Proposed Raised Road/Path/Driveway
- Possible Pump Station
- Approximate Spillway Location

Reference: 2010 Orthophoto and existing GIS information from City of Abbotsford.

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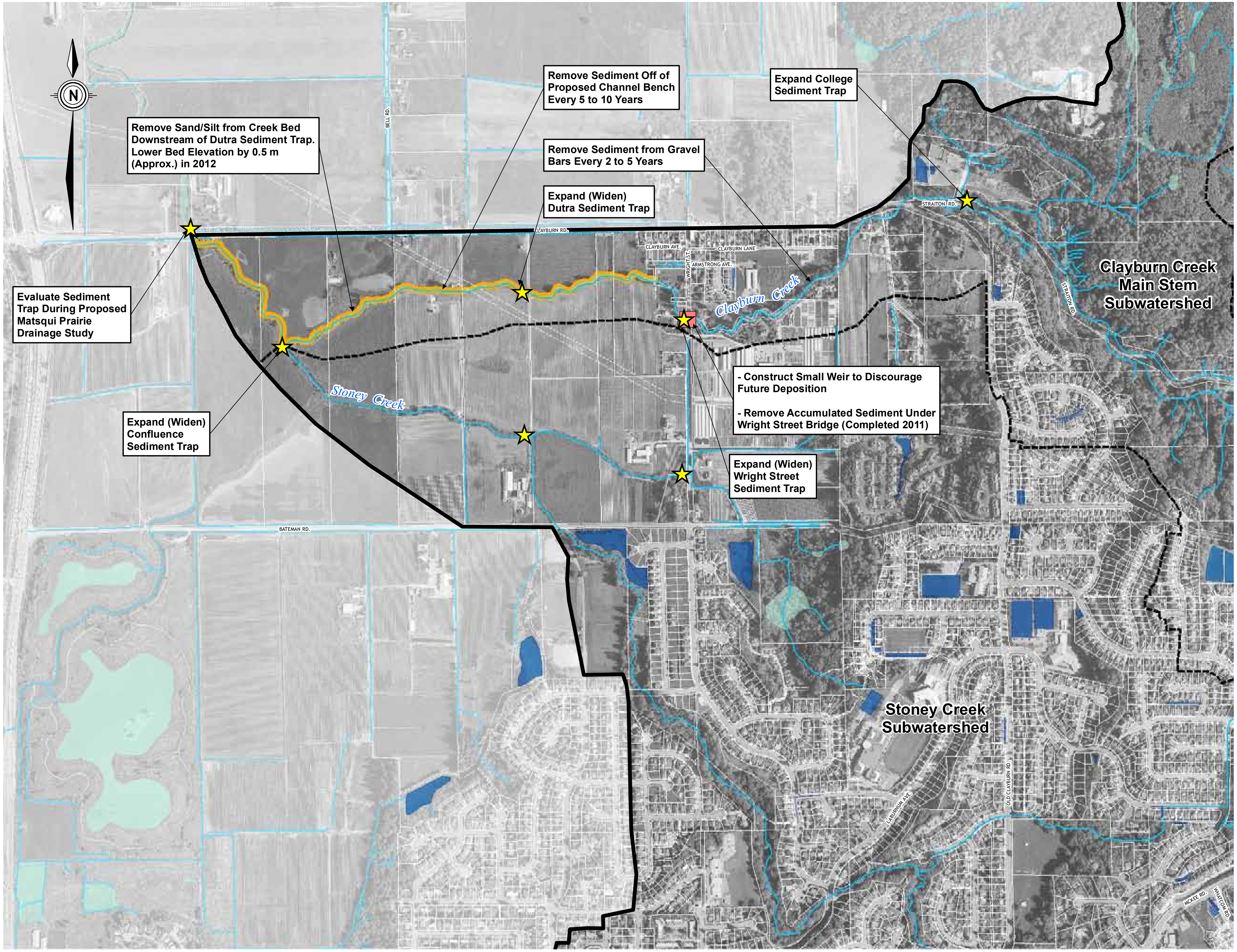
Project No.	Date
510-057	May 2012

Lower Clayburn Creek Flood Management Plan

Figure 8-1



City of Abbotsford
Clayburn Creek
ISMP

Legend

- Watershed Boundary
- Subwatershed Boundary
- Creeks and Streams
- Detention Facility
- Open Water and Marshes

Approximate Location of Existing Sediment Traps

- Continue Annual Sediment Removal from Sediment Trap

Reduce Erosion in Upland Areas by:

1. Applying source controls for future development.
2. Reducing flows down ravine slopes.
3. Installing sediment trapping weirs in select channels.
4. Creek stabilization in non-ravine areas.

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

Sediment Management Plan

Figure 8-2

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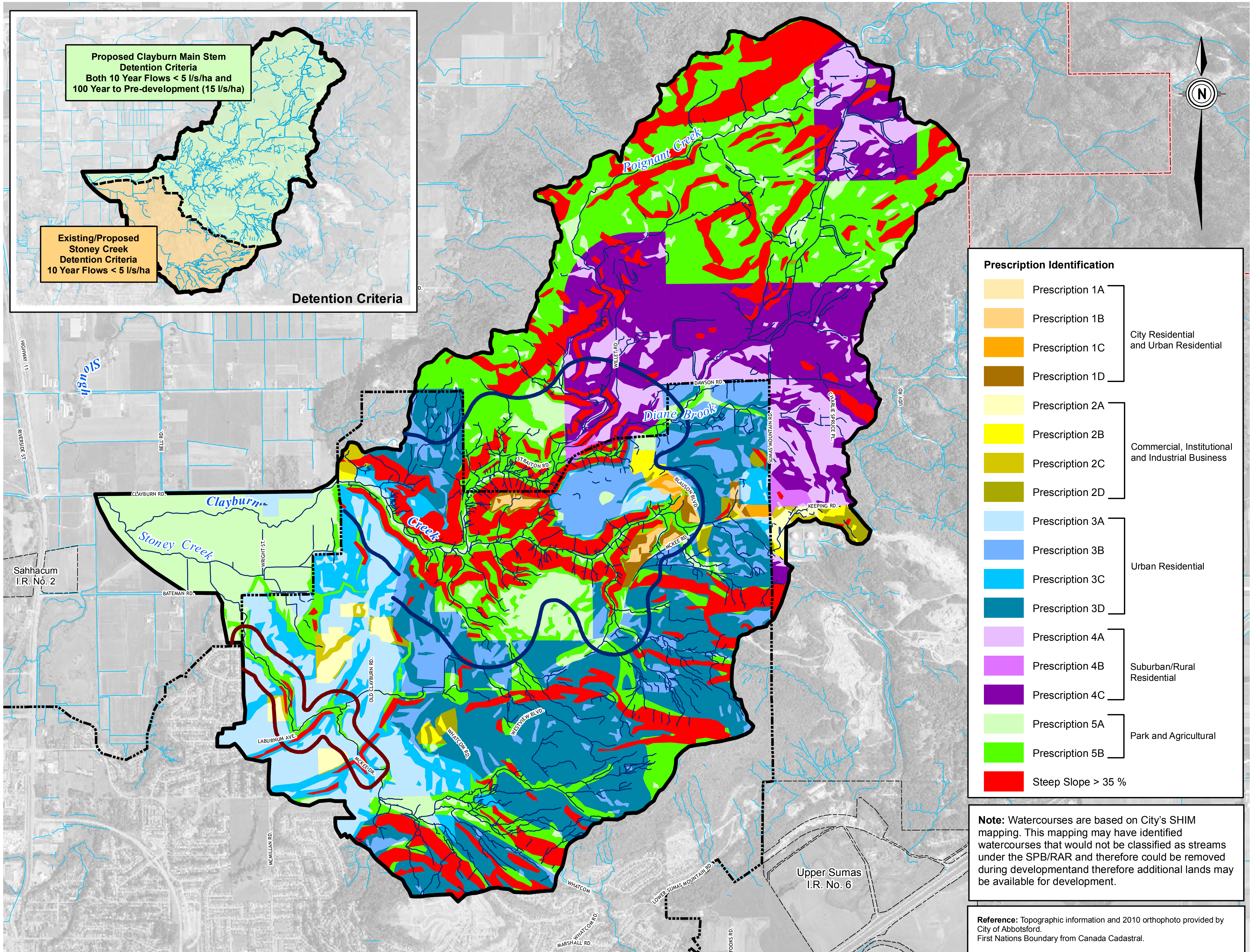

City of Abbotsford
Clayburn Creek
ISMP

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

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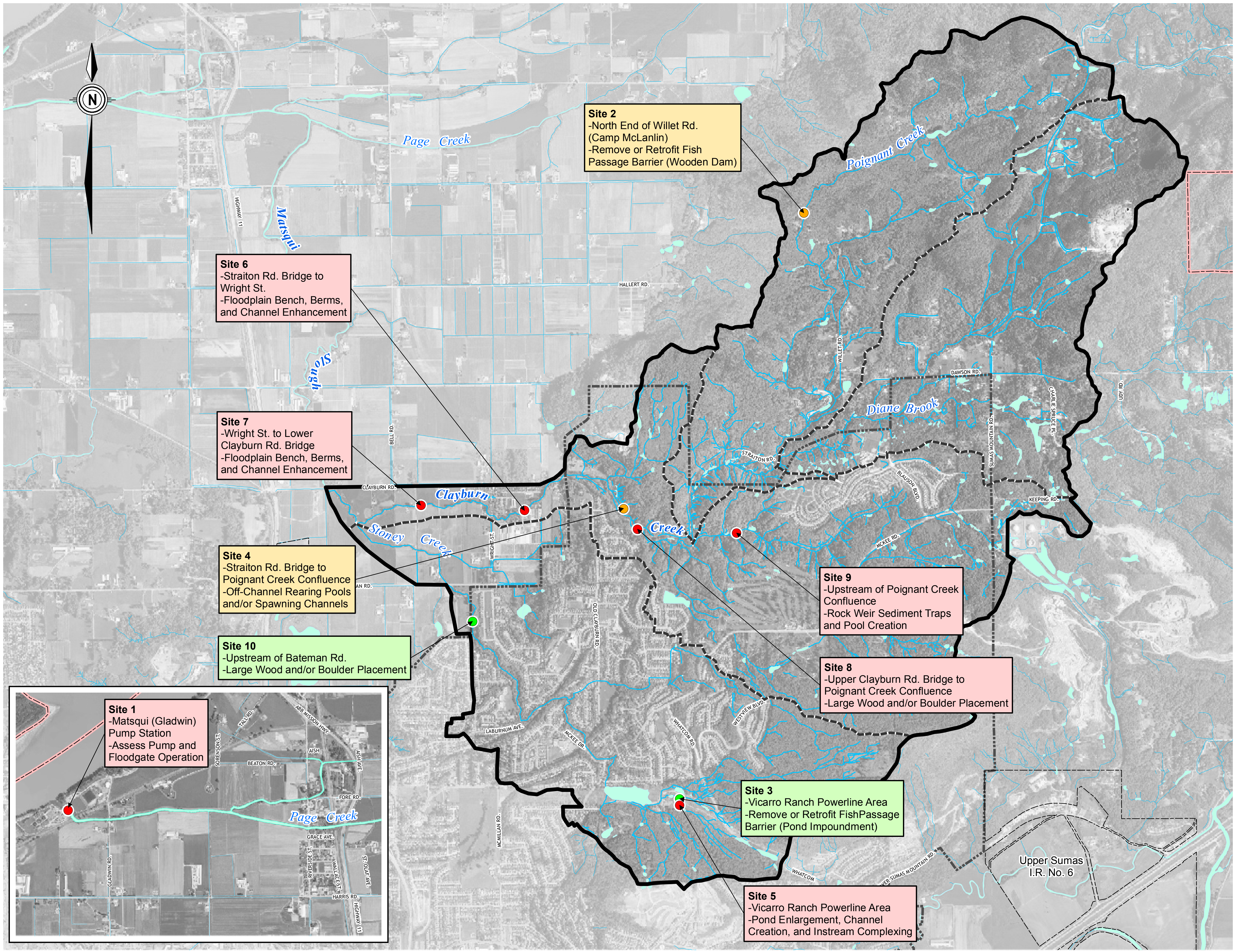
Project No.	Date
510-057	May 2012

Source Control Prescriptions and Detention Requirements

Figure 8-3



City of Abbotsford
Clayburn Creek
ISMP

Legend

City Boundary
Watershed Boundary
Subwatershed Boundary
Approximate Urban Development Boundary
Creek
Open Water and Marshes

Restoration and Enhancement Opportunities

Priority

Low
Medium
High

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

Aquatic Habitat Restoration and Enhancement Projects

Figure 8-4

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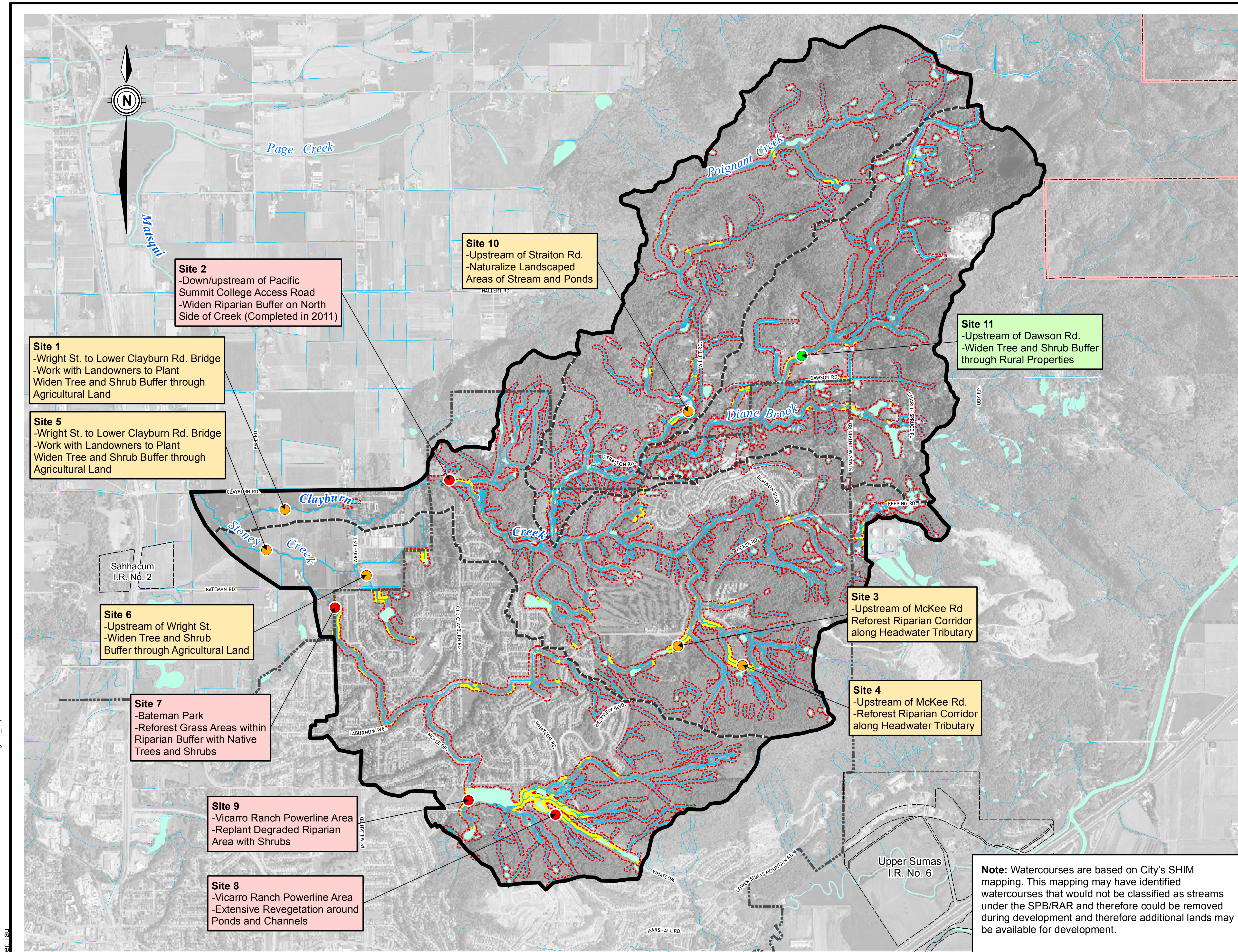

City of Abbotsford
Clayburn Creek
ISMP

Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creek
- Open Water and Marshes
- SPR Setback
- Potential Riparian/Reforestation Sites within 30 m of Permanent Streams

Restoration and Enhancement Opportunities

Priority

- Low
- Medium
- High

Note: For planning purposes, setbacks shown from creekline but will be measured from top of banks in field. Subject to detailed on-site assessment.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

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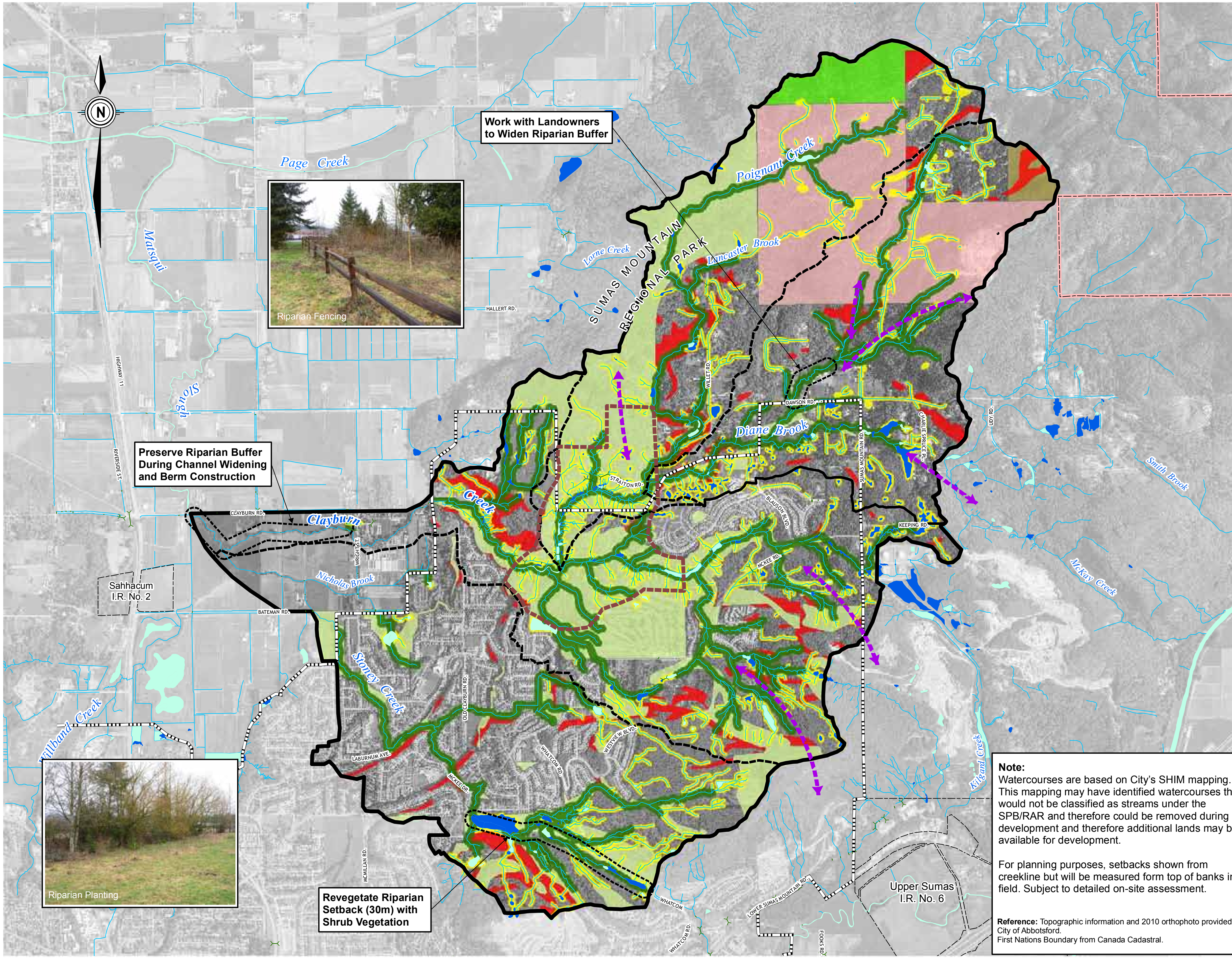
Project No.	Date
510-057	May 2012

Riparian Habitat Restoration and Enhancement Projects

Figure 8-5

City of Abbotsford
Clayburn Creek
ISMP



Legend

- City Boundary
- Watershed Boundary
- Subwatershed Boundary
- Approximate Urban Development Boundary
- Creeks and Streams
- Ponds
- Wetlands
- Proposed Habitat and Steep Slope Protection Area
- Wildlife Corridor Study Area/Opportunity
- Ground Slope (> 35 %)

Riparian Setback

- 15 m on Non-permanent Streams
- 30 m on Permanent Streams

OCP Designation

- Limited Use
- Park
- Resource/Conservation
- Forest

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Project No.	Date
510-057	May 2012

Note:
Watercourses are based on City's SHIM mapping. This mapping may have identified watercourses that would not be classified as streams under the SPB/RAR and therefore could be removed during development and therefore additional lands may be available for development.

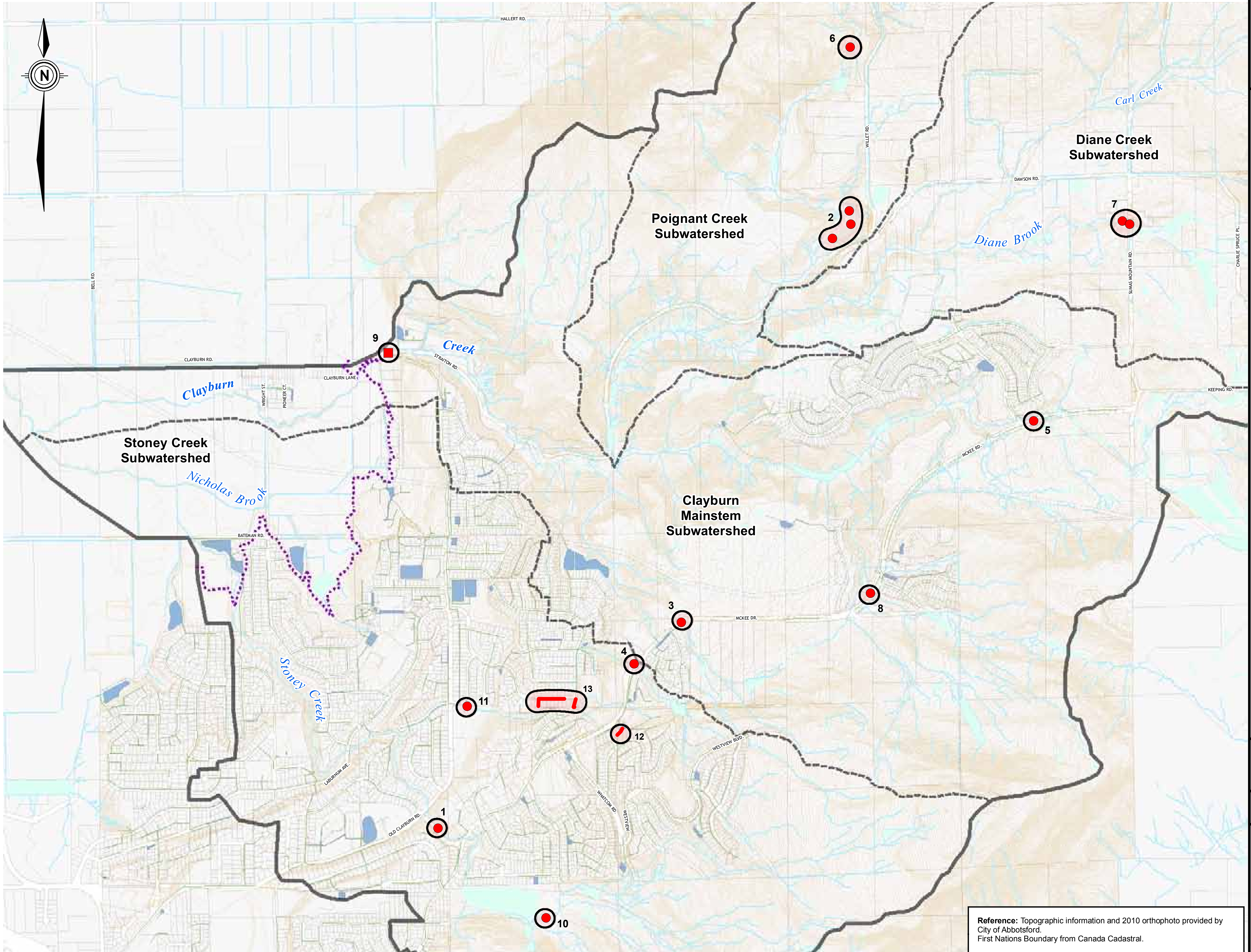
For planning purposes, setbacks shown from creekline but will be measured form top of banks in field. Subject to detailed on-site assessment.

Reference: Topographic information and 2010 orthophoto provided by City of Abbotsford.
First Nations Boundary from Canada Cadastral.

Wildlife Corridors

Figure 8-6

City of Abbotsford
Clayburn Creek
ISMP



Legend

- Watershed Boundary
- Subwatershed Boundary
- Contour (2 m Interval)
- Lowland Boundary (12 m)
- Creeks and Streams
- Detention Facility
- Open Water and Marshes
- Storm Main
- Storm Main Upgrade
- Bridge Upgrade
- Culvert Upgrade
- **Project ID** (Refer to Table 8-8)

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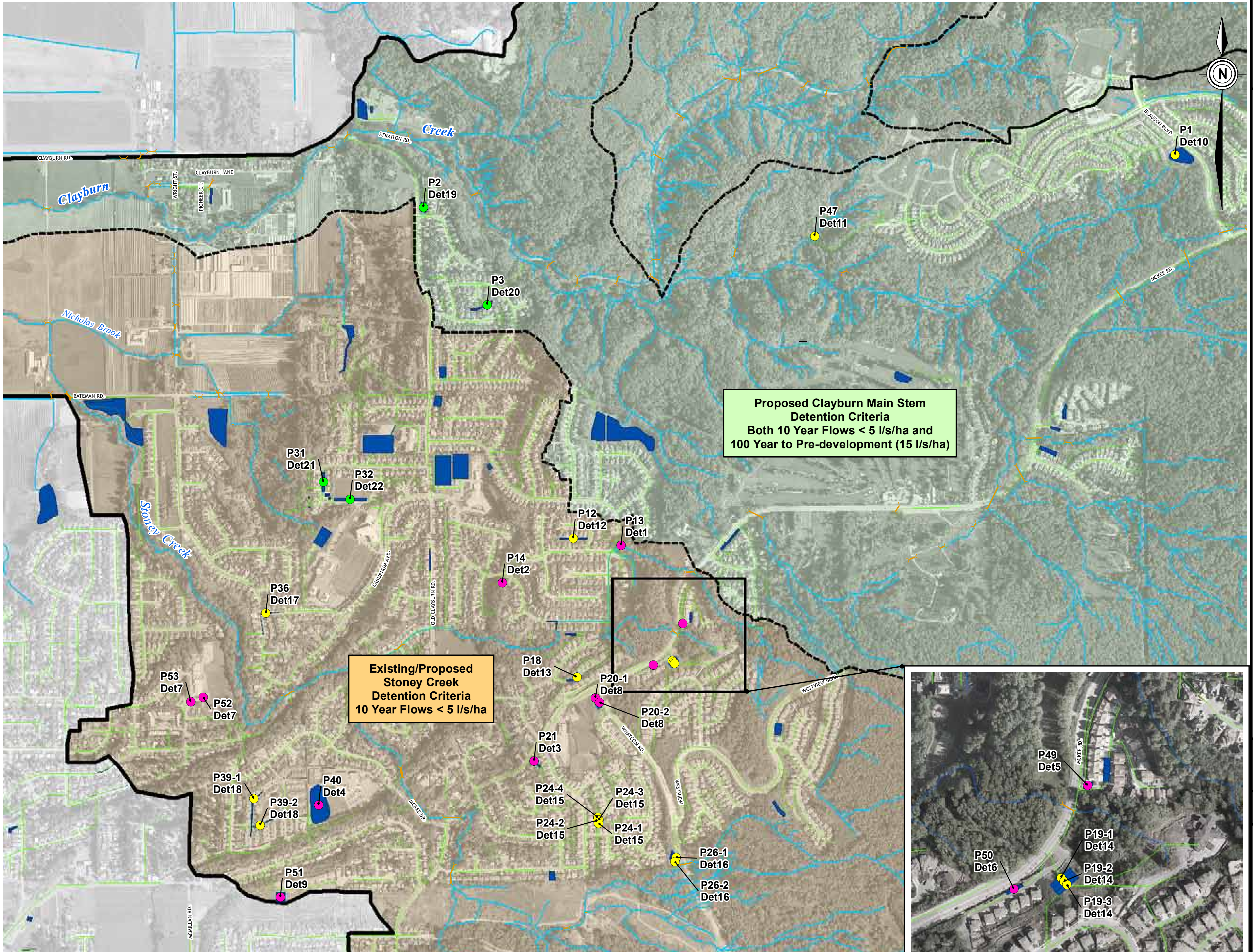
Project No.	Date
510-057	May 2012

Proposed Storm Sewer and Culvert Upgrades

Figure 8-7



City of Abbotsford
Clayburn Creek
ISMP

Legend

- Watershed Boundary
- Subwatersheds Boundary
- Culvert
- Storm Main
- Creeks and Streams
- Detention Facility

Proposed Detention Modification Projects

Priority

- High - (Det1 to Det9)
- Medium - (Det10 to Det18)
- Low - (Det19 to Det22)

P__ - KWL Facility ID
Det_ - Project No.

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 Facility Upgrades

Figure 8-8

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Section 9

Summary and Recommendations

9. Summary and Recommendations

9.1 Summary

Key Watershed Characteristics and Issues

Description	Clayburn Creek Watershed
Drainage Area	• 2253 ha. • Discharges to Matsqui Slough to the Fraser River.
Stream Structure	• Clayburn Mainstem 657 ha Stoney Creek 627 ha • Poignant Creek 504 ha Diane Creek 465 ha
Topography	• Mountainous terrain with lowland area. El. 532 m – El. 4 m. Areas with relatively steep slopes exceeding 35% in places. • Steep ravine sections in Clayburn, Poignant and Stoney Creeks.
Land Use	• Existing land use is mostly undeveloped or vacant land with residential acreages and single family residential. • Future development proposed in OCP includes high density, medium density, and low density residential, as well as commercial / industrial use. • Total impervious area increases from 12% to 27% over the 2253 ha area.
Drainage System	• Storm sewer network and detention facilities in single-family subdivisions. • Ditches, channels, culverts, bridges.

Environmental Values

1. Clayburn Creek and its tributaries support a diverse fish community of at least 20 species including floodplain, anadromous, and resident fish communities. Five salmon and trout species reproduce in the mid-reaches of the watershed: chum, coho, steelhead, cutthroat trout, and possibly pink salmon.
2. Water and sediment quality in the watershed is generally good. The largest water quality issue is turbidity caused by sedimentation within the Clayburn Creek mainstem ravine. Localized issues with metals, oil, and grease and bacteriological contamination exist, and are expected for the level and type of upstream development present.
3. Clayburn Creek and its tributaries are in relatively good ecological health as reflected by the 2009 mean B-IBI score of 32.8 and a mean taxa richness of 29.3. The watershed is in the top five of over 35 streams that have been previously monitored in Metro Vancouver.
4. Almost 70% of the study area is forested. Mean riparian forest integrity across the subwatersheds was 78.4%, and ranged from 55.7% in Stoney Creek subwatershed to 92.7% in the Poignant Creek subwatershed.
5. The watershed encompasses a large number of sensitive or important terrestrial habitats, and a high number of species at risk, including Pacific Water Shrew, Mountain Beaver, Red-legged Frog, Pacific Waterleaf, and Oregon Forest Snail are found throughout the watershed. Other species, such as Townsend's Mole, Pacific Giant Salamander, and Phantom Orchid are found at one or two locations.

Lowland Flooding

6. Clayburn Village currently floods in approximately a 2-year return period event. It has flooded eight times in the last seven years. Prior to 2005, flooding was less frequent.
7. The farmland and Clayburn Road west of Clayburn Village flood in less than a 2-year return period event.
8. The potential causes of the increased flooding include sediment accumulation in the Clayburn Creek lowland channel reducing capacity, climate change resulting in higher and more frequent flows, and increased roughness due to vegetation growth. The small amount of development in the uplands has not been shown to increase peak flows in the lowlands.
9. The 2005 Drainage Study recommended berms to protect the farmland but DFO asked for further analysis to justify the works.
10. Downstream of the study area boundary, the Matsqui Prairie also floods due to insufficient conveyance capacity in the watercourses.
11. The following options were considered for addressing lowland flooding: detain upland flows to existing channel capacity, floodway to divert excess flows around Clayburn lowlands, deepen/enlarge Clayburn Creek channel, construct berms along creek, construct ring berm around areas to be protected, raise flooded roads, fill low land areas, or relocate residences and allow flooding to occur.

Erosion and Slope Instabilities

12. The City's 2006 SHIM mapping noted numerous erosion sites throughout the study area, particularly in the ravine sections of Clayburn and Poignant Creeks.
13. Of all the erosion sites, 68% were found in steep areas, where the slopes are over 12%.
14. Only 13% of the severe erosion sites are downstream of single-family residential subdivision areas suggesting that a large majority of the erosion is not necessarily caused by development.
15. Alternatives considered for addressing erosion including avoiding outfalls at tops of ravines, stabilizing major erosion in accessible areas, adding stormwater source controls to developments, detaining flow peaks to values less than the erosion threshold, and enforcing geotechnical setbacks.
16. Some natural erosion that does not pose an immediate risk to life or property would be allowed to continue.

Lowland Sedimentation

17. DFO stopped permitting large scale channel dredging in 1989.
18. The lower Clayburn Creek channel has been surveyed in detail in 1990, 1992, 2007, and 2009. Using this survey information, and sediment removal quantities (from sediment traps and gravel bars) over this time frame, it was estimated that the annual sediment influx into the lowland reach between Clayburn Road and Straiton Road is approximately 168 m^3/year.
19. The sediment removals accounted for approximately 124 m^3/year on average, leaving 44 m^3/year to accumulate in the channel.

20. During high flows spilling onto the floodplain, sediment is deposited in residents' yards and on agricultural fields. Overland flows also erode gravel driveways, moving the gravels to deposition locations.

21. Alternatives considered for dealing with sedimentation including expanding existing sediment traps, constructing new sediment traps, removals from gravel bars, periodic dredging of creek channel, and instream works to discourage deposition in unwanted locations. Preventing sediment deposition on yards and fields can be accomplished by containing higher flows within the creek channel.

Mitigating the Impacts of Future Development

22. Unmitigated development typically results in increased runoff peak flows and volumes, and increased frequency of peak flows that can cause flooding, erosion and deterioration of fish habitat; decreased infiltration can cause reduced creek baseflows and poor water quality.

23. The Watershed Health Tracking System shows that, if left unmitigated, future development would result in degradation of watershed health (8 B-IBI point drop over entire study area).

24. The baseflows in Clayburn Creek are typical of Lower Mainland creeks (approximately 0.024 L/s/ha in summer and 0.2 L/s/ha in winter) and are essential to aquatic life. Maintaining baseflows while allowing development to proceed can be accomplished by incorporating infiltration/retention source controls, constructing baseflow release facilities, preserving wetlands and maximizing input to natural recharge areas, or supplementing creek flows with well water in the summer.

25. Mitigating the impacts of development should include:

    - Protection of ravines, steep slopes geotechnical areas, and riparian setbacks
    - Protection of natural bogs, wetlands, some forested areas and wildlife movement corridors
    - Minimization and mitigation of impervious areas by incorporating source controls to hold and infiltrate runoff
    - Construction of detention facilities (ponds and tanks) to reduce peak flows
    - Construction of water quality treatment facilities

Upland Flood Management

26. Computer modelling of the existing storm drainage system showed that 70 storm sewer pipes do not have adequate capacity for the minor flow and 6 do not have adequate capacity for the major flow under existing land use conditions. Under unmitigated future land use conditions, an additional 32 minor pipes and 3 major pipes are under capacity.

27. Fifteen culverts and 2 bridges have insufficient capacity under existing land use conditions. Under unmitigated future land use conditions, an additional 9 culverts and 3 bridges are under capacity.

28. To address the storm sewer, culvert, and bridge capacity issues, the City could upgrade all undersized structures, allow more surcharging and overland flows in safe areas, or increase detention requirements to reduce flows to the undersized structures.

29. Out of 51 detention facilities in the Stoney Creek catchment, 14 may require outlet adjustments and 17 appear undersized to meet the City's current detention criterion of 10-year flow released at 5 L/s/ha. Three facilities may be undersized because many were built prior to the current criterion being applied in 1992 and two due to a change made to the IDF curves in 1995.

30. Out of 13 detention facilities in the Clayburn Creek catchment, 4 appear undersized to meet the City's current detention criterion of 100-year flow released at 5 L/s/ha. One of these facilities may be undersized due to a change made to the IDF curves in 1995.
31. To address the detention deficiencies, the City could consider changing the detention criteria, increasing detention volume where possible, requiring over-detention in future developments, or reconfiguring detention facilities so that they are not in series.

Stakeholder Program

32. Public meetings were held at the beginning to inform stakeholders of the study and solicit input to the key issues (April 2010), after assessments and alternatives were identified to present findings and potential solutions, solicit input regarding solution preferences, and identify additional alternatives (June 2011), and after the draft plan to present the proposed draft plan and solicit any final feedback (October 2011) and seek endorsement of the plan (December 2011).
33. Two Advisory Committee meetings were held in December 2010 and October 2011.
34. Four meetings with various City departments and regulatory agencies were also held throughout the study.
35. Both written and verbal feedback were received and documented. Stakeholder comments and input has been included and integrated in this study.

9.2 Recommendations

Based on the foregoing, it is recommended that the City of Abbotsford:

General

1. Pursue a Letter of Endorsement from DFO for the Clayburn Creek ISMP and work out agreed schedule for construction of lowland flood management works.
2. Install and maintain regularly new Rainfall Station in Clayburn watershed; Ledgeview data is spotty.
3. Commit to monitoring and review of Clayburn Creek Watershed Performance Indicators on a recurring basis, minimum every five years and undertake adaptive management measures if needed.

Lowland Flood Management

4. Plan to implement the recommended lowland flood management works as soon as possible to alleviate lowland flooding. Allocate funding and a timeline for implementation. Proceed with feasibility, acquisition of property right-of-ways, design, instream approvals, etc.
5. Conduct additional flood studies: A lowland flood inundation modelling and assessment is required as this study addressed peak flow conveyance only. This could be included in the overall Matsqui Prairie Drainage Study to evaluate the impact of Matsqui Prairie flooding on Clayburn Creek water levels and determine the Clayburn Road raising Flood Construction Level. The Matsqui Prairie Drainage Study is one of the recommended studies in the 5-Year Plan.

Sediment Management

6. Develop a Memorandum of Understanding between the City and DFO on the sediment management plan outlining amounts and frequency of sediment removals.
7. Plan to implement the recommended sediment management works as soon as possible to prevent the conveyance capacity of the lowland channel from being further reduced and exacerbating flooding.
8. Continue removing sediment from the sediment traps annually. Identify gravel bars where sediment removals could be performed during low flow conditions and incorporate these into the annual maintenance program.
9. Expand and improve the existing sediment traps: College, Wright Street, Dutra, and Clayburn/Stoney confluence.
10. During construction of the lower Clayburn Creek channel widening downstream of the Dutra sediment trap, excavate the sand/silt to lower the channel invert by 0.5 m to remove accumulated sand/silt.
11. Remove sand/silt deposited on the proposed Clayburn Creek bench as required every 5 to 10 years.

Erosion

12. Undertake a watershed-wide erosion inventory ranking the severity and consequences of erosion and scour sites with the goals to identify and prioritize any rehabilitation works, and compare with 2006 sites. Determine if erosion is getting worse, staying the same or stabilizing with vegetation since 2006 and evaluate if existing development has affected them. If erosion sites have worsened or additional sites noted downstream of development, the existing detention facilities upstream should be assessed and modified to minimize erosion if possible.
13. Undertake a detailed assessment of high priority/high consequence erosion and scour sites and refine the rehabilitation priority and proceed with design of associated bank stabilization works.

Mitigation of the Stormwater Impacts of Future Development

14. Require volumetric reduction, water quality, and peak flow attenuation source controls/facilities on all future development. Include less common source control options, such as green roofs and stormwater re-use (‘purple pipe’) for high density land uses.
15. Ensure the rainwater management source controls meet the stormwater target for Clayburn Creek to capture 51 mm of runoff.
16. Develop typical details and specifications for common stormwater source controls on roads and in developments and incorporate into Section No. 10 – Engineering Standard Design Drawings of Appendix D of the Development Bylaw.
17. Incorporate requirements for inspecting source controls as part of the City’s Building Permit and Development Permit processes.
18. Develop simple source control approval and review procedures into existing subdivision and building permit systems.

19. Produce a summary of requirements for developers. This would be a simplified summary of the criteria to be achieved or the prescriptive approach to be followed for each type of development.
20. Review development application stormwater designs to check that they meet the requirements of the plan, including mitigation for impervious area (TIA).
21. Educate the various City departments (Engineering, Development and Planning, Environmental, and Parks) on the stormwater criteria in the Clayburn Watershed and obtain commitment for enforcing these criteria prior to, during and following the development process,
22. Design, construct and monitor source control pilot programs for each land use and surface outlined in Table 8-2.

Other Municipal Initiatives

23. Continue to enforce the current City of Abbotsford Streamside Protection Bylaw to protect the environmental sensitivities and species at risk. If encroachment cannot be avoided, apply a no-net-loss variance policy.
24. Continue to enforce the City of Abbotsford Sediment and Erosion Control Bylaw to protect water quality.
25. Continue to review applications with the City's Tree Protection Bylaw. Investigate requirement to specify a 1-for-1 compensation in the Clayburn watershed for cut trees that have a trunk diameter smaller than 20 cm.
26. Incorporate references to the ISMP where appropriate in any municipal initiatives such as sustainability, land use, transportation, etc. studies.
27. Due to the extent of future development planned, the high environmental values, and susceptibility of erosion within this watershed, undertake a land use planning process to ensure sustainable development with minimal impact of watercourse crossings, impervious area targets, terrestrial habitat conservation strategy, etc. Include a review of stormwater harvesting and reuse options to reduce potable water demand.

Environmental Enhancements

28. Initiate riparian and instream enhancement projects when compensation works are required. Work with environmental groups to initiate opportunities. These projects should accompany any other works adjacent to or within the creeks such as repair and restoration of erosion sites, construction of diversion outlets and/or sediment traps, treatment basins, etc.

Upland Flood Management Capital Works

29. Assess the existing detention facilities that have been screened as potentially not meeting the criteria in detail and determine if they meet criteria. For facilities upstream of undersized infrastructure and/or erosion sites, determine if facility modifications could alleviate the need for infrastructure upgrades and minimize erosion.
30. Include the high priority drainage system upgrades in the 5-year Capital Plan.
31. Provide hydraulic grade lines, from the Clayburn Creek XP-SWMM model created in this study, to landowners undertaking redevelopment projects on surcharged pipes, to design their drainage systems.

Report Submission

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Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
1.	Jan 2012	Final Draft	Addressed City, agencies, stakeholder and public comments	DZ
2.	May 2012	Final	Addressed Final Draft report comments	DZ/CC